Penerbit Akademia Baru

Malaysian Journal on Composites Science and Manufacturing

Journal homepage:
https://www.akademiabaru.com/submit/index.php/mjcsm/
ISSN: 2716-6945

Multi-Criteria Decision Analysis for Optimal Material Selection in Unmanned Aerial Vehicle Manufacturing

Open Access

Mohd Suhaimi Omar[1], Wan Hasrulnizzam Wan Mahmood[1,*], Noor Irinah Omar[2], Nur Diyanah Faizal[1], Nur Azmina Muhammad Haris Ong[1], Abdurrahman Faris Indriya Himawan[3]

[1] Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[2] Fakulti Teknologi dan Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[3] School of Economics and Business, Telkom University, Terusan Buahbatu, Bandung 40257, Indonesia.

ARTICLE INFO

Article history:
Received 1 March 2025
Received in revised form 24 March 2025
Accepted 25 March 2025
Available online 30 March 2025

ABSTRACT

Unmanned Aerial Vehicles or UAVs were pilotless aircraft or aircraft with minimum human interaction. UAVs material and structure were critical aspects to consider throughout the development phase. UAVs were utilized in both the military and the civilian sector. However, because of this diversity of uses, their materials and structure differed due to the requirements and resilience needed for those uses. Due to the different materials used in the other development of UAVs, this study aimed to study the appropriate structure material for the development of UAVs. Moreover, this study investigated the process of preparing the body structure of the selected material from developed UAVs particularly for military specifications. Additionally, this study analyzed the best approach that was used to reduce the maximum take-off weight. This study focused on the best structure from the successful product of UAVs from the selected company. This case study was performed to investigate what had been practiced and for further analysis while analytical hierarchy process (AHP) and quality function deployment (QFD) were used as research methods to perform the multi-criteria decision analysis. Carbon fiber was selected as suitable material for wing and propellor while fiberglass composite was identified as suitable material for tail and body of UAVs. This study provided a strong basis for future UAV development, this all-encompassing strategy sought to create an organized framework for decision-making that synchronized technical specifications with operational and customer objectives.

Keywords:

Unmanned Aerial Vehicles (UAVs), Analytical Hierarchy Process (AHP), Quality Function Deployment (QFD), Carbon Fiber, Composites

* *Corresponding author.*
E-mail address: hasrulnizzam@utem.edu.my (Wan Hasrulnizzam Wan Mahmood)
E-mail of co-authors: msuhaimi.omar@gmail.com, nooririnah@utem.edu.my, diyanahfaizal0710@gmail.com, nurazminaharis01@gmail.com, farislike@telkomuniversity.ac.id

https://doi.org/10.37934/mjcsm.16.1.8599

1. Introduction

The Unmanned aerial vehicles (UAVs) is an aircraft without any human pilot or human intervention needed to control the aircraft [1]. UAVs are becoming increasingly popular all over the globe [2] and are currently utilized in a wide range of sectors. Their applications are not restricted to the military [3], they are widely used in fields like agriculture [4] and the arts. Since more than 200 years ago, UAVs had been utilized. The first unmanned device was the unmanned balloon. When the Montgolfier Brothers flew a variety of creatures in their balloons, this unmanned balloon was present [5]. The unmanned vehicle was first put to suitable use in 1849 when it was employed as a weapon in combat. Over the city, the UAVs was equipped with bombs. UAVs technology evolves further for military application especially for surveillance purpose. UAVs actively employed in the military sector up till the end of the 20th century.

UAVs have become a feasible alternative in this industry thanks to the quick and innovative designs that ensure last-mile delivery while being environmentally benign. UAVs offer numerous benefits such as effortless and rapid deployment, adaptability and expansion, economic viability, self-management, and exceptional agility [6]. UAVs come in a wide range of designs, materials, sizes, weights, ranges, and performance qualities to carry a variety of payloads, such as communication devices, navigational aids, sensors, and cameras [7]. Many factors, including configuration, engine type, weighting, domain and extent, allow UAVs to be categorized.

The widespread use of drones in many different industries emphasizes how crucial it is to choose the right foundational materials when building them. However, while a wide range of materials, from lightweight polymers to strong metals, are readily available, selecting the best mix offers a difficult problem. It is crucial to strike a balance between aspects including cost-effectiveness, resilience to wear and damage, and performance in a range of environmental circumstances. An additional layer of complication is introduced by the changing regulatory environment surrounding the use of materials in drones. This study aims to review successful case studies and the practice that has been done by the company.

From material selection to final assembly, the development of UAVs for military applications involves a complicated series of procedures. This creates a research gap in the methodical selection of structural materials for military UAVs that meet mission specific and performance requirements. Recognizing the complex sequence flow of these procedures is essential for maximizing effectiveness, guaranteeing superior performance, and fulfilling demanding military specifications. This study's importance stems from its methodical and structured approach to material selection, which can enhance the dependability and performance of UAVs. The integrated QFD-AHP approach also improves decision making flexibility and traceability which makes it a useful tool for military UAVs engineers and designers. This empirical study is done to study the appropriate structure material for the development of unmanned aerial vehicles, to investigate the process of preparing the body structure of the selected material from developed UAVs particularly for military specification using AHP and QFD approach and to analyse the best approach that is used to reduce the maximum take-off weight through real world data and case studies.

