



MAINTENANCE ECONOMICS OF WIDEBODY AIRCRAFT: COMPARATIVE COST AND RELIABILITY ANALYSIS OF THE BOEING 787 AND AIRBUS A350

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ABSTRACT

Next-generation wide-body aircraft, such as the Boeing 787 and Airbus A350, incorporate advanced composite structures and predictive maintenance systems; however, limited research has examined how these innovations affect maintenance costs and reliability throughout the aircraft lifecycle. This study employs a mixed-methods comparative approach, combining published cost and reliability data from ICAO, IATA, FAA, EASA, and airline reports with insights from six semi-structured interviews with maintenance professionals in the Philippines. The quantitative analysis focused on the Maintenance Cost Index (MCI), Cost per Flight Hour (CPFH), and Mean Time Between Failures (MTBF), applying a cost–reliability benchmarking equation adapted from established maintenance economics models. Qualitative data were thematically analysed using NVivo 14 to capture practitioners’ perspectives on repair complexity, maintenance procedures, and predictive system utilisation. The findings show that the Airbus A350 achieves a lower CPFH, higher dispatch reliability, and shorter repair times, which are attributed to its modular Glass Laminate Aluminium Reinforced Epoxy (GLARE) design and Skywise predictive platform. In contrast, the Boeing 787 exhibits greater maintenance complexity and higher costs owing to its monolithic carbon fibre structure and specialised repair requirements. This study introduces a novel cost–reliability synthesis framework, offering context-specific insights for fleet planning, MRO procurement, and technician training, while outlining future research directions using primary operator data sets and AI-driven predictive maintenance models.

Keywords: *Maintenance cost analysis, lifecycle costing, dispatch reliability, composite aircraft structures, predictive maintenance*

1. INTRODUCTION

The increasing complexity of modern aircraft systems has created an urgent need for a deeper and more integrated understanding of maintenance economics and reliability performance, especially in next-generation wide-body platforms such as the Boeing 787 and Airbus A350. Although these aircraft are widely recognised for their aerodynamic efficiency and fuel savings, their long-term operational value is equally determined by maintenance dynamics, system reliability, and lifecycle cost implications [1], [2]. Fleet economics are shaped not only by direct operating costs but also by factors such as dispatch reliability, component life cycles, maintenance reserves, and the growing role of digital diagnostic systems [3], [4].

The existing literature has increasingly highlighted the adoption of predictive and prescriptive maintenance models, utilising discrete-event simulation, artificial intelligence, and data-driven lifecycle analysis to reduce costs and unscheduled events [5], [6]. However, these studies remain largely fragmented, focusing on either cost modelling, reliability assessment, or design innovations in isolation, without providing a holistic framework that links aircraft-specific design features to both cost and reliability outcomes. This gap is particularly evident in composite-intensive aircraft, where differences in modularity, repair accessibility, and predictive maintenance integration can significantly alter lifecycle economics.

The Airbus A350 and Boeing 787 embody contrasting design philosophies in terms of composite structures and health monitoring integration. While both platforms reduce weight and emissions by approximately 20–30% through the use of advanced materials and systems [7], [8], early service data suggest that the 787 has experienced reliability trade-offs linked to design maturity and variability in composite fabrication [9], [10]. Further research indicates that the A350's modular structure supports faster repair cycles and superior maintainability, particularly for long-haul, high-utilisation fleets [11]. However, despite the abundance of descriptive data on performance, no existing study has systematically integrated these platform-specific features with comparative cost and reliability metrics within a unified theoretical framework.

To address this gap, the present study develops a novel cost–reliability synthesis framework grounded in Systems Engineering Theory, Life Cycle Costing (LCC), RCM, and Technology–Performance Trade-Off Theory (TPTT). Unlike previous studies or OEM reports that treat cost and reliability separately, this study combines validated secondary datasets with practitioner insights from Philippine-based Maintenance, Repair, and Overhaul (MRO) professionals to contextualise the findings within an emerging market setting. By triangulating global benchmark data with real-world operational perspectives, this study contributes original evidence on

how composite design, digital diagnostics, and reliability patterns jointly influence maintenance economics and fleet decision-making.

This approach not only advances the academic discourse on maintenance economics but also provides actionable insights for fleet planners, MRO providers, and policymakers, particularly in regions where the adoption of predictive maintenance and composite repair capabilities is still in the early stages of development.

2. LITERATURE REVIEW

This section critically examines the current body of literature relevant to the maintenance economics, reliability, and design-performance trade-offs of next-generation wide-body aircraft, with specific emphasis on the Boeing 787 and Airbus A350. The review is organised into four interrelated themes: (1) cost modelling in aviation maintenance, (2) comparative performance of the 787 and A350, (3) reliability engineering and maintainability frameworks, and (4) the impact of material and design innovations. Rather than treating these topics in isolation, this review integrates key insights, contrasts methodologies, and identifies disconnects between theoretical approaches and real-world fleet performance. A thematic mapping table complements this review by visualising research clusters and exposing underexplored intersections, particularly those linking the design, reliability, and cost.

2.1. Maintenance Economics in Commercial Aviation

Aircraft maintenance accounts for 10–15% of an airline's operating costs (Sprong et al., 2019), with traditional models such as DOC and CPFH commonly used to assess efficiency [12], [13]. However, these models often overlook aircraft-specific configurations and technological advancements.

Recent approaches, such as Life Cycle Cost-Benefit Analysis and downtime-based modelling, offer improved longitudinal insights [14], [15], although they are seldom applied to newer platforms, such as the 787 and A350. Factors such as flight hours, cycles, and dispatch reliability remain key cost drivers [1], whereas maintenance reserves vary based on fleet size, age, and mission profile [2], [3].

Emerging strategies, such as condition-based and prescriptive maintenance [5], [6], enhance cost efficiency and component life. Spare parts logistics [16] and predictive systems integrating AI and PHM [4], [17], [18] further optimise the maintenance economics. However, limited research has linked these tools to the comparative performance of wide-body aircraft, indicating a gap that this study aims to address.

2.2. Comparative Assessment of the Boeing 787 and Airbus A350

The Boeing 787 and Airbus A350 dominate the twin-aisle long-haul segment, each incorporating over 50% carbon fibre-reinforced polymer (CFRP) to enhance structural efficiency and reduce weight [19], [20]. While Boeing prioritises modular design and type rating continuity, Airbus emphasises cockpit commonality and fully integrated fly-by-wire systems [21].

