

Operational Challenges in Maintenance: A Lean and Agile Approach

Mohd Shahrulnizam Ab Rahim¹, Noor Aslinda Abu Seman^{2*}

¹ Faculty of Technology Management and Business,
Universiti Tun Hussein Onn Malaysia, MALAYSIA

² Johor Business School,
Universiti Tun Hussein Onn Malaysia, MALAYSIA

*Corresponding Author: naslinda@uthm.edu.my

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Abstract

The Malaysian maintenance industry is vital in sustainable infrastructure and facility management. This paper examines key operational challenges in maintenance and construction, including project delays, workforce shortages, safety risks, miscommunication, and weather disruptions. These inefficiencies can be mitigated by integrating Lean Manufacturing, Agile methodology, Six Sigma, and continuous improvement frameworks. Lean principles and Agile methodology enhance process optimization, reduce delays, and facilitate real-time communication for rapid adjustments. Six Sigma provides data-driven insights to identify sources of operational errors, particularly in safety and communication. Kaizen fosters continuous improvement, addressing emerging issues such as weather disruptions. Research indicates that practitioners and researchers can achieve greater efficiency and cost-effective project outcomes by integrating these methods. Future empirical studies should explore their interrelationships and potential synergy with emerging technologies to further optimize maintenance project success.

1. Introduction

The Malaysian maintenance industry is vital in maintaining infrastructure and achieving operational efficiency across all sectors, including housing, aviation, and public works. The industry faces ongoing difficulties that block successful project management, resulting in delayed work, expanded costs, and stakeholder conflicts. Despite efforts to modernize project management frameworks, planning, resource allocation, and coordination inefficiencies continue to impact performance.

A significant concern is the prevalence of ailing projects where government and private-sector initiatives fail to meet stipulated timelines. As of the end of last year, 202 federal projects under the 12th Malaysia Plan were classified as ailing, representing 5.93% of the 3,404 projects in progress (The Edge Malaysia, 2024). These projects exceeded deadlines by over two months or surpassed 20% of the planned schedule, straining client relationships and damaging industry credibility. Similarly, according to KPKT Minister Datuk Seri Reezal Merican Naina Merican, the 78 projects comprised 17,605 housing units and involved 11,735 buyers (Bernama, 2021). The high frequency of such delays reflects deeper systemic inefficiencies in project management and regulatory enforcement.

Beyond construction, maintenance-related challenges extend to the aviation sector. Demand for aircraft maintenance technicians is on the rise, and companies in the aviation industry are working to match capability

with opportunity. The most pressing concerns surround hiring, training, retaining, and compensating the technicians and mechanics who can turn this moment's aviation dreams into tangible realities. The industry's recent growth in demand for aircraft maintenance technicians and engineers with unique skills has been staggering, and this is excellent news for those who are now beginning their careers in aviation. Executive Vice President of the National Air Transportation Association (NATA), Ryan Waguespack, offered his insights into the employment outlook for aircraft maintenance roles. He described the general aviation sector's growth over the past 18 to 22 months as unprecedented (Reed, 2022).

Despite these issues, the Malaysian maintenance industry faces these challenges but moves toward contemporary project management methods to enhance performance and handle potential hazards. According to Dehdasht et al. (2021), advancements in construction technology and project execution frameworks present opportunities and challenges. The Malaysian Institute of Economic Research (MIER) identifies financial constraints, miscommunication, and coordination failures among stakeholders as key contributors to project delays. The significance of structured project management becomes crucial because these challenges need to be mitigated through risk reduction and improved efficiency. Malaysian SMEs encounter considerable challenges in their project execution due to resource constraints and inefficiencies in operations, as Abdul Wahab et al. (2022) explained. Yaacob et al. (2024) point out that applying digital transformation along with Industry 4.0 technologies helps stakeholders work together more efficiently by fixing communication issues, which leads to better project results.

Two practical approaches to address operational challenges in the maintenance and construction industries include Lean Six Sigma and Agile project management. The waste reduction capabilities of Lean Six Sigma correspond to industry needs for lower costs combined with optimized efficiency levels. El Azzaoui et al. (2024) used Lean Six Sigma to reduce maintenance process downtime through DMAIC framework implementation that allowed the identification of key problems and their solution development. Suppremaniam and Muthusamy (2011) described the essential components of Six Sigma implementation in Malaysian multinational corporations because this methodology will help boost operational performance.