2. Literature Review

2.1 Material Selection for UAVs

UAVs have become a powerful presence in both military and civilian spheres, surpassing traditional boundaries in recent years. Apart from their critical roles in military operations, UAVs have become true all-around heroes of adaptability, opening up a plethora of uses in several industries. UAVs act as "eyes in the sky" in military regions, offering vital reconnaissance and surveillance capabilities without endangering human life. The dynamics of modern warfare are radically altered by their quick mobility and real-time data transmission capabilities, which allow for quick and strategic decision-making. But UAVs have a profound impact on fields other than military combat, like science and environmental conservation. With their unparalleled ability to access previously unreachable areas and their capacity to facilitate ground-breaking discoveries, UAVs are an essential tool for researchers doing everything from remote scientific expeditions to the furthest arctic regions to complex population surveys of wildlife habitats.

Furthermore, when it comes to environmental surveillance, UAVs are sustainability's best friends because UAVs make it possible to measure air pollution and ecological dynamics precisely. These aerial sentinels, outfitted with cutting-edge sensors and imaging technology, offer priceless insights about environmental health, assisting politicians and conservationists in their efforts to protect our world. Grodzki & Łukaszewicz [8] have documented that the proliferation of UAVs heralds an era where unmanned aircraft transcend conventional boundaries to deliver innovation and impact across multifaceted domains, from research to conservation, from defence to exploration. This represents a paradigm shift in aviation.

A paradigm change in industrial engineering has been sparked by the widespread use of fibre-reinforced plastic composite materials, which has led practitioners to reconsider conventional design and manufacturing techniques. To satisfy the changing needs of contemporary markets, industrial engineers are using these cutting-edge materials more and more, with a focus on cost-effectiveness and quick manufacturing. UAVs are one field where demand for creative solutions is rising. Composite materials become essential components in the pursuit of high-performance aircraft as the need for cargo-efficient, manoeuvrable UAVs grows. These materials have a special combination of qualities that make them stand out, especially in terms of strength-to-weight ratios, which are crucial for designing UAVs with maximum performance.

Kassapoglou [9] highlighted the critical significance of composite materials in defining the next generation of UAVs, emphasizing the importance of high-strength and lightweight construction. Composite materials have double the Young's modulus of traditional metals and aluminium alloys, providing unmatched structural stability at the lowest possible weight. However, careful consideration of several issues beyond mechanical qualities is required when integrating composite materials into UAVs design. The importance of characteristics including vibration damping, thermal and acoustical insulation, corrosion resistance, and stiffness is emphasized by Chung [10]. These complicated factors highlight how difficult it is to design UAVs so that performance goals are balanced with reliability, durability, and operational viability. Fundamentally, the use of composite materials in UAVs production is a result of the fusion of engineering creativity and technological innovation, propelling aerial platforms' advancement towards previously unheard-of levels of effectiveness, agility, and adaptability in the dynamic field of aerospace exploration and application.

3. Methodology

This study mainly focused on the development of the military tactical surveillance UAVs by Company XYZ. Primary data were those that were gathered specifically for the study subject at hand, utilizing methods that were most appropriate for the problem. Every time primary data was gathered, new information was contributed to the body of social knowledge already in existence. This included case study, semi structured interview, field observation, focus group discussion and selection method namely analytical hierarchy process (AHP) and quality function deployment (QFD). Meanwhile, it was easy and simple to obtain secondary data from an official data archive. This included document reviews, journal or articles and books. The data collected for this study solely relied on the methods mentioned before and from the real-world case from Company XYZ.

The goal of the data collection process was to examine and comprehend the fundamentals of the UAVs development for military tactical surveillance and reconnaissance. A survey of the literature review and precious UAVs development efforts by other companies were used to conduct a complete investigation. There were evidences from the case study that used fixed wings and rotary wings, the material selection and design and each of them have benefits and drawbacks. The aerodynamics of UAVs determined their maximum take-off weight, drag force, and stability during flight, all of which were influenced by their design. This project demonstrated how the upgraded UAVs for military had their own system and component integration for the user's convenience. Given that it was intended for surveillance purposes in military sector, choosing the right design, material and engine was important. There was also the data for the testing of the flight done to see how reliable the flight.

Selection method that was used in this study were AHP and QFD. AHP and QFD were utilized to develop a thorough framework for military UAVs material selection. While QFD converts customer and engineering needs into material properties, AHP assists in prioritizing and quantifying these. A methodical, multi-criteria assessment for the best choice of UAVs airframe material is ensured by this comprehensive approach. All the criteria that were needed to fulfil the requirements usage of the methods were determined by experts and professional workers that specialized in UAVs. A list of important parameters was determined in a focus group discussion.

3.1 AHP

AHP was a widely used multi-criteria decision-making technique that uses pairwise comparison to establish the priority of options and the weights of criteria in an organised way [11][12].The method started with the structure of problems and objectives in this study and was presented in a hierarchical structure as in Figure 1. In determining the selection of material, there would be four different types of AHP hierarchy. This included wing, propellor, tail and body. In Figure 1, the criteria that was considered for wing were aerodynamic efficiency, weight, strength and fatigue resistance while the alternatives were carbon fibre, fiberglass composites and aluminium as UAVs required careful selection of materials that are lightweight and strong [13].