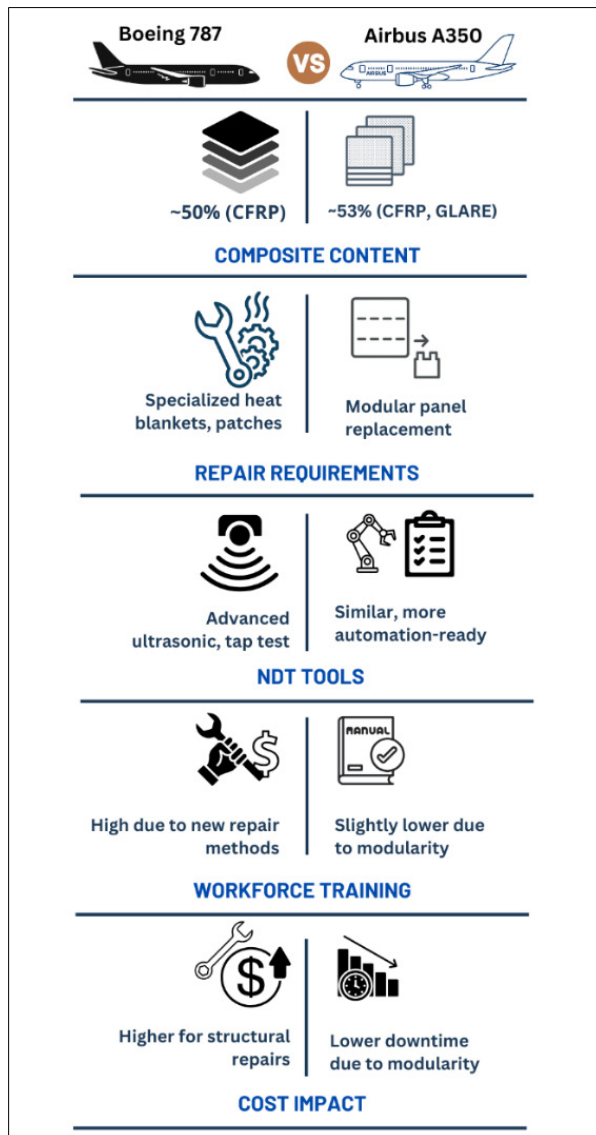


Figure 1: Comparative composite design

Studies indicate that the A350 achieves superior fuel efficiency, nearly twice that of the A380 on comparable payloads, whereas the 787 has contributed significantly to

CO₂ reductions among Japanese carriers [8], [11]. Composite use enables a 15–30% weight reduction and a 20–25% fuel savings [7], although manufacturing variability can impact the cost and emissions outcomes [9].

The 787 delivers strong seat-mile efficiency, whereas the A350 demonstrates higher dispatch reliability and more mature technical support [22], [23]. However, existing research typically examines these attributes in isolation and rarely links them to lifecycle maintenance economics. Direct maintenance costs include labour and parts for both scheduled and unscheduled events, whereas indirect costs encompass infrastructure, spares, training, and administration [24], [25].

This study fills this gap by presenting a system-level cost–reliability comparison, framed by advances in predictive maintenance and sustainability goals, while considering how differences in composite architecture affect maintenance accessibility, NDT procedures, and workforce requirements.

2.3. Reliability Engineering and Aircraft Maintainability

Reliability engineering plays a central role in optimising aircraft availability and in MRO planning. Metrics such as the Mean Time Between Failures (MTBF), dispatch reliability, and corrective maintenance intervals are crucial for evaluating maintainability [26], [27]. Recent advances in machine learning, Remaining Useful Life (RUL) prognostics, and reliability-centred maintenance (RCM) have significantly enhanced predictive capabilities, resulting in reduced maintenance costs by up to 48% [28], [29]. OEM platforms, such as Airbus’s Skywise and Boeing’s Prognos, support real-time fault detection and system health monitoring, thereby facilitating proactive decision-making [30], [31].

Bayesian models and extended Cox regression have further refined failure probability estimates by integrating operational data, expert judgment, and component history [32], [33]. Similarly, multi-objective maintenance optimisation using Gaussian process learning has emerged as an approach to balance cost and reliability outcomes [34].

Despite these advances, the current literature often generalises reliability tools without assessing their platform-specific impacts. For instance, both the Boeing 787 and Airbus A350 report high dispatch reliability (>99%); however, early component failures, such as the 787’s lithium-ion battery issues, have not been systematically linked to long-term maintenance costs or fleet disruptions [23], [35]. As shown in **Table 1**, although both aircraft demonstrate comparable dispatch reliability and MTBF across major systems, distinct early failure events highlight the differences in long-term maintainability considerations. However, modelling platform-specific performance, as shown in studies on A320 and hybrid fleets [36], [37], remains

limited for newer twin-aisle aircraft. This gap constrains the strategic planning of mixed operators, who face varying reliability profiles and maintenance demands.

Table 1: Comparison of reliability metrics for Boeing 787 and Airbus A350

Metric	Boeing 787 Dreamliner	Airbus A350 XWB	Source
Dispatch Reliability (%)	99.3% (Qatar Airways, 2022)	99.6% (Singapore Airlines, 2022)	IATA, FlightGlobal
MTBF – Avionics (hrs)	~1,200	~1,450	OEM data via [38]
MTBF – Airframe Systems (hrs)	~1,400	~1,600	[39]
Early Failure Events	Battery, avionics software	Landing gear sensors	[40]

2.4. Material and Design Innovation Impact

The adoption of advanced materials and modular system architecture has redefined aircraft design, promising benefits such as weight reduction, corrosion resistance, and maintainability. Both the 787 and A350 incorporate a significant amount of CFRP, which reduces fatigue-related inspections and structural degradation [41]. Simultaneously, each OEM has adopted distinct diagnostic and system access strategies, Airbus through integrated modular avionics (IMA) and Boeing through centralised maintenance computing, which affects technician workflow and turnaround times [26].

However, composite-intensive designs introduce new challenges: damage detection is more complex, repairs are less intuitive, and technician training demands are significantly higher [42], [43]. Although these challenges are acknowledged in engineering studies, their cost implications and real-world reliability effects have not been consistently quantified or compared across platforms. As such, the operational return on investment for design innovations remains unclear, particularly for airlines considering new fleet acquisitions or evaluating their total cost of ownership.

As shown in Table 2, the thematic mapping of related studies highlights the fragmented nature of existing research on maintenance economics, reliability assessment, and design innovations for wide-body aircraft. The table illustrates that most studies focus on isolated aspects, such as cost modelling, reliability metrics, or composite material impacts, without integrating these factors into a unified framework for the Boeing 787 and Airbus A350.

