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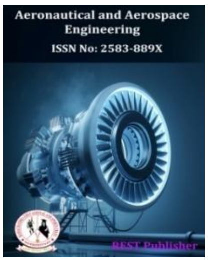

Assessment on Selection of Appropriate Materials for Fuselage of an Aircraft

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Abstract: *Considering composites, after treatments like heat processing, and the creation of composite substances in addition to pure components, the range of engineering components is steadily expanding. It is crucial to choose the best material from such a huge material source for each unique part that needs to be made. The picking of acceptable composition for the fuselage, A critical aircraft component, its importance lies in its lightweight and cost-effective nature, along with its thermal and mechanical characteristics. The criteria and options in this study, which attempts to choose components for the fuselage of a commercial airplane, have first been established following expert viewpoints. During the research, the COPRAS technique was employed to evaluate various materials, considering factors such as "density, tensile strength, shear strength, and cost." According to the ranking of options using the COPRAS approach, CFRP is the best option, followed by GFRP, AISI 4130, Al 2024-T3, Al 5052-H32, Al 6061-T6, Al 7075-T6, and AZ31B. In comparison to other chosen materials, CFRP recorded the highest importance with the tensile strength of 1240 MPa, shear strength of 740 MPa, and elastic modulus of 145 Gpa, whereas AZ318 recorded the lowest relevance with the tensile strength of 290 MPa, shear strength of 130 MPa, and elastic modulus of 45 Gpa. The order is summarized as " CFRP> GFRP>AISI 4130> Al 7075-T6> Al 2024-T3> Al 6061-T6> Al 5052-H32> AZ31B ".As per the result of the COPRAS approach, the three choices that were most suited for the fuselage were "CFRP, GFRP, and AISI 4130", with "AZ318 being the least appropriate.*

Keywords: *Fuselage, Material selection, tensile strength,* density, tensile strength, shear strength

1. INTRODUCTION

The choice of manufacturing and commercial materials is crucial in designing products. However, due to the complex relationships between a large numbers of contradictory choice criteria for picking alternatives, the process is onerous and thought-provoking. While failure and reduced weight are important factors influencing material selection, the primary driving forces are typically improved performance and cost reduction. For instance, in the aircraft sector, one of the main objectives for design enhancements is to minimize weight [1, 2]. A poor choice of materials could result in producers and consumers not being happy. Additionally, it may cause an assembly to fail and products to function worse, which would negatively impact efficiency and productivity and harm the organization's brand [3].Various techniques have been used in the research to address the issue of choice of materials, and one of the most widely used techniques is the MCDM approach. MCDM (Multi-Criteria Decision Making) provides a systematic approach for selecting the most suitable option from a list of alternatives by considering "decision criteria, benefit and cost data, and input from decision makers" concurrently [4, 5]. The fuselage, known as the aircraft's body, serves as the main structure that holds together all the components of an airplane. It is a long tubular structure, and its hollow nature contributes to its lightweight design. The configuration of the fuselage is usually determined by the aircraft's intended purpose, much like other components. For instance, in a supersonic fighter plane, the fuselage is designed to be extremely thin and streamlined, aiming to reduce drag during high-speed operations [6]. To accommodate the highest passenger capacity, the fuselage of an airliner is designed to be wider. The cabin, where passengers sit, is situated towards the rear of the fuselage, while the cockpit, where the pilots operate the aircraft, is located in the front. In many airliners, the fuel is stored in the wings, and the rear section of the fuselage is dedicated to transporting passengers and their luggage. This layout allows for efficient distribution of weight and ensures a comfortable and spacious interior for the passengers. In a fighter aircraft, the cockpit is typically positioned on top of the fuselage, offering the pilot a good vantage point. The wings are utilized to carry armaments, and towards the rear of the fuselage, you can find the engines and ammunition storage [7,8]. The weight of an airplane is evenly distributed across its entire structure to maintain stability and ensure proper flight dynamics. An aircraft's fuselage, together with the people within and the goods it carries, weighs a lot. The weight is typically distributed inside the fuselage, where the center of gravity of the aeroplane is placed on average. Due to the obvious torques produced by the "elevator, rudder, and ailerons", the aeroplane rotates about its center of gravity when flying.

