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COMPARATIVE FUEL EFFICIENCY ANALYSIS AND OPERATIONAL IMPLICATIONS OF EXTENDED TWIN ENGINE OPERATIONS (ETOPS) FOR JAKARTA – JEDDAH ROUTE

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Abstract: This study analyzes ETOPS fuel planning for an Airbus A330-343 on the Jakarta (CGK) to Jeddah (JED) route, comparing 90-minute and 120-minute diversion times across four flight cases: standard, pressure loss, engine failure, and combined pressure loss with engine failure**.** A comparative analysis was conducted using an industry-standard formula to calculate fuel requirements, payload capacities, and flight durations for each scenario. Results indicate that the 120-minute diversion time generally offers advantages in fuel efficiency and payload capacity. The standard fuel plan for 120-minute diversion required 63,790 kg of fuel, compared to 64,689 kg for the 90-minute scenario. Pressure loss cases demanded the highest fuel consumption in both scenarios. The 120-minute diversion time also allowed for a more direct flight path, reducing overall flight duration in most cases. This research provides practical insights for airlines operating on this route; enabling them to optimize fuel policies, reduce operational costs, and minimize environmental impact.

Keywords: Fuel Plan, ETOPS, Diversion Time, Efficiency, Long-haul Flight

Introduction

Extended-range Twin-engine Operations Performance Standards (ETOPS) have transformed the landscape of commercial aviation, expanding the operational range of twin-engine aircraft operations on routes that were once restricted to planes with three or four engines. Introduced in the 1980s, ETOPS guidelines were developed in response to advancements in engine reliability, which made it feasible for twin-engine planes to undertake long-haul routes over oceans or remote areas (ICAO, 2017). Since its introduction, ETOPS has provided airlines increased flexibility, reduced costs, and the ability to optimize long-haul operations, allowing twin-engine aircraft to operate efficiently on transoceanic and other extended routes. This regulatory shift has been a turning point, enabling airlines to reduce operational costs and enhance efficiency through the use of twin-engine aircraft instead of larger, more fuel-intensive planes (Kim, 2024; Moore, 1993).

The introduction of ETOPS certification has been a significant advancement in aviation, particularly in terms of fuel efficiency and route planning, allowing airlines to operate on previously challenging routes. For example, the implementation of ETOPS by an Indonesian airline on the Cengkareng-Perth route resulted in fuel savings of 105 liters per flight, demonstrating the operational and economic advantages of ETOPS-certified flights. This highlights the potential of ETOPS to enhance fuel efficiency and reduce operational costs,

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positioning it as a valuable strategy for airlines on high-demand routes. (Purwaningsih et al., 2018; World Population Review, 2024).

The adoption of ETOPS guidelines has had a particularly strong impact on commercial aviation, as it provides airlines with greater flexibility in route planning and enhances fuel efficiency. Implementing ETOPS could be a viable strategy for reducing emissions by optimizing flight routes (Tuladhar et al., 2021). This regulatory framework was established by the International Civil Aviation Organization (ICAO) and has since been widely implemented across the industry (Claramunt Segura & Jordi, 2017). ETOPS certification enables twin-engine aircraft to operate on extended routes with a designated diversion time, meaning that in the event of an engine failure or other emergency (Inouye et al., 2018), the aircraft must reach an alternate airport within the specified time limit. This provision has been critical in promoting the use of twin-engine aircraft for transoceanic and other long-distance flights, expanding operational possibilities for airlines globally (Airbus, 1998; ICAO, 2017).

Despite the widespread adoption of ETOPS, route-specific studies remain limited, particularly for high-demand corridors such as Jakarta-Jeddah (Putra & Kusumastuti, 2020). This study aims to fill this gap by providing a comparative analysis of ETOPS fuel planning for this route, which is crucial given to its role in transporting Indonesian pilgrims for Hajj and Umrah**.** Indonesia, with the world's largest Muslim-majority population, is a leading source of Hajj and Umrah pilgrims, sending hundreds of thousands of travelers to Saudi Arabia each year (Showail, 2022). High demand has led substantial wait times, with some Indonesian regions experiencing Hajj waiting lists as long as 91 years and annual quotas surpassing 92,000 in populous areas like East Java (Andni et al., 2023).To address this need, airlines on the Jakarta-Jeddah route strive to balance safety, efficiency, and capacity to meet the peak demand during these spiritual journeys. The introduction of ETOPS-certified twin-engine aircraft on this route has been a game-changer, improving fuel efficiency and enhancing operational flexibility for airlines, allowing them to manage high passenger volumes more efficiently (DeSantis, 2013).