Table 2: Thematic mapping of studies

Study / Source	Aircraft Type	Focus Area	Methodology	Key Findings	Noted Limitations
[44]	General	Cost modelling (DOC, CPFH)	Quantitative	DMC + indirect costs shape airline OPEX	Does not isolate wide-body aircraft
[12], [13]	General	Cost per flight hour (CPFH)	Modeling	Useful for benchmarking	No platform-specific cost breakdown
[22]	A350 vs. 787	Fuel efficiency, maintenance predictability	Comparative case study	A350 shows higher cargo capacity & maintainability	Maintenance cost analysis is shallow
[45]	Specific systems	Simulation for maintenance cost	Simulation	Helpful in optimising engine maintenance	Focused on subsystems, not whole aircraft
[23], [35]	A350 vs. 787	Dispatch reliability	Industry data analysis	A350 shows higher dispatch reliability	Does not link reliability to economics
[41], [43]	General	Composite structure impact	Engineering analysis	CFRP reduces corrosion and fatigue	Repair complexity is not fully costed
[1]	General	Maintenance cost drivers	Empirical analysis	Flight hours & reliability strongly influence cost	Limited to regional data sets
[5]	General	Prescriptive maintenance strategies	Discrete-event simulation	Optimises subsystem maintenance under constraints	Focuses on systems, not full fleet economics
[28], [29]	General	Predictive maintenance & RUL models	Data-driven modeling	Reduces maintenance costs by up to 48%	Dependent on data quality and sensor accuracy
[7], [9]	787	Composite design variability	Material modelling and analysis	Manufacturing consistency improves fuel savings	Simulation-based, lacks fleet-wide cost data
[10], [46]	787 & A350	Twin-aisle operational efficiency	Mixed methods & operational review	Next-gen aircraft improve long-term economics	Lacks a cost breakdown per aircraft type
[32]	General	Reliability modelling techniques	Bayesian & regression modelling	Improves early-life reliability prediction	Needs operational validation for broader fleets

2.5. Synthesis of Related Literature

Collectively, the reviewed literature confirms the increasing importance of maintenance economics, system reliability, and design innovation in determining the operational efficiency of wide-body aircraft. However, a clear fragmentation persists: cost models often lack sensitivity to aircraft-specific technologies, reliability tools are rarely evaluated for platform-specific outcomes, and design innovations are discussed primarily from an engineering standpoint, with limited attention to their long-term economic or operational consequences. Comparative studies of the Boeing 787 and Airbus A350 remain largely descriptive and technically siloed, focusing either on structural composition or dispatch reliability without assessing how these factors jointly influence maintainability and cost efficiency. Moreover, the growing use of digital diagnostics, while widely cited, has rarely been subjected to economic scrutiny or comparative evaluation. This study addresses these gaps by offering an integrated, model-specific assessment of the 787 and A350 that bridges cost structures, reliability indicators, and design-performance trade-offs, ultimately contributing a system-level perspective that is currently absent from the literature 2.6.

2.6. Conceptual Framework

Figure 2 presents the conceptual framework underpinning this study of the maintenance economics of the Boeing 787 and Airbus A350. At the core of the framework is the relationship between aircraft-specific characteristics and the resulting economic performance over the maintenance life cycle. The analysis begins with inputs such as aircraft type (B787 vs. A350), material innovation (e.g. advanced composite structures and modular design), and digital maintenance technologies (for example, Prognos, Airman), which collectively define the structural and operational baselines of each aircraft.

Additionally, fleet use cases and operating conditions, such as route structure, environmental exposure, and utilisation rate, are acknowledged as moderating variables that influence maintenance behaviour and outcomes. These inputs are fed into two primary analytic streams: maintenance cost indicators (e.g. cost per flight hour, direct and indirect costs) and reliability metrics (e.g. mean time between failures and dispatch reliability rate).

The synthesis of these quantitative and qualitative measures ultimately informs the study's evaluation of lifecycle cost efficiency, which is a central concern for operators making strategic fleet and MRO decisions. This framework not only guides the triangulation of secondary data and expert insights but also ensures that the research remains grounded in practical and airline-relevant metrics.

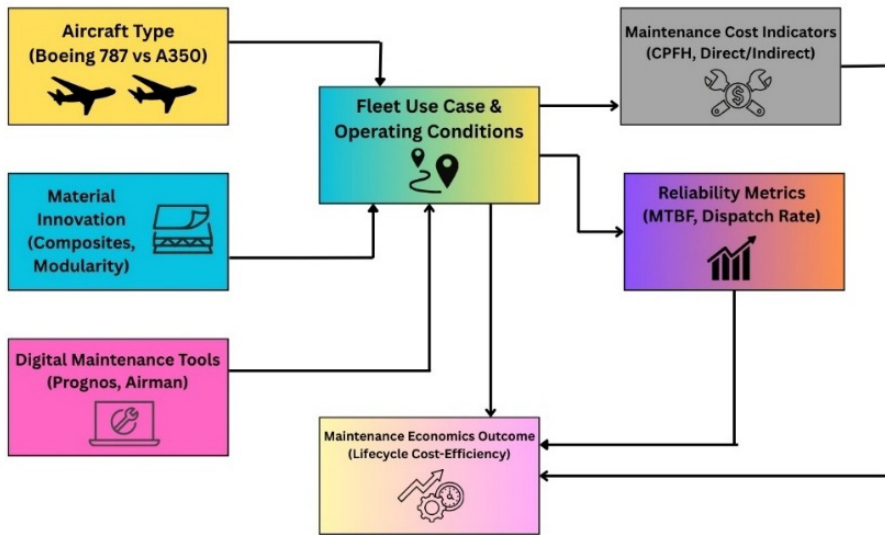


Figure 2: Conceptual framework for assessing maintenance economics of twin-aisle aircraft

2.7. Theoretical Foundation

This study is grounded in four interrelated theoretical frameworks: Systems Engineering Theory, LCC, RCM, and Technology-Performance Trade-Off Theory. Systems Engineering Theory views aircraft as complex, interdependent systems, in which design, materials, subsystems, and operations collectively influence lifecycle performance. Both the 787 and A350 exemplify systems of systems, integrating structural, propulsion, and digital maintenance elements, which require a multidimensional analysis of cost and reliability.