The method proceeds with the computing weight vector of the criteria selected by the experts and professionals. The suggestion of weight is such as numerical scale 1, 3, 5, 7 and 9 for equally important, weakly important, moderately important, very important and extremely important respectively.

The consistency index, CI and the consistency ratio, CR are calculated using Eq. 1 and Eq. 2. The value of λ_{max} is calculated using the multiplication matrix by multiplying the pairwise comparison score with priority vector.

$$D = \begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ m & n & o & p \end{bmatrix} \times \begin{bmatrix} r \\ s \\ t \\ u \end{bmatrix}$$

The λ or EI values is calculated by dividing the D values with priority vector. λ_{max} is calculated by taking the average of all λ values. RI is the mean random consistency index or random index. The value of RI depends on the number of criteria used in the hierarchy.

The value of CR is supposed to be less than ten percent to show that the weight given and judgements are consistent and acceptable.

$$CI = \frac{\lambda \max - n}{n - 1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

The score matrix of alternatives, S with be calibrated and the global alternatives scores will be obtained using Eq. 3.

$$V = SW \quad (3)$$

where S is the score matrix and W is the weight vector. The priority of alternatives will depend on the global score whereby the highest score will be selected.

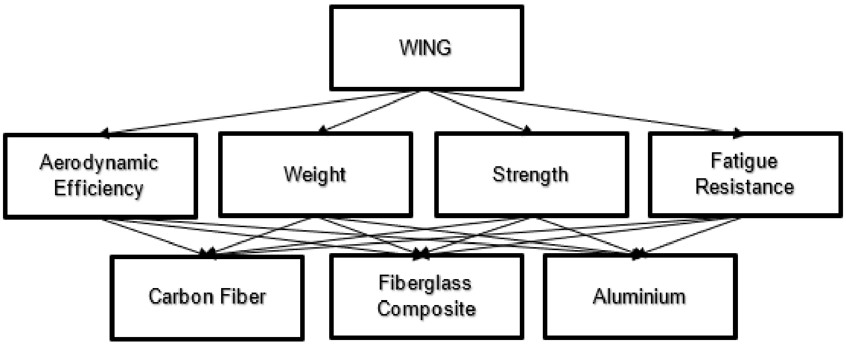

Fig. 1. AHP diagram for Wing Material Selection

In Figure 2, it was to determine the selection of material for propellor, the key elements were aerodynamic efficiency, corrosion resistance, strength and fatigue resistance while the alternatives were carbon fibre, fiberglass composites and aluminium.

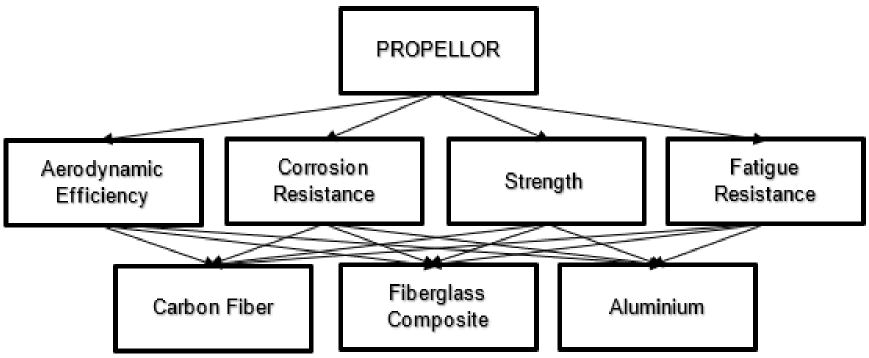

Fig. 2. AHP diagram for Propellor Material Selection

Figure 3 displays the three-level hierarchy process with selection of material for tail as its goal. The key elements or criteria considered were aerodynamic efficiency, corrosion resistance, strength and fatigue resistance. The alternative material for tail were titanium, fiberglass composite and aluminium.

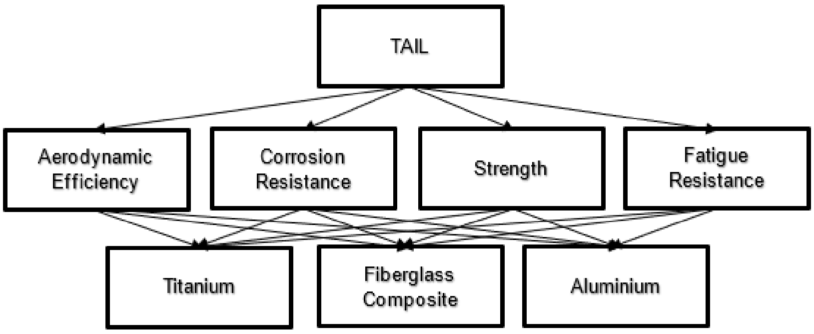

Fig. 3. AHP diagram for Tail Material Selection

Figure 4 showed the level 3 AHP that was used to determine the material selection for body while considering the criteria such as aerodynamic efficiency, lightweight, strength and fatigue resistance. The alternatives for the body's material were stainless steel, fiberglass composite and aluminium.

