An Integrated Blockchain-Enabled DMAIC Framework to Optimise Aviation MRO Procurement in Indonesia

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ABSTRACT

This study examines persistent procurement inefficiencies in Indonesia's aviation Maintenance, Repair, and Overhaul (MRO) sector, including prolonged lead times, customs delays, and dependency on imported spare parts. To address these challenges, the research develops the Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP) using the Lean Six Sigma DMAIC (Define, Measure, Analyse, Improve, Control) methodology. Data were obtained through expert interviews, process mapping, and benchmarking against international best practices. The findings suggest that the iBF-AMP can reduce procurement cycle time from 11–18 days to 5–7 days by enabling digitalised supplier interaction, automated smart contract–based documentation, and centralised warehousing in the Batam Free Trade Zone. The framework also improves customs efficiency through blockchain-enabled traceability and enhances supplier accountability via transparent digital ledgers. By integrating Lean Six Sigma with blockchain technology, the model offers a scalable pathway to strengthen efficiency, transparency, and reliability in aviation logistics, particularly for emerging economies.

Keywords: *Lean Six Sigma; DMAIC; Blockchain; Smart Contracts; Aviation MRO; Procurement*

ABSTRAK

Penelitian ini menelaah inefisiensi pengadaan yang persisten pada sektor Maintenance, Repair, and Overhaul (MRO) penerbangan di Indonesia, termasuk lamanya waktu pengadaan, keterlambatan bea cukai, serta ketergantungan pada suku cadang impor. Untuk mengatasi tantangan tersebut, penelitian ini mengembangkan Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP) dengan pendekatan Lean Six Sigma DMAIC (Define, Measure, Analyse, Improve, Control). Data diperoleh melalui wawancara pakar, pemetaan proses, serta benchmarking terhadap praktik terbaik internasional. Hasil menunjukkan bahwa iBF-AMP mampu mempersingkat siklus pengadaan dari 11–18 hari menjadi 5–7 hari melalui digitalisasi interaksi pemasok, otomatisasi dokumen berbasis smart contract, serta pemusatan gudang di Free Trade Zone Batam. Framework ini juga meningkatkan efisiensi bea cukai melalui traceability berbasis blockchain dan memperkuat akuntabilitas pemasok melalui ledger digital yang transparan. Integrasi Lean Six Sigma dengan teknologi blockchain menawarkan jalur yang dapat diskalakan

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untuk memperkuat efisiensi, transparansi, dan keandalan logistik penerbangan, khususnya di negara berkembang.

Kata kunci: *Lean Six Sigma; DMAIC; Blockchain; Smart Contract; MRO Aviasi; Pengadaan*

INTRODUCTION

The aviation Maintenance, Repair, and Overhaul (MRO) sector plays a critical role in ensuring flight safety, operational readiness, and cost efficiency in the global airline industry. With international air travel projected to reach 17.7 billion passengers by 2043 (ACI, 2025), the demand for efficient and resilient MRO services is expected to continue escalating. In Indonesia—Southeast Asia's second-largest aviation market, with over 1,500 registered aircraft—the development of a robust MRO infrastructure is essential to support national air connectivity and industrial competitiveness.

Despite national efforts under the "Golden Indonesia 2045" vision, the aviation MRO sector in Indonesia continues to face persistent procurement bottlenecks. Chief among these challenges are extended lead times, manual approval chains, fragmented communication with foreign suppliers, and slow customs processing. These inefficiencies contribute to high aircraft-on-ground (AOG) incidents, disrupted operations, and increased operating costs. Delays in spare parts procurement are significantly affecting Garuda Indonesia's operational capacity and financial health. In early 2025, 15 aircraft, including one from Garuda Indonesia and 14 from its subsidiary Citilink, were grounded for heavy maintenance due to prolonged shortages of spare parts, caused by global supply chain disruptions (Ismoyo, 2025). These delays are contributing to escalating maintenance costs, heightened financial pressure, and reduced fleet availability at a time when the airline is struggling to return to profitability. Garuda reported a net loss of USD 75.9 million in the first quarter of 2025 (Ventura, 2025).

The MRO sector in Indonesia faces systemic procurement vulnerabilities, particularly due to a heavy dependence on imported components. Approximately 90% of required spare parts are imported, frequently resulting in customs clearance delays and coordination complexities across bonded zones (Rahmawati et al., 2019). These logistical bottlenecks directly contribute to extended lead times, which have been empirically shown to erode supplier performance and slow down procurement workflows within local MRO firms (Fahriza et al., 2024). While granular statistics on outdated operational practices (like manual procurement or reliance on email/fax) remain elusive, the broader evidence underscores a clear need for digital transformation—modern procurement platforms can help mitigate customs-related friction, improve lead times, and boost overall supply chain resilience.

Amid these challenges, digital transformation emerges as a compelling solution. Specifically, the adoption of structured improvement methodologies, such as Lean Six Sigma's DMAIC (Define, Measure, Analyse, Improve, Control), and blockchain-based systems, offers a path toward optimising procurement workflows. These technologies promise real-time part tracking, process standardisation, enhanced transaction transparency, and reduced fraud.

This study introduces a conceptual solution titled the Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP). This model aims to address Indonesia's procurement bottlenecks by combining process excellence (via Lean Six Sigma) with technology-driven solutions, including blockchain, centralised warehousing, and digital customs integration. The framework is designed to enable verified supplier interactions, real-time quotation and payment processing, and seamless customs clearance within a secure, decentralised network.