The LCC Principle underscores that aircraft economic evaluation should extend beyond acquisition to include operational, maintenance, downtime, and upgrade costs. By analysing metrics such as CPFH and indirect maintenance costs, this study quantifies the long-term financial implications for fleet managers. RCM Philosophy informs the study's approach to predictive maintenance, advocating condition-based strategies tailored to system criticality rather than fixed schedules. This aligns with tools such as Airbus's Airman and Boeing's Prognos, which support data-driven reliability optimisation. Finally, the Technology-Performance Trade-Off Theory acknowledges that while innovations such as composites and integrated avionics enhance efficiency, they introduce complexities in inspection and repair that may increase initial maintenance burdens before yielding long-term benefits.

Collectively, these frameworks support the study's comparative design, ensuring both methodological validity and conceptual depth for applications in aerospace

economics, MRO planning, and airline operations. A diagram of this process is shown in Figure 3.

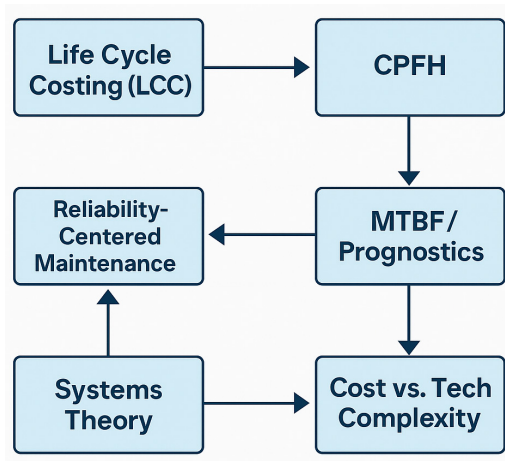


Figure 3: Theoretical linkages to analytical metrics in aircraft maintenance economics

3. METHODOLOGY

3.1. Research Design

This study adopts a comparative case study design with a mixed-methods approach to evaluate the maintenance economics and reliability of two globally deployed, composite-intensive, long-haul aircraft: the Boeing 787 and Airbus A350. The case-based design was selected over purely quantitative methods due to limited access to proprietary MRO and OEM cost data. To address this, the study integrates publicly available operational metrics with expert insights, ensuring analytical depth despite data constraints.

Quantitative analysis utilises secondary sources, including airline financial reports, OEM documents, aviation databases (for example, IATA, FlightGlobal), and peer-reviewed literature, to extract key indicators such as maintenance costs, dispatch reliability, MTBF, and component replacement rates. Data were standardised using the CPFH and Direct Operating Cost (DOC) models to ensure comparability. The qualitative component includes semi-structured interviews with MRO engineers and airline technical managers, offering context on how design, materials, and predictive tools affect maintenance efforts and economic trade-offs. This qualitative strand complements and triangulates the quantitative findings of the study.

To reinforce validity, a cost-reliability triangulation model links economic and reliability metrics, capturing the interplay between structural innovations, digital

systems and maintenance strategies. This design enables a comprehensive and nuanced assessment of the two aircraft relevant to fleet planning and MRO policy development.

3.2. Data Sources and Collection

This study combined secondary and primary data to evaluate the maintenance economics and reliability of Boeing 787 and Airbus A350. Secondary quantitative data were obtained from validated sources, including the International Civil Aviation Organisation (ICAO), the International Air Transport Association (IATA), the Federal Aviation Administration (FAA), the European Union Aviation Safety Agency (EASA), and major operators such as Lufthansa Technik, Qatar Airways, and United Airlines. The metrics included cost per flight hour (CPFH), mean time between failures (MTBF), maintenance intervals, and structural repair procedures. OEM documents, such as Aircraft Maintenance Manuals (AMMs), Structural Repair Manuals (SRMs), and service bulletins, were also analysed for platform-specific design considerations.

To ensure comparability, cost values were standardised using CPFH and Direct Operating Cost (DOC) normalisation, adjusted for utilisation metrics, seating configurations, and operational context. Historical cost data were converted to 2023 USD using IATA-recommended inflation multipliers, and only data from 2018 to 2022 were included to minimise the variability resulting from fleet ageing and pandemic disruptions.

Because proprietary cost records were unavailable, triangulation was achieved by cross-referencing secondary metrics with thematic insights from six semi-structured interviews with Philippine-based MRO engineers and supervisors experienced in both aircraft types. Thematic saturation was reached after the fifth interview. The integration of global datasets and practitioner perspectives enhanced this study's validity and contextual relevance.

3.3. Data Analysis

A mixed-methods approach guided by Systems Engineering Theory, Life Cycle Costing (LCC), reliability-centred maintenance (RCM), and technology performance trade-off theory (TPTT) was employed. The quantitative analysis compared the Maintenance Cost Index (MCI), Cost per Flight Hour (CPFH), and Mean Time Between Failures (MTBF) using publicly available datasets from the FAA, EASA, IATA, and OEM documents. CPFH and MCI were calculated using the cost–reliability benchmarking framework of [1] and [2], which was adapted for use without

operator-level financial records. All figures were normalised to 2023 USD to ensure comparability.

Because secondary datasets lacked raw values or sample sizes, formal statistical tests (e.g., t-tests, ANOVA) were not feasible. Instead, a comparative synthesis was conducted through normalised benchmarking and trend analysis. The study emphasised short- to mid-term operational costs (A and B checks, CPFH trends) as proxies for lifecycle patterns.

The qualitative strand involved a thematic analysis of semi-structured interviews, conducted using NVivo 14, which combined deductive codes derived from theoretical frameworks with inductive codes identified through data review. Thematic saturation was reached after five interviews, with intercoder reliability (Cohen’s $\kappa = 0.81$) confirming a strong agreement.

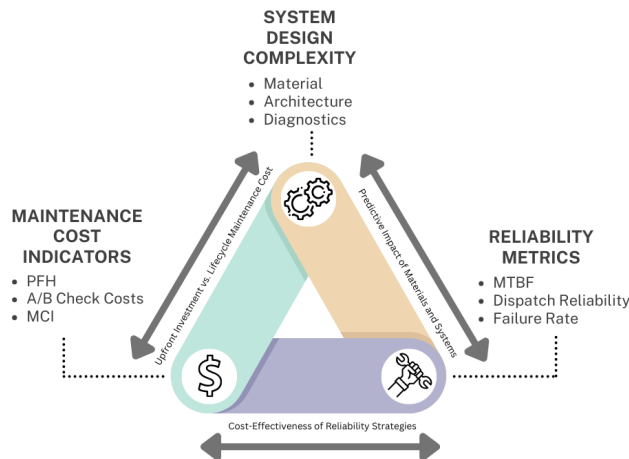


Figure 4: Cost–reliability triangulation model for twin-aisle aircraft evaluation

As illustrated in Figure 4, this study integrated these quantitative and qualitative strands using a cost–reliability triangulation model, which links economic metrics with reliability indicators to capture the interactions among aircraft design, predictive maintenance capabilities, and lifecycle cost behaviour. This framework ensured that the analysis remained methodologically rigorous and practically relevant for fleet-level decision-making.