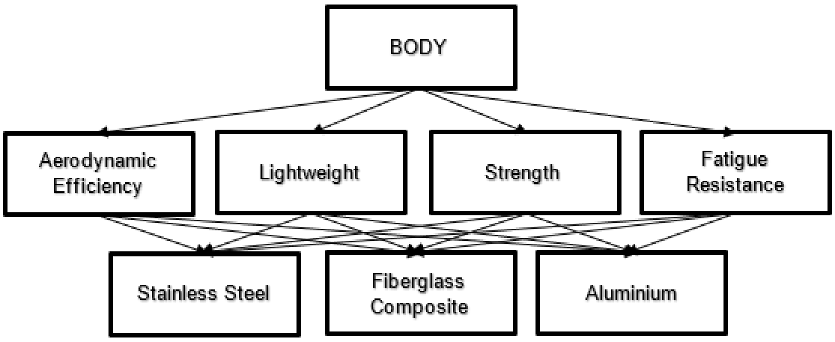

Fig. 4. AHP diagram for Body Material Selection

3.2 QFD

QFD was a methodical and structured approach in planning and product development [14]. The development team precisely identified the needs and desires of the target market. When using the QFD method to the product design process, the first step was to create a matrix, often known as the House of Quality (HoQ). When a customer requested a technical response to meet their needs, HoQ showed their voice to the customer (VOC). In this study, HoQ was used to determine the prioritization of design process and to select the best materials for UAVs. Figure 5 showed the HoQ for design of UAVs with the customer requirements namely aerodynamics performance, payload capacity, structural integrity, easy to manufacture and environmental considerations including its sustainability. As the study progressed, the preliminary requirements were improved and clarified as the study went on to better suit the material selection procedure. Technical requirements such as wing shape, surface smoothness, material selection, payload capacity, environmental considerations and manufacturing process were identified to have a greater impact on material characteristic required for the best UAVs performance. This improvement made it possible to choose the best materials for UAVs airframes through a more thorough and focused assessment. Figure 5 showed the HoQ to determine the prioritization of selecting the best materials for UAVs. In this HoQ, the technical requirements were aerodynamic, lightweight, strength, corrosion resistance and payload resistance. All the criteria were analyzed for its primary requirements such as wing, propellor, tail and body. The figures presented were an overview of the process and stages of developing new UAVs. The best design and material selected for each component in UAVs were analyzed and examined properly through proper method.

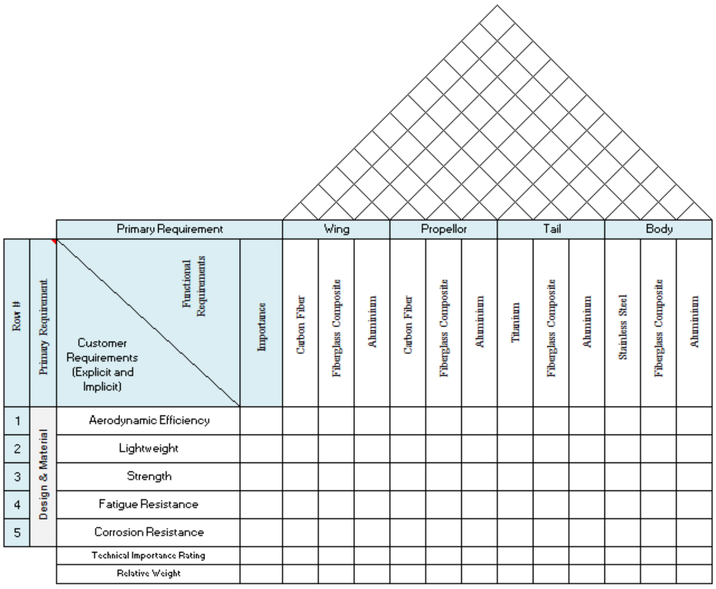

Fig. 5. HoQ for Material selection

4. Results

4.1 AHP for Material Selection

The AHP was used to evaluate the material selection for critical components of an unmanned aerial vehicle, including the wing, propellor, body and tail. The analysis considered key material options such as aluminum, titanium, fiberglass composite, carbon fiber and stainless steel. Based on factors such as weight, strength, corrosion resistance, cost and manufacturability. This systematic approach ensured optimal material choices to enhance the UAV's performance, durability and efficiency while meeting design and operational requirements. The goal of the AHP was to prioritize materials for UAVs production, recognizing the critical role of material selection in determining manufacturing success and overall performance. The criteria for evaluation were established based on expert input during a focus group discussion. The materials considered as alternatives in the AHP process included titanium, carbon fiber, fiberglass composite, aluminum and stainless steel. Material selection was vital in UAVs development as it directly affected factors such as structural integrity, weight, durability, cost and manufacturability.

4.1.1 AHP for Material-Wing

The pairwise comparison of criteria for UAV material selection was shown in Table 1. When comparing identical criteria, such as aerodynamic efficiency vs aerodynamic efficiency, the value was set to 1 as neither criterion holds superiority over the other. For comparison between different criteria, the value represented the ratio of the row criterion to the column criterion.