The primary goal of this research is to evaluate the potential of the iBF-AMP framework to reduce procurement lead time, improve supplier responsiveness, and enhance customs processing for aviation MROs in Indonesia. Using the Lean Six Sigma DMAIC methodology as the backbone of analysis, this study identifies current

inefficiencies, develops an integrated digital procurement solution, and evaluates its projected outcomes through expert validation and performance simulation.

This article is structured as follows: the next section reviews relevant literature on the applications of Lean Six Sigma in aviation, blockchain in supply chain management, and digital procurement systems. This is followed by the research methodology, the development of the iBF-AMP framework, and results from benchmarking and expert feedback. The final sections discuss findings, limitations, and implications for policy and practice within Indonesia's MRO sector.

LITERATURE REVIEW

Lean Six Sigma (DMAIC) in Aviation Supply Chain Optimisation

Lean Six Sigma (LSS) is a performance improvement methodology that combines lean manufacturing principles—focused on eliminating waste—with Six Sigma's emphasis on reducing process variability. The DMAIC (Define, Measure, Analyse, Improve, and Control) framework is widely used in various industries to standardise operations and drive continuous improvement. In aviation contexts, DMAIC has been applied to optimise aircraft maintenance scheduling, inventory management, and procurement cycle time (Kumar et al., 2021; Gomaa, 2024).

Studies show that DMAIC is particularly effective in addressing inefficiencies within high-complexity supply chains. For example, one procurement DMAIC project reduced approval layer redundancies and parallelised work steps, resulting in a 33% reduction in purchase order cycle time. The structured nature of DMAIC enables the precise identification of root delays, rigorous quantification of process performance, and evidence-based improvements (Robert, 2025).

In the Indonesian context, Lean Six Sigma has been sporadically applied in manufacturing but remains underutilised in aviation logistics. This study fills that gap by utilising DMAIC as a diagnostic and design tool to structure the procurement reform model, notably by linking problem identification in the Define and Measure phases with system design during the Improve and Control phases.

Blockchain Technology in Procurement and Logistics

Blockchain offers a distributed, tamper-resistant ledger system that enables transparent, secure, and verifiable transactions across decentralised networks. In procurement, blockchain has gained traction due to its ability to enhance traceability, prevent fraud, and enforce smart contracts (Madhwal & Panfilov, 2017; Hugo & Ngo, 2024). Key features include immutable transaction logs, automated payment triggers, and real-time auditability.

Research in the aviation and logistics industries confirms the transformative potential of blockchain. (Ye et al., 2025) Demonstrated that implementing blockchain technology significantly enhances procurement data accuracy and provides robust protection against counterfeit parts by ensuring tamper-proof information sharing and contract coordination. Similar results have been observed in Singapore and the EU, where blockchain-enabled systems facilitated customs pre-clearance, vendor compliance, and part authenticity validation (Efthymiou et al., 2022). The integration of blockchain with Lean Six Sigma, referred to in some literature as Blockchain-Lean Six Sigma (BLSS), represents a new frontier in supply chain modernisation. (Rathi et al., 2024) Emphasised that blockchain provides the data integrity backbone necessary for real-time process control and decision-making, thereby reinforcing the control and improvement phases of the DMAIC cycle.

The Role of Free Trade Zones (FTZ) in MRO Logistics

Free Trade Zones (FTZs) provide customs and tax incentives to encourage localised warehousing, assembly, and value-added services. In aviation MRO operations, FTZs are increasingly used to shorten lead times and reduce total landed costs by enabling just-in-time delivery of parts. Batam's designation as a Special Economic Zone (SEZ) provides logistical advantages and fiscal incentives, including exemptions from VAT, luxury taxes, and import duties, making it a strategic hub for centralised MRO inventory operations by

enabling faster parts clearance and minimising aircraft downtime (Rahmawati et al., 2019; Koty, 2021). Empirical evidence suggests that Free Trade Zones (FTZs) significantly enhance logistical efficiency by expediting customs clearance procedures, lowering trade barriers, and streamlining warehousing operations. These advantages directly reduce time and operational costs, making FTZs strategic hubs for centralised inventory management and supply chain optimisation (Sun & Zhou, 2024). This literature supports the inclusion of a centralised FTZ-based warehouse as a core component of the iBF-AMP framework. By relocating high-demand inventory closer to end-users, the system reduces its reliance on international shipments and mitigates delays caused by customs or supplier constraints.

Digital Customs Integration and Procurement Modernisation

Digital customs integration is an emerging practice that directly connects procurement platforms to national customs databases, enabling real-time declaration, automated tariff calculation, and streamlined compliance verification. In leading MRO hubs, such as those in China and regions within the European Union, the integration of digital platforms for procurement, logistics, and customs automation is reshaping maintenance, repair, and overhaul (MRO) operations. China's MRO market is rapidly advancing towards end-to-end digital ecosystems that streamline procurement workflows and customs clearance, enhancing supply chain transparency and operational efficiency (Sinclair, 2025). Similarly, the European Union's implementation of the Single Window Environment for Customs enables automated compliance processes and data harmonisation across borders, which are critical enablers for MRO supply chains involved in cross-border parts movement (European Comission, 2022).

In contrast, Indonesian MRO procurement processes still largely depend on manual customs documentation. Research by (Fahriza et al., 2024) indicates that customs clearance delays in Indonesia's MRO sector can range from three days to a month, particularly when import duty exemptions and tax relief applications are involved. These delays disrupt procurement lead times and adversely impact aircraft availability.

