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Research Article

Comparative Economic Analysis of Aircraft Maintenance Expenses and Operational Revenue: A Present Value Approach for Fleet Profitability

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Abstract

In the current era of intensifying global competition within the aviation industry, the strategic management of aircraft maintenance expenditures has emerged as a critical determinant of commercial success. Beyond ensuring airworthiness, efficient maintenance protocols directly influence an airline's operational readiness, allowing for maximized aircraft utilization. When executed with precision and timeliness, these technical interventions significantly stabilize the profit-and-loss equilibrium of the carrier. Furthermore, while the primary objective of maintenance is the provision of rigorous safety and security standards, it also serves as a potent instrument for institutional marketing and service reliability. This study presents a longitudinal investigation into the maintenance expenditures of commercial passenger aircraft over a ten-year horizon within an aviation economics framework. By integrating maintenance costs with comprehensive operational overheads, the research establishes a robust framework for assessing fleet-based profitability. A central contribution of this work is the development of a diagnostic model that facilitates comparative profit-loss analyses across specific aircraft types. By delineating cost metrics such as "cost per flight hour" and "cost per available seat", the study provides air carriers with the empirical tools necessary for informed fleet procurement. Ultimately, this methodology empowers stakeholders to evaluate historical data against future value projections (present value), thereby optimizing investment decisions and enhancing long-term corporate viability.

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1. Introduction

1.1. Global Market Dynamics and the Strategic Role of Maintenance

The aviation industry represents a unique sector of the global economy, characterized by intensifying international competition. Within this high-stakes environment, aircraft maintenance expenditures emerge as a pivotal factor in operational success. The efficacy of maintenance protocols directly governs a carrier's fleet availability and aircraft utilization rates; when technical interventions are executed with precision and timeliness, they fundamentally stabilize the organization's fiscal equilibrium (Bazargan & Hartman, 2012). From the perspective of aviation economics, maintenance is not merely a technical necessity but a strategic financial lever that influences direct operating costs, asset utilization, and long-term fleet value (Zorbacı & Baynal, 2011).

1.2. The Convergence of Safety, Marketing, and Operational Continuity

While the primary objective of aeronautical maintenance is the provision of rigorous safety and security standards, these technical processes simultaneously function as a strategic marketing asset for the airline. A failure to deliver secure and reliable maintenance services leads to a significant reduction in scheduled flight hours and increases "Aircraft on Ground" (AOG) intervals (Gerdes et al., 2016). Consequently, the diversification and frequency of maintenance cycles are essential not only for operational continuity but also for the maximization of flight safety and passenger confidence.

1.3. Research Objectives and Historical Context

Our analysis aims to study the maintenance cost trajectories of airplanes within the Turkish aviation sector over a ten-year operational lifecycle. The research examines the temporal patterns of maintenance entries alongside the specific technical characteristics defined by original equipment manufacturers (OEMs) from the point of initial delivery. By establishing a robust analytical link between historical development processes and future value projections, this study provides a comprehensive framework for understanding the evolution of fleet maintenance and its long-term economic implications (Hsu et al., 2010). This work therefore contributes directly to the field of aviation economics by quantifying the trade-offs between initial acquisition costs, recurring maintenance expenditures, and operational revenues.

1.4. Methodological Framework and Model Formulation

This research utilizes a "Future Value" (FV) economic assessment model to analyze the multi-dimensional expenditures associated with aircraft maintenance over a ten-year operational horizon. The model's formulation is strategically constructed by integrating critical technical and logistical variables, including aircraft classification, prescribed maintenance intervals, and specific check categories (e.g., A, B, C, and S checks). Furthermore, the analytical framework incorporates seating capacities and various operational constraints to ensure a realistic representation of fleet dynamics.

1.5. Empirical Validation and Comparative Case Studies

The proposed methodology was empirically validated through the rigorous application of primary fleet maintenance data sourced from "Airline X." To demonstrate the model's versatility and accuracy, the future-value-based approach was applied to comprehensive case studies involving for wide-body and narrow-body aircraft. Specifically, the analysis evaluates the Airbus A320 and A330 families alongside the Boeing B737 and B777 series, facilitating a comparative assessment of lifecycle costs and technical depreciation across the industry's most prevalent aircraft types.