However, the unique challenges of these religious travel, including peak season demands and the need for reliable, cost-effective transportation, make optimizing ETOPS operations on this route particularly crucial. Fuel planning for these flights involves complex calculations that must account for various scenarios, such as potential diversions to alternate airports (Airbus, 1998; da Fonseca Filho et al., 2019). The diversion time, which determines the maximum distance an aircraft can fly from a suitable airport, is a key factor in these calculations, affecting not only fuel requirements but also payload capacity and overall flight efficiency (Troutt, 2020).

With ETOPS certification, twin-engine aircraft such as the Airbus A330-343 have been allowed to operate on this route, providing airlines with a more flexible and cost-effective way to meet demand. By allowing longer diversion times—typically up to 120 minutes or more—ETOPS certification enables these aircraft to follow more direct flight paths and operate with a high reliability over the vast distances between alternate airports (Airbus, 1998). The fuel efficiency of twin-engine aircraft compared to their larger counterparts provides additional advantages in both cost savings and environmental impact. Given the high passenger volumes and seasonal peaks of the Jakarta-Jeddah route, the adoption of ETOPS-certified twin-engine aircraft has significantly enhanced airlines' ability to optimize route planning, reduce fuel costs, and accommodate increased passenger demand during peak travel times (W. Wang, 2022).

Safety is paramount in ETOPS operations, as these flights frequently traverse remote areas with limited landing options. ETOPS regulations ensure that twin-engine aircraft can reach alternate airports within the specified diversion time, even in emergencies, maintaining operational safety. This requirement enhances passenger safety while ensuring compliance with stringent safety protocols (Goncalves & de Andrade, 2010). Airlines must consider various emergency scenarios when planning fuel loads for ETOPS routes, including descend to lower altitudes in cases of cabin pressure loss or operate on a single engine in the event of engine failure. Recent advancements in aircraft technology and engine reliability have led to a trend of extending ETOPS diversion times, as aircraft technology has improved and engine reliability has reached unprecedented levels. The shift from a 90-minute to a 120-minute ETOPS configuration provides airlines additional operational flexibility, enabling to reduce overall flight time and fuel consumption by taking more direct paths (Jung & Grimme, 2022). For the Jakarta-Jeddah route, which is relatively isolated from other suitable landing options, the increased diversion time can be particularly advantageous (Airbus, 1998). However, longer ETOPS times also demand stricter fuel planning and emergency readiness to account for the additional time required to reach an alternate airport in an emergency (Huiru & Xuyang, 2018).

Fuel represents 20-30% of total operational costs for airlines, making efficient fuel planning essential for both economic reasons and also for environmental sustainability. Lowering fuel consumption directly lowers carbon emissions, supporting the aviation industry’s commitment to achieving carbon-neutral growth and net-zero emissions by 2050 (Camilleri, 2018). Optimizing fuel use on long-haul flights aligns with these goals, as reducing fuel consumption also reduces CO_2 emissions. ETOPS-certified twin-engine aircraft play a key role in this context, as their enhanced fuel efficiency makes them better suited for meeting these environmental standards (Brueckner & Abreu, 2017). On the Jakarta-Jeddah route, where large numbers of travelers embark on religious pilgrimages, even minor fuel efficiency improvements in fuel efficiency can yield significant economic and environmental benefits over time. For example, a reduction in fuel consumption of 899 kg per flight, as demonstrated by the 120-minute ETOPS configuration, can translate into substantial cost savings and emission reductions over multiple flights (W. Wang, 2022).

Recent studies highlight the increasing complexity of managing ETOPS operations on high-demand religious travel routes, particularly in the context of evolving aviation regulations and sustainability requirements (Khaled Gamraoyi, 2016). The Jakarta-Jeddah corridor presents a unique case study for examining these challenges, as it combines the technical demands of ETOPS compliance with the logistical challenges of accommodating large volumes of pilgrimage travelers. Airlines operating on this route must navigate a delicate balance between maximizing operational efficiency and maintaining robust safety margins, all while managing the seasonal surge in passenger demand during Hajj and Umrah periods (Dimas et al., 2018). The relationship between ETOPS certification and fuel planning is especially critical, considering factors such as alternate airport availability, weather conditions, and the need to maintain adequate payload capacity for maximum passenger transport (Rahman & Ali, 2021). Additionally, the aviation industry's increasing focus on environmental sustainability adds complexity to ETOPS fuel planning decisions, as airlines must optimize their operations to reduce emissions while maintaining the highest safety standards. This research addresses these intersecting challenges by analyzing specific fuel planning scenarios for the A330-343 aircraft, providing practical insights that can benefit both airline operators and aviation regulators in optimizing long-haul religious travel routes.