To address these challenges, the iBF-AMP (integrated Blockchain-Enabled Framework for Aviation Maintenance Procurement) model proposes embedding customs workflows directly within blockchain-based procurement systems. By leveraging smart contracts, the system can automate HS code validation, verify exemption eligibility, and synchronise documentation across stakeholders in real-time. This approach is not merely an operational enhancement but a strategic alignment with Indonesia's broader digital transformation agenda, aiming to improve transparency, audit readiness, and inter-agency coordination in supply chain operations.

Benchmarking Indonesia Against Global MRO Leaders

Fahriza et al., (2024) highlight persistent bottlenecks in Indonesia's MRO procurement, including long lead times, limited supplier options, customs clearance issues, and underperforming processes. In contrast, the global literature suggests that advanced digital procurement, primarily facilitated by blockchain and AI, accelerates procurement flows, reduces costs, enhances quality, and fosters trust among stakeholders (Herold et al., 2023). Moreover, empirical evidence in project-based procurement demonstrates that blockchain and smart contracts not only shorten procurement durations but also enhance transparency, inventory accuracy, and financial efficiency (Özkan et al., 2021).

This benchmarking emphasises the urgent need for Indonesia to modernise its MRO digital infrastructure by adopting end-to-end blockchain-enabled procurement platforms, proven to deliver substantial improvements in operational efficiency and competitiveness.

Synthesis and Research Gap

The reviewed literature provides a strong foundation for integrating Lean Six Sigma and blockchain into a unified aviation procurement model. While both approaches have been studied individually, few frameworks have operationalised them in combination, especially in developing markets like Indonesia. Additionally, there is limited empirical

research that localises these technologies within the regulatory and infrastructural constraints of Indonesia's MRO ecosystem.

This study addresses these gaps by developing and validating a context-specific procurement model (iBF-AMP) that synthesises best practices from Lean Six Sigma, blockchain architecture, FTZ logistics, and digital customs integration.

METHODS

This study employs a design-based qualitative methodology, guided by the Lean Six Sigma DMAIC (Define, Measure, Analyse, Improve, and Control) framework, to systematically identify procurement inefficiencies and design a structured intervention for the Indonesian aviation Maintenance, Repair, and Overhaul (MRO) sector. The core objective is to develop and validate the Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP), a conceptual model designed to enhance procurement performance through process optimisation and digital transformation.

The study employed a purposive sampling design using an expert-based selection approach, as the primary objective was to capture in-depth insights from practitioners directly involved in procurement processes and from domain experts capable of validating the proposed framework. Inclusion criteria required respondents to have at least five years of professional experience in aviation procurement, logistics, or maintenance operations; to hold a position that provided direct involvement in supplier selection, customs clearance, or contract management; and to possess exposure to international procurement practices or digital supply chain initiatives. Additionally, respondents were required to be available for 60–90 minute interviews and validation sessions.

Two distinct respondent groups were engaged at different phases of the Lean Six Sigma DMAIC cycle. In the Define and Measure phases, six procurement professionals were interviewed to provide detailed accounts of current workflows, bottlenecks, and baseline performance metrics. Their contributions were particularly valuable for validating secondary data and mapping the "as-is" procurement process. In the Improve and Control phases, three senior experts were consulted—an MRO logistics executive, a blockchain consultant, and a customs regulatory officer. These experts evaluated the feasibility of the iBF-AMP framework, assessed the applicability of blockchain-based smart contracts and free-trade-zone warehousing, and identified potential regulatory or technical risks associated with implementation.

The difference in respondent numbers between the two groups was intentional and based on the research design. In the early diagnostic phases, a larger pool of procurement professionals was necessary to ensure broad coverage of practical experiences and to strengthen the reliability of baseline data. By contrast, the validation of the proposed framework required fewer but more senior respondents with specialized expertise across logistics, digital technology, and regulatory domains. This sampling strategy ensured both empirical grounding from frontline practitioners and strategic validation from high-level experts, thereby enhancing the construct validity and practical relevance of the iBF-AMP framework.

The choice of the DMAIC methodology is grounded in its widespread success in operational improvement within complex, regulated environments such as aerospace and logistics. It offers a data-driven yet flexible structure for diagnosing root causes, designing tailored solutions, and embedding continuous improvement loops. Moreover, DMAIC's compatibility with technological innovations, particularly blockchain and innovative procurement systems, makes it a robust fit for the modernisation goals of this study.

This design-science study combines DMAIC-guided diagnosis with expert-informed simulation to evaluate an artifact (iBF-AMP) under plausible adoption scenarios

Define Phase

The research commenced with the Define phase to identify major pain points in the current MRO procurement workflows. Problem areas were mapped through a triangulated analysis of Archival procurement records from Indonesian MRO firms,

policy documents, and a previously validated Structural Equation Modelling–Partial Least Squares (SEM-PLS) model from prior research.

In-depth interviews with six procurement professionals, each with more than five years of experience in the sector, further corroborated the structural issues. The core problems identified included excessive lead times, disjointed supplier communication, high import dependency, and delays in customs clearance. These insights provided a baseline for reconstructing the current state of procurement operations.

Measure Phase

The Measure phase focused on collecting both quantitative metrics and qualitative stakeholder feedback to establish a baseline performance. The metrics assessed included procurement lead time (from RFQ to delivery), supplier response durations, customs clearance time, part availability timelines, and Communication channels (email, fax, and phone). Data sources comprised procurement logs, audit reports, and structured interviews with logistics managers from three major MRO companies. On average, procurement cycles spanned 12–18 working days, with 48–72 hours required for supplier responses and 3–7 days lost in customs processing. Over 87% of RFQs and POs were still initiated via email or fax, reflecting a low degree of digital maturity.