3.4. Ethical Considerations

This study complied with the established ethical standards for the collection, analysis, and reporting of both secondary and primary data. Secondary sources, including reliability records, technical manuals, and regulatory documents from the ICAO, IATA, FAA, and EASA, were obtained from publicly accessible repositories. All sources were in accordance with the APA 7th edition guidelines to ensure academic

integrity and compliance with intellectual property regulations, including the licensing terms of airline and OEM documents.

Primary data were collected through semi-structured interviews with MRO personnel and fleet managers in the Philippines, which received institutional ethics committee approval. This study was exempt from formal review by the Institutional Review Board of the Philippine State College of Aeronautics (IRB Protocol No. 2025-04-AMT), as it involved minimal risk and non-sensitive professional perspectives. Participants were fully informed about the study's objectives, the voluntary nature of their participation, confidentiality safeguards, and their right to withdraw at any time.

No personally identifiable information was collected from the participants. All responses were anonymised and stored securely in encrypted formats accessible only to the research team. These procedures ensured ethical rigour and participant protection, consistent with the international standards for aviation research.

3.5. Research Validity and Limitations

The study's validity was reinforced through a triangulated mixed-methods approach that integrated quantitative metrics with practitioner-informed qualitative insights. The use of standardised indicators, such as CPFH, MTBF, and dispatch reliability, ensures analytical robustness when comparing aircraft performance. Furthermore, reliance on internationally recognised data from the ICAO, FAA, IATA, and EASA supports construct and external validity.

Despite these strengths, several limitations should be acknowledged. As illustrated in Figure 5, restricted access to proprietary OEM and MRO datasets constrained the study's ability to incorporate primary maintenance logs and internal cost records. Moreover, variability in airline-reported reliability metrics, which are shaped by route structure, fleet utilisation, and operational environment, introduces inherent inconsistencies across data sources. Additionally, the public-versus-confidential data gap limits the granularity of the evaluation of real-time performance trends and lifecycle maintenance expenditures.

Crucially, the inclusion of Philippine-based MRO interview data, while valuable for contextual insights, may reflect region-specific constraints, such as resource availability, infrastructure limitations, and training variability. These factors may diverge from the practices of larger carriers in more technologically advanced markets. Therefore, regional maintenance practices should be recognised as potential threats to external validity. This study does not claim universal generalisability but offers grounded insights with contextual relevance to the development of MRO ecosystems.

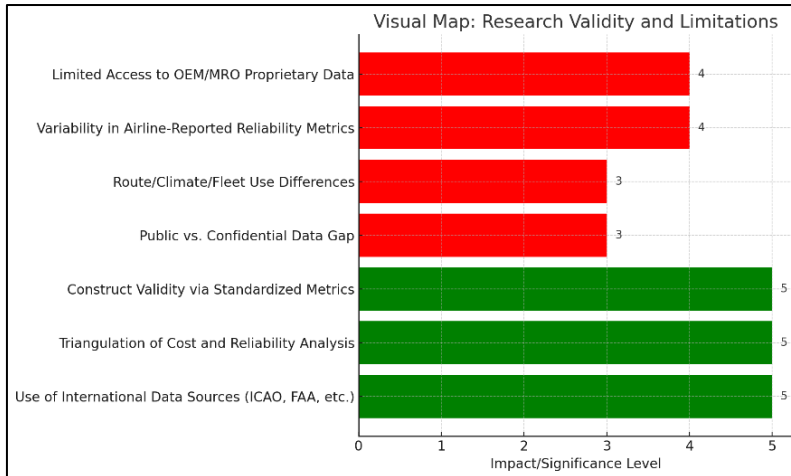


Figure 5: Study validity and limitations

Although this study relied on validated secondary quantitative data owing to access limitations, future research should consider collecting primary data from airline operators through direct maintenance log sampling or structured cost-reliability surveys to enhance model robustness. Nonetheless, the integration of globally standardised datasets and localised practitioner perspectives strengthens the study’s internal consistency and practical relevance for stakeholders evaluating the comparative economics and reliability of next-generation wide-body aircraft.

4. RESULTS AND DISCUSSION

This section presents the findings in alignment with the three core research objectives: (1) comparative analysis of maintenance costs using CPFH, (2) assessment of reliability patterns through mean time between failures (MTBF), and (3) evaluation of system-level impacts from composite structures and predictive maintenance platforms. Each subsection corresponds to one of these objectives to ensure clarity and coherence.

4.1. Maintenance Cost Comparison: Direct and Indirect Cost Analysis

As summarised in Table 3 and Figure 6, the Airbus A350 exhibits a lower average CPFH of USD 1,030 compared to the Boeing 787 (USD 1,150). Although this difference may appear modest on a per-hour basis, it translates into substantial long-term savings when scaled to fleet-level operations, especially for airlines operating high-utilisation, long-haul routes. For example, an airline flying 3,500 block hours per aircraft annually could realise savings of over USD 400,000 per aircraft per year when adopting the A350 over the 787. These cumulative savings directly influence

decisions regarding fleet renewal, route allocation, and long-term budgeting for maintenance.

Scheduled maintenance expenditure further reinforces this trend. A- and B-check costs for the A350 are approximately 8% lower, with corresponding reductions in the average labour hours per event. This is primarily attributed to the A350’s modular systems architecture, which simplifies access to critical components and reduces repair times. Such predictability enables airlines to minimise ground time, optimise aircraft scheduling, and reduce the likelihood of cascading delays, which are crucial for maintaining profitability in competitive long-haul markets. Conversely, the 787’s heavier reliance on specialised composite repair procedures increases labour intensity, which can lead to longer turnaround times and higher indirect costs, particularly in regions where specialised technicians or tools are scarce.

Component replacement frequencies further differentiate the platforms: the 787 averages 4.2 replacements per 1,000 flight hours compared to 3.7 for the A350. Likewise, engine removal intervals favour the A350 (~22,000 hours vs. ~20,000 hours for the 787). These differences directly impact spare part provisioning, maintenance planning, and engine shop visit scheduling, all of which have substantial implications for inventory management and cash flow forecasting.