This study addresses the gap in route-specific ETOPS research by providing a comparative analysis of ETOPS fuel planning for the Jakarta (CGK) to Jeddah (JED) route, using an A330-343 aircraft as a case study. It examines 90-minute and 120-minute diversion time scenarios across different flight cases, including standard operations, pressure loss, engine failure, and combined pressure loss with engine failure. The 180-minute scenario is not applicable due to the geographical constraints of the Jakarta-Jeddah corridor, 120-minute range is sufficient to make a range comparison.

The findings of this study have significant implications for airlines serving the Indonesian market for religious travel to Saudi Arabia and operating on similar long-distance routes. By understanding the relationship between diversion times, fuel consumption, payload capacity, and flight duration, airlines can make more informed decisions about their ETOPS operations, potentially improving both safety margins and economic performance while better serving the needs of travelers. This research also underscores the importance of fuel optimization in achieving sustainability goals, reduce operational costs, and enhance overall flight efficiency.

Method

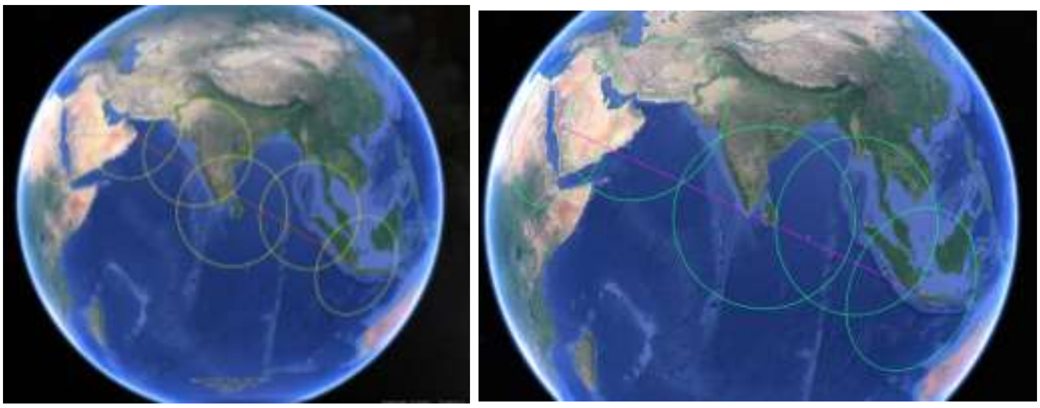
This study employed a comprehensive approach to analyze ETOPS operations on the Jakarta (CGK) to Jeddah (JED) route using an Airbus A330-343 aircraft. The A330-343 was selected due to its widespread use in long-haul operations, with key specifications including a Maximum Take-Off Weight (MTOW) of 242,000 kg, a Maximum Landing Weight (MLW) of 187,000 kg, and a fuel capacity of 111,272 kg in its 3-tank configuration (Airbus, 2003, 2023). The aircraft is powered by two Rolls-Royce Trent 772B-60 turbofans and cruises at Mach 0.83 (Miguel & Silva, 2018). The route analyzed stretches from Soekarno-Hatta International Airport in Jakarta (CGK) to King Abdulaziz International Airport in Jeddah (JED), with Taif International Airport (TIF) designated as the alternate airport . A comparison of airport route points used as references for diversion times is shown in Figure 1. Ground distances were calculated for both 90-minute and 120-minute ETOPS configurations to allow for comparative analysis displayed in . Four scenarios were analyzed for each ETOPS configuration: Standard Flight Plan, Pressure Loss, Engine Failure, and a combined Pressure Loss and Engine Failure scenario(Airbus, 1998; Federal Aviation Administration, 2007; X. Wang et al., 2024). Four operational scenarios were analyzed for each ETOPS configuration:

