Analyzing Fixed-Wing Drone Design and Evaluating Financial Viability in Unmanned Aerial Vehicle

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***Abstract*— This study explores the growing role of drones in advanced air mobility applications within urban areas, addressing their significance in tasks such as traffic surveillance, aerial photography, and delivery. With the rapid expansion of the Unmanned Aerial Vehicle (UAV) industry, understanding the financial implications of drone operations is crucial. The study focuses on large fixed-wing UAVs, known for extended endurance and heavy payload capacities, which are crucial for missions involving long distances and significant cargo transport. This research emphasizes analyzing the relationship between payload weight, range, and takeoff weight to assess operational costs and fees. It introduces a comprehensive equation that incorporates key parameters like vehicle energy efficiency and weight efficiency coefficient, serving as a tool for stakeholders to evaluate mission-specific financial impacts and make informed decisions in areas like resource allocation, mission planning, and decision-making. By offering data-driven insights, the study assists stakeholders in optimizing their UAV technology investments for both mission success and financial efficiency. While specifically considering drones with 4-stroke or Wankel engines, the principles outlined possess the potential to improve cost-effective UAV operations across diverse contexts and applications.**

Keywords*— *Unmanned Aerial Vehicle; UAV economics; Cost estimation; Fixed-wing drones

I. INTRODUCTION

Advanced air mobility applications are widely observed in urban areas for activities such as traffic surveillance, aerial photography, and delivery. It has been expected that drone activities in urban areas will continue to rise. The Unmanned Aerial Vehicle (UAV) industry has significantly grown over recent decades, with drones serving diverse roles, such as traffic monitoring, photography, and weather prediction [1]. These drones are vital to Urban Air Mobility (UAM) and feature in plans for future smart cities. As UAVs continue to play an increasingly crucial role in civil and military applications, there is a growing need to assess the financial consequences of their operations. The configuration and performance parameters are computed based on the needed payload and range as primary inputs. Two key parameters, vehicle energy efficiency (measured as a specific range per unit fuel weight) and weight efficiency coefficient (a comparison of useful load to take-off weight), are employed to determine the UAV's takeoff weight. One of the key factors influencing the cost and feasibility of UAV missions is the relationship between payload weights (Wpl), range, and take-off weight (Wto) [2].

Large fixed-wing UAVs, characterized by their extended endurance and greater payload capacity, are particularly relevant for missions requiring long distances or heavy equipment transport. It is crucial to understand how these factors interact to determine the operational fees and costs of these UAVs. This understanding is essential for efficient resource allocation, mission planning, and decision-making. A model for evaluating risk in efficiently planning UAV paths within urban areas has been investigated by Hu et al. [3]. The total risk assessment model quantitatively included risk distribution in urban environments for UAV path planning, while the risk-cost method generated cost-effective paths for safe UAV operations. Risk costs are highest in downtown areas due to controlled route changes compared to airport surroundings. Incorporating more risk types improves path planning outcomes, and the approach's applicability to complex urban environments is suggested through parameter and data integration in future work [3]. The study by Chang [4] focused on estimating the cost of rerouting for drones during waypoint flight plans, considering real-time route changes through the Internet. An algorithm was proposed to predict rerouting costs based on flight direction and drone speed. The algorithm's accuracy was verified by comparing estimated flight time, including rerouting costs, with actual flight time after changing waypoints multiple times. Experimental flight trials were conducted on various routes with up to five waypoints and five reroutings, showing that the modified algorithm achieves over 92% accuracy in rerouting cost estimation during multiple rerouting scenarios.

While UAVs excel in rough territory and adverse weather, their increased sensor capabilities increase costs. Despite drawbacks, they can operate effectively in field conditions such as mountainous, forested, or land covered with vegetation, where planes and satellites fall short. For instance, the US uses Predator B drones with an 18 million-dollar procurement cost and 3,234 dollars/hour operational cost, while Turkey employs Heron drones with a nearly 16 million-dollar procurement cost and almost 4,000 dollars/hour operational cost [5]. This demonstrates the trade-off between procurement and operational expenses. However, due to the significant importance of national defense, countries dealing with terrorism occasionally prioritize security over costs, as seen in the case of Turkey [5].