The fuselage needs to be built strong enough to bear these torques [9,10]. During the initial design phase of an airplane, a crucial aspect is the aerodynamic modeling of the fuselage, especially for a local transport flight. The fuselage plays a significant role in the overall aerodynamics, accounting for approximately "30% of zero lift drag." The efficiency of an aircraft during its cruise phase, including factors like top speed and fuel efficiency, largely depends on the drag coefficient. Improving the precision of the aerodynamic configuration, particularly concerning the fuselage, can lead to enhanced performance and overall flight efficiency. A precise evaluation of the fuselage's aerodynamic characteristics can lead to significant improvements in the design of the tailplane and the overall stability of the aircraft. The fuselage has a direct influence on the aircraft's longitudinal and directional stability characteristics. Therefore, understanding and optimizing the aerodynamics of the fuselage can positively impact the tailplane design and enhance the overall stability of the aircraft [11,12]. The criteria and options in this study, which attempts to choose components for the fuselage of a commercial aeroplane, have first been established under expert viewpoints. In the study, factors like "cost, density, tensile strength, and shear strength" were considered.

2. MATERIALS AND METHODS

Complex Proportional Assessment (COPRAS) is a rating method introduced by Zavadskas, Kaklauskas, and Sarka in 1994. This approach takes into account both the best and worst outcomes separately. By identifying the optimal best solution and the ideal worst solution, the COPRAS method allows for the selection of the best alternative value. This enables a comprehensive assessment that considers both the positive and negative aspects of each option in the decision-making process. Indeed, the COPRAS technique is frequently employed in the engineering field for evaluating and selecting various projects. Its primary objective is to rank each option by incorporating appropriate weights for every parameter considered in the assessment. By assigning weights to the different criteria, the COPRAS method allows decision-makers to systematically compare and prioritize the alternatives based on their overall performance and suitability for the given engineering problem [13,14]. This makes it a valuable tool for making informed decisions and optimizing project selections. Despite a few minor flaws, "COPRAS MCDM" has many significant positive qualities that more than help compensate for them. The primary and most significant advantage of the "COPRAS" method is its capability to treat favorable and unfavorable factors independently [15]. By considering both the best and worst outcomes separately, the COPRAS technique allows decision-makers to better understand the strengths and weaknesses of each alternative, leading to more robust and well-informed decisions. This ability to handle positive and negative elements separately enhances the method's effectiveness and practicality in complex decision-making scenarios across various fields, including engineering and project selection. The relevance and usefulness level of the variants under consideration is determined by a set of criteria, according to COPRAS. These criteria effectively specify the variables as well as the weights and quantities of each criterion. The COPRAS method, being a fundamental MCDM technique and a valuable decision-making tool, is guided by key principles [16]. It assesses options using a unified evaluation process that considers both cost and benefit criteria. What sets COPRAS apart from other MCDM approaches is its consideration of the utility degree of options. This utility degree, represented as a percentage, indicates the extent to which one solution is superior or inferior to the other alternatives being evaluated [17]. Recent studies have demonstrated that COPRAS outperforms WSM (Weighted Sum Model) when dealing with changes in data, making it a more reliable choice. Moreover, when judgments are integrated with COPRAS, the results are more accurate and less biased compared to those obtained using TOPSIS and WSM. In addition to these benefits, COPRAS offers several advantages over other MCDM techniques such as PROMETHEE, DEA, VIKOR, AHP, and ELECTRE. It features a straightforward and evident MCDM approach that requires significantly less computational effort. Furthermore, it offers a higher potential for graphical comprehension, making it easier for decision-makers to interpret and understand the results [18,19].

Step 1: The decision matrix X is constructed to depict the performance of different options concerning specific criteria. This matrix allows decision-makers to compare and evaluate the alternatives based on their performance across the various criteria under consideration. By organizing the data in a structured manner, the decision matrix facilitates the decision-making process, enabling a more systematic and objective approach to selecting the most suitable option.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \qquad (1)$$

Step 2: The criteria's weights are given as

$$w_j = [w_1 \cdots w_n], \qquad (2)$$

$$\sum_{j=1}^{n}(w_1 \;\cdots\; w_n) = 1$$

The weights assigned to the various evaluation parameters must add up to one.