- Standard Flight Plan
  This scenario represents normal flight operations. It assumes that both engines are functioning correctly and that the aircraft maintains its planned cruising altitude throughout the flight. The standard flight plan is used as a baseline for comparison with other scenarios and reflects the most common operational conditions.
- Pressure Loss
  This scenario simulates an in-flight cabin pressure loss, requiring the aircraft to descend to a lower altitude—typically around 10,000 feet—where the air is breathable without pressurization. This descent affects fuel consumption due to increased air density at lower altitudes. The scenario is crucial for ensuring that sufficient fuel is carried to handle this type of emergency while still reaching a suitable airport.
- Engine Failure
  This scenario simulates an in-flight engine failure. This situation requires the aircraft to operate on a single engine, descend to a lower altitude, and fly at a reduced speed, which significantly affects fuel consumption. The aircraft must carry enough fuel to reach a suitable airport using only one engine. This scenario is fundamental to ETOPS certification, as it tests the aircraft's ability to fly extended distances with only one operational engine.

- Pressure Loss + Engine Failure
  This combined scenario represents a worst-case situation where the aircraft experiences both a loss of cabin pressure and an engine failure simultaneously. In this case, the aircraft must descend to a lower altitude while operating on a single engine, significantly increasing fuel consumption due to the combined effects of increased air density and reduced engine efficiency. This scenario tests the most extreme conditions that could be encountered during an ETOPS flight and ensures that the aircraft carries sufficient fuel reserves to handle such an unlikely but critical situation.

Fuel requirements were calculated using a custom-developed spreadsheet based on Airbus fuel planning guidelines (Airbus, 1998, 2023; Federal Aviation Administration, 2007; X. Wang et al., 2024). The calculation included components such as taxi fuel, trip fuel, contingency fuel (set at 3% of trip fuel), alternate fuel, final reserve fuel, and additional fuel required for specific ETOPS scenarios. To ensure consistency across calculations, several assumptions were made: International Standard Atmosphere (ISA) temperature conditions, a cruise altitude of FL340, a cruise speed of Mach 0.8, and a ramp weight of 240,500 kg (Airbus, 2023). For each scenario, fuel requirements were calculated based on the specific conditions of that scenario. These calculations took into account factors such as altitude changes, speed adjustments, and the increased fuel consumption associated with flying at lower altitudes or with a single engine(X. Wang et al., 2024). This study focused on standard atmospheric conditions, excluding weather and external variables, which are acknowledged as limitations to be addressed in future research.

Data analysis involved a comparative study between 90-minute and 120-minute ETOPS configurations across the different scenarios. The analysis focused on comparing fuel requirements, payload capacities, and flight durations for each scenario and ETOPS configuration. This approach provided a thorough evaluation of how different ETOPS configurations impact operational efficiency on this long-haul route.



(a) **(b)**

Figure 1 ETOPS circle for (a) 90-minute diversion time and (b) 120-minute diversion time

Table 1 Operatial plan ground distance

ETOPS Ground Distance		
Route	90 minute	120 minute
CGK-JED	4370 nm	4305 nm
Critical Point - JED	427 nm	572 nm

JED-TIF	78 nm	78 nm

Result

The analysis of Extended-range Twin-engine Operations Performance Standards (ETOPS) for the Jakarta (CGK) to Jeddah (JED) route using an Airbus A330-343 revealed significant differences between 90-minute and 120-minute ETOPS configurations across various operational scenarios. Table 2 and Figure 2 present the results of fuel planning calculations and flight time requirements for the Jakarta (CGK) to Jeddah (JED) route. The 120-minute ETOPS configuration demonstrated superior fuel efficiency in the standard flight plan, requiring 899 kg less fuel compared to the 90-minute configuration. However, in the pressure loss scenario, the difference was minimal, with the 120-minute configuration requiring only 16 kg less fuel.

As shown in Table 3 and Figure 3, the 120-minute ETOPS configuration enabled a higher payload capacity across all scenarios. In the standard flight plan, it provided an additional 899 kg of payload capacity compared to the 90-minute configuration. Flight durations were generally shorter for the 120-minute ETOPS configuration, with the standard plan showing a 9-minute reduction compared to the 90-minute ETOPS.