2. Methodology

2.1. The Strategic Significance of Maintenance in Aviation Operations

While the strategic importance of MRO was discussed in Section 1.1, the present section focuses on the operational and technical aspects of maintenance planning. In airline operations, maintenance is a critical application designed to ensure equipment reliability and maximize the operational lifespan of high-value assets. The foundational stages of a robust maintenance process involve:

- Identification of specific components or systems requiring intervention, based on manufacturer MPDs and regulatory thresholds.
- Strategic planning and scheduling of specialized personnel, tools, and hangar space.

- Execution of scheduled checks (A, B, C, S) and unscheduled repairs.
- Throughput optimization to shorten aircraft downtime (turnaround time) and mitigate associated operational costs through systematic efficiency.

2.2. Core Objectives of Aircraft Maintenance

The primary purpose of an aviation maintenance program is to systematically optimize both passenger safety and airline operational efficiency. The fundamental objectives are defined as follows:

- **Preservation:** To ensure and safeguard in terms of operational reliability and safety of all aircraft equipment.
- **Restoration:** To restore systems and components to their original factory airworthiness standards in the event of degradation or failure.
- **Data Generation:** To capture and provide critical reliability data, supplying necessary information for the continuous development and improvement of aircraft systems.
- **Availability:** To maximize aircraft uptime and keep the fleet in active commercial service.
- **Cost Efficiency:** To achieve all aforementioned operational imperatives while minimizing total maintenance expenditures.

2.3. Market Dynamics: The Boeing and Airbus Duopoly

The global market for commercial and cargo aviation is dominated by two primary manufacturers: Boeing and Airbus. Airlines with international flight networks rely almost exclusively on the diverse portfolios offered by these two entities, which include both wide-body (twin-aisle) and narrow-body (single-aisle) configurations. There exists intense competition between these manufacturers across all market segments. Airlines select specific models based on critical performance metrics, including passenger configuration capacity, fuel efficiency (specific fuel consumption), mechanical reliability, and maximum operational range.

Aircraft are categorized based on their physical dimensions and interior configurations. Narrow-body aircraft are defined by a single aisle, whereas wide-body aircraft feature twin aisles and larger fuselage diameters. While many modern commercial aircraft utilize twin-engine configurations for efficiency, certain large-scale wide-body models, such as the Airbus A340 and the Boeing 747, are equipped with four engines to support heavy payloads and ultra-long-haul missions.

3. Supply Chain Implications for MRO Costs

The cost and efficiency of aircraft maintenance, repair, and overhaul (MRO) are significantly influenced by the original equipment manufacturers' (OEMs) global supply chain structures. Both Airbus and Boeing operate highly distributed production networks, which directly affect the availability, lead time, and pricing of spare parts—key drivers of maintenance expenditure.

3.1. Airbus Supply Chain and Spare Parts Logistics

Airbus maintains major production sites in France, Germany, Spain, the United Kingdom, and China, with over 1,500 suppliers worldwide (Encyclopædia Britannica, 2018a). Approximately one-third of its components are sourced from U.S. firms. Wing assemblies are manufactured in the UK, tail sections in Spain, and final assembly occurs in Toulouse (A320, A330, A350, A380) and Hamburg (A319, A321) (Airbus, 2018). For MRO providers, this decentralized network implies:

- Geographically dispersed spare parts inventory: Components may need to be shipped across continents, increasing lead times and requiring larger safety stocks.
- Pooling and rotable pools: Airbus offers pooled spare parts programs (e.g., "Flight Hour Services") that reduce airline inventory but at a fixed cost per flight hour. The efficiency of these programs depends on the proximity of regional distribution centres. In Turkey, myTECHNIC and THY Technical Inc. benefit from Airbus's European distribution hub in Hamburg, with typical spare parts delivery times of 24–48 hours for critical items.
- Customs and logistics costs: Cross-border shipments add brokerage fees and potential delays, which are factored into MRO pricing.

3.2. Boeing Supply Chain and Spare Parts Availability

Boeing's commercial production is concentrated in Renton (B737), Everett (B767, B777), and Charleston (B787) (Encyclopædia Britannica, 2018b). The company operates a global network of distribution centres, including a major facility in Amsterdam for European customers (Boeing, 2009; Boeing, 2012; Boeing, 2018). Key MRO cost implications:

- B737 parts ubiquity: Due to the B737's market dominance, spare parts are widely available, often through multiple third-party suppliers, which exerts downward pressure on prices and reduces lead times. This partly explains the lower maintenance costs observed for the B737 in our analysis (TC1 = $0.116/FH).
- Wide-body parts scarcity: For less common types like the B777, certain components have longer lead times (up to 5–7 days for non-pooled items), forcing MROs to hold higher inventory or pay for expedited shipping, increasing total maintenance cost.
- Proprietary repair networks: Boeing's "Boeing Component Services" offers time and material contracts that guarantee parts availability but at a premium. Airlines using third-party MROs (e.g., myTECHNIC) may face higher costs if they opt out of these programmes.