Step 3: The matrix x_{ij}'s normalized values are computed as

$$n_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \qquad (3)$$

Step 4: Weighted normalized matrix N_{ij} according to the formula below.

$$N_{ij} = w_j \times n_{ij} \qquad (4)$$

Step 5: Equations 5 and 6 are used, respectively, to calculate the sum of the benefit and cost criterion.

$$B_i = \sum_{j=1}^{k} N_{ij} \qquad (5)$$

$$C_i = \sum_{j=k+1}^{m} N_{ij} \qquad (6)$$

Step 6: The relative importance of the choices should be determined. Calculations of alternative significance are based on Q_i. Higher the value of Q_i, the better the response. Alternatives with the highest Q_i value are $Q_{(\max)}$. The following is a Qi equation:

$$Q_i = B_i + \frac{\min(C_i) \times \sum_{i=1}^{n} C_i}{C_i \times \sum_{i=1}^{n}\left(\frac{\min(C_i)}{C_i}\right)} \qquad (7)$$

Step 7: Next U_i is calculated.

$$U_i = \frac{Q_i}{\max(Q_i)} \times 100\% \qquad (8)$$

Cmax is the related level of importance that is highest. The relative relevance value for a given choice determines whether its utility function increases or decreases. The utility rating is achievable between 0% and 100%. This approach enables the evaluation of "operational features, utility stages of weight, and instantaneous and relative relevance" in a decision-making scenario where numerous criteria are involved [20,21].The criteria and options in this study, which attempts to choose components for the fuselage of the commercial plane, have first been established under expert viewpoints. In the study, the factors of "cost, density, tensile strength, and shear strength" were taken into account and considered in the analysis or decision-making process. These factors were likely used to evaluate and compare various options or alternatives based on their performance with respect to these specific criteria. By incorporating these factors into the equation, the researchers aimed to make a well-informed and comprehensive assessment of the options being studied.

3. ANALYSIS AND DISCUSSION

TABLE 1. Material Properties

Material	Tensile strength [MPa]	Shear strength [MPa]	Modulus of elasticity [GPa]	Cost [$US/kg]	Density [g/cm^3]
CFRP	1240	740	145	238	1.6
GFRP	1020	440	45	24	2.1
AISI 4130	560	420	209	1.95	7.85
Al 2024-T3	485	283	72.4	16	2.77
Al 5052-H32	228	138	70.3	4.98	2.68
Al 6061-T6	310	207	69	7.55	2.7
Al 7075-T6	572	331	71	13	2.8
AZ31B	290	130	45	36.8	1.77

Table 1 presents the dataset containing the properties of each alternative material considered in the research. The following materials were studied: CFRP (Carbon Fiber Reinforced Polymer), GFRP (Glass Fiber Reinforced Polymer), AISI 4130 (a type of steel), Al 2024-T3 (Aluminum Alloy 2024 in T3 temper), Al 5052-H32 (Aluminum Alloy 5052 in H32 temper), Al 6061-T6 (Aluminum Alloy 6061 in T6 temper), Al 7075-T6 (Aluminum Alloy 7075 in T6 temper), and AZ31B (a magnesium alloy).

The properties evaluated for the selection of these materials include:

1. Tensile strength [MPa] (measuring the material's resistance to tension forces)

2. Shear strength [MPa] (measuring the material's resistance to shear forces)
3. Modulus of elasticity [GPa] (measuring the material's stiffness)
4. Cost [$US/kg] (the cost of the material per kilogram)
5. Density [g/cm3] (the mass per unit volume of the material)

These properties were likely used to assess and compare the materials' performance and characteristics, aiding in the selection of the most suitable material for the intended application in the research.