The 120-minute ETOPS configuration also allowed for a more direct route, reducing the total flight distance from 4,370 nm to 4,305 nm, a decrease of 65 nm. Table 4 and Figure 4 illustrate the differences in flight durations between the ETOPS configurations. Emergency scenarios, including pressure loss and engine failure, were found to be manageable within both ETOPS configurations. The fuel requirements for these scenarios remained within operational limits, affirming the robustness of current ETOPS safety standards.

Table 2 Fuel Requirements for Different Flight Scenarios (in kg)

ETOPS	Standard Plan	Pressure Loss	Engine Failure	Pressure Loss + Engine Failure
90	64,689	64,473	63,900	64,014
120	63,790	64,457	63,550	63,824

Table 3 Payload Capacity for Different Flight Scenarios (in kg)

ETOPS	Standard Plan	Pressure Loss	Engine Failure	Pressure Loss + Engine Failure
90	53,611	53,827	54,400	54,286
120	54,510	53,843	54,750	54,476

Table 4 Flight Duration for Different Scenarios (in minutes)

ETOPS	Standard Plan	Pressure Loss	Engine Failure	Pressure Loss + Engine Failure
90	583	597	594	593
120	574	595	593	594

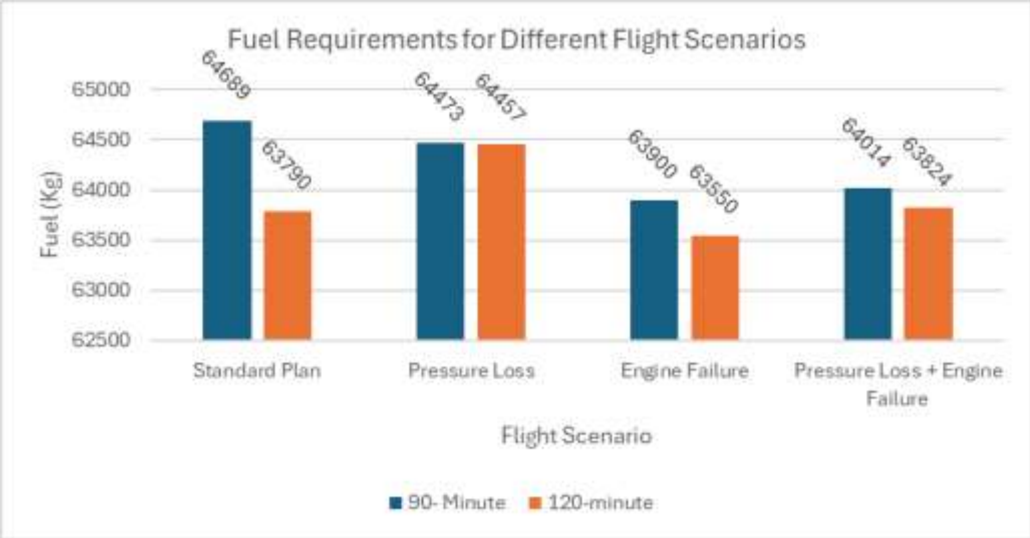


Figure 2 Fuel requirement comparison on ETOPS 90 and 120 minute diversion time

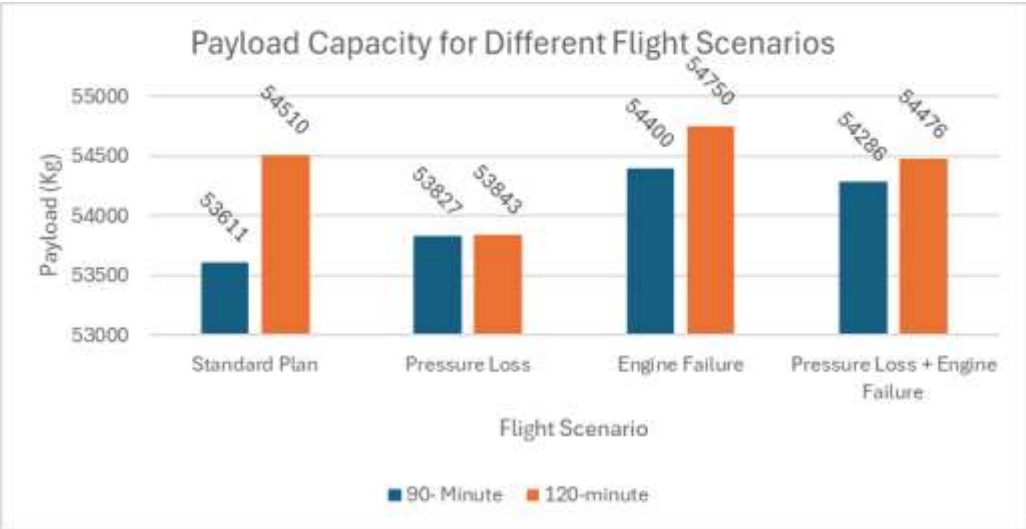


Figure 3 Payload capacity comparison on ETOPS 90 and 120 minute diversion time

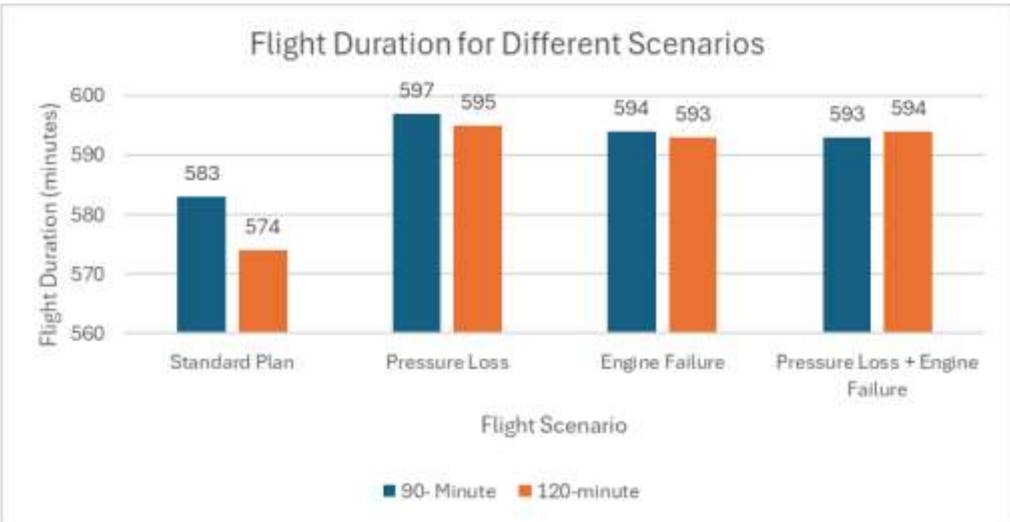


Figure 4 Flight Duration comparison on ETOPS 90 and 120 minute diversion time

Discussion

The consistent advantage in fuel efficiency demonstrated by the 120-minute ETOPS configuration, particularly in the standard flight plan, aligns with the broader industry trend towards extended ETOPS times. This trend is driven by the potential for cost savings and reduced environmental impact, as highlighted by Kim (2024) and Moore (1993), who noted that ETOPS certification has enabled airlines to optimize long-haul