Typically, UAV designs are tailored to suit specific mission requirements, resulting in a demand for diverse forms, dimensions, propulsion setups, and sensor combinations. Calculating their cost necessitates accounting for distinct work breakdown structure (WBS) components that go beyond those of a manned aircraft system [6]. The Cognitive Engineering Research Institute (CERI) addressed UAV myths and automation realities, cautioning that overlooking these aspects during estimation can skew cost projections:

• The term "unmanned" doesn't necessarily imply a lack of control

• Comparisons to piloting ignore extensive research on factors like time delay, diminished visual cues, depth perception, and functions beyond flight (re-tasking, replanning, sensor operation)

• Operators (pilots) are remote but play an active role in UAV operation

• Costs on the ground (equipment, personnel, training) currently exceed vehicle-related savings

• The control task entails more than just monitoring and managing aircraft position

• UAVs are not only vehicles but also comprehensive systems comprising vehicles, ground control, air operations, operators, intelligence, weather, personnel, payload operators, maintainers, etc.

Numerous UAV groups and classifications are in existence. Common categories are introduced, followed by an estimation framework that outlines specific considerations for estimating the above-mentioned aspects [6].

By developing a comprehensive equation, that considers payload weight, range, and take-off weight, the present study aims to provide an innovative and essential tool for evaluating the financial implications of UAV operations. This model can potentially revolutionize market strategies and project planning, providing stakeholders with data-driven insights that enhance decision-making and operational efficiency. The primary goal of this research is to develop a comprehensive formula that assesses the impact of payload weight and range on the operational costs and fees associated with large fixed-wing UAVs. Simultaneously, the formula will admit the significance of take-off weight in this context. The resulting formula will provide a valuable tool for UAV operators, manufacturers, and stakeholders, allowing them to analyze mission-specific financial implications and adjust their strategies accordingly. This paper presents the analysis method, theoretical foundations, and practical insights from the study's findings. This research illuminates the financial intricacies of large fixed-wing UAV operations, aiding the understanding of UAV economics and guiding decisions for operational efficiency and cost-effectiveness in missions. This understanding helps organizations optimize their UAV technology investment, achieving mission success and cost-effectiveness. Please note that these guidelines are specifically designed for drones using 4-stroke or Wankel engines.

II. Preliminary Research

A. *Basics of UAV Designing and Measurements (Aerodynamic)*

Before beginning, it is necessary to understand the basic definitions of Aircraft and UAV Aerodynamic design.

Weight of an aircraft = Assume weight including Structure and Payload.

Wing geometry = Wing geometry plays a crucial role in determining the flight performance, stability, maneuverability, and efficiency of the UAV.

"***Wing loading***" is the parameter that determines the level surface needed to lift the critical load (Fig. 1). Wing loading can be determined according to Equation 1.

Wing loading=Weight/(Surface Area) (eq.1)

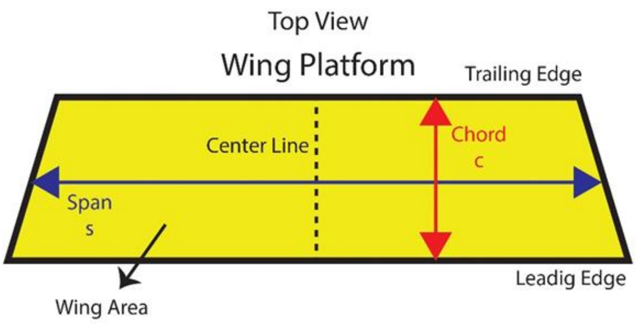

Fig. 1. *Top view of wing platform.*

"***Aspect ratio***" determines the distribution of the wing area (eq.2). The aspect ratio varies from 6 to 8 based on requirements such as stability, speed, wing shape, engine location, and engine type.

$$\text{Aspect Ratio} = \frac{Span^{\ 2}}{Chord} \qquad \text{(eq.2)}$$

In addition to the rectangular wings, there are various "***Wing shapes***" to choose from. Format selection is based on speed, stability, performance requirements, and manufacturability. The method of wing installation to ensure lateral stability as the aircraft initiates rolling movements is known as the "***Dihedral Angle***" (Fig. 2a). The "***Sweepback Angle***" denotes the angle reached by the wing, ensuring stability around the horizontal axis. A sweep angle between 2 to 3 degrees suits smaller drones, with flexibility based on construction complexity (Fig. 2b).