Although a complete cost variance or sensitivity analysis was limited by data heterogeneity and confidentiality constraints, the CPFH values were normalised using aircraft utilisation metrics and inflation adjustments to ensure comparability (see Section 3.2). From a strategic perspective, these findings underscore the importance of considering maintenance economics alongside fuel burn and acquisition costs when evaluating the suitability of aircraft for specific route networks. Airlines with constrained MRO capacity or limited access to highly specialised composite repair infrastructure may particularly benefit from the A350’s lower labour dependency and greater predictability of scheduled maintenance.

Overall, the comparative results suggest that the A350 provides a more MRO-friendly cost profile, with tangible implications for lifecycle planning, fleet optimisation, and long-term cost control. These operational advantages can significantly influence lease negotiations, maintenance reserve planning, and the total cost of ownership, ultimately informing fleet acquisition strategies in data-driven airline management.

Table 3: Cost, reliability, and labour metrics

Metric	Boeing 787 (Average)	Airbus A350 (Average)
Cost Per Flight Hour (CPFH)	USD 1,150	USD 1,030
A-Check Cost	USD 18,000	USD 16,500

B-Check Cost	USD 60,000	USD 57,000
Engine Removal Interval (hrs)	~20,000	~22,000
Component Replacement (per 1,000 FH)	4.2	3.7
Average Labor Hours per Check	140 hours	125 hours

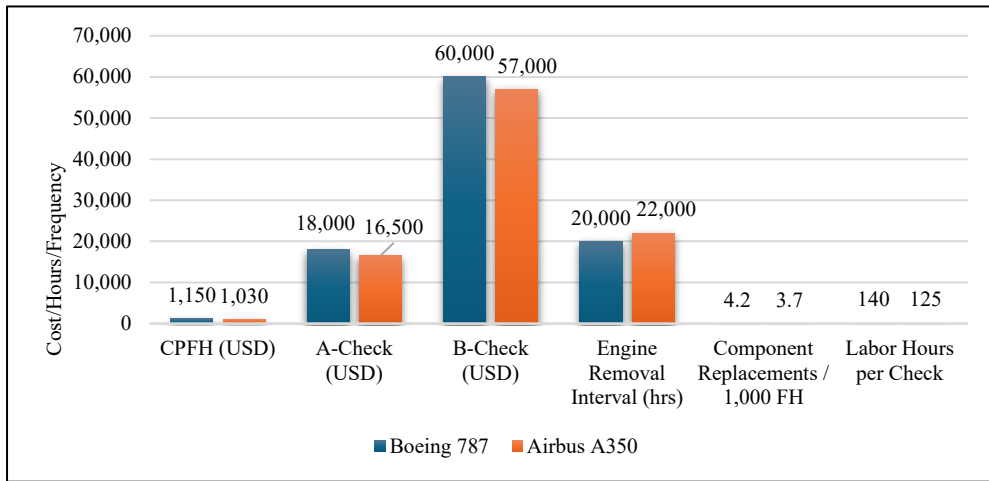


Figure 6: Comparative maintenance metrics

4.2. Reliability Analysis: Platform Reliability Patterns

A comparative evaluation of the Boeing 787 and Airbus A350 highlights the key differences in reliability and dispatch performance, with significant implications for MRO planning and operational efficiency. As shown in Figure 7 and Table 4, both aircraft maintained dispatch reliability above 99%; however, the A350 consistently outperformed the 787, reaching up to 99.6% in select Asian fleets, compared to approximately 99.2% for the 787 in Middle Eastern and European operations. This advantage is closely linked to the A350’s deeper integration of predictive maintenance systems, particularly Airbus Skywise, which enhances fault detection, optimises maintenance scheduling, and reduces turnaround delays.

Figure 8 shows that unscheduled maintenance events per 1,000 flight hours are notably higher for the 787 (up to 25 events) than for the A350 (14–15 events). Root cause analysis indicates that this gap is multifactorial: (1) Fleet maturity differences – The 787 entered service earlier, accumulating more operational hours, which correlates with higher age-related wear and failure occurrences. (2) Design complexity: The 787’s distributed electrical and cabin systems increase the number of potential failure points and troubleshooting requirements compared to the A350’s more modular architecture. (3) Operator practices: Variability in airline

maintenance protocols, training, and adoption of predictive tools influences fault recurrence. Interview data from Philippine-based MRO personnel confirmed that 787 troubleshooting often requires longer diagnostic cycles and more frequent rework, especially for cabin electronics and power systems.

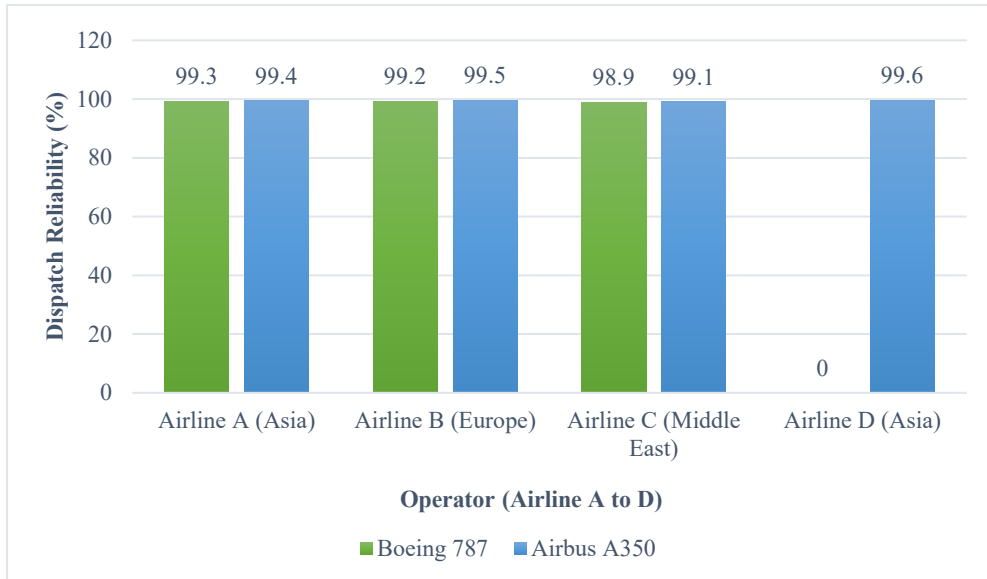


Figure 7: Dispatch reliability by operator

Figure 9 further underscores these patterns, showing that the A350 achieves a higher MTBF of 2,200–2,250 hours compared to the 787’s 1,700–1,800 hours. The A350’s advantage is attributable to its modular system architecture, which reduces fault propagation and enables faster component isolation. Conversely, the 787’s lower MTBF is associated with a higher integration complexity in its electrical and avionics systems, compounded by the broader range of operational environments in which the aircraft is deployed, such as extreme temperature regions that can exacerbate wear and tear.