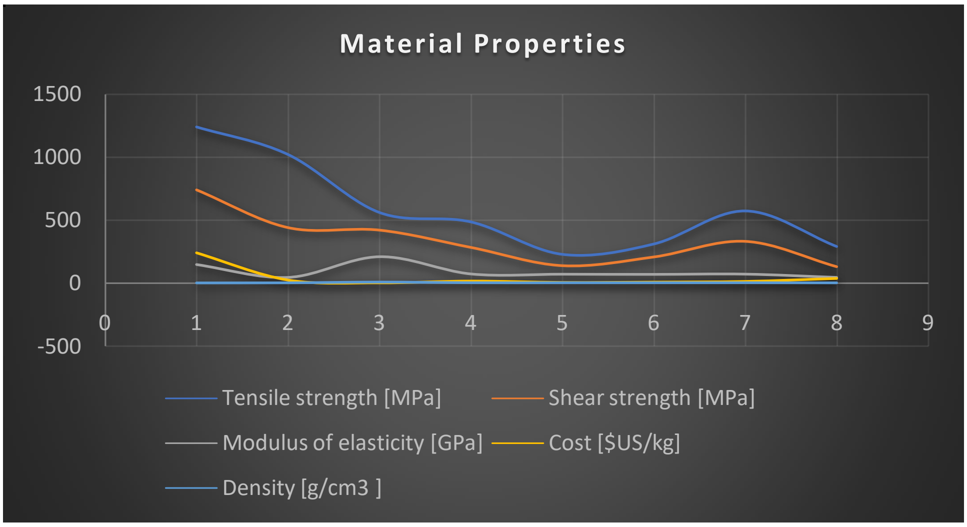

FIGURE 1. Parameters of Energy source

The figure depicts the dataset representing the properties of each alternative material under consideration. The study includes the assessment of "CFRP, GFRP, AISI 4130, Al 2024-T3, Al 5052-H32, Al 6061-T6, Al 7075-T6, and AZ31B" as the alternate materials. The properties evaluated for the selection process include Tensile strength [MPa], Shear strength [MPa], Modulus of elasticity [GPa], Cost [$US/kg], and Density [g/cm3]. These properties were analyzed to aid in determining the most suitable material for the specific purpose of the research.

TABLE 2. Normalized matrix

0.3510	0.3662	0.2677	0.8353	0.0941
0.2887	0.2177	0.0831	0.0842	0.1235
0.1585	0.2078	0.3858	0.0068	0.4618
0.1373	0.1400	0.1337	0.0562	0.1629
0.0645	0.0683	0.1298	0.0175	0.1576
0.0877	0.1024	0.1274	0.0265	0.1588
0.1619	0.1638	0.1311	0.0456	0.1647
0.0821	0.0643	0.0831	0.1292	0.1041

The normalized matrix of Performance Ratings of parameters of each base station is displayed in Table 2 above. Equation 3 was used to create this matrix.

TABLE 3. Weight Distribution

0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20
0.20	0.20	0.20	0.20	0.20

The preferred weight for the evaluation parameters is shown in Table 3. In this case, weight is equally distributed among evaluation criteria and the sum of weight distributed is one.

TABLE 4. Weighted normalized decision matrix

0.07020	0.07323	0.05354	0.16706	0.01882
0.05774	0.04354	0.01661	0.01685	0.02471
0.03170	0.04156	0.07716	0.00137	0.09235
0.02746	0.02801	0.02673	0.01123	0.03259
0.01291	0.01366	0.02596	0.00350	0.03153
0.01755	0.02048	0.02548	0.00530	0.03176
0.03238	0.03276	0.02621	0.00913	0.03294
0.01642	0.01286	0.01661	0.02583	0.02082

The Performance Ratings of the parameters of each base station are shown in Table 4 as a normalized matrix. Equation 4 was used to calculate this matrix, which was produced by multiplying tables 2 and 3.

TABLE 5. the sum of benefit criteria and the sum of cost criterion

Material	Bi	Ci
CFRP	0.197	0.186
GFRP	0.118	0.042
AISI 4130	0.150	0.094
Al 2024-T3	0.082	0.044
Al 5052-H32	0.053	0.035
Al 6061-T6	0.064	0.037
Al 7075-T6	0.091	0.042
AZ31B	0.046	0.047

Table 5 displays the total cost and total benefit criteria that were determined using equations 5 and 6. “Tensile strength [MPa], Shear strength [MPa], Modulus of elasticity [GPa], Cost [$US/kg] and Density [g/cm3]” are used to optimize the Comprehensive Performance of alternate materials**.**