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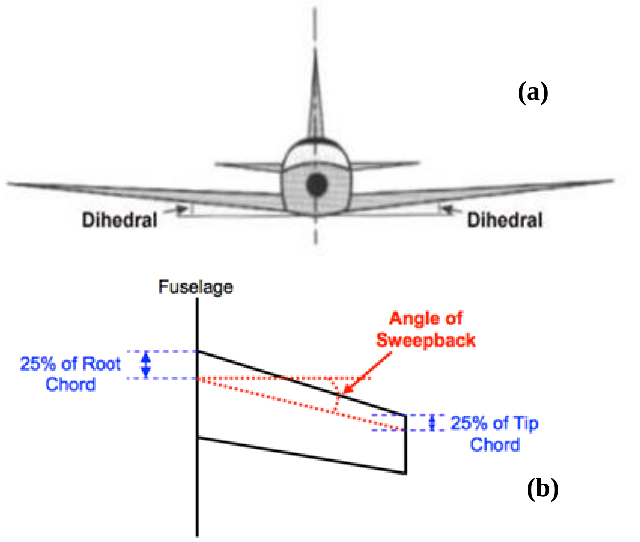

Fig. 2. *Wing parameters (a) Dihedral Angle, (b) Sweepback Angle.*

"***Wing Cross Section Shape (Airfoil Shape)***" is an imperative parameter. The selection of an airfoil carries substantial importance, as it directly influences lift production and flight characteristics. A variety of airfoils are available to address specific requirements, ranging from those suited for low-speed applications, particularly suitable for compact drones, to those optimized for high-speed and robust scenarios, specifically designed for Medium Altitude Long Endurance (MALE) or High Altitude Long Endurance (HALE) drones. For example, flat-bottomed airfoils are suitable for small UAVs due to their ease of construction, while cambered airfoils are more appropriate for medium-sized UAVs. Additionally, there are alternative airfoil designs, one of which is illustrated in Fig. 3.

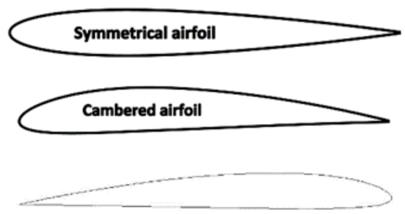

Fig. 3. *Various possible Wing Cross-Section Shapes (Airfoil Shapes).*

The Reynolds number is a dimensionless quantity used in fluid dynamics to predict the behavior of fluid flow around objects or within channels. It is named after Osborne Reynolds, who introduced the concept in the 19th century. The Reynolds number is a crucial parameter in determining the flow type a fluid will exhibit (laminar or turbulent) and how forces like viscosity and inertia will affect the fluid's behavior.

The Reynolds number was calculated using the data sourced from [15]. Furthermore, reference [16] was consulted for generating the NACA Airfoil Profile. The choice of the airfoil is determined by assessing its C_1 value (Lift Coefficient) based on the selected speed and angle of attack (α). To achieve this, it is necessary to refer to the C_1 Vs α graph corresponding to the particular speed (which aligns with the Reynolds number) (Fig. 4). The selected airfoil should generate sufficient lift to carry the designated weight. Equation 3 is employed to validate the suitability of the selected airfoil, where V represents velocity, S signifies the wing's surface area, and ρ denotes the air density. The value of V depends on the flight speed.

$$L = \frac{1}{2} C_{l\rho} V^2 S \qquad \text{(eq.3)}$$

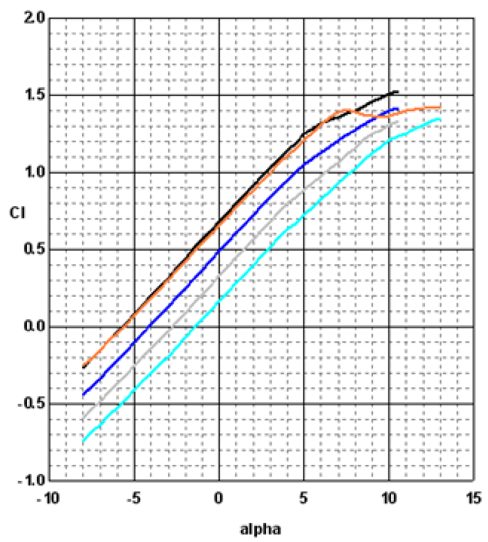

Fig. 4. *The graph of Lift Coefficient* (C_1) *Vs angle of attack* (α) *[17].*

Fuselage, Stabilizer, and Control Surface Geometry

The design process for Fuselage, Stabilizer, and Control Surfaces involves the utilization of individually calculated formulas by each manufacturer. This approach arises from the diverse and varying objectives and requirements of each product (Fig. 5). For standard wing shape, the length of the ***fuselage*** could be around 50% to 71% of the Span of the Wing. The ***horizontal stabilizer*** (tail) area is 18 to 24% of the Wing area. The ***vertical stabilizer*** area is 13 to 22% of the Horizontal Stabilizer area, and the shape of this element will not affect much on small size UAV performance.