operations using twin-engine aircraft, which are more fuel-efficient than their larger counterparts. A study on an Indonesian airline implementing ETOPS on the Cengkareng-Perth route reported fuel savings of 105 liters per flight (Purwaningsih et al., 2018), reinforcing this study's findings on the operational and economic benefits of ETOPS-certified.

The increased payload capacity observed in the 120-minute ETOPS configuration across all scenarios represents another operational advantage for airlines. This finding is particularly relevant in the context of growing demand for air travel and air freight between Southeast Asia and the Middle East. The ability to carry an additional 899 kg of payload in the standard flight plan could translate to increased revenue potential for airlines operating on this route. This aligns with the findings of Tuladhar et al. (2021), who emphasized that ETOPS adoption improves fuel efficiency and operational flexibility, enabling airlines to maximize payload capacity on high-demand routes like Jakarta-Jeddah.

The shorter flight durations and more direct routes enabled by the 120-minute ETOPS configuration have implications beyond fuel efficiency and payload capacity. These factors can potentially improve scheduling efficiency and aircraft utilization for airlines. The reduction of 65 nm in flight distance and 9 minutes in flight time for the standard flight plan, while seemingly small, can accumulate to significant time and cost savings over multiple flights. This is consistent with the observations of Jung & Grimme (2022), who noted that extending ETOPS diversion times from 90 to 120 minutes allows airlines to take more direct paths, reducing overall flight time and fuel burn. For the Jakarta-Jeddah route, which is relatively isolated from other suitable landing options, the increased diversion time is particularly advantageous (Airbus, 1998, 2023).