3.3. Summary for MRO Cost Modeling

The supply chain characteristics described above directly influence two variables in our cost model:

- Maintenance event duration (aircraft downtime): Longer spare parts lead times extend the time an aircraft remains out of service, reducing revenue generation and potentially increasing the cost of base maintenance checks.
- Inventory holding costs: For MRO facilities, holding a larger safety stock of slow-moving parts increases warehousing and working capital costs, which are passed on to airlines in the form of higher labour and material rates.

Future research could quantify the elasticity of maintenance costs with respect to spare parts lead times using airline-specific procurement data (Zorbacı & Baynal, 2011). For the present study, we note that the observed differences in TC1 between aircraft types (e.g., B737 vs. A320) are partly attributable to the relative efficiency of their respective spare parts supply chains.

4. MRO Facilities in Turkey: Client Base and Technical Capabilities

The Turkish aviation maintenance market is served by three principal MRO providers, each with distinct specialisations and client portfolios. Their capabilities directly affect the maintenance costs and turnaround times analysed in this study.

myTECHNIC: Established in 2008 and headquartered at Istanbul Sabiha Gökçen Airport, myTECHNIC operates as an independent MRO provider serving over 30 airlines from Europe, Russia, the Middle East, and Africa (Mytechnic Aircraft Maintenance Center, n.d.). Its technical capabilities include narrow-body (Airbus A320 family, Boeing B737) and wide-body (A330, A340, B777) airframe maintenance, engine overhaul (CFM56, V2500), and component repair. The facility holds EASA Part-145 and FAA certifications, and its lean management model minimises turnaround times for A-checks (typically 24-48 hours) and C-checks (10-14 days).

THY Technical Inc.: A wholly-owned subsidiary of Turkish Airlines, THY Technical is the largest MRO provider in the region, serving more than 100 airlines worldwide. Its client base includes major network carriers, low-cost airlines, and cargo operators (Turkish Airlines, 2018). The facility operates nine hangars with a total enclosed area of 576,000 m², capable of handling A320, B737, B777, A330, A350, and B787 aircraft. Services range from line maintenance to full D-checks, cabin retrofits, and engine overhaul. THY Technical holds both EASA and FAA certifications and is a key maintenance provider for the aircraft types analysed in this study (A320, A330, B737, B777).

Detailed historical, corporate, and infrastructural information (e.g., exact hangar dimensions, founding dates, workforce numbers, ISO certifications) has been omitted as it does not directly inform the maintenance cost model. The reader is referred to the companies' official websites for such operational details.

5. Aircraft Types and Maintenance Intervals

5.1. Utilization Metrics

Aircraft maintenance scheduling is governed by three standard metrics: calendar days (DY), flight hours (FH), and flight cycles (FC), where a maintenance event is triggered by whichever threshold is reached first.

- **Calendar Days (DY):** The chronological time elapsed, regardless of flight activity.
- **Flight Hours (FH):** The total airborne duration, measured specifically from the moment of wheel lift-off to the moment of touchdown.
- **Flight Cycles (FC):** The total number of complete operational sequences, with one cycle defined as a single take-off and its subsequent landing.

5.2. Maintenance Planning and Interval Scheduling

Manufacturers' Maintenance Planning Documents (MPD) specify intervals for A, B, C, and S checks. Table 1 summarises these intervals for the four aircraft types analysed in this study. Detailed descriptions of each check type are provided in Section 5.4.2.

Table 1. Aircraft Types and Basic Maintenance Intervals

Aircraft Type	A-Check	B-Check	C-Check	S-Check (Structural)
Boeing 777 (Wide Body)	1,500 FH / 120 DY	730 DY	1,125 DY	—
Boeing 737	1,000 FH	—	7,500 FH / 730 DY*	—
Airbus A320	750 FH / 120 DY*	—	7,500 FH / 24 MO*	6 YE
Airbus A330 (Wide Body)	800 FH	42 MO	10,000 FH / 24 MO*	6 YE

Source: Airline THY consolidated financial and maintenance data, 2008–2018 (Airline THY, 2008-2018b)