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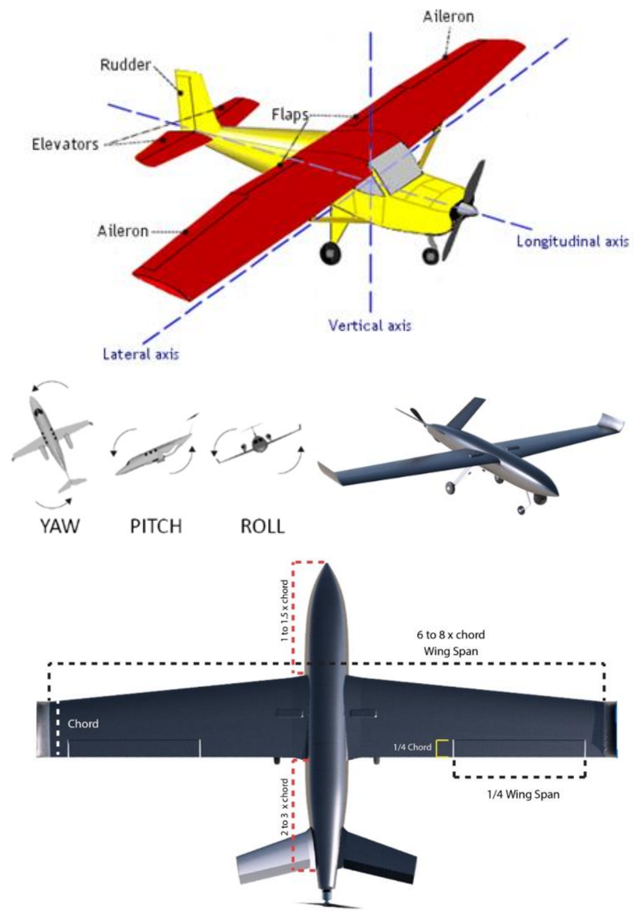

Fig. 5. *Standard Aerodynamic and Parametric Designs of Fixed Wing UAV.*

Main Control Surfaces are comprised of (1) an elevator, responsible for pitching the aircraft up and down; (2) a rudder, controlling yaw motion; and (3) an aileron, used for rolling the aircraft. After the first flight, these values can be fine-tuned according to control requirements. The alteration of these surfaces is achieved through the implementation of a four-bar mechanism and servos.

III. METHOD OF ANALYSIS

Several parameters are applicable for cost and fee computation in the context of developed fixed-wing UAVs and drones. This study endeavors to devise a formula based on the comparison of main design variables and the output function of individual UAV/drone components. The objective is to derive essential elements such as endurance, performance, and cost/value of UAVs. The formulation, developed in this study, is introduced to simplify the precision of cost estimation for both existing and ongoing UAV/drone projects, utilizing key attributes inherent to each designed UAV.

IV. THE DATA USED IN THE TREND ANALYSIS IS BASED ON AEROSONDE I [7], PREDATOR MQ-1 [8], TAM 5 [9], SHADOW 200 [10], HERMES 180 [11], HERMES 450 [12,13], HERMES 1500 [14].

V. FORMULATED EQUATION

This section contains formulations for measuring different parameters, including takeoff weight, wing span, length (fuselage), endurance speed, endurance time, engine power, engine capacity, engine weight, weight of fuel, and weight of airframe. Finally, a formula has been developed for the cost estimation of UAVs.

The calculation of ***takeoff weight*** is facilitated by Equation 4, which establishes a relationship between takeoff weight and payload weight multiplied by the distance in kilometers. This correlation is vividly illustrated in Fig. 6(a), where the data points follow the trendline with a high R-squared value of 0.966, thus affirming the accuracy of the formulated equation. Notably, a higher takeoff weight directly corresponds to an increased capability to cover extended distances efficiently. The calculation of takeoff weight (WTow) is carried out using the equation:

$$W_{Tow}=0.180\times(W_{Tow}\times W_{Plw})0.654=[Kg] \qquad \text{(eq.4)}$$

Here, W_{Tow} = Tow signifies the takeoff weight, and W_{Plw} = Wpl represents the payload weight in kilograms. It's essential to acknowledge that the range is expressed in kilometers.