Table 1
Pairwise Comparison for Wing

Criteria	Aerodynamic Efficiency	Weight	Strength	Fatigue Resistance
Aerodynamic Efficiency	1	2	4	5
Weight	1/2	1	3	4
Strength	1/4	1/3	1	2
Fatigue Resistance	1/5	1/4	1/2	1

The weights of the criteria were further calculated using the scale finalized in Table 2. The weight was the sum of the individual criteria's weight in each column shown.

Table 2
Sum of Column Criteria's Weight (Wing)

	Aerodynamic Efficiency	Weight	Strength	Fatigue Resistance
Sum	1.95	3.58	8.50	12

Each score was divided by the sum of its corresponding column to get the normalized pairwise comparison results, which were shown in Table 3. By ensuring uniform scale across all criteria, this normalization made comparison relevant. All calculations were performed in advance using Microsoft Excel, which enabled precise computation and efficient organization of the data for further analysis.

Table 3
Normalized Pairwise Comparison (Wing)

Criteria	Aerodynamic Efficiency	Weight	Strength	Fatigue Resistance
Aerodynamic Efficiency	0.51	0.56	0.47	0.42
Weight	0.26	0.28	0.35	0.33
Strength	0.13	0.09	0.12	0.17
Fatigue Resistance	0.10	0.07	0.06	0.08

The average of each row was calculated. The result was equivalent to the priority vector in Table 4.

Table 4
Arithmetic Average (Priority Vector for Wing)

Column	Average
Aerodynamic Efficiency	0.49
Weight	0.31
Strength	0.13
Fatigue Resistance	0.08

As shown in Table 4, the finalized weight was determined accordingly. Based on the results, aerodynamic efficiency emerged as the most important criterion. Next was followed by weight, strength and lastly fatigue resistance. These findings were utilized to verify the consistency of the response. The key parameters involved in this process were the compliance index (CI), random value index (RI) and compliance rate (CR). To calculate the value of CI, it was necessary to calculate λmax which in turn required the values of the D column vector and EI values. The D column vector was obtained by multiplying the arithmetic average or priority vector with the elements of the initial pairwise comparison matrix. The calculation was simplified and is represented in the matrix below. The EI values were calculated by dividing the D column vector by the priority vector.

$$D = \begin{bmatrix} 1 & 2 & 4 & 5 \\ 1/2 & 1 & 3 & 4 \\ 1/4 & 1/3 & 1 & 2 \\ 1/5 & 1/4 & 1/2 & 1 \end{bmatrix} \times \begin{bmatrix} 0.49 \\ 0.31 \\ 0.13 \\ 0.08 \end{bmatrix}$$

$$D = \begin{bmatrix} 2.03 \\ 1.27 \\ 0.51 \\ 0.32 \end{bmatrix}$$

The result of the calculation was labeled as D columns vector in Table 5.

Table 5
Calculation Results (Wing)

Criteria/Criteria	Priority Vector	D columns vector	EI values
Aerodynamic Efficiency	0.49	2.03	4.14
Weight	0.31	1.27	4.10
Strength	0.13	0.51	3.92
Fatigue Resistance	0.08	0.32	4.00

Hence,
λ_{max} = 4.14 + 4.10 + 3.92 + 4.00 / 4
λ_{max} = 16.16 / 4
λ_{max} = 4.04

To calculate the CI,
CI = $\frac{\lambda \max - n}{n-1}$, where the n is the number of criteria.

CI = $\frac{4.04 - 4}{4-1}$

CI = 0.0133

To calculate CR,
CR = CI / RI
The value of RI was determined by Table 6.

Table 6
Random Index [15]

Matrix Size	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The value of RI is 0.90 since there were four criteria. Hence,
CR = 0.0133 / 0.90
CR = 0.015 ~ 1.5 %
The result of CR was 1.5%. The acceptable inconsistency in AHP was below 10%.

4.1.2 AHP for Material – Propellor

The pairwise comparison of criteria for UAVs material selection was shown in Table 7.

Table 7
Pairwise Comparison for Propellor

Criteria	Aerodynamic Efficiency	Corrosion Resistance	Strength	Fatigue Resistance
Aerodynamic Efficiency	1	4	5	7
Corrosion Resistance	1/4	1	3	5
Strength	1/5	1/3	1	3
Fatigue Resistance	1/7	1/5	1/3	1

The average of each row was calculated. The result was equivalent to the priority vector in Table 8.

Table 8
Arithmetic Average (Priority Vector) for Propellor

Column	Average
Aerodynamic Efficiency	0.58
Weight	0.24
Strength	0.12
Fatigue Resistance	0.06

Hence,
CR = 0.0667 / 0.90
CR = 0.074 ~ 7.40%
The result of CR was 7.40 %. The acceptable inconsistency in AHP was below 10%.

3.1.3 AHP for Material – Tail

The pairwise comparison of criteria for UAV material selection was shown in Table 9.