5.3. Aircraft Maintenance Intervals and Associated Financial Implications

As illustrated in the preceding data, maintenance schedules and specific interval parameters vary significantly across different aircraft models. Table 2 details aircraft maintenance intervals and associated cost values. Heavy maintenance (C-checks and S-checks) differs from routine line maintenance in three critical respects:

- Extended Aircraft Downtime: These comprehensive procedures require the aircraft to be removed from revenue-generating commercial service for prolonged periods, often weeks or months.
- Resource Intensity: Heavy checks necessitate extensive labor hours, specialized engineering oversight, and deep structural tear-downs to inspect hidden components.
- Exponential Capital Expenditure: Consequently, the financial costs associated with heavy maintenance are substantially higher than those of standard operational checks, representing a major variable in an airline's direct operating costs.

Table 2. Aircraft Maintenance Intervals and Associated Cost Values

Aircraft Types	Maintenance Type	Interval	Cost ($)
B777	A	1500 FH 120 DAY	120000
B777	B	730	500000
B777	C	1125 DY	750000
B737	A	1000 FH	30000
B737	C	7500 FH 730 DAY	600000
A330	B	42 MO	500000
A330	C	10000 FH 24 MO*	700000
A330	S	6 YE	1,500000
A330	A	800	64000
A320	A	700 FH 120 DAY*	28000
A320	S	6 YE	700000
A320	C	7500 FH	450000

Source: Airline THY operational logs and financial ledgers, 2008–2018. Fleet composition (Airline THY, 2008-2018a)

5.4. Maintenance Classifications and Fundamental Objectives

5.4.1. Regulatory Framework and System Complexity

Commercial aircraft maintenance is strictly governed by manufacturer specifications and approved by relevant aviation regulatory authorities. The increasing technological complexity of modern airframes necessitates that maintenance personnel possess not only advanced mechanical proficiency but also a comprehensive understanding of integrated avionics, system functionality, and standardized maintenance protocols. (As referenced in Table 3, the average annual maintenance frequencies vary significantly across the Airbus A320, Airbus A330, Boeing 737, and Boeing 777 platforms.)

5.4.2. Classification of Periodic Maintenance Checks

Scheduled maintenance actions are systematically categorized into four progressive tiers of inspection. Table 3 shows the detailed average values of the numbers related to different maintenance types according to aircraft types. The scope and complexity of these checks increase concurrently with the length of their respective intervals, which are ultimately dictated by the specific aircraft type and its operational profile:

- **A-Check:** A routine, lower-level evaluation focusing on the operational verification of critical technical systems required for standard flight operations.
- **B-Check:** A more targeted inspection assessing system integrity, specifically focusing on structural fatigue, surface cracks, and corrosion detection. Interval parameters are highly type-specific; for instance, they are executed every 42 months for the A330 and every 730 days for the B777.
- **C-Check and S-Check (Heavy Maintenance):** Representing major maintenance milestones, these checks require exhaustive structural inspections of the airframe and rigorous, comprehensive testing of all integrated aircraft systems.

D-checks are not included in this analysis as they are typically performed only once in an aircraft's life and fall outside the ten-year study horizon.

Table 3. Average Value of Aircraft Maintenance Counts

	Aircraft Count	A	B	C	S
A330	104	10,95	0,28	0,87	0,16
A320	88	11,68	-	1,1	0,16
B737	66	8,76	-	1,1	-
B777	38	5,84	0,5	0,32	-

Source: Airline THY operational logs and financial ledgers, 2008–2018. (Airline THY, 2008-2018a)

The company that owns these aircraft is THY Technic, which is affiliated with the Turkish Airline as THY.

6. Calculation of Maintenance and Operational Expenditures

The financial framework surrounding aircraft maintenance is multifaceted, encompassing a diverse array of cost-driving variables. This section provides a longitudinal analysis of these expenditures, modeling maintenance costs over a projected ten-year operational lifecycle. It is crucial to recognize that these financial requirements are not static. The cumulative cost of maintenance is subject to compounding annual escalation. This upward trajectory is typically driven by fluctuating economic conditions, market inflation, and the natural increase in required structural and systemic interventions as an airframe and its components age over time.

To ensure transparency and reproducibility, the following indicators are defined mathematically:

- Passenger Flight Time (PFT) – total seat hours occupied by passengers in a given year:

PFT = Aircraft Capacity × Cumulative Flight Hours (FH)

- Value-Added Rate (VAR): seat utilization efficiency:

VAR = PFT / (Aircraft Capacity × Cumulative FH) (Equivalent to the ratio of passenger flight time to available seat hours.)