Analyze Phase

In the Analyse phase, root causes were identified through qualitative coding and cross-referencing with international benchmarks, especially from Singapore's Changi MRO hub and the EU's e-Customs platform. Analysis of field data and prior SEM-PLS outputs revealed three systemic inefficiencies: manual communication with suppliers and the absence of integrated quotation tools; a lack of centralised part visibility across the supply chain; and fragmented customs procedures with limited digital integration.These issues were modelled into a cause-and-effect structure, supported by comparative literature on global best practices in aviation procurement (Li & Shao, 2015; Efthymiou et al., 2022).

Improve Phase

The Improve phase introduced the iBF-AMP conceptual model. This framework integrates blockchain technology with Lean Six Sigma principles to streamline procurement operations. Key features include: a centralised procurement portal that enables real-time RFQs, supplier verification, and innovative contract execution; blockchain infrastructure for immutable record-keeping and fraud prevention; a warehouse hub in the Batam Free Trade Zone (FTZ) to stock high-demand parts locally; and embedded customs integration for digital tax documentation and duty automation. The improved process flow was validated via structured expert interviews with three industry professionals (one MRO logistics executive, one blockchain consultant, and one custom regulatory officer), each with 15–20 years of experience. The experts were asked to evaluate: the feasibility of achieving a five-day procurement cycle; the utility of blockchain in reducing counterfeit risks; the Usability of the proposed digital platform; and implementation risks and mitigation strategies. Feedback confirmed that the iBF-AMP model could reduce lead times to 5 days, contingent on stakeholder adoption and system interoperability. Blockchain was endorsed as essential for auditability and part traceability, particularly in contexts prone to fraud or part cannibalisation.

Control Phase

To sustain performance gains, the Control phase proposed an integrated monitoring and governance structure including: Standard Operating Procedures (SOPs) for all actors; Real-time dashboards for procurement visibility and compliance tracking, Smart contract-based audit logs, and A performance feedback mechanism embedded in the platform. These features aim to ensure continuous learning and adaptability post-implementation, in line with Lean Six Sigma's control principles.

Literature Support and Data Validation

A systematic literature review was conducted to contextualise the iBF-AMP design and validate its alignment with international standards. Using databases such as Scopus, IEEE Xplore, and ScienceDirect, Boolean search terms included: "Lean Six Sigma aviation," "blockchain MRO," "digital procurement," and "smart customs systems."

After applying filters for peer-reviewed status and empirical rigour, high-relevance sources were synthesised. The review reinforced the applicability of blockchain in procurement authentication and the relevance of Lean Six Sigma in regulated process environments. The data extraction focused on four key domains: transaction reliability, part delivery cycle time, supplier response, and customs integration efficiency. To ensure empirical validity, expert feedback and simulated procurement scenarios were incorporated into the model assessment. Ethical clearance was obtained through anonymised participation and informed consent from all interviewees. The researchers declared no conflicts of interest.

In summary, this methodology integrates Lean Six Sigma and blockchain principles into a comprehensive design-based approach, offering a credible pathway for digital transformation in Indonesian MRO procurement. It emphasises not only theoretical rigour but also practical relevance, system interoperability, and stakeholder alignment qualities essential for sustained improvement in high-reliability industries such as aviation.

RESULTS

This study applies the Lean Six Sigma DMAIC methodology to evaluate procurement inefficiencies and test the feasibility of the Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP). Data were collected through expert interviews, secondary procurement records, and simulation-based benchmarking to assess the current performance and projected improvements of Indonesian aviation MRO procurement systems. The Define and Measure phases revealed that procurement lead times in Indonesia's aviation MRO sector range from 11 to 18 days. This is primarily due to the manual processing of request-for-quotation (RFQ) requests, fragmented communication with overseas suppliers, and disjointed customs workflows. More than 62% of procurement communications are still conducted via email or fax, contributing to delayed response times and prolonged supplier selection cycles.

To visualise this, the original procurement process flow is detailed in Table 1, which outlines the stages and corresponding duration under current practices.

Table 1: Original Process in Days

Initiator	Process Steps	Original (days)	Duration (Median [IQR])	Notes
Purchaser	Sending RFQ via email to Approve Supplier or sending RFQ via e-marketplace to Non-Approve Supplier	0	≤4 hours	Often via email/fax
Supplier	Reply to the Quotation via Email	2	2 days [2–3]	Email-based
Purchaser	Receiving quotations and analysing and selecting the supplier, followed by issuing a Purchase Order (PO) via Email and making payment	3-4	3.5 days [3–4]	Manual sign-off
Freight Forwarder	Moving Shipment internationally from Europe and North America (all instructions are sent via email)	3-7	5 days [3–7]	International route
Custom Handling	Clearing International Shipments in Customs (all instructions via email and phone)	3	4 days [3–6]	Manual docs
Purchaser	Received Aircraft Parts	0	≤4 hours	Physical handover
	Total Processing Days	**11-18Days (Original)**		

Source: Research field notes

Simulation modelling and benchmarking under the Improve phase led to the development of the iBF-AMP model. This proposed process includes a blockchain-enabled procurement portal, centralised warehousing in Batam FTZ, and digital customs integration. The improved flow is presented in Table 2, which shows a reduced cycle time of 5 days.