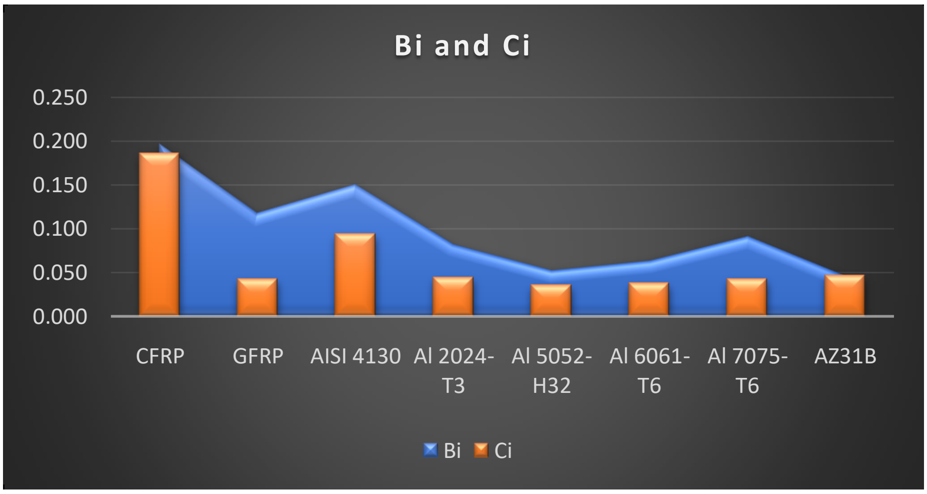

FIGURE 2. Bi and Ci

Equations 5 and 6 were used to calculate the total beneficial criteria and total cost criterion shown in Figure 2. “Tensile strength [MPa], Shear strength [MPa], Modulus of elasticity [GPa], Cost [$US/kg] and Density [g/cm3]” are used to evaluate the Comprehensive Performance of selected materials**.**

TABLE 6. Relative significance and Utility degree

Material	Qi	Ui
CFRP	0.214	100.0000
GFRP	0.195	91.1152
AISI 4130	0.185	86.2127
Al 2024-T3	0.156	72.5820
Al 5052-H32	0.144	67.3233
Al 6061-T6	0.150	70.0977
Al 7075-T6	0.168	78.2825
AZ31B	0.115	53.5609

Using equations 7 and 8, Table 6 displays the relative relevance and utility degree. Here utility degree value CFRP is hundred, GFRP is 91.1152, AISI 4130 is 86.2127, Al 2024-T3 is 72.5820, Al 5052-H32 is 67.3233, Al 6061-T6 is 70.0977, Al 7075-T6 is 78.2825 and AZ31B is 53.5609.

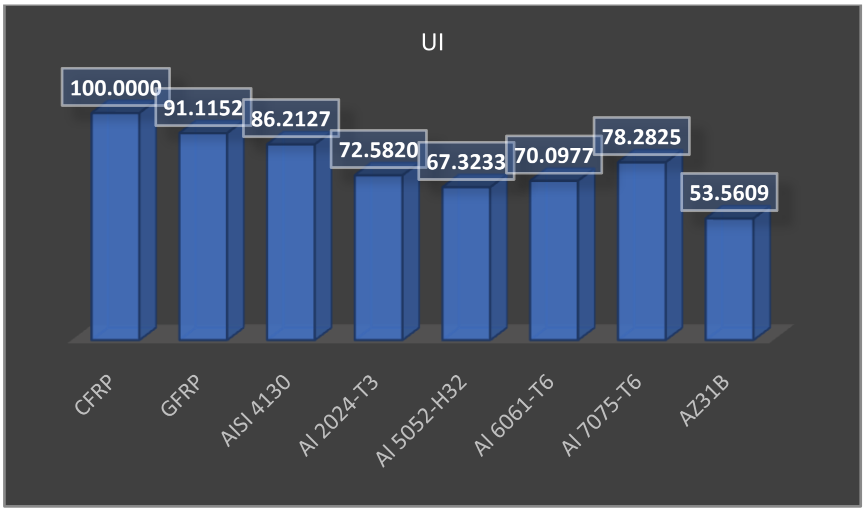

FIGURE 3. Utility Degree

Figure 3 shows the illustration of the Relative significance and Utility degree calculated by using equations 7 and 8. Here utility degree value CFRP is hundred, GFRP is 91.1152, AISI 4130 is 86.2127, Al 2024-T3 is 72.5820, Al 5052-H32 is 67.3233, Al 6061-T6 is 70.0977, Al 7075-T6 is 78.2825 and AZ31B is 53.5609.

TABLE 7. Rank

Material	Rank
CFRP	**1**
GFRP	**2**
AISI 4130	**3**
Al 2024-T3	**5**
Al 5052-H32	**7**
Al 6061-T6	**6**
Al 7075-T6	**4**
AZ31B	**8**

Table 7 shows the rank of alternatives "solar PV, solar thermal, hydro, wind and biomass" using utility degree values in table 6. Here rank of alternatives using the COPRAS method for value CFRP is first, GFRP is second, AISI 4130 is third, Al 2024-T3 is fifth, Al 5052-H32 is seventh, Al 6061-T6 is sixth, Al 7075-T6 is forth and AZ31B is eight.