- Operating Profit (OP): net financial yield from core commercial operations.

OP = Ticket Sales Revenue – (Maintenance Costs + Fuel + Crew + Airport Fees + Other Direct Operating Costs)

In this study, OP is not shown directly in Tables 4–5; it is derived in Table 8 after aggregating all costs.

- Net Operating Cash Flow (NCF): cash surplus before financing and taxes:

NCF = Ticket Sales Revenue – (Maintenance Costs + Non-Maintenance Direct Operating Costs)

- Future Value (FV): adjustment to 2018 purchasing power using exchange rates:

$FV_t = NCF_t \times (ER_2018 / ER_t)$

where ER = average annual TL/USD exchange rate (Table 9).

All monetary values are in nominal USD unless stated otherwise.

Tables 4, 5, 6, and 7 below list the Core Operational and Utilization Metrics related to maintenance and operating costs and revenues for the aircraft types specified, over a 10-year period. To accurately assess the operational efficiency and revenue generation of the aircraft, the following standardized parameters are utilized:

- Value-Added Rate: An indicator of operational efficiency, mathematically defined as the ratio of total passenger flight time to the aggregate available seat hours.
- Aircraft Capacity: The maximum authorized passenger seating configuration of the airframe.
- Cumulative Flight Hours: The total aggregate airborne time logged by the aircraft over the course of a single operational year.
- Passenger Flight Time: The total accumulated hours during which the aircraft's seats are actively occupied by passengers within a given year, often referred to in the industry as revenue passenger hours.
- Operating Revenue and Financial Returns: Within the aviation economics framework, operating revenue (often referred to as operating profit) represents the net financial return an airline derives solely from its core business activities. This critical performance metric is calculated by subtracting all direct operating expenses—such as maintenance costs, fuel consumption, and flight crew expenses—from gross operating revenue from passenger and cargo transportation.

The following tables present empirical data from Airline THY (a commercial airline operating in Turkey) for the period 2008–2018:

Table 4 present data separately for A320 aircraft type. The fleet composition (number of aircraft per type) is given in Table 3.

Table 4. Operational and Maintenance Specifications of the Airbus A320 Aircraft

AC Type	Aircraft Capacity	Cumulative Flight Hours	Value-Added Rate	Passenger Flight Time	Ticket Sales Revenue ($) (Operating Income)
A320		4229046253			
2008	190	28786711	14%	5469475090	677.438.457
2009	190	64771907	23%	12306662330	1.068.609.000
2010	190	112592604	30%	21392594760	1.697.210.616
2011	190	160891427	33%	30569371130	2.315.310.776
2012	190	223412645	34%	42448402550	2.783.586.415
2013	190	332497086	36%	63174446340	3.590.374.921
2014	190	463890783	36%	88139248770	4.022.031.807
2015	190	560843117	32%	106560192230	3.334.791.338,
2016	190	661040602	31%	125597714380	3.063.597.362
2017	190	753126080	31%	143093955200	3.366.422.603
2018	190	867193291	29%	164766725290	3.730.351.639

Source: Airline THY operational logs and financial ledgers, 2008–2018. Fleet composition (Airline THY, 2008-2018a)

***Note*:** The values in this column are gross ticket sales revenue, not operating profit. Operating profit (revenue minus all direct operating costs) is calculated in Table 5 after aggregating maintenance and non-maintenance expenses.

Table 5 present data separately for A330 aircraft type. The fleet composition (number of aircraft per type) is given in Table 3.

Table 5. Operational and Maintenance Specifications of the Airbus A330 Aircraft

AC Type	Aircraft Capacity	Cumulative Flight Hours	Value-Added Rate	Passenger Flight Time	Ticket Sales Revenue ($) (Operating Income)
A330	-	2003243706	-	-	
2008	290	18233508	14%	5287717320	654.926.297
2009	290	26748316	15%	7757011640	673.554.878
2010	290	33706555	14%	9774900950	775.505.068
2011	290	48574995	15%	14086748550	1.066.924.163
2012	290	72317976	17%	20972213040	1.375.268.886
2013	290	105288171	18%	30533569590	1.735.305.473
2014	290	182158237	22%	52825888730	2.410.587.878
2015	290	275183114	24%	79803103060	2.497.430.713
2016	290	343336365	25%	99567545850	2.428.665.779
2017	290	374849966	23%	108706490140	2.557.424.490
2018	290	522846503	26%	151625485870	3.432.831.348

Source: Airline THY operational logs and financial ledgers, 2008–2018. Fleet composition (Airline THY, 2008-2018a)

Table 6 present data separately for B737 aircraft type. The fleet composition (number of aircraft per type) is given in Table 3.