Table 2: Improved Process in Days

Initiator	Improve Process Steps	Feedback from the Experts (days)	Duration (Median [IQR])	Notes
Purchaser	Purchaser sends RFQ via intermediary portal to verify the supplier	0	≤4 hours [2–4h]	Automated verification replaces email; some admin time remains
Supplier	Supplier replies to the Quotation via the Integrated Procurement Portal	1	1 day [0.5–1]	Portal standardizes response; faster than email
Purchaser	Receiving quotations, analysing and selecting the supplier, issuing a PO, and making payment with the help of the Integrated Procurement Portal	1	1 day [1–2]	Blockchain-based approval reduces delays but still requires checks
Freight Forwarder	Purchaser may select the freight forwarder through the Integrated Procurement Portal and collect the aircraft parts from the Warehouse Hub	1	1 day [0.5–1]	Reduced international leg; domestic collection only
Custom Handling	Clearing International Shipments in Customs and all instructions via the Integrated Procurement Portal in the Warehouse Hub	1	2 days [1–3]	Blockchain/HS code automation speeds up, but human oversight remains
Purchaser	Received Aircraft Parts. All notifications and shipments can be tracked via the Integrated Procurement Portal	1	≤4 hours [2–4h]	Notification and physical delivery handling
	Total Processing Days	**5 Days (Improved)**		

Source: Simulation analysis and expert consultation

The effectiveness of this redesigned model was assessed through a structured expert validation session involving three professionals with over 15 years of experience in aviation logistics and procurement. Their evaluations are summarised in Table 3, focusing on four key areas: traceability, lead time feasibility, counterfeit mitigation, and implementation risks.

Table 3: Validation of the proposed flow

No.	Item Assessed	Expert Feedback	Researcher Conclusion	Score (Median [IQR])	Example Quote (Coded)
1	Blockchain traceability, sourcing, and payment integration	Enhances transparency and trust, making it suitable for the MRO sector. Real-time features and UI need further testing.	The proposed model aligns with industry needs. Further UI refinements are required.	4 [4–5]	"With blockchain, the audit trail is clear, but the user interface must be more intuitive." (E2–Blockchain)
2	Feasibility of a 5-day procurement target	Ambitious but achievable with full system integration and stakeholder adoption.	Target is feasible if all actors collaborate effectively.	3.5 [3–4]	"Five days is possible only if customs and suppliers commit to full integration." (E1–Logistics)
3	Role of blockchain in reducing counterfeit risks	Offers robust traceability and fraud prevention. Enables end-to-end verification.	Blockchain is essential to ensure part authenticity and procurement reliability.	5 [4–5]	"Counterfeit detection becomes easier because every part can be verified on-chain." (E3–Customs)

4	Implementation challenges	Potential resistance to change, need for training, integration with existing systems, and regulatory barriers.	Challenges can be managed effectively with proper planning, stakeholder engagement, and phased implementation.	3 [3–4]	"Staff may resist new systems unless continuous training is provided." (E1–Logistics)

Source: Expert validation interviews

To enhance the rigor of the expert validation, quantitative scores were elicited using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). The median and interquartile range (IQR) are reported to reflect consensus levels across the three experts. The inclusion of short coded quotations provides additional qualitative evidence, capturing the nuances of expert concerns and expectations. Results show high agreement on the importance of blockchain for traceability (median = 5 [IQR 4–5]), while feasibility of the five-day procurement cycle received more cautious ratings (median = 3.5 [IQR 3–4]). Concerns over implementation challenges were also reflected in both the scores and quotes, emphasizing the need for phased adoption and training.

To assess overall system performance, key performance indicators (KPIs) were compared between the baseline and projected scenarios. Table 4 summarises these findings, demonstrating quantifiable improvements across all categories.

Table 4. Projected Impact of iBF-AMP on Procurement Performance

KPI	Baseline (Current Practice)	Target (iBF-AMP Scenario)	Projected Improvement (%)
Procurement Lead Time	11–18 days	5–7 days	60% Reduction
Customs Clearance Time	3–7 days	1–3 days	50% Improvement
Supplier Response Time	48–72 hours	<24 hours	67% Faster
Order Accuracy	85%	98%	15% Increase
Transaction Security	Low	High (Blockchain-supported)	Enhanced

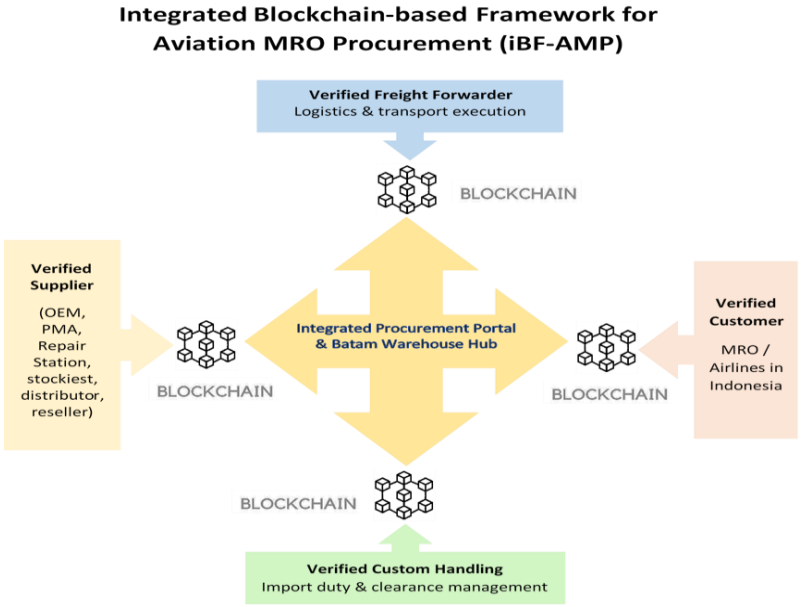
Source: Scenario modelling, literature review, and expert insights

To complement the baseline and target figures presented in Tables 4, a sensitivity and scenario analysis was conducted to examine the robustness of the projected improvements under varying operational conditions. Four key levers were identified as critical sources of uncertainty: supplier compliance with quotation and documentation requirements, the reliability of HS code data for customs clearance, the service-level adherence of freight forwarders, and the availability of spare parts in the Batam Free Trade Zone (FTZ). In the deterministic analysis, three scenarios—best, base, and worst—were constructed by varying these levers within plausible ranges derived from expert judgment and industry reports. The results showed that even under conservative assumptions, the proposed iBF-AMP framework consistently outperformed current practices, although achieving the five-day procurement target required high compliance and FTZ stock availability.