The fact that fuel requirements for emergency scenarios remain manageable, even in the most challenging combined pressure loss and engine failure situation, underscores the effectiveness of current ETOPS regulations in ensuring flight safety. However, the variation in fuel requirements across different emergency scenarios emphasizes the need for comprehensive emergency planning in ETOPS operations. This finding is supported by Goncalves & de Andrade, (2010), who highlighted that ETOPS regulations ensure twin-engine aircraft can safely reach alternate airports within the specified diversion time, even in emergencies. The Jakarta-Jeddah route, with its unique challenges of peak season demands and the need for reliable, cost-effective transportation, benefits significantly from these safety provisions (DeSantis, 2013).

While this study provides valuable insights, it is important to acknowledge its limitations. The calculations assume standard atmospheric conditions and do not account for variations in weather patterns, which can significantly impact fuel consumption and route planning in real-world operations. This limitation is consistent with the findings of Huiru & Xuyang (2018), who emphasized the importance of accounting for dynamic weather conditions in ETOPS fuel planning. Additionally, the study focuses on the A330-343 aircraft, and further research is needed to generalize these findings to other aircraft types and routes.

Conclusion

This study analyzed Extended-range Twin-engine Operations Performance Standards (ETOPS) for the Jakarta (CGK) to Jeddah (JED) route using an Airbus A330-343, by evaluating 90-minute and 120-minute ETOPS configurations across various operational scenarios. The analysis yielded several key findings with important operational implications.

1. Fuel Efficiency: The 120-minute ETOPS configuration demonstrated superior fuel efficiency compared to the 90-minute option, particularly in standard flight conditions.
2. Payload and Flight Duration: Extended ETOPS times allowed for increased payload capacity and shorter flight durations.
3. Safety Standards: Emergency scenarios, including pressure loss and engine failure, were manageable within both ETOPS configurations, affirming the robustness of current ETOPS safety standards.
4. Industry Implications: Airlines operating on similar long-haul routes may benefit from adopting extended ETOPS times, potentially reducing fuel costs and environmental impact while increasing payload capacity.
5. Emergency Planning: The study underscores the importance of comprehensive emergency planning in ETOPS operations.
6. Industry Trends: The results support the trend towards longer ETOPS times in the industry, suggesting that further extensions could yield operational benefits without compromising safety.

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Supplementary data

Data for this research available at https://bit.ly/CGKJEDFuelPlanStudy

Bibliography

Airbus. (1998). *getting to grips with ETOPS* (Vol. 5). Airbus SAS.

Airbus. (2003). *A330 Flight Crew Operating Manual*. Airbus SAS.

Airbus. (2023). A330 Aircraft Characteristics Airport and Maintenance Planning. In *Airbus* (Vol. 1, Issue 32). Airbus.

Andni, R., Widodo, S. F. A., & Afendi, A. H. (2023). Investment multiplier effect of Hajj funds on economic growth in Indonesia. *ISLAM. J. Studi Keislam.*, *17*(2), 313–334.

Brueckner, J. K., & Abreu, C. (2017). Airline fuel usage and carbon emissions: Determining factors. *Journal of Air Transport Management*, *62*, 10–17. https://doi.org/https://doi.org/10.1016/j.jairtraman.2017.01.004

Camilleri, M. A. (2018). Aircraft Operating Costs and Profitability. In M. A. Camilleri (Ed.), *Travel Marketing, Tourism Economics and the Airline Product: An Introduction to Theory and Practice* (pp. 191–204). Springer International Publishing. https://doi.org/10.1007/978-3-319-49849-2_12

Claramunt Segura, & Jordi. (2017). *FAA regulation analysis for ATR ETOPS validation* [Universitat Politècnica de Catalunya]. http://hdl.handle.net/2117/109258 da Fonseca Filho, V. F., Gama Ribeiro, R. F., & Lacava, P. T. (2019). Turbofan engine performance optimization based on aircraft cruise thrust level. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, *41*(2), 64. https://doi.org/10.1007/s40430-018-1562-1

DeSantis, J. A. (2013). Engines Turn or Passengers Swim: A Case Study of How ETOPS Engines Turn or Passengers Swim: A Case Study of How ETOPS Improved Safety and Economics in Aviation Improved Safety and Economics in Aviation. *Journal of Air Law and Commerce*, *77*. http://digitalrepository.smu.edu.