Table 6. Operational and Maintenance Specifications of the Boeing B737 Aircraft

AC Type	Aircraft Capacity	Cumulative Flight Hours	Value-Added Rate	Passenger Flight Time	Ticket Sales Revenue ($) (Operating Income)
B737		5768926753			
2008	150	183199379	72%	27479906850	3.403.607.369
2009	150	215414912	62%	32312236800	2.805.727.998
2010	150	263842167	56%	39576325050	3.139.841.604
2011	150	306086135	49%	45912920250	3.477.424.464
2012	150	343636893	41%	51545533950	3.380.137.755
2013	150	406543392	35%	60981508800	3.465.744.340
2014	150	491509975	30%	73726496250	3.364.339.010
2015	150	751834040	33%	112775106000	3.529.286.489
2016	150	817669097	31%	122650364550	2.991.705.185
2017	150	909992149	29%	136498822350	3.211.265.775
2018	150	1079198614	28%	161879792100	3.664.990.894

Source: Airline THY operational logs and financial ledgers, 2008–2018. Fleet composition: 88 A320 aircraft (from Table 3) (Airline THY, 2008-2018a)

Table 7 present data separately for B777 aircraft type. The fleet composition (number of aircraft per type) is given in Table 3.

Table 7. Operational and Maintenance Specifications of the Boeing B777 Aircraft

AC Type	Aircraft Capacity	Cumulative Flight Hours	Value-Added Rate *	Passenger Flight Time	Operating Income
B777		876490394	-	-	-
2010	370	42964	0%	15896680	2.333.887
2011	370	7687982	5%	2844553340	384.251.313
2012	370	28705388	15%	10620993560	1.236.139.812
2013	370	51563879	20%	19078635230	2.016.999.480
2014	370	73731536	22%	27280668320	2.398.565.799
2015	370	104413562	22%	38633017940	2.350.092.744
2016	370	140677398	22%	52050637260	2.098.094.805
2017	370	203359160	22%	75242889200	2.429.288.801
2018	370	266308525	25%	98534154250	3.217.971.402

Source: Airline THY operational logs and financial ledgers, 2008–2018. Fleet composition: 88 A320 aircraft (from Table 3) (Airline THY, 2008-2018a)

Table 8 presents consolidated maintenance costs, non-maintenance direct operating costs, ticket sales revenue, net operating cash flow, and future values for all four aircraft types as a total fleet.

Table 9 aggregates all four aircraft types to show total cumulative flight hours and seat hours per year.

Table 10 presents standardized cost metrics (TC1, TC2) **per aircraft type based on cumulative ten-year data.

All monetary values are in nominal USD unless stated otherwise.

6.1. Discounted Cash Flow Framework

To properly account for the time value of money, we adopt a Net Present Value (NPV) approach. All cash flows (maintenance costs, non-maintenance operating expenses, and ticket sales revenues) are discounted to the base year (2008) using a real discount rate of 8%, which represents the weighted average cost of capital (WACC) for a typical commercial airline (IATA, 2019). This discounted cash flow methodology is a cornerstone of aviation economics, enabling the comparison of investment alternatives (e.g., different aircraft types) on a consistent present-value basis.

Table 8 presents a comprehensive financial analysis spanning a ten-year operational period from 2008 to 2018. This model systematically calculates both maintenance-specific expenditures and non-maintenance operational costs. Notably, the financial assessment incorporates macroeconomic variables, specifically accounting for exchange rate fluctuations observed in 2018.

To accurately model these costs and revenues, several foundational metrics and financial formulas were established as follows:

- Maintenance Costs = scheduled A, B, C, S check costs (from Table 2).
- Non-Maintenance Direct Operating Costs = fuel, crew salaries, airport fees, catering, ground handling, and other expenses directly tied to flight operations (excludes sales, general, and administrative expenses).
- Net Operating Cash Flow (before interest and taxes) = Ticket Sales Revenue – (Maintenance Costs + Non-Maintenance Direct Operating Costs). This represents the cash generated from core flying activities before financing and tax payments.
- Future Value (2018 USD) = Net Operating Cash Flow × (ER_2018 / ER_year/),

  where ER = average annual TL/USD exchange rate (Table 9).