Table 9
Pairwise Comparison for Tail

Criteria	Aerodynamic Efficiency	Corrosion Resistance	Strength	Fatigue Resistance
Aerodynamic Efficiency	1	2	3	4
Corrosion Resistance	1/2	1	2	4
Strength	1/3	1/3	1	3
Fatigue Resistance	1/4	1/4	1/2	1

The average of each row was calculated. The result was equivalent to the priority vector in Table 10.

Table 10
Arithmetic Average (Priority Vector) for Tail

Column	Average
Aerodynamic Efficiency	0.46
Corrosion Resistance	0.29
Strength	0.16
Fatigue Resistance	0.09

Hence,
CR = 0.04 / 0.90
CR = 0.044~ 4.40%
The result of CR was 4.40%. The acceptable inconsistency in AHP was below 10%.

4.1.4 AHP for Material – Body

The pairwise comparison of criteria for UAV material selection was shown in Table 11.

Table 11
Pairwise Comparison for Body

Criteria	Aerodynamic Efficiency	Weight	Strength	Fatigue Resistance
Aerodynamic Efficiency	1	3	4	6
Weight	1/3	1	3	5
Strength	1/4	1/3	1	3
Fatigue Resistance	1/6	1/5	1/3	1

The average of each row was calculated. The result was equivalent to the priority vector in Table 12.

Table 12
Arithmetic Average (Priority Vector) for Body

Column	Average
Aerodynamic Efficiency	0.53
Weight	0.28
Strength	0.13
Fatigue Resistance	0.06

Hence,
CR = 0.0467 / 0.90
CR = 0.052 ~ 5.20%
The result of CR was 5.20%. The acceptable inconsistency in AHP was below 10%.

4.2 QFD for Material

The determination of the material selection for UAVs involved gathering insight from the customer's requirements, which referred to professionals working in the UAVs sector at Company XYZ. This was done through focus group discussions where experts shared their needs, preferences, and experiences related to UAVs

Material selection for UAVs was further refined through the AHP, which established a hierarchy including, strength, lightweight, aerodynamic efficiency, corrosion resistance, and fatigue resistance. The importance score used in HoQ were based on the priority vector calculated in the AHP. Since there were four different parts, the values were summarized in Table 13.

Table 13
Summary of Priority Vector

Customer Requirement	Parts				Total Priority
	Wing	Propellor	Tail	Body	
Aerodynamic Efficiency	0.49	0.58	0.46	0.53	2.06
Lightweight	0.31	-	-	0.28	0.59
Strength	0.13	0.12	0.16	0.13	0.54
Fatigue Resistance	0.08	0.06	0.09	0.06	0.29
Corrosion Resistance	-	0.24	0.29	-	0.53
				TOTAL	4.01

The new importance was calculated using Eq. 4 of normalization from Bhattacharya *et al*. [16].

$$wj = \frac{Pj}{\sum Pj} x100 \tag{4}$$

The final importance was listed in Table 14 and the HoQ was shown in Figure 6.

Table 14
Importance for HoQ

Customer Requirement	Importance
Aerodynamic Efficiency	51
Lightweight	15
Strength	14
Fatigue Resistance	7
Corrosion Resistance	13

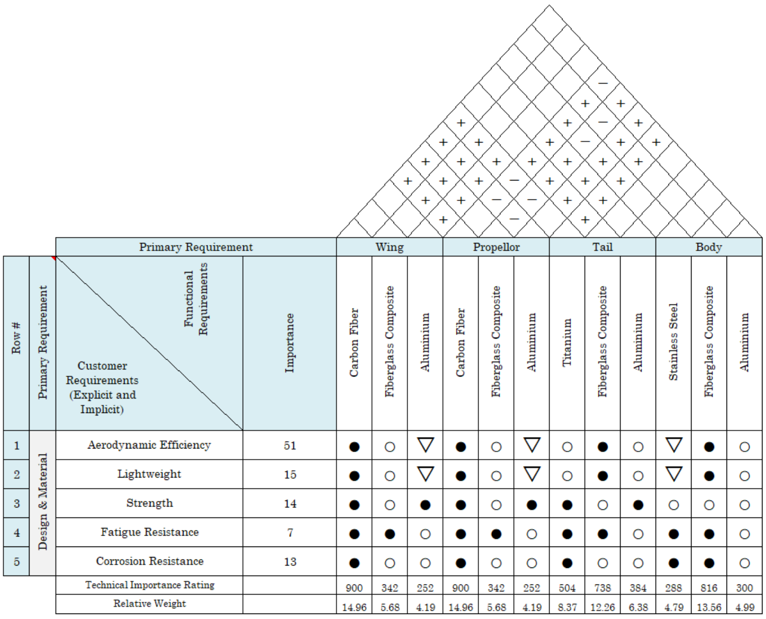

Fig. 6. HoQ for Material Selection

From previous study, aluminium matrix composites had a characteristic of low density, high specific strength, high thermal conductivity, and abrasion resistance, making them ideal for advanced structural, automotive, and aerospace applications [17]. Apart from that, fiber-reinforced polymer composites were always considered as UAVs application due to their outstanding strength which was preferrable in UAVs material [18].