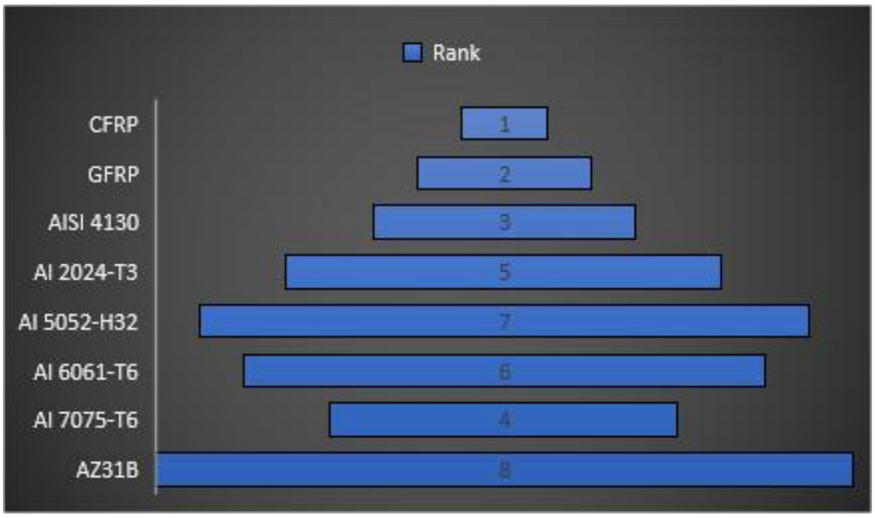

FIGURE 4. Rank

CFRP, with a Tensile strength of 1240 MPa, Shear strength of 740 MPa, and Elastic Modulus of 145 GPa, holds the most significant position compared to the other materials selected. On the other hand, AZ318, with a Tensile strength of 290 MPa, Shear strength of 130 MPa, and Elastic Modulus of 45 GPa, records the least importance. In the ranking order based on the COPRAS results is: CFRP > GFRP > AISI 4130 > Al 7075-T6 > Al 2024-T3 > Al 6061-T6 > Al 5052-H32 > AZ31B. According to the COPRAS approach, the three most suitable choices for the fuselage are CFRP, GFRP, and AISI 4130, while AZ318 is the least suitable option.

4. CONCLUSION

The level of advancement in aircraft materials today demonstrates the propensity for using cutting-edge structural components. The capacity of these materials to absorb moisture from the surroundings is one of their most significant drawbacks, as a result of which layers of composite frameworks disbanded and ultimately lost their usefulness. This problem serves as a good example of the limitations of using complex composite architectures.Considering this, the weight of the design and manufacturing ability limit the utilisation of common materials (such as "aluminium or titanium alloys"). The material is taken into consideration in the article's efficiency for selecting an aeroplane. The need to balance minimal weight with acceptable strength drives designers to create new, innovative materials, whose mechanical and physical properties pass stringent criteria for strength given the material's lighter-weight nature. Indeed, in this study aimed at selecting components for the fuselage of a commercial plane, expert opinions were utilized to establish the parameters and alternatives for evaluation. The COPRAS technique was then employed to grade several materials based on specific factors, including density, tensile strength, shear strength, and cost. By considering these critical criteria and expert viewpoints, the research sought to identify the most suitable materials for the fuselage, which plays a pivotal role in the performance and safety of commercial aircraft. The study utilized the COPRAS method to rank and evaluate various materials for the fuselage of a commercial plane. Among the alternatives considered, CFRP obtained the highest rank, followed by GFRP and AISI 4130 in second and third positions, respectively. The materials Al 7075-T6, Al 2024-T3, Al 6061-T6, and Al 5052-H32 secured the fourth, fifth, sixth, and seventh ranks, respectively. AZ31B was ranked last at the eighth position. CFRP demonstrated superior properties with a Tensile strength of 1240 MPa, Shear strength of 740 MPa, and Elastic Modulus of 145 GPa, making it the most significant choice compared to the other materials. Conversely, AZ31B displayed the least significant attributes with a Tensile strength of 290 MPa, Shear strength of 130 MPa, and Elastic Modulus of 45 GPa. Thus, according to the COPRAS approach, the top three materials that best suit the fuselage requirements are CFRP, GFRP, and AISI 4130, while AZ318 is considered the least suitable option for this application.

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