Meanwhile, Agile methodologies emphasize adaptability, collaboration, and iterative improvements, particularly relevant in Malaysia's multicultural and multi-stakeholder project environment. The Scrum framework and Kanban systems from Agile practices boost project management by enabling complete visibility, together with simultaneous task observation and active stakeholder engagement, according to Cesarotti et al. (2019). Such practices help teams respond effectively to unexpected challenges for continuous workflow enhancement.

However, organizations are still inconsistent in adopting these frameworks because their employees resist change and are not well-trained. They do not have enough research-based evidence to support their application in Malaysia. They must overcome these barriers to demonstrate effectiveness by coordinating awareness promotion, training, and localized studies.

This paper explains the review of the key operational challenges in the maintenance and construction industry, which is conducted by evaluating the practical impact of Lean Manufacturing, Six Sigma, and Agile methodologies. As a result, this research sheds light on optimizing project delivery, reducing delay, addressing the lack of workforce, improving safety, enhancing communication, and mitigating weather disruption impact to improve overall industry performance by analyzing their implementation challenges and effectiveness.

2. Literature Review

2.1 Operational Challenges in the Maintenance Industry

The maintenance industry is a leading industry that ensures operational efficiency and sustainability in construction, telecommunications, healthcare, oil and gas, and manufacturing. In their effort to address continuous operational challenges such as workforce performance and governing rules, maintenance and construction companies have to deal with the project delivery process. Wahab et al. (2022) indicate that Malaysian SMEs face two primary obstacles associated with resource constraints and operational issues that prevent them from achieving project management excellence. Implementing digital transformation strategies and embracing Industry 4.0 technologies improve workforce productivity and better regulatory compliance functions (Yaacob et al., 2024). Unresolved problems create multiple cost increases, performance delays, enhanced safety hazards, and damaged reputations. The review examines primary operational challenges in maintenance alongside their business performance repercussions and their subsequent effects when neglected.

Several studies highlighted the most common operational inefficiencies affecting the maintenance industry. One of the most prevalent issues in the industry is project delay. Resource-driven scheduling is one of the most critical issues of construction management. Tasks whose durations are affected by the addition or subtraction of resources are called resource-driven tasks. In a real-world project environment, the accuracy of time estimations often faces challenges due to variations in individuals' skill levels and work speeds, which remain a significant

concern in project management. Research indicates that task productivity does not scale linearly with team size or effort distribution, as individual differences play a crucial role in task completion time (Salas et al., 2012). Moreover, inefficiencies such as supply chain disruptions are a significant challenge for businesses in Malaysia. TMX Global's analysis highlights that these disruptions cost Malaysia's economy RM8.7 billion annually, stemming from labour shortages, climate change, and geopolitical challenges, which collectively impede economic growth (TMX Global, 2023). Similarly, Mesran et al. (2024) examine Malaysia's supply chain vulnerabilities and highlight resource misallocation as a key factor affecting industry resilience. The study constructs a Malaysia Supply Chain Pressure Index (MSCPI) to assess economic disruptions caused by rising costs, climate change, and geopolitical instability, providing insights for policymakers and industry stakeholders.

Research has established project delays as the primary problem in the maintenance and construction sector. Project delays stem from mismanagement and scheduling problems, according to Egwim et al. (2021) and Darsa and Negash (2023). Recent studies, such as those by Jonbi et al. (2020) and Kowalczyk et al. (2018), reiterate the relationship between project planning inefficiencies and delays, while Abdullah et al. (2022) described how planning interruptions could distort the construction timeline. In addition, Auhan and Rarasati (2022) analysed the complexities of project execution and management that affect the project's timely completion. In other words, other studies such as Nguyễn et al. (2023) support their results that ineffective planning and inadequate response to on-site issues are still critical unfinished aspects leading to late project delivery.