Cash flow definition: Our "Net Operating Cash Flow" excludes financing costs, depreciation, taxes, and working capital changes. Consequently, the profit margin included in ticket sales revenue remains entirely within this cash flow measure, which may overstate liquidity compared to a free cash flow to firm (FCFF) calculation. Future research should incorporate these adjustments.

Table 8. Aggregate data for Turkish Airlines' maintenance-related expenses and non-maintenance operating costs and revenues for its entire fleet (A320, A330, B737, B777) between 2008 and 2018

Year	Maintenance Costs ($)	Non-Maintenance Direct Operating Costs ($)	Total Direct Operating Costs ($)	Ticket Sales Revenue ($)	Net Operating Cash Flow ($)	Future Value (2018 USD)
2008	2,606,837	488,651,553	491,258,390	677,438,457	186,180,067	240,172,286
2009	3,388,093	722,059,120	725,447,213	1,068,609,000	343,161,787	530,851,000
2010	3,285,069	1,232,946,584	1,236,231,653	1,697,210,616	460,978,963	691,468,445
2011	3,383,473	1,842,488,807	1,845,872,280	2,315,310,776	469,438,496	784,562,288
2012	6,404,498	2,169,063,429	2,175,467,927	2,783,586,415	608,118,488	1,088,532,093
2013	9,881,614	3,265,551,576	3,275,433,190	3,590,974,921	314,941,731	598,389,289
2014	9,560,034	3,808,198,637	3,817,758,671	4,022,031,807	204,273,136	447,137,667
2015	4,910,264	2,919,334,237	2,924,244,501	3,334,791,338	410,546,837	1,116,687,396
2016	6,329,840	2,523,090,959	2,529,420,799	3,063,597,362	534,176,563	1,613,213,221
2017	7,407,438	2,933,041,921	2,940,449,359	3,362,422,603	425,973,244	1,554,802,341
2018	4,875,129	2,691,007,170	2,695,882,299	3,730,351,639	1,034,469,340	4,975,797,525

Source: Airline THY consolidated financial and maintenance data, 2008–2018 (aggregated for all four aircraft types: A320, A330, B737, B777). (Airline THY, 2008-2018b)

Note: The Net Operating Cash Flow includes the profit margin embedded in ticket prices by definition. This is standard for operating cash flow calculations. However, this metric does not account for financing costs, depreciation, taxes, or changes in working capital. For a full free cash flow analysis, those adjustments would be required (see limitation in Section 7.4)

6.2. Exchange Rate Integration and Time Value Adjustments

Following Table 9 details the average annual exchange rates derived from official central bank data, which are subsequently applied to calculate the future value. This methodological adjustment ensures that all recorded costs across the 10-year longitudinal study are economically standardized, adjusting for currency fluctuations to render them equivalent to their present value.

Table 9. Average annual exchange rates derived from official central bank data

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
TL/ SD $ Exchange rate	1,29	1,55	1,5	1,67	1,79	1,9	2,19	2,72	3,02	3,65	4,81

Source: Central Bank of the Republic of Turkey (n.d.)

6.3. Fleet Utilization and Seat Flight Time Calculation

Table 10 below shows the total flight hours and Grand Total Seat Hour values for each aircraft type in the fleet by year, as well as the total flight hours (Grand Total AC Hour) for all aircraft. This table helps to see how efficiently each aircraft operates per seat.

Table 10. Total Flight Hours and Seat Hours for each aircraft types, by year

Year	A320 FH	A330 FH	B737 FH	B777 FH	Grand Total Seat Hour	Grand Total AC Hour
2008	28 786 711	18 233 508	183 199 379	-	38 237 099 260	230 219 598
2009	64 771 907	26 748 316	215 414 912	-	52 375 910 770	306 935 135
2010	112 592 604	33 706 555	263 842 167	42 964	70 759 717 440	410 184 290
2011	160 891 427	48 574 995	306 086 135	7 687 982	93 413 593 270	523 240 539
2012	223 412 645	72 317 976	343 636 893	28 705 388	125 587 143 100	668 072 902
2013	332 497 086	105 288 171	406 543 392	51 563 879	173 768 159 960	895 892 528
2014	463 890 783	182 158 237	491 509 975	73 731 536	241 972 302 070	1 211 290 531
2015	560 843 117	275 183 114	751 834 040	104 413 562	337 771 419 230	1 692 273 833
2016	661 040 602	343 336 365	817 669 097	140 677 398	399 866 262 040	1 962 723 462
2017	753 126 080	374 849 966	909 992 149	203 359 160	463 542 156 890	2 241 327 355
2018	867 193 291	522 846 503	107 9198 614	266 308 525	576 806 157 510	2 735 546 933