Dimas, P., Tafsir, R., An, C., Antonius, S., & Ariyaka, S. (2018). *Fleet Analysis for Route Jakarta-Jeddah for Umrah Flights Based on Total Operating Costs*. https://doi.org/https://doi.org/10.25292/atlr.v1i1.92

Federal Aviation Administration. (2007). *New ETOPS Regulations*.

Goncalves, C. A. M., & de Andrade, D. (2010). ETOPS aircraft maintenance: Additional tasks that made ETOPS flight safer. *SAE Technical Paper Series, 2010-36–0311*.

Huiru, T., & Xuyang, W. (2018). The verification of cabin temperature compliance in the case of aircraft ETOPS flight with cold day emergency ventilation. *CSAA/IET International Conference on Aircraft Utility Systems (AUS 2018)*, 344–347. https://doi.org/10.1049/cp.2018.0191

ICAO. (2017). *Doc 10085 Extended Diversion Time Operations (EDTO) Manual* (1st ed.). International Civil Aviation Organization.

Inouye, E. C., De Paula, A. A., Guedes, P. L., & Alves, W. M. (2018). Twin-jet and trijet aircraft: A study for an optimal design of regional aircraft. *Transportation Research Procedia*, *29*. https://doi.org/10.1016/j.trpro.2018.02.015

Jung, M., & Grimme, W. (2022). Availability of en-route alternate aerodromes as potential limitation in flight planning for hybrid-electric regional aircraft. *Transportation Research Procedia*, *65*(C), 44–51. https://doi.org/10.1016/J.TRPRO.2022.11.006

Khaled Gamraoyi. (2016). *Exploring the Development Potential of Saudi Arabian Airlines, the National Flag Carrier of Saudi Arabia* [Master Thesis]. Massey University.

Kim, K.-I. (2024). Reflections on the Activities of the Aviation Industry in Response to Climate Change. *Journal of the Korean Society for Aviation and Aeronautics*, *32*(4), 147–157. https://doi.org/10.12985/ksaa.2024.32.4.147

Miguel, J., & Silva, R. (2018). FUEL BURN BENEFITS OF ALTITUDE OPTIMIZATION STRATEGIES IN THE CRUISE PHASE OF LONG-HAUL FLIGHTS. *XVII SITRAER – Air Transportation Symposium*.

Moore, P. E. (1993). British Airways ETOPS Flight Planning System. *Journal of Navigation*, *46*(2), 192–199. https://doi.org/DOI: 10.1017/S037346330001153X

Purwaningsih, R., Pritandari, L., & Santoso, H. (2018). Cost-benefit analysis of flight extended operations (ETOPS) for Garuda Indonesia airways. *SHS Web of Conferences*, *49*, 02015. https://doi.org/10.1051/shsconf/20184902015

Putra, A. M. B., & Kusumastuti, R. D. (2020). *Forecasting Airline Passenger Demand for the Long-Haul Route: The Case of Garuda Indonesia*. https://doi.org/10.5220/0008433305300537

Showail, A. J. (2022). Solving Hajj and Umrah Challenges Using Information and Communication Technology: A Survey. *IEEE Access*, *10*, 75404–75427. https://doi.org/10.1109/ACCESS.2022.3190853

Troutt, J. E. (2020). Fuel Conservation Technology Development and Use in Large Transport Category Aircraft. *2020 Intermountain Engineering, Technology and Computing (IETC)*, 1–6. https://doi.org/10.1109/IETC47856.2020.9249183

Tuladhar, S., Bajracharya, T. R., & Shakya, S. R. (2021). Evaluation and mitigation analysis of carbon footprint for an airline operator: Case of Nepal airlines corporation. *Journal of Innovations in Engineering Education*, *4*(1). https://doi.org/10.3126/jiee.v4i1.34817

Wang, W. (2022). Research on civil aircraft ETOPS type design and approval. *Proc.SPIE*, *12261*, 1226129. https://doi.org/10.1117/12.2638575

Wang, X., Feng, C., Jiang, M., & Zhang, B. (2024). ETOPS Test Flight Study of Civil Aircraft Fuel System. *Proceedings of the 2024 3rd International Symposium on Intelligent Unmanned Systems and Artificial Intelligence*, 177–181. https://doi.org/10.1145/3669721.3674533

World Population Review. (2024, January 2). *Muslim Population by Country 2024*. World Population Review. https://worldpopulationreview.com/country-rankings/muslim-population-by-country