The results as in Figure 7 reflected the effectiveness of the integrated framework [19]. Resisting the aerodynamics load of UAVs while being in the for a long time required lightweight and high strength material [20]. Carbon fibre reached the maximum overall score due to its high aerodynamic efficiency and being light in weight for wing. Carbon fibre was also chosen for propellors for its excellent fatigue resistance and efficiency, as long-lasting propulsion systems are preferred by users. In the case of the body and tail, fiberglass composite showed the best performance, as it balanced the aerodynamic efficiency with strength and resistance to corrosion. QFD analysis also justified this choice, highlighting the requirement for low-cost and durable materials. These results proved that AHP and QFD, if integrated, provided a more balanced consideration of technical, operational, and customer-focused factors toward well-rounded material decisions [21].

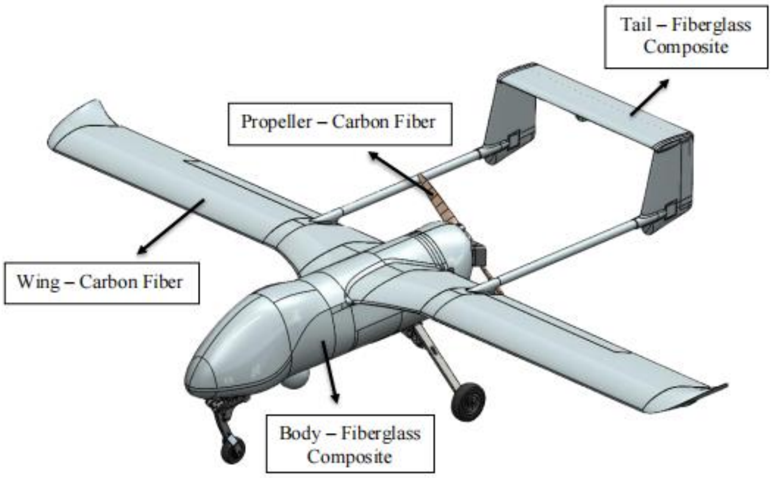

Fig. 7. Selected Material Used for Each Part

5. Conclusions

The study indicated that carbon fiber and fiberglass composites were the best materials for UAV development due to their exceptional mechanical properties. Carbon fiber had a higher strength-to-weight ratio, making it ideal for applications that required high performance aerodynamics and durability. Fiberglass composite, with its excellent corrosion resistant and cost-effectiveness complements carbon fiber in environments requiring exposure to diverse operational conditions. Kassapoglou [9] highlighted the critical significance of composite materials in defining the next generation of UAVs, emphasizing the importance of high-strength and lightweight construction. Additionally, it was discovered that these materials improved UAV resilience under varying stresses including fatigue and environmental wear which was important for both military and civilian uses. They are the standard materials in contemporary UAV manufacturing due to their broad availability and versatility, making them the benchmark materials in modern UAV manufacturing.

Refining production techniques and implementing innovative materials were essential to improving UAVs manufacturing even more. By offering an integrated QFD-AHP framework designed specifically for material selection in military UAVs, this study contributed to the field. It allowed for a systematic and impartial decision-making process by bridging the gap between engineering standards and client requirements. This study illustrated the framework's usefulness and applicability for upcoming aerospace design and material evaluation projects by using it on an actual UAVs airframe case. Future studies should explore the potential of hybrid composites and emerging lightweight alloys to complement existing materials like carbon fiber and fiberglass. Additional advantages like improved impact resistance and thermal stability may be offered by these materials, making UAVs more versatile in extreme operating conditions. The importance of characteristics including vibration damping, thermal and acoustical insulation, corrosion resistance, and stiffness was emphasized by Chung [10]. Another concern that should be emphasized was regulatory compliance, which ensured that the choice of materials and the methods of manufacturing adapt to the changing requirements and standards for UAVs. It was essential to create cross-sectoral partnerships between industry representatives, authorities and research organizations to solve problem of UAV designing and their production.

Acknowledgment
The authors extend their gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for their financial support.

References

[1] Hentati, Aicha Idriss and Lamia Chaari Fourati, "Comprehensive Survey of UAVs Communication Networks," Computer Standards & Interfaces 72, (June 2, 2020): 103451. https://doi.org/10.1016/j.csi.2020.103451

[2] Ritu Maity, Ruby Mishra, Prasant Kumar Pattnaik and Anish Pandey, "Selection of sustainable material for the construction of UAV aerodynamic wing using MCDM technique," Materials Today: Proceedings 1, no. 1 (2023): 2214-7853. https://doi.org/10.1016/j.matpr.2023.12.025

[3] Adnan Wardatul Hayat and Mohd Fadly Khamis, "Drone Use in Military and Civilian Application: Risk to National Security," Journal of Media and Information Warfare 15, no 1 (2022): 60-70. https://jmiw.uitm.edu.my/images/Journal/Vol15No1/5-Drone-Use-in-Military-and-Civilian-Application-Risk-to-National-Security.pdf

[4] Dutta Gopal and Purba Goswami, "Application of Drone in Agriculture: A Review," International Journal of Chemical Studies 8, no. 5 (2020): 181–187. https://doi.org/10.22271/chemi.2020.v8.i5d.10529