Source: Airline THY operational logs and financial ledgers, 2008–2018. (Airline THY, 2008-2018a)

***Note*:** Grand Total Seat Hours = Sum of (Aircraft Capacity × Cumulative FH) for all four types.

Grand Total AC Hours = Sum of Cumulative FH for all four types

7. Conclusion

7.1. Methodological Framework and Case Study Validation

Our study presents a practical, future-value-based methodology designed to project and analyze the maintenance costs of a commercial aircraft fleet. The proposed analytical model is comprehensively formulated to integrate key variables, including aircraft type, operational status, maintenance scheduling, seat capacity, and various logistical constraints. Table 11 details the standardized cost metrics for a 10-year fleet operational lifecycle.

To empirically validate the proposed methodology, a detailed case study was conducted utilizing historical maintenance data from an active commercial airline. This evaluation analyzed four distinct aircraft platforms, providing a cross-sectional comparison of both narrow-body and wide-body fleets: the Airbus A320, Airbus A330, Boeing 737, and Boeing 777.

Table 11. Standardized Cost Metrics for a 10-Year Fleet Operational Life Cycle

AC Type	AC Purchasing Cost	Maint Cost	Cumulative Seat Hour FH_2	AC's Cumulative FH_1	TC1	TC2
B777 (wide body)	$375.000.000	$331.947.962	324301445780	876490394	$0,807	0,00218
B737	$106.000.000	$561.363.015	580940674740	5768926753	$0,116	0,00115
A330 (wide body)	$265.000.000	$976.758.198	865339012950	2003243706	$0,620	0,00143
A320	$101.000.000	$827.559.933	803518788070	4229046253,00	$0,220	0,00116

Source: Airline THY operational logs and financial ledgers, 2008–2018. Fleet composition (Airline THY, 2008-2018a)

7.2. Total Cost per Flight Hour Calculation

The following formulas describe the methodology used to calculate standardized hourly costs for aircraft types. According to our study, both Total Cost 1 (TC1) and Total Cost 2 (TC2) use the same basic economic equations; these equations have been applied to different aircraft types and fleet scenarios in our study.

The metric is derived by aggregating the initial capital acquisition cost and the cumulative maintenance expenses, and subsequently dividing this sum by the aircraft's total accumulated flight hours (FH).

This relationship can be formally expressed as:

TC1, 2 =[Aircraft Purchasing Cost + Maintenance Cost] \ Total Flight Hours (FH)

Alternatively, using standard academic notation:

TC1 =[Aircraft Purchasing Cost + Maintenance Cost] \ AC's Cumulative (FH_1)

TC1, 2 =[Aircraft Purchasing Cost + Maintenance Cost] \ Cumulative Seat Hour (FH_2)

7.3. Economic Analysis and Profitability Outcomes

Throughout the study, cumulative maintenance expenditures, direct operational costs, and auxiliary expenses were rigorously calculated for each of the four aircraft types. The primary operational outcomes of this research include:

- Comparative Profitability: By synthesizing all operational and financial criteria, the study offers a robust framework for airlines to evaluate the comparative profitability of different aircraft models. This specifically aids operators in making data-driven strategic decisions regarding the economic viability of narrow-body versus wide-body configurations.
- Standardized Cost Metrics: As detailed in Table 11, the research successfully calculated the total cost per Flight Hour (FH) and the standardized cost per available seat over a projected 10-year operational lifecycle.

Ultimately, these quantified metrics provide airline operators with a definitive, financial baseline to identify and optimize the most economically advantageous fleet composition.

7.4. Recommendations for Future Research in Aviation Economics

The methodological framework developed here can be extended in several directions within the field of aviation economics:

- Incorporating dynamic pricing models: Linking seat utilization and yield management to maintenance scheduling.
- Environmental Economics: Adding carbon pricing and emissions trading schemes to the cost model.
- Real options Analysis: Valuing the flexibility to defer, expand, or scrap fleet investments under uncertainty.
- Macroeconomic linkages: Modeling the impact of GDP growth, oil prices, and exchange rates on maintenance cost structures.

These extensions would further solidify the bridge between aircraft maintenance engineering and aviation economic theory.

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