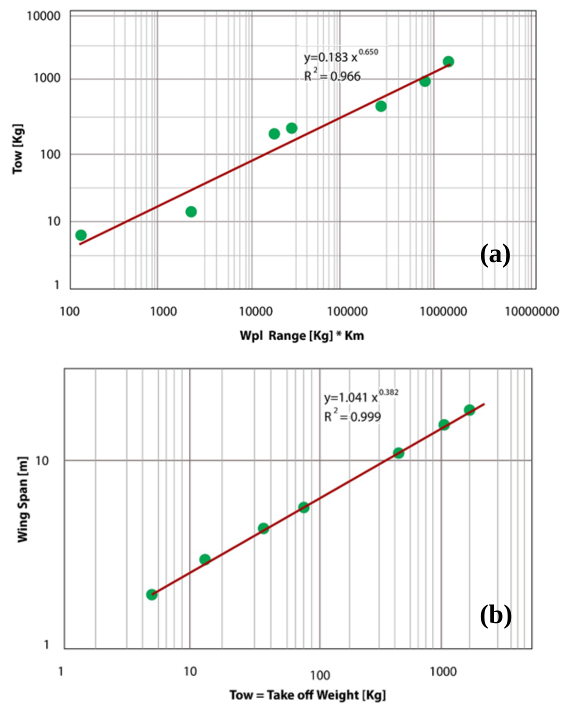

Fig. 6. *(a)WPL vs. Tow, (b) Wing span vs. takeoff weight.*

The wingspan of the drone can be determined using Equation 5, as demonstrated by the relationship depicted in Fig. 6(b). The equation's fitting to the data points is remarkable, indicated by a highly impressive R-squared value of 0.999. This

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observation confirms the reliability of the equation in predicting the wingspan of the drone accurately. The concept is straightforward, indicating that greater wing dimensions and an increased wing area could directly lead to an enhanced ability to lift payloads.

$$\text{Wingspan}=1.040\times W_{Tow}^{0.382}=[m] \qquad (eq.5)$$

This equation emphasizes the significance of takeoff weight (WTow) in determining the wingspan of the drone, thereby establishing an essential link between the drone's physical attributes and its operational capabilities.

Equation 6 offers a systematic approach for deducing the length of the fuselage (FLength). The coefficient "1.775" embedded in this equation is derived from the average measurements of four widely encountered UAV models that are readily available in the market. These UAV models exhibit common characteristics further illustrated in Table 1, providing a comprehensive reference point for understanding their shared attributes and design considerations. It's noteworthy that the insights gained from these representative models contribute to a broader understanding of fuselage length variations in UAV design.

$$\text{FLength}=\text{Wingspan}/1.775 = [m] \qquad (eq.6)$$

TABLE I. Overview of Tow, Wing Span, and Fuselage Length (FLength) for four different types of UAVs.

UAV	Tow [Kg]	Wingspan [m]	FLength = L [m]	WS / L
Aerosonde I	131.1	2.86	1.74	1.644
Hermes 450	450	10.50	6.10	1.721
Predator MQ-1	1020	14.84	8.14	1.824
Hermes 1500	1650	18.00	9.40	1.915
Average				1.775

Moving forward, the subsequent parameter under examination is the ***endurance speed***. In light of the data's inherent variability, for simplification purposes, a consistent 100 km/h speed is assumed to be the sustained endurance speed (Endurance Speed = V_{Endure} = 100 Kph). It's worth noting that the typical range for VEndure spans from 75 to 125 Kph, specifically calculated at cruise speed. Cruise speed, representing the velocity at which UAVs can efficiently glide through the air without necessitating an increase in engine speed, holds pivotal importance in the context of unmanned aerial vehicles. To further quantify the endurance, Equation 7 offers a precise method for calculating the endurance time. This equation establishes the connection between endurance time and range, highlighting the duration a UAV can remain flying based on the specific endurance speed.

$$\text{Endurance Time}=T=\text{Range}/V_{Endure}=[hrs] \qquad (eq.7)$$

Visualized in Fig. 7(a), the graph depicting the relationship between endurance speed and takeoff demonstrates that the attainable speed of a drone varies based on its payload capacity, but there isn't a direct linear relationship. It's crucial to recognize that the complex interaction of factors, including wing configuration and aerodynamic properties, greatly contributes to the diverse speed characteristics observed in drones.

The maximum engine power can be determined using Equation 8. Here, it's important to consider an assumed 80% efficiency in converting mechanical energy to electrical energy, which also includes the required electrical energy for the load. It's worth noting that specific brushless electric motors exhibit efficiencies exceeding 80%. The graphical representation of the relationship between endurance time and takeoff weight is depicted in Fig. 7(b). The power of the engine used in each drone directly and significantly impacts its payload capacity and weight-bearing capability.

$$\text{Maximum engine power}=P_{eng\_max}=0.169\times W_{Tow}^{0.925}=[Watts] \qquad (eq.8)$$

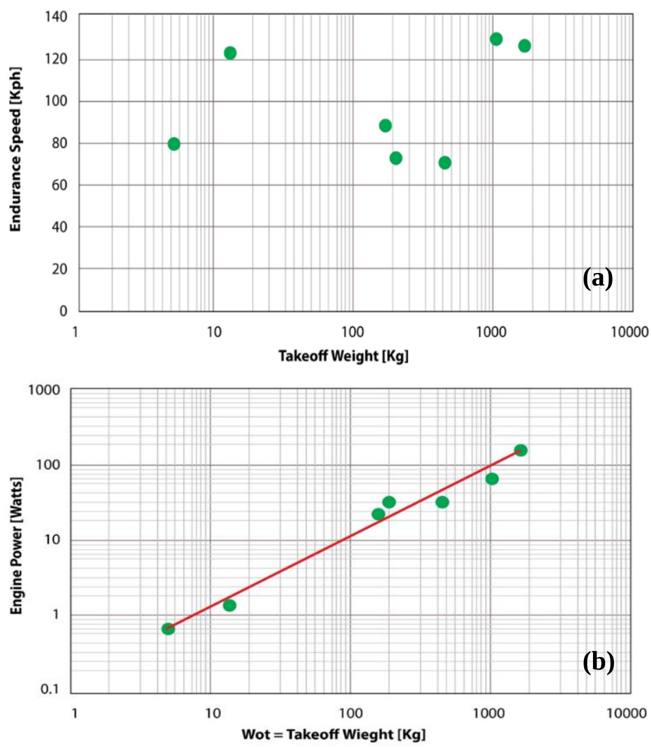

Fig. 7. *(a) Endurance speed vs takeoff weight, (b) Maximum engine power vs Wot.*

The calculation of ***engine capacity*** (CAP) stands as another crucial parameter for UAVs. When considering a four-stroke engine, Equation 9 is employed to determine the ***power output***, wherein 'x' denotes the engine capacity measured in cubic centimeters (cc). The quantification of engine capacity can be derived using Equation 10. Notably, the airframe weight encompasses the avionics' weight as well.

P_{out} (KWatts)=0.073 × x + 0.031 (eq.9)

CAP=(P_{eng_max}-0.031)/0.073=[cc] (eq.10)

Furthermore, it's worth exploring the influence of engine capacity on UAV performance. Engine capacity directly impacts the power output of the engine, subsequently affecting the drone's thrust generation and overall flight capabilities. A higher engine capacity often increases power output, potentially allowing the UAV to carry heavier payloads or achieve higher speeds. On the other hand, a smaller engine capacity might limit the drone's performance metrics, which could involve a careful balance between improved fuel efficiency or reduced weight. As such, striking the right balance between engine capacity, power output, and the specific mission requirements becomes a critical design consideration. This complicated relationship between engine capacity and UAV performance highlights the significance of accurate calculations and informed decision-making in the design process.

When evaluating engine performance, an important parameter to account for is the power-to-weight ratio (Rptw), a metric that has considerable influence over the overall efficiency and capabilities of a UAV. This indicator assumes a critical role in shaping the course of design decisions. When considering a standard four-stroke engine, this power-to-weight ratio assumes a value of 1.814 KW/kg, while the power-to-weight ratio for a Wankel engine is approximated at 2.3 KW/kg, suggesting a tendency for elevated power output in relation to weight. The engine weight can be determined through the subsequent equation:

Engine weight=W_{eng}=P_{eng_max}/R_{ptw}=[Kg] (eq.11)

In this equation, W_{eng} represents the maximum engine power in kg, P_{eng_max} represents the maximum engine power in kilowatts, and R_{ptw} denotes the engine's power-to-weight ratio, expressed in Kwatts/kg. This power-to-weight ratio constitutes a pivotal parameter with extensive implications for the UAV's performance capabilities and overall operational efficiency. A higher power-to-weight ratio typically translates to increased drive and potentially superior flight performance, emphasizing its fundamental significance in the UAV design area. This aspect becomes significantly more crucial when coordinating the design of the drone to align with specific mission requirements, demanding a careful equilibrium between power, weight, and mission goals.

When aiming to sustain flight at a consistent speed, a fundamental assumption asserts that the force requisite to drive the aircraft forward correlates directly with the total weight of the aircraft. As flight progresses and fuel is consumed, this force experiences a non-linear reduction over time. The weight of the aircraft at a specific distance "x" can be expressed using Equation 12:

W(x)=W_a × exp (−x/D) (eq.12)

Here, W_a signifies the takeoff weight of the aircraft, while D represents a numerical parameter recognized as the "characteristic distance" of the aircraft. This parameter holds considerable significance within the aircraft's flight dynamics (as depicted in Fig. 8(a)). The parameter D can be determined by employing the subsequent Equation:

D=R/ln(W_{Tow}/W_{nf}) (eq.13)

In this expression, R represents the range, W_{Tow} stands for the takeoff weight, and W_{nf} is the weight of the aircraft with no fuel. For simplicity, it is assumed that the drone becomes depleted of fuel after covering distance R. This dynamic relationship between weight, distance, and fuel consumption underscores the intricate factors influencing a drone's endurance and range during flight.

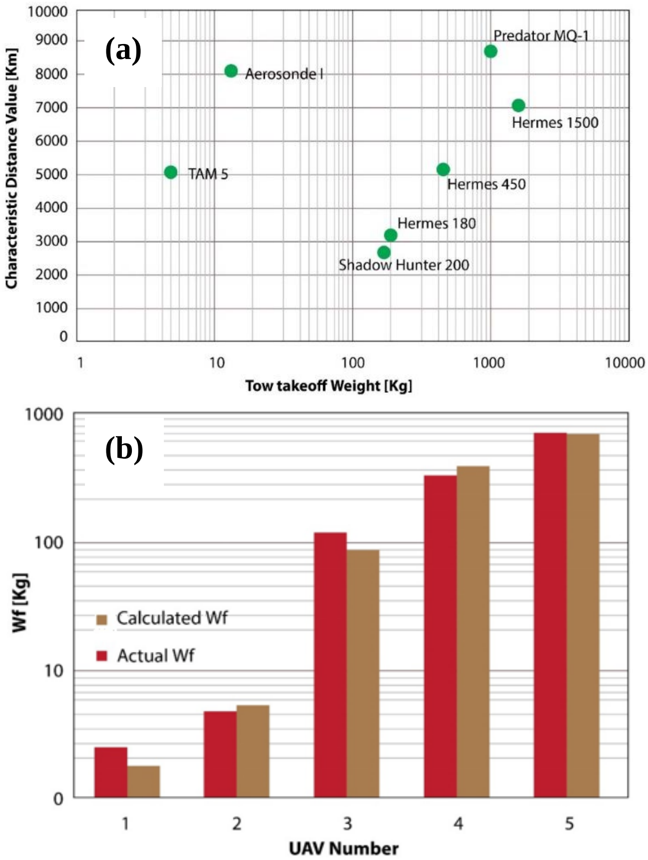

Fig. 8. *(a) characteristic distance value vs Tow, (b) predicted and actual weight of the plane with fuel on board (Wf) values.*

The graph in Fig. 8(a) visually presents the individual D-values associated with several well-known UAVs. Notably, a higher D-value is indicative of heightened drone efficiency. This graphical depiction explains the intricate correlation between engine power, wing area, their cumulative influence on takeoff weight, and the consequential characteristic distance value associated with each analyzed UAV. Observing this graph gives valuable insights into how these variables collectively influence a drone's performance and operational range.

Except for the comparatively lower values in Shadow 200 and Hermes 180, the calculated average for the characteristic distance value (D) is approximately 6966 km. This D-value is a valuable metric for evaluating drone efficiency, essentially quantifying the distance a drone can cover per kilogram of its weight. The overall characteristic distance is subject to various factors, including weather conditions that affect the drone's weight, fuel consumption, and the weight of the aircraft itself. The relationship between the characteristic distance (D) and the weight of the aircraft with fuel (Wf) is effective, and (R) is the Range that the UAV can fly with fully loaded Fuel. Shown in Equation 14:

$$W_f=W_{Tow}\times(1-\exp(-R/D)=[Kg] \qquad \text{(eq.14)}$$

Here, W_f denotes the weight of the aircraft with fuel on board, while W_{Tow} represents the takeoff weight, and R represents the range. Specifically, the established value of D is set at 7200 km, determined through the minimization of squared error values. It's important to note that this D value can display considerable variation among different UAV models, highlighting its crucial role as an input parameter within the framework of the UAV design tool. This characteristic distance parameter significantly influences a drone's operational range and overall performance capabilities, shaping the considerations for its design and optimization strategies.

Visualizing the histogram (Fig. 8(b)) involves a comprehensive evaluation of the actual weights against the anticipated fuel weights across diverse UAVs, subsequently employing a least squares minimization technique to mitigate errors contingent on the D value. The UAV error mentioned earlier reaches its minimum point at a D value of 7200 km. It is important to highlight that the comparison between Shadow 200 and Hermes 180 has been excluded due to their relatively limited characteristic range values.

Furthermore, this comparative analysis provides a valuable understanding of how different UAVs perform in terms of weight distribution and fuel consumption, contributing to a better understanding of their operational efficiency and design optimization possibilities. Utilizing the characteristic distance D as a reference parameter further enhances the accuracy of these assessments, enabling designers and engineers to make informed decisions for achieving optimal performance and range capabilities in UAVs.

The ***weight of airframe*** ($W_{airframe}$) can be calculated using Equation 15. The weight of the UAV airframe includes the avionics' weight.

$$\text{Airframe + avionics weight}=W_{airframe}=W_{Tow} - W_{Plw} - W_f - W_{eng} = [Kg] \qquad \text{(eq.15)}$$

Following the comprehensive measurement of crucial parameters in drone design, a formula is developed for ***estimating the cost of UAVs***, which is also known as ***UAV worth calculation*** (Eq. 16). This stands as one of the most complicated endeavors, aiming to mitigate expenses linked to sensor systems commonly present in military drones. Notably, this study excludes data points related to military UAVs such as Predator UAV and Global Hawk UAV, as these drones incorporate costly avionics, communication, and sensor systems.

$$\text{Estimated price per UAV}=0.972\times(W_{Plw}\times\text{Range})^{0.891} = [\$K\_FY22] \qquad \text{(eq.16)}$$

where W_{Plw} represents the weight of the payload in Kg, and Range indicates the range in Km.

This formulation establishes a fundamental basis within the domain of unmanned aerial vehicle design, drawing upon understandings derived from a diverse array of pre-existing drone models. Furthermore, there is an approximate price list, although it is based on a value of FY22$K. However, it is imperative to acknowledge that these estimations should be regarded as preliminary benchmarks. While they offer a comprehensive overview of essential cost considerations for UAV design and development, the subtle intricacies specific to each project may lead to disparities. Consequently, this fundamental developed formula serves as a navigational guide, directing conversations related to cost implications and design factors while simultaneously allowing for adaptable modifications based on the unique characteristics of specific projects.

VI. Conclusion

The production of advanced air mobility applications in urban areas has given rise to various drone activities ranging from surveillance to photography and delivery. With the increasing significance of drones in urban air mobility and smart city plans, understanding the financial implications of their operations has become essential. The UAV industry has grown significantly, encompassing various roles, from traffic monitoring to weather prediction. Large fixed-wing UAVs, offering extended endurance and high payload capacities, are critical in missions requiring extensive distances and heavy equipment transport. Evaluating the relationship between payload weight, range, and takeoff weight is crucial in assessing operational fees and costs for such UAVs.

This study has developed a comprehensive equation that considers payload weight, range, and takeoff weight to evaluate the financial implications of UAV operations. By incorporating key parameters such as vehicle energy efficiency and weight efficiency coefficient, the model provides a valuable tool for UAV stakeholders to analyze mission-specific financial implications, aiding in resource allocation, mission planning, and decision-making. The presented analysis method, theoretical foundations, and practical insights shed light on the complex dynamics of large fixed-wing UAV operations, offering guidance for achieving operational efficiency and cost-effectiveness in missions.

Generally, this study contributes to understanding UAV economics and offers a transformative approach to market strategies and project planning. By providing data-driven insights, stakeholders can make informed decisions, optimizing UAV technology investments for mission success and financial efficiency. Although the guidelines provided are specifically designed for drones that utilize 4-stroke or Wankel engines, the fundamental principles they encompass have the potential to facilitate economically efficient operations of UAVs in various scenarios and applications.

During the first few months of the simulation period there were only few unwanted mails received in the Registration Group, and none in other groups. In the Web Page Group of e-mail addresses there were no unwanted mails received before the web page became searchable through Google. Also, unwanted mail continued coming into inboxes, even when simulation actions stopped after first year. The ratio of unwanted mail received on average per account per month between address groups is illustrated in Fig. 2.

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