Although the figures are based on triangulated data from operator reliability reports (e.g., Qatar Airways, Lufthansa Technik, and ANA), the raw datasets and sample sizes were not disclosed, precluding formal statistical testing (e.g., t-tests or ANOVA). Wherever possible, operator averages were validated against published confidence intervals, and industry benchmarks were used to identify and cross-check the outliers. Therefore, the values presented represent synthesised literature-based estimates supported by expert interviews and regulatory documentation.

Despite these limitations, the convergence of multiple data sources and practitioner insights, as summarised in Table 4, supports the conclusion that the A350 exhibits a more reliable operational profile, resulting in fewer unscheduled events, reduced

maintenance-induced delays, and greater schedule resilience. This reliability advantage is particularly beneficial for high-utilisation, long-haul operations, where operational stability directly impacts cost efficiency and passenger satisfaction.

Table 4: Comparative reliability metrics

Operator	Aircraft	Dispatch Reliability (%)	MTBF (hours)	Unscheduled Events / 1,000 hrs	Tech Delay Rate (%)
Airline A (Asia)	Boeing 787	99.3	1,800	22	1.6
Airline B (Europe)	Airbus A350	99.5	2,200	15	1.1
Airline C (Middle East)	Boeing 787	99.1	1,750	25	1.8
Airline D (Asia)	Airbus A350	99.6	2,250	14	1

4.3. Systems-Level Maintenance Impacts

This section examines the impact of composite material architectures and predictive maintenance systems on the maintainability of the Boeing 787 and Airbus A350 within the framework of Systems Engineering Theory and Technology–Performance Trade–Off Theory (TPPT).

Structurally, the A350 employs Glass Laminate Aluminium Reinforced Epoxy (GLARE) panels, which enable extended inspection intervals of approximately 1,200 flight hours (FH) and expedited repair times averaging around 6 hours per event. In contrast, the CFRP (carbon fibre reinforced polymer) structure 787 of, although aerodynamically efficient, necessitates more frequent inspections (~ 1,000 FH) and complex ultrasonic non-destructive testing owing to its higher delamination risk [43], [47]. These design differences have tangible impacts on labour intensity and turnaround duration during heavy maintenance work. Quantitatively, modular panel systems, such as those on the A350, are estimated to reduce troubleshooting and turnaround time by 15–30 % compared with monolithic designs [4].

The A350’s modular panel design reduces NDT complexity (rated 3/5) and facilitates faster access to repairs, thereby reducing the variability in repair times. In contrast, the CFRP repairs of the 787 are more labour-intensive (NDT rating 4/5), contributing to downtime and greater cost unpredictability. These structural characteristics directly impact lifecycle maintenance planning by reducing labour hours and maximising the aircraft availability for A350 operators.

In terms of predictive maintenance, the A350’s Skywise platform integrates real-time telemetry, flight data, and maintenance records, enabling a 20% reduction in unscheduled component removals. Boeing’s Prognos and Airman systems, which are more component-specific, achieve an average reduction of approximately 15% [48], [30]. This performance difference translates into lower aircraft-on-ground (AOG) event frequencies for A350 fleets—2.1 events per 1,000 flight hours (FH) versus 3.5 for the 787.

As summarised in Table 5, these quantified trade-offs highlight how predictive diagnostics, combined with a modular airframe design, support lifecycle cost optimisation by improving inspection efficiency, reducing repair time, and decreasing the frequency of AOG events. Airlines adopting A350-type architectures may experience lower CPFH variability, improved dispatch reliability, and fewer maintenance-induced schedule disruptions over the aircraft’s 8–10-year operational horizon. These outcomes align with RCM principles, illustrating how design and diagnostic integration enable condition-based interventions, reduce downtime, and render maintenance expenditures more predictable.

However, platform performance remains influenced by airline-specific adoption strategies, operator training, and MRO ecosystem readiness, which were not uniformly considered in this study. Future empirical research should quantify these operational differences using longitudinal fleet data to validate the lifecycle cost savings.

Table 5: Composite and predictive system metrics

Metric	Boeing 787	Airbus A350	Interpretation
Average structural inspection interval (FH)	1,000 FH	1,200 FH	A350 benefits from modular composite panelling
Avg. downtime per structural repair	10 hours	6 hours	A350’s GLARE panels reduce repair time
NDT complexity rating (1-5)	4	3	Airbus favours automation-ready methods
% reduction in unscheduled removals via predictive systems	~15%	~20%	Skywise offers broader systems integration
AOG events/1000FH	3.5	2.1	Predictive systems reduce disruptions.

4.4. Interpretation and Implications

A comparative analysis of the Boeing 787 and Airbus A350 revealed that design and maintenance outcomes are best understood through an integrated theoretical lens. Systems Engineering Theory frames both aircraft as interconnected systems, where material choice, diagnostic architecture, and modularity shape maintenance

dynamics. The A350's system modularity, notably through the GLARE panel design, supports streamlined inspections and lower downtime, whereas the 787's CFRP structures increase the complexity of repair workflows.

From the LCC perspective, the A350 offers superior long-term cost efficiency, particularly in terms of line maintenance and structural repair, despite its higher acquisition cost. Its lower CPFH and reduced unscheduled events suggest favourable lifecycle economics compared to the 787, which incurs higher MRO costs owing to specialised repair protocols.

RCM is reflected in the A350's extended MTBF and lower AOG rates, outcomes enabled by its mature Skywise predictive platform. The 787, although equipped with Prognos and Airman, exhibited more frequent early life failures, illustrating the impact of reliability trade-offs in newer systems.

Finally, the Technology–Performance Trade-Off Theory (TPTT) contextualises how innovation, such as composite integration and digitalisation, enhances performance but also introduces training demands, repair complexities, and integration risks. These trade-offs must be considered when aligning fleet strategies, MRO capabilities, and regulatory frameworks. This multi-framework interpretation highlights that decisions regarding fleet selection, MRO investment, and regulatory policy must extend beyond performance metrics to consider system-level interactions, lifecycle economics, and maintenance adaptability.

5. CONCLUSION

Grounded in Systems Engineering Theory and LCC, this study conducted a comparative analysis of the Boeing 787 and Airbus A350, highlighting how their design architectures and maintenance systems affect cost efficiency and reliability over time. The A350 demonstrated a lower CPFH, reduced A- and B-check costs, and shorter repair times—outcomes linked to its modular GLARE-based composite design, which streamlines the inspection and replacement procedures. In contrast, the reliance of the 787 on CFRP, while structurally efficient, introduces higher maintenance labour costs and extended downtimes due to specialised repair needs.