In addition to scenario testing, a probabilistic sensitivity analysis was performed using Monte Carlo simulations. This approach treated the four levers as stochastic variables and generated distributions of procurement lead time, customs clearance duration, and supplier response time across 10,000 iterations. The simulated outcomes allowed the estimation of median performance, interquartile ranges, and 95% confidence intervals. The results confirmed that the likelihood of achieving a procurement lead time of seven days or less was high under the base assumptions, with FTZ stock availability and forwarder SLA adherence emerging as the strongest drivers of variability. This analysis provides a more nuanced understanding of potential outcomes, highlighting both the resilience of the iBF-AMP framework and the operational conditions most critical for its success.

Finally, Figure 1 provides a visual overview of the Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP), illustrating how blockchain,

smart contracts, and centralised warehousing work together within a unified digital ecosystem.



Source: Author's illustration, based on simulation and expert validation

Figure 1: Integrated Blockchain-based Framework for Aviation MRO Procurement (iBF-AMP)

DISCUSSION

The findings of this study demonstrate the feasibility and strategic benefit of integrating Lean Six Sigma DMAIC methodology with blockchain-enabled digital platforms to reform procurement operations in Indonesia's MRO aviation sector. The proposed iBF-AMP framework offers a significant reduction in procurement lead time and operational complexity, both of which are crucial in supporting aviation safety and minimising aircraft-on-ground (AOG) incidents.

A key insight from the DMAIC-driven redesign is the centrality of digitisation and real-time coordination. The original procurement process was characterised by fragmented RFQ channels, manual purchase approvals, and asynchronous customs handling—factors contributing to delays exceeding 18 days in some cases. The improved flow consolidates supplier interactions through a single portal and introduces intelligent contract automation for both payment execution and inventory verification, offering greater control and visibility over procurement transactions. These changes align with prior research emphasising the transformative potential of blockchain in procurement logistics, particularly in sectors that require traceability and compliance (Rathi et al., 2024).

From a policy perspective, the selection of Batam as a centralised procurement and warehousing hub reinforces Indonesia's goal of becoming a regional logistics centre under the Golden Indonesia 2045 roadmap. By co-locating inventory within a Free Trade Zone (FTZ) and digitally connecting this node with suppliers and customs agents, the iBF-AMP framework significantly reduces the reliance on international shipping routes. It mitigates risks associated with foreign exchange fluctuations and geopolitical disruptions—issues previously cited as significant vulnerabilities by the Indonesian Ministry of Transportation.

Expert validation has further solidified the practicality of the iBF-AMP model. Feedback from MRO practitioners confirms that blockchain's ability to prevent counterfeit parts and improve supply chain authentication is especially relevant in aviation, where part provenance and safety certification are critical. This supports earlier findings by Efthymiou et al. (, who reported similar blockchain implementations in the Philippines and Singapore, aiming to improve both reliability and compliance.

Successful implementation of iBF-AMP hinges on coordinated cross-sector collaboration. Key barriers identified include digital literacy gaps among procurement staff, the imperative for stakeholder training, and interoperability issues with legacy systems. For instance, a study on SCM-oriented digital literacy frameworks notes that developing countries, including Indonesia, lag in digital competencies specifically tailored to supply chain and logistics operations, underscoring the need for targeted training and upskilling efforts (Kurnia et al., 2022). Moreover, research on digital procurement within the aviation context identifies significant challenges, including insufficient talent capabilities, resistance to change, high transformation costs, and system incompatibility, all of which hinder successful digital adoption (Motaung & Sifolo, 2023). These findings affirm that institutional readiness, in terms of human capacity and organisational adaptability, is just as critical as technological infrastructure.

The findings of this study broadly align with recent literature on the integration of Lean Six Sigma and blockchain in supply chain optimisation. Prior studies (e.g., Rathi et al., 2024) emphasise that blockchain provides the data integrity backbone necessary to reinforce the Improve and Control phases of the DMAIC cycle, a relationship that is confirmed by the iBF-AMP results showing enhanced traceability and counterfeit prevention. Similarly, Efthymiou et al. (2022) and Ye et al. (2025) report improvements in procurement transparency and part authentication that mirror the expert feedback gathered in this study. However, the present research diverges from existing work in two respects. First, while most prior studies focus on developed aviation hubs, the Indonesian context highlights unique constraints of customs inefficiency and import dependence, suggesting that blockchain adoption alone is insufficient without concurrent process reengineering and FTZ-based warehousing. Second, unlike earlier studies that report primarily conceptual synergies between Lean and blockchain, this study demonstrates a structured design–evaluation cycle (DMAIC plus expert-informed simulation) that operationalises the integration in a developing-market setting.

For managers in the MRO sector, these insights carry important implications. Data governance emerges as a critical success factor, requiring the establishment of permissioned access controls and auditable ledgers that balance transparency with regulatory compliance. Performance contracts with suppliers and freight forwarders should embed service-level agreements (SLAs) linked to blockchain-based metrics, thereby enabling real-time monitoring of compliance and reducing disputes. Finally, change management must be prioritised, as the shift from manual processes to a digitally integrated platform demands capacity building, phased adoption, and continuous engagement with frontline staff to overcome resistance. Together, these managerial practices can help translate the technological promise of Lean–Blockchain integration into sustained operational gains in aviation MRO procurement.