A critical problem is caused by insufficiently skilled personnel in maintenance functions, several production concerns, and reduced quality standards. Moreover, this challenge is worsening because of two factors: older workers and younger generations not interested in technical and vocational careers. Poo (2022) stated that the industries in Malaysia especially are becoming more dependent on Technical and Vocational Education and Training (TVET) graduates to fulfil various skills gaps in the labour market. Nonetheless, TVET is still limited by the lack of coordination between colleges and industrial businesses for disjointed delivery systems. Workforce ageing and talent migration also prompt the Federation of Malaysian Manufacturers (FMM) to develop fresh programs to recruit and nurture young, skilled professionals.

This has an impact on delayed projects with inconsistent service delivery as well as higher operational spending. Padmasree and N (2023) establish a causality between the unavailability of resources, resulting in cost overruns and delays in project schedules. Auhan and Rarasati (2022) and Ibrahim et al. (2022) also mention increasing productivity and tackling workforce shortages with stakeholder cooperation to maximise operational efficiency.

Safety concerns continue to be a significant concern in the maintenance and construction industries. In case organizations fail to follow safety regulations, there are several severe outcomes, including workplace injuries, higher insurance costs, legal consequences, and enforced stoppage. Many prosecution cases have been initiated against the construction sector in Malaysia as they have not appropriately complied with the occupational safety and health (OSH) regulation (Fauziah Fazal, 2020). Tarra Boggs (2023) also holds that disrespect for safety regulations can result in accidents, legal issues, and reputational damage, further inflating operational costs.

Accordingly, these findings highlight the need for proper safety measures to prevent accidents and conform to regulatory requirements. As a result, organizations that do not adopt structured safety measures operate at heightened operational risk, while employee morale is depressed. Briggs et al. (2022), Adegboyega et al. (2021), and Lee et al. (2022) deliberated on safety risk normalization in the context of global crises (e.g. COVID-19 pandemic). In contrast, Azil and Jabar (2022) addressed the struggling safety team to control hazards on a Malaysian construction project. Abdillah et al. (2022) shared some insights about how the pandemic has changed the construction industry's safety measures, indicating that safety efforts in construction shall be adaptive and reactive.

These tangible risks, however, are not the only risks that exist. In addition to these are communication breakdowns, which are no less disruptive. Stakeholders do not get an effective means of communication during the project, leading to delayed project choices, conflicting organisational targets, and parallel working processes. As per Abdelalim et al. (2024), poor communication is key, among other reasons, as to why construction project costs exceed the budgeted cost. Adding to this, Cui and Tai (2020) explained how incorporating Building Information Modelling (BIM) could reduce the risk of miscommunication and diminish team friction by having one place to refer to and increasing the team's visibility. Clear communication is increasingly recognised in successful project execution, especially when delivering projects in complex, multi-stakeholder environments.

Finally, climate change issues with the current climatic conditions have caused weather disruptions to become an increasingly prevalent issue for the maintenance and construction industries. Extreme weather conditions, such as those affecting tools and infrastructure, affect project schedules, reducing the ability to find workers. Schuldt et al. (2021) discuss in detail the impact of weather patterns on project duration in construction. Namuag et al. (2024), Usman et al. (2024), and Oruç et al. (2024) showed recent empirical evidence that extreme weather is associated with scheduling delays and resource inefficiencies in maintenance projects. Ballesteros-Pérez et al. (2018) and Moohialdin et al. (2019) incorporated advanced weather modelling and management strategies to mitigate weather-related disruptions. In addition, Alvanchi and Javadiaghdam (2019) introduced a job site

weather index to evaluate and manage weather impacts on construction resources, offering further insight into improving resilience in project scheduling.

Malaysia's significant barriers to efficient maintenance operations are five challenges: delays, workforce constraints, safety risk, miscommunication, and weather. The operational difficulties in the maintenance industry are summarised in Table 1. Therefore, it studies understanding their root causes and interdependencies to develop strategic project management solutions using Lean Six Sigma and Agile approaches.

Table 1 Key operational challenges in the maintenance and construction industry

Challenge	Description	References
Project Delays	This is caused by poor scheduling, resource misallocation, mismanagement, and unforeseen complications. Leading to financial losses and client dissatisfaction.	Egwim et al. (2021); Darsa & Negash (2023); Jonbi et al. (2020); Kowalczyk et al. (2018); Abdillah et al. (2022); Auhan and Rarasati (2022); Nguyễn et al. (2023)
Manpower Constraints	Shortage of skilