Open access: https://journal.icpa-banyuwangi.ac.id/index.php/skyhawk

SKYHAWK: Jurnal Aviasi Indonesia
Volume. 6, Number. 1, 2026, pp. 599-608

P-ISSN: 2745-6102
E-ISSN: 2776-3854

Comparative Study of Fixed-Wing and Rotary-Wing Aircraft: A Systematic Literature-Based Analysis of Flight Efficiency, Maneuverability, and Operational Function

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ARTICLE INFO

Article History

Received: 06 Januari 2026
Revised: 07 Februari 2026
Accepted: 27 Maret 2026

Keywords

Fixed-wing aircraft, Rotary-wing aircraft, Flight efficiency, Maneuverability, Operational function.

ABSTRACT

This study compares fixed-wing and rotary-wing aircraft in terms of flight efficiency, maneuverability, and operational function by addressing the lack of an integrated framework for mission-based aircraft comparison. A systematic literature-based comparative analysis was conducted using aerodynamics textbooks, aviation handbooks, technical references, regulatory documents, and recent scholarly articles. The analysis was structured around three parameters: flight efficiency, including energy consumption, cruising speed, and range; maneuverability, including takeoff and landing capability, hovering, and movement flexibility; and operational function, including mission suitability and operating environment. The findings show that fixed-wing aircraft provide higher cruise efficiency, greater range, and better payload effectiveness because lift is generated through forward motion over fixed airfoils. In contrast, rotary-wing aircraft offer superior maneuverability, vertical takeoff and landing, and hovering capability, making them more suitable for confined-area, emergency, and point-access missions. The novelty of this study lies in its structured analytical matrix, which clarifies the trade-off between cruise efficiency and spatial flexibility. The study concludes that neither aircraft type is universally superior; effectiveness depends on the alignment between aerodynamic characteristics, operational constraints, and mission requirements.

1. INTRODUCTION

The rapid development of aviation technology has expanded the operational role of aircraft beyond passenger and cargo transportation to include surveillance, disaster response, medical evacuation, offshore logistics, environmental monitoring, and tactical missions (Mohsan et al., 2022). Within this broad operational landscape, aircraft are commonly classified into two major categories: fixed-wing and rotary-wing platforms. Although both are designed to generate lift and perform aerial missions, they differ fundamentally in lift-generation mechanism, energy demand, flight behavior, infrastructure requirement, and mission suitability (Federal Aviation Administration, 2000; Federal Aviation Administration, 2012). These differences make aircraft selection a strategic operational decision rather than a purely technical preference.

Fixed-wing aircraft generate lift through airflow over a stationary wing as the aircraft moves forward. This configuration supports efficient cruise flight, higher forward speed, longer range, and wider area coverage, which explains their extensive use in transportation, patrol, mapping, and environmental monitoring missions (Fontenla et al., 2023; Rufino et al., 2024). However, fixed-wing aircraft generally require runway access or sufficient takeoff and landing space, which may limit their applicability in confined, remote, or infrastructure-limited environments. By contrast, rotary-wing aircraft generate lift directly from rotating blades, enabling vertical takeoff and landing, hovering, and high maneuverability at low speed. These capabilities are particularly important in mountainous terrain, offshore platforms, urban rescue zones, disaster-affected areas, and other locations where runway infrastructure is unavailable or impractical (Liu et al., 2024).

The distinction between the two aircraft types reflects a broader engineering trade-off between cruise efficiency and spatial flexibility. Fixed-wing systems generally offer better energy economy during sustained forward flight, whereas rotary-wing systems provide superior point access, stationary flight capability, and maneuver precision in constrained environments (Etewa et al., 2024; Osman et al., 2025). This trade-off has also become increasingly relevant in the development of hybrid and convertible vertical takeoff and landing systems, which attempt to combine the endurance and cruise efficiency of fixed-wing platforms with the operational flexibility of rotary-wing aircraft (Ducard & Allenspach, 2021; Liang et al., 2024). Therefore, the comparison between fixed-wing and rotary-wing aircraft remains an important issue not only in conventional aviation but also in emerging aircraft design and unmanned aerial system development.

Previous studies have discussed fixed-wing and rotary-wing aircraft from different technical perspectives. Some studies emphasize fixed-wing performance in relation to endurance, aerodynamic efficiency, propulsion systems, and wide-area monitoring capability (Fontenla et al., 2023; Etewa et al., 2024; Rufino et al., 2024). Other studies focus on rotary-wing and VTOL platforms, particularly their hovering capability, vertical mobility, confined-area operation, and mission adaptability (Ducard & Allenspach, 2021; Liu et al., 2024; Osman et al., 2025). However, these studies tend to examine aircraft performance from separate perspectives, such as aerodynamic efficiency, propulsion design, or mission-specific application. A structured comparative framework that integrates flight efficiency, maneuverability, and operational function into a single mission-based analytical model remains limited, especially in aviation-oriented studies intended to support aircraft selection, operational planning, and aviation education.

This gap is important because aircraft effectiveness cannot be determined solely by one performance attribute. A fixed-wing aircraft may be superior in cruise efficiency and range, but it may be less suitable for missions requiring vertical access or operation in confined areas. Conversely, a rotary-wing aircraft may have higher power demand and lower cruise efficiency, but it may provide greater operational value when hovering, precise positioning, and direct access are required. Therefore, aircraft selection should be evaluated based on the alignment between aerodynamic characteristics, operational constraints, and mission requirements.

Based on this rationale, this article aims to comparatively analyze fixed-wing and rotary-wing aircraft by focusing on three integrated parameters: flight efficiency, maneuverability, and operational function. The novelty of this study lies in the development of a structured literature-based comparative framework that clarifies the trade-off between cruise efficiency and spatial flexibility. The study is expected to strengthen the theoretical basis for mission-based aircraft selection, support aviation learning, and provide a clearer operational framework for interpreting the strengths and limitations of both aircraft categories.

2. METHODS

This study employed a systematic literature-based comparative analysis to examine the characteristics of fixed-wing and rotary-wing aircraft in terms of flight efficiency, maneuverability, and operational function. This approach was selected because the study aimed to synthesize, compare, and interpret established technical and operational knowledge from authoritative sources rather than to conduct experimental testing or direct flight measurement (Prayitno et al., 2023).

The study was designed as a non-experimental comparative review. Fixed-wing and rotary-wing aircraft were treated as the two main units of analysis and were evaluated using the same analytical parameters to ensure consistency and comparability. Flight efficiency was operationally defined as the capability of an aircraft to perform sustained flight with lower energy demand, higher cruising speed, and longer operational range. Maneuverability referred to the ability of an aircraft to take off and land under different spatial conditions, hover when required, and maintain movement flexibility at low speed or in constrained environments. Operational function referred to the suitability of each aircraft type for specific mission categories, infrastructure conditions, and operating environments (Yannu Alfaridzi & Indriyanto, 2024).

The literature search was conducted using major academic and technical sources, including Google Scholar, ScienceDirect, MDPI, FAA publications, aviation handbooks, aeronautics textbooks, technical reports, and peer-reviewed journal articles. The search focused on publications discussing aerodynamic principles, propulsion systems, aircraft performance, fixed-wing aircraft, rotary-wing aircraft, UAV platforms, VTOL systems, and mission-based aircraft operation. The keywords used included “fixed-wing aircraft efficiency,” “rotary-wing maneuverability,” “aircraft operational function,” “VTOL aircraft performance,” “fixed-wing UAV endurance,” “rotary-wing UAV hovering,” and “aircraft mission suitability.”

The literature selection followed inclusion and exclusion criteria to improve methodological transparency. The inclusion criteria were: (1) sources published between 2000 and 2025; (2) studies or technical documents directly discussing fixed-wing or rotary-wing performance; (3) sources containing information related to at least one of the three analytical parameters; and (4) publications issued by credible academic journals, aviation authorities, publishers, or technical institutions. Foundational references such as FAA handbooks were retained because they provide established aerodynamic and operational principles (Federal Aviation Administration, 2000; Federal Aviation

Administration, 2012). The exclusion criteria were: (1) sources not directly related to aircraft performance or operation; (2) non-technical opinion articles; (3) duplicate publications; and (4) sources with insufficient methodological or technical information.

Data collection was carried out in four stages. First, potentially relevant literature was identified using predetermined keywords. Second, the identified sources were screened based on title, abstract, and relevance to the research focus. Third, eligible sources were reviewed in full to extract information related to flight efficiency, maneuverability, and operational function. Fourth, the extracted information was organized into a comparative analysis matrix to enable systematic synthesis across the two aircraft categories. This staged procedure was intended to reduce selection bias and improve the reproducibility of the review process (Setiawan et al., 2025).

The main research instrument was a comparative analysis matrix consisting of five components: analytical aspect, indicators, fixed-wing characteristics, rotary-wing characteristics, and operational implications. The matrix functioned as a structured analytical guide rather than a numerical scoring tool. No weighting or ranking system was applied because the objective of the study was qualitative comparative interpretation rather than quantitative performance modeling. However, the consistency of analysis was maintained by applying the same indicators to both aircraft types and by cross-checking each interpretation against multiple credible sources (Rufino et al., 2024).

Data analysis was conducted using descriptive-comparative synthesis. The extracted information was first categorized according to the predefined indicators. It was then compared to identify similarities, differences, relative advantages, limitations, and mission-based implications between fixed-wing and rotary-wing aircraft. The interpretation emphasized the relationship between aerodynamic characteristics and operational suitability, particularly the trade-off between cruise efficiency and spatial flexibility (Prayitno et al., 2022).

To strengthen validity, this study applied source triangulation by comparing findings from textbooks, technical documents, aviation authority publications, and peer-reviewed journal articles. This triangulation was used to reduce dependence on a single source type and to improve the credibility of the comparative interpretation. Through this procedure, the study provides a more systematic basis for analyzing aircraft selection according to mission requirements.

Table 1. Research Analysis Matrix

Aspect	Indicators	Fixed-Wing	Rotary-Wing	Operational Implication
Flight efficiency	Energy consumption, cruising speed, flight range	Generally more efficient during cruise and long-range flight	Requires greater power to maintain lift	Determines suitability for long- or short-range missions
Maneuverability	Takeoff and landing, hovering, movement flexibility	Requires a runway and wider operating space	Capable of vertical takeoff and landing and hovering	Determines capability for operations in confined or emergency areas
Operational function	Mission type, operating environment, usage flexibility	Suitable for transportation, patrol, and wide-area surveillance	Suitable for rescue, medical evacuation, and tactical operation	Serves as a basis for aircraft selection according to mission needs

This matrix was used as a structured comparison tool. No scoring or weighting technique was applied; instead, objectivity was maintained by using uniform indicators and cross-checking the interpretation of each indicator across multiple authoritative sources.

3. RESULTS

The comparative analysis revealed systematic differences between fixed-wing and rotary-wing aircraft across three main aspects: flight efficiency, maneuverability, and operational function. These differences are primarily determined by their lift-generation mechanisms, which influence energy demand, cruising capability, operational range, spatial flexibility, and mission suitability. Overall, the results indicate a consistent trade-off between cruise efficiency and point-access maneuverability.

In terms of flight efficiency, fixed-wing aircraft showed a stronger performance profile. Fixed-wing aircraft generate lift through airflow over fixed airfoils during forward motion, allowing propulsion energy to be used more efficiently for sustained cruise flight. This configuration supports higher cruising speed, longer range, and better endurance for route-based and wide-area missions (Federal Aviation Administration, 2012; Fontenla et al., 2023; Rufino et al., 2024). By contrast, rotary-wing aircraft must continuously generate lift through rotating blades. This mechanism provides vertical mobility but requires greater power to maintain rotor-driven lift, particularly during hovering and low-speed operation (Federal Aviation Administration, 2000; Savino et al., 2024). Therefore, fixed-wing aircraft are more suitable for missions prioritizing distance, speed, and endurance.

In terms of maneuverability, rotary-wing aircraft demonstrated the clearest operational advantage. Their ability to perform vertical takeoff and landing, hover, and maneuver at low speed enables operation in confined, remote, or infrastructure-limited environments. These characteristics are essential for missions requiring precise positioning, rapid access, and stationary flight, such as search and rescue, medical evacuation, offshore access, and tactical response (Li, 2025; Osman et al., 2025). In contrast, fixed-wing aircraft generally require a runway or prepared takeoff and landing area, which limits their flexibility in locations where aviation infrastructure is unavailable or constrained.

In terms of operational function, the findings show that both aircraft categories serve complementary rather than competing roles. Fixed-wing aircraft are more appropriate for transportation, patrol, environmental monitoring, mapping, and wide-area surveillance because their aerodynamic configuration supports efficient flight over longer distances. Rotary-wing aircraft are more appropriate for emergency response, confined-area access, offshore operations, and missions requiring hovering or direct point access. Thus, aircraft effectiveness is not determined by aerodynamic performance alone, but by the alignment between platform characteristics and mission requirements.

To clarify these findings, Table 2 presents a comparative synthesis of fixed-wing and rotary-wing aircraft based on the main analytical indicators.

Table 2. Comparative Results of Fixed-Wing and Rotary-Wing Aircraft

Aspect	Fixed-Wing	Rotary-Wing	Operational Interpretation
Lift-generation mechanism	Fixed wings generate lift through airflow during	Rotating rotor blades directly generate lift	Determines the basic distinction between

	forward motion (Federal Aviation Administration, 2012)	(Federal Aviation Administration, 2000)	cruise-oriented and vertical-lift aircraft
Energy efficiency	More efficient during sustained cruise because lift is maintained aerodynamically during forward motion (Fontenla et al., 2023)	Requires greater power to maintain continuous rotor-driven lift, especially during hovering (Savino et al., 2024)	Fixed-wing aircraft are more efficient for long-distance missions
Cruising speed	Relatively higher and better suited for sustained route travel (Rufino et al., 2024)	Relatively lower because of rotor-based lift and propulsion limitations in cruise configuration (Li, 2025)	Fixed-wing aircraft are preferable for missions requiring speed and route efficiency
Flight range	Longer operational range and better endurance for area coverage missions (Etewa et al., 2024)	More limited range under comparable mission conditions (Osman et al., 2025)	Fixed-wing aircraft are more suitable for patrol, mapping, and surveillance
Takeoff and landing	Generally requires runway or prepared takeoff–landing area (Federal Aviation Administration, 2012)	Capable of vertical takeoff and landing in confined areas (Federal Aviation Administration, 2000)	Rotary-wing aircraft are more suitable for infrastructure-limited environments
Hovering	Not capable of hovering under normal operation (Federal Aviation Administration, 2012)	Capable of hovering and stationary positioning (Federal Aviation Administration, 2000)	Rotary-wing aircraft are superior for rescue, inspection, and point-access missions
Operational flexibility	More limited in constrained terrain or areas without runway access (Liang et al., 2024)	Higher flexibility for difficult terrain, emergency access, and confined-space missions (Li, 2025)	Rotary-wing aircraft provide greater spatial flexibility
Dominant function	Transportation, patrol, environmental monitoring, mapping, and wide-area surveillance (Rufino et al., 2024)	Search and rescue, medical evacuation, offshore access, and tactical/direct-access operations (Li, 2025)	Platform selection should follow mission requirements rather than aircraft type preference

Based on Table 2, fixed-wing aircraft are more suitable for missions requiring range, speed, cruise efficiency, and broad area coverage. In contrast, rotary-wing aircraft are more suitable for missions requiring vertical access, hovering, low-speed maneuverability, and operational flexibility in limited spaces. These results support the development of a mission-based aircraft selection framework, in which aircraft choice is determined by the interaction between efficiency requirements, maneuverability needs, infrastructure availability, and operational environment.

4. DISCUSSION

The findings of this study confirm that the fundamental distinction between fixed-wing and rotary-wing aircraft is rooted in their lift-generation mechanisms, which subsequently shape their efficiency, maneuverability, and operational suitability. Fixed-wing aircraft generate lift through airflow over fixed airfoils during forward motion, allowing propulsion energy to be used more efficiently for cruise flight. This aerodynamic advantage explains why fixed-wing platforms are more suitable for long-distance transportation, patrol, mapping, environmental monitoring, and wide-area surveillance missions. This interpretation is consistent with recent studies showing that fixed-wing aircraft remain advantageous for endurance-oriented operations due to their efficient aerodynamic configuration and stronger range capability (Fontenla et al., 2023; Rufino et al., 2024).

In contrast, rotary-wing aircraft provide greater maneuverability because their rotor systems generate lift independently of sustained forward motion. This enables vertical takeoff and landing, hovering, and low-speed maneuvering in confined or infrastructure-limited environments. Such capability is particularly important in missions where direct access, precise positioning, and rapid response are more critical than cruise efficiency. Therefore, rotary-wing platforms remain highly relevant for search and rescue, medical evacuation, offshore support, disaster response, and tactical operations despite their higher power requirements during hovering and sustained rotor-driven flight (Ahmed et al., 2023; Li, 2025).

The main implication of these findings is that aircraft performance should not be evaluated through a single technical parameter. Efficiency, speed, range, maneuverability, and access capability must be interpreted as interrelated variables within a mission-based decision context. A fixed-wing aircraft may be technically superior in terms of cruise efficiency, but it becomes less effective when the mission requires vertical access, hovering, or operation in areas without runway infrastructure. Conversely, a rotary-wing aircraft may be less efficient in sustained forward flight, but it becomes operationally superior when missions require point access, stationary flight, and maneuver precision. Thus, the comparison between the two aircraft types reflects a context-dependent performance trade-off rather than a simple hierarchy of superiority.

Based on this interpretation, this study proposes a mission-based aircraft selection framework. In this framework, aircraft selection should be guided by four operational considerations: mission distance, infrastructure availability, maneuverability requirement, and access urgency. Fixed-wing aircraft are more appropriate when the mission requires long range, high cruising speed, efficient fuel or energy use, and broad area coverage. Rotary-wing aircraft are more appropriate when the mission requires vertical takeoff and landing, hovering, low-speed maneuvering, direct access to confined areas, or rapid deployment in emergency situations. This framework strengthens the theoretical contribution of the study by shifting the comparison from a descriptive classification of aircraft types to an operational decision model.

The results also support the concept of an efficiency–flexibility trade-off in aircraft design and operation. Fixed-wing platforms represent the efficiency-oriented side of this trade-off because they optimize aerodynamic lift during forward motion. Rotary-wing platforms represent the flexibility-oriented side because they prioritize vertical mobility, hovering, and spatial adaptability. This trade-off explains why neither platform can be considered universally superior. Instead, the operational value of each aircraft type depends on how well its aerodynamic characteristics match mission constraints and environmental conditions (Osman et al., 2025).

The emergence of hybrid and convertible VTOL configurations further reinforces the relevance of this trade-off. Tiltrotor, tilt-wing, and hybrid UAV systems are designed to combine fixed-wing cruise efficiency with rotary-wing vertical mobility. Their development indicates that current aircraft innovation is moving toward platforms capable of balancing endurance, efficiency, maneuverability, and infrastructure independence (Panigrahi et al., 2021; Ducard & Allenspach, 2021; Huang et al., 2024). Therefore, the findings of this study contribute not only to the comparison of conventional aircraft categories but also to broader discussions on future aircraft design and mission-adaptive aviation systems.

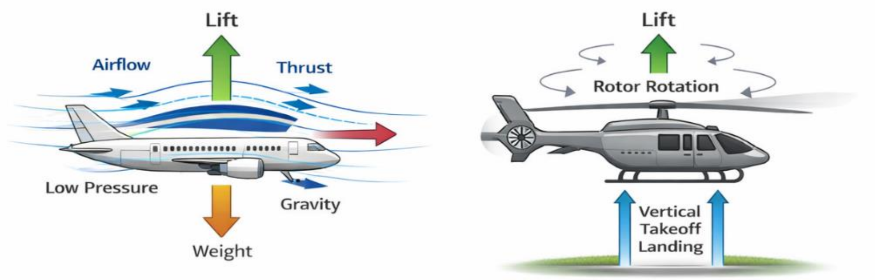

Figure 1: Illustration of lift principle on fixed wing aircraft

Figure 2: Illustration of rotor system and hovering capability on rotary wing aircraft

Figure 1. Fundamental difference between fixed-wing and rotary-wing aircraft

Figure 1 illustrates the fundamental aerodynamic and operational difference between fixed-wing and rotary-wing aircraft. Fixed-wing platforms depend on forward motion to generate lift efficiently, making them more suitable for route-based and long-range missions. Rotary-wing platforms generate lift through rotating blades, enabling vertical flight, hovering, and confined-area operation. The figure therefore supports the central argument of this study: aircraft selection should be determined by the relationship between lift mechanism, mission requirement, and operating environment.

Nevertheless, this study has several limitations. First, the analysis relies on secondary literature and does not include experimental flight testing or direct operational measurement. Second, the comparison remains primarily qualitative and does not apply statistical modelling or numerical weighting. Third, the study does not compare specific aircraft models under standardized mission scenarios. Future studies should incorporate quantitative indicators such as fuel consumption rate, energy use per kilometre, payload-to-range ratio, cruise speed, hover endurance, maintenance demand, and mission cost efficiency. Further research may also evaluate hybrid VTOL platforms to determine how effectively they balance the efficiency of fixed-wing aircraft and the manoeuvrability of rotary-wing aircraft.

5. CONCLUSION

This study concludes that the comparison between fixed-wing and rotary-wing aircraft reflects a fundamental trade-off between cruise efficiency and spatial-operational flexibility. Fixed-wing aircraft are more advantageous in terms of cruise efficiency, speed, range, and endurance, making them more suitable for transportation, patrol, environmental monitoring, mapping, and wide-area surveillance missions. In contrast, rotary-wing aircraft provide stronger vertical takeoff and landing capability, hovering, low-speed maneuverability, and operational flexibility, making them more appropriate for search and rescue, medical evacuation, offshore access, disaster response, and other missions in confined or difficult-to-reach areas.

The main contribution of this study is the development of a structured literature-based comparative framework that integrates flight efficiency, maneuverability, and operational function into a mission-based aircraft selection perspective. This framework shows that neither aircraft type is universally superior; rather, aircraft effectiveness is determined by the alignment between aerodynamic characteristics, infrastructure conditions, operational constraints, and mission requirements.

Practically, these findings may support aviation education institutions, operational practitioners, fleet planners, and policymakers. Aviation education institutions may use the framework to strengthen understanding of the relationship between aircraft design and mission suitability. Operational practitioners and fleet planners should consider mission distance, access requirements, geographic conditions, infrastructure availability, and maneuverability needs when selecting an aircraft platform. Future research should incorporate quantitative performance indicators such as fuel consumption rate, cruise speed, payload-to-range ratio, hover endurance, maintenance demand, and mission cost efficiency. Further studies are also recommended to evaluate hybrid and convertible VTOL aircraft to determine how effectively they combine fixed-wing cruise efficiency with rotary-wing operational flexibility.

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