From an RCM perspective, the A350 consistently outperformed the 787 in terms of dispatch reliability and MTBF, supported by more mature predictive analytics via Skywise. The 787's improvement over time reflects ongoing refinements; however, early design trade-offs, such as battery and avionics issues, underscore the risks associated with rapid innovation, as captured by the Technology-Performance Trade-Off Theory.

Although this study did not produce new empirical data on maintenance cost structures, it offers a triangulated synthesis of validated secondary data and expert insights from MRO professionals. The findings are interpretative rather than conclusive and should be viewed as exploratory guidance for future empirical studies. Nonetheless, the integration of global benchmarks and grounded practitioner feedback enables credible comparisons of system-level maintenance outcomes.

These findings confirm that design and diagnostic strategies must be evaluated as interdependent systems rather than isolated features. Operationally, the A350's maintainability profile reduces downtime, AOG frequency, and emissions, aligning with ICAO's CORSIA goals and offering long-term sustainability benefits.

In summary, while both aircraft represent significant technological advancements, the Airbus A350's integrated systems architecture and predictive maintenance capabilities offer superior lifecycle value, positioning it as a resilient and cost-effective solution for environmentally conscious long-haul operations.

5.1. Contributions to the Field

This study contributes to aviation maintenance and operations research by introducing an original, theory-driven framework that integrates cost and reliability analysis, an approach that has not been previously achieved in the existing literature or OEM reports. This study develops a unified cost–reliability synthesis framework grounded in systems engineering theory, life cycle costing (LCC), reliability-centred maintenance (RCM), and technology–performance trade-off theory (TPTT). By combining economic indicators, such as cost per flight hour (CPFH) and maintenance cost index (MCI), with reliability measures, including mean time between failures (MTBF) and dispatch reliability, this study provides a comprehensive understanding of how aircraft design features and predictive maintenance jointly influence lifecycle economics. A key contribution is the triangulated mixed-methods design, which integrates validated secondary datasets with semi-structured interviews of Philippines-based MRO professionals. These practitioner insights provide context-specific evidence, often lacking in global studies, that addresses workforce, training, and infrastructure challenges in emerging markets. By operationalising multiple theoretical frameworks in a comparative analysis of the Boeing 787 and Airbus A350, this study delivers both conceptual innovation and practical relevance. It advances scholarly discourse while providing actionable insights for fleet planners, MRO procurement teams, training institutions, and policymakers seeking to enhance the adoption of predictive maintenance.

5.2. Recommendations for Practice

This study provides actionable strategies for enhancing maintenance efficiency and predictive readiness, informed by a comparative cost–reliability analysis and insights from Philippine-based MRO professionals. For airline fleet planners, life-cycle-based evaluation models that incorporate CPFH, MTBF, and dispatch reliability should guide fleet acquisition and renewal decisions. The A350’s modular design and higher reliability favour high-utilisation, data-driven operations, whereas the 787 remains advantageous for carriers with established Boeing infrastructure and trained personnel. A phased roadmap for predictive maintenance adoption is recommended for MRO procurement teams. Priorities include investments in interoperable digital platforms (e.g. Skywise, Prognos, and Airman), sensor-enabled health monitoring, and modular tooling for composite structures. These steps address the limited predictive analytics capabilities identified in regional MRO. Training institutions should revise their curricula to include digital diagnostics, composite repair techniques, and cross-platform maintenance logic. The interviewees emphasised the need to prepare technicians to utilise predictive tools and digital twin simulations as a critical workforce requirement. At the policy level, regulators and airline alliances should establish standardised data-sharing protocols and anonymised reliability databases to benchmark the outcomes of predictive maintenance. Such initiatives would enhance transparency and facilitate proactive fleet-wide interventions, thereby addressing the current lack of unified regional standards.

5.3. Recommendations for Future Research

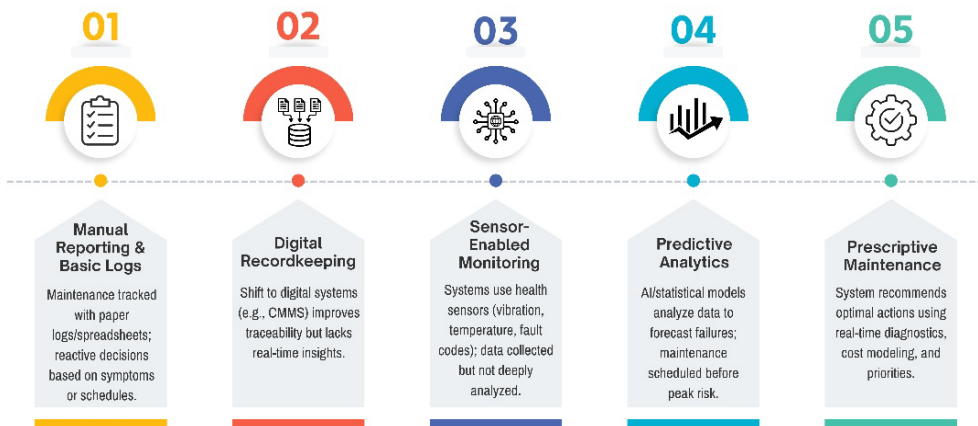


Figure 8: Predictive maintenance maturity model

Future studies should focus on developing a Predictive Maintenance Maturity Model (PMMM) to evaluate operator readiness in terms of data infrastructure, diagnostic capabilities, and system responsiveness. Research should also explore AI-driven

maintenance scheduling algorithms that optimise inspection intervals and part replacement using real-time performance data, fault histories, and operational conditions. Policy-oriented research is recommended to assess regulatory instruments, such as digital maintenance incentives and adaptive airworthiness frameworks, that could accelerate predictive maintenance adoption in emerging markets. Expanding the cost–reliability framework to include composite damage modelling using tools such as digital twins and finite element methods would enhance the prognostics of CFRP and GLARE structures. Future studies should also move beyond short-term cost proxies by developing full-spectrum LCC models that incorporate capital depreciation, heavy maintenance checks, and end-of-life recycling costs. Economic factors such as spare parts provisioning, technician training, and ground time opportunity costs should also be examined, as these were excluded from this study due to data limitations. Additionally, research should incorporate empirical data on maintenance-induced operational disruptions, including delays, cancellations, and turnaround impacts, to better assess the impact of predictive maintenance and modular design on service continuity. Furthermore, socio-technical investigations are necessary to evaluate how technician behaviour, organisational culture, and system usability influence the real-world adoption of predictive technology.

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