[5] Theobald, Catherine J. Lewis, "Soaring Imaginations: The First Montgolfier Ballooning Spectacle at Versailles in Word and Image," Lumen Selected Proceedings From the Canadian Society for Eighteenth-Century Studies 39 (May 14, 2020): 23–53. https://doi.org/10.7202/1069403ar

[6] Yoo, Lee-Sun, Jung-Han Lee, Yong-Kuk Lee, Seom-Kyu Jung and Yosoon Choi, "Application of a Drone Magnetometer System to Military Mine Detection in the Demilitarized Zone," Sensors 21, no. 9 (May 3, 2021): 3175. https://doi.org/10.3390/s21093175

[7] Al-Zahrani, Ali Y, "Unauthorized Drones: Classifications and Detection Techniques," International Conference on Systems and Control, (December 18, 2023): 548–55. https://doi.org/10.1109/icsc58660.2023.10449795

[8] Grodzki, W. and A. Łukaszewicz, "Design and Manufacture of Umanned Aerial Vehicles (UAV) Wing Structure Using Composite Materials," Materialwissenschaft Und Werkstofftechnik 46, no. 3 (March 1, 2015): 269–78. https://doi.org/10.1002/mawe.201500351

[9] Kassapoglou Christos, Design and Analysis of Composite Structures : With Applications to Aerospace Structures (New York: John Wiley & Sons., 2010), 1. https://doi.org/10.1002/9780470972700

[10] Deborah D. L. Chung, Composite Materials : Science and Applications (London: Springer, 2010).

[11] Santos, Marcos Dos, Igor Pinheiro De Araujo Costa and Carlos Francisco Simões Gomes, "Multicriteria Decision-Making In The Selection Of Warships: A New Approach To The Ahp Method," International Journal of the Analytic Hierarchy Process 13, no. 1 (May 19, 2021): 147-169. https://doi.org/10.13033/ijahp.v13i1.833

[12] Canco, Irina, Drita Kruja and Tiberiu Iancu, "AHP, a Reliable Method for Quality Decision Making: A Case Study in Business," Sustainability 13, no. 24 (December 16, 2021): 13932. https://doi.org/10.3390/su132413932

[13] Yilmaz, M. Atif, Kemal Hasirci, Berk Gündüz and Alaeddin Burak Irez, "Advanced Composite Wing Design for Next-generation Military UAVs: A Progressive Numerical Optimization Framework," Defence Technology 1, no. 1 (February 1, 2025): 2215-91477. https://doi.org/10.1016/j.dt.2025.02.020

[14] Mina-Raiu Laura, Viorela Negreanu and Cătălin Valentin Raiu, "Improving Local Public Administration Responsiveness to Citizens' Needs Using Quality Function Deployment," Romanian Statistical Review 2, no. 1 (2023): 53-65.

[15] Saaty, R.W., "The Analytic Hierarchy Process—What It Is and How It Is Used," Mathematical Modelling 9, no. 3–5 (January 1, 1987): 161–76. https://doi.org/10.1016/0270-0255(87)90473-8

[16] Bhattacharya, Arijit, Bijan Sarkar and Sanat Kumar Mukherjee, “Integrating AHP With QFD for Robot Selection Under Requirement Perspective,” International Journal of Production Research 43, no. 17 (September 1, 2005): 3671–3685.
https://doi.org/10.1080/00207540500137217

[17] Hasan, Touhid, Ma Wadud, Mahmudul Hasan Niaz, Md. Kutub Uddin and Md Shariful Islam, “Fabrication and Characterization of Rice Husk Ash Reinforced Aluminium Matrix Composite,” Malaysian Journal on Composites Science and Manufacturing 14, no. 1 (July 29, 2024): 34–43.
https://doi.org/10.37934/mjcsm.14.1.3443

[18] Haydar Uz Zaman, “The Influence of Process Parameters on Tensile Properties of Vetiver Fiber-Reinforced Polymer Matrix Composites,” Malaysian Journal on Composites Science and Manufacturing 15, no. 1 (2024): 13-24. https://doi.org/10.37934/mjcsm.15.1.1324

[19] Tanasić Zorana, B. Kecman and Goran Janjić, “QFD Method-A Model For Product Improvement And Development,” Annals of the Faculty of Engineering Hunedoara- International Journal of Engineering 19, no. 4 (2021): 75-80. https://annals.fih.upt.ro/pdf-full/2021/ANNALS-2021-4-09.pdf

[20] Shria Anand and Ankit Kumar Mishra, “High-Performance Materials used for UAV Manufacturing: Classified Review,” International Journal of All Research Education and Scientific Methods 10, no. 7 (2022): 2811-2819. https://www.ijaresm.com/uploaded_files/document_file/Ankit_Kumar_MishraKQuJ.pdf

[21] Ginting Rosnani, Aulia Ishak, Alfin Fauzi Malik and M. Riski Satrio, “Product Development with Quality Function Deployment (QFD): A Literature Review,” IOP Conference Series: Materials Science and Engineering 1003, no. 1 (2020): 012022.
https://doi.org/10.1088/1757-899X/1003/1/012022