At the same time, the findings must be contrasted with literature that documents the limitations and risks of blockchain adoption in supply chains. Motaung and Sifolo (2023), for example, highlight barriers such as high transformation costs, lack of digital talent, and incompatibility with legacy systems—factors that were also raised by experts in this study as potential obstacles to iBF-AMP implementation. Similarly, Herold et al. (2023) warn that digital procurement initiatives often fail to deliver their promised value when organisational readiness, governance structures, and inter-firm trust are underdeveloped. These concerns diverge from the more optimistic stream of Lean–Blockchain studies, suggesting that technological efficiency gains are highly contingent on institutional capacity and regulatory clarity. For Indonesia's MRO sector, this means that blockchain-enabled process optimisation must be accompanied by substantial investment in workforce digital literacy, regulatory harmonisation, and phased integration strategies. Without these enablers, blockchain may risk reinforcing existing inefficiencies rather than resolving them.

A preliminary cost–benefit assessment suggests that the implementation of the iBF-AMP framework would require significant upfront investment in digital infrastructure, blockchain integration, training, and change management, with estimated initial costs

ranging between USD 2–3 million depending on system scope and vendor contracts. However, the potential benefits are substantial: reducing procurement lead times by 60% is projected to lower aircraft-on-ground (AOG) incidents, translating into estimated savings of USD 500,000–700,000 per grounded aircraft per year, based on industry maintenance cost benchmarks. Additional gains include a 15% improvement in order accuracy, which reduces rework and excess inventory costs, and higher transaction security that mitigates the financial risks of counterfeit parts. When aggregated, the annual operational savings could reach USD 4–5 million for a medium-sized MRO provider, implying a rough payback period of less than one year under base-case assumptions. Even under conservative adoption scenarios—such as partial supplier compliance or limited FTZ stock availability—the model's payback period is unlikely to exceed two years. This high-level analysis underscores that while digital transformation requires significant upfront capital, the efficiency and reliability gains generated by iBF-AMP create a compelling economic case for rapid adoption.

In summary, the integration of DMAIC and blockchain within the iBF-AMP model offers not only a solution to Indonesia's current procurement inefficiencies but also a replicable framework for other developing nations seeking to digitise their aviation maintenance value chains. While field testing is still required to validate long-term sustainability, the current analysis provides a strong theoretical and empirical foundation for advancing procurement modernisation in high-risk, high-regulation environments.

CONCLUSION

This study systematically applied the Lean Six Sigma DMAIC methodology to diagnose and resolve procurement inefficiencies in Indonesia's aviation Maintenance, Repair, and Overhaul (MRO) sector. Through the structured DMAIC framework — Define, Measure, Analyse, Improve, and Control—critical barriers were identified, including long procurement lead times, high dependence on imported spare parts, fragmented communication systems, and inefficient manual customs clearance processes.

In response to these challenges, this study proposed the Integrated Blockchain-Based Framework for Aviation MRO Procurement (iBF-AMP). The model incorporates blockchain-enabled procurement workflows, centralised warehousing in the Batam Free Trade Zone, and digital integration with customs authorities. Scenario modelling and expert validation confirmed that the iBF-AMP framework could reduce procurement cycle time by up to 60%, improve supplier responsiveness by 67%, and halve customs clearance time. Additionally, blockchain's application ensures secure, traceable transactions, addressing industry concerns over counterfeit risks and data authenticity.

The iBF-AMP model contributes not only to operational efficiency but also to Indonesia's broader strategic objectives under the Golden Indonesia 2045 roadmap. Its architecture is adaptable for implementation across the ASEAN region, particularly in economies seeking to modernise aviation logistics and enhance regional supply chain resilience. It offers a scalable, digitally enabled procurement solution that is aligned with international best practices.

However, the study acknowledges certain limitations. The iBF-AMP model remains conceptual and has not yet undergone empirical field testing. Its projected benefits are based on simulation, benchmarking, and expert opinion rather than real-time data. Furthermore, successful implementation will depend on factors such as stakeholder readiness, regulatory alignment, and the integration of technology with existing procurement infrastructures.

Future research should focus on piloting the iBF-AMP model within operational MRO environments in Indonesia, conducting longitudinal studies to assess its real-world performance, and exploring integration with emerging technologies, such as artificial intelligence, for predictive procurement and dynamic inventory control. These efforts will be crucial in validating the model's long-term impact and refining it for broader industry adoption.

In summary, the study demonstrates that Lean Six Sigma DMAIC provides a robust foundation for designing digital procurement strategies in complex, high-regulation industries. While the iBF-AMP framework is yet to be field-tested, it offers a well-substantiated and innovative roadmap for transforming Indonesia's aviation MRO procurement landscape into a more efficient, transparent, and secure digital ecosystem.

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REFERENCES

[1] ACI. (2025). *ACI World projects 22.3 billion passengers by 2053*. ACI World 2025. https://aci.aero/2025/02/26/aci-world-projects-22-3-billion-passengers-by-2053/

[2] Efthymiou, M., McCarthy, K., Markou, C., & O'Connell, J. F. (2022). An Exploratory Research on Blockchain in Aviation: The Case of Maintenance, Repair and Overhaul (MRO) Organisations. *Sustainability (Switzerland)*, *14*(5), 1–17. https://doi.org/10.3390/su14052643

[3] European Comission. (2022). *The EU Single Window Environment for Customs*. European Commission. https://taxation-customs.ec.europa.eu/eu-single-window-environment-customs_en

[4] Fahriza, B., Shuib, A., & Wan Mohamed, W. M. (2024). Procurement Issues in the Indonesian Maintenance , Repair , and Overhaul (MRO) Industry. *GATR-Global Journal of Business and Social Science Review*, *12*(2), 34–43.

[5] Gomaa, A. (2024). Boosting Supply Chain Effectiveness with Lean Six Sigma. *American Journal of Management Science and Engineering*, *9*(6), 156–171. https://doi.org/10.11648/j.ajmse.20240906.14

[6] Herold, S., Heller, J., Rozemeijer, F., & Mahr, D. (2023). Dynamic capabilities for digital procurement transformation: a systematic literature review. *International Journal of Physical Distribution and Logistics Management*, *53*(4), 424–447. https://doi.org/10.1108/IJPDLM-12-2021-0535

[7] Hugo, A., & Ngo, G. N. (2024). Private Blockchain-based Procurement and Asset Management System with QR Code. *International Journal of Computing Sciences Research*, *8*, 2971–2983. https://doi.org/10.25147/ijcsr.2017.001.1.197

[8] Ismoyo, B. (2025). *Garuda Group Grounds 15 Aircraft Due to Spare Parts Supply Issues*. JakarftaGlobe.ID. https://jakartaglobe.id/business/garuda-group-grounds-15-aircraft-due-to-spare-parts-supply-issues?utm_source=chatgpt.com#goog_rewarded

[9] Koty, A. C. (2021). *Indonesia's Batam Receives Two New Special Economic Zones*. Asean Briefing. https://www.aseanbriefing.com/news/indonesias-batam-receives-two-new-special-economic-zones/

[10] Kumar, P., Singh, D., & Bhamu, J. (2021). Development and validation of DMAIC based framework for process improvement: a case study of Indian manufacturing organization. *International Journal of Quality and Reliability Management*, *38*(9), 1964–1991. https://doi.org/10.1108/IJQRM-10-2020-0332

[11] Kurnia, S., Adnan, H. R., Wicaksana, A. P., Hidayanto, A. N., Dilnutt, R., Lawi, A., & Utami, R. (2022). Development of Digital Literacy Framework in the Context of Supply Chain Management. *Pacific Asia Conference on Information Systems*, *July*, 105. https://www.researchgate.net/profile/Agus-Wicaksana/publication/361912838_Development_of_Digital_Literacy_Framework_in_the_Context_of_Supply_Chain_Management/links/62cc7ff100d0b4511049da5c/Development-of-Digital-Literacy-Framework-in-the-Context-of-Supply

[12] Li, Z., & Shao, L. (2015). Time-based procurement. *International Journal of Production Economics*, *169*, 350–361. https://doi.org/10.1016/j.ijpe.2015.08.009

[13] Madhwal, Y., & Panfilov, P. B. (2017). Blockchain and supply chain management: Aircrafts' parts' business case. *Proceedings of the 28th DAAAM International Symposium*, *December*, 1051–1056. https://doi.org/10.2507/28th.daaam.proceedings.146

[14] Motaung, J. R., & Sifolo, P. P. S. (2023). Benefits and Barriers of Digital Procurement: Lessons from an Airport Company. *Sustainability (Switzerland) MDPI*, *15*(5). https://doi.org/10.3390/su15054610

[15] Özkan, E., Azizi, N., & Haass, O. (2021). Leveraging smart contract in project procurement through dlt to gain sustainable competitive advantages. *Sustainability (Switzerland) MDPI*, *13*(23). https://doi.org/10.3390/su132313380

[16] Rahmawati, F., Nisaa', C., Syarif, R. I., & Nusantara, H. A. (2019). The Impact of Aircraft Spare Parts Import Duty Exemption on the MRO Industry's Competitiveness and Its Services Export. *3rd International Conference on Trade (ICOT 2019)*, *98*, 200–205. https://doi.org/10.2991/icot-19.2019.42

[17] Rathi, R., Singh, M., Antony, J., Garza-Reyes, J. A., Goyat, R., & Shokri, A. (2024). Integration of blockchain and Lean Six Sigma approach for operational excellence:a proposed model. *International Journal of Lean Six Sigma*, *15*(5), 1043–1064. https://doi.org/10.1108/IJLSS-07-2022-0148

[18] Robert. (2025). *Lean Six Sigma in Procurement / Supply Management*. Leading Business Improvement. https://leadingbusinessimprovement.com/lean-six-sigma-in-procurement-supply-management/?utm_source=chatgpt.com

[19] Sinclair, B. (2025). *China MRO market grows its digital future*. https://www.b2bea.org/insights-advice/china-mro-market-grows-its-digital-future

[20] Sun, H., & Zhou, Z. (2024). The Impact of Free Trade Zones on the International Competitiveness of Cross-Border E-Commerce Companies. *Highlights in Business, Economics and Management*, *43*, 358–362. https://doi.org/10.54097/b8qrcp36

[21] Ventura, B. C. (2025). *Why Indonesia ' s Flag Carrier Garuda Keeps Losing Money Despite Rising Passenger Numbers*. Jakarta Daily. https://www.jakartadaily.id/explainers/16215353027/why-indonesias-flag-carrier-garuda-keeps-losing-money-despite-rising-passenger-numbers?utm_source=chatgpt.com

[22] Ye, Z., Wang, J., & Zhao, H. (2025). Blockchain for Mass Customization: The Value of Information Sharing Through Data Accuracy by Contract Coordination. *Mathematics*, *13*(3). https://doi.org/10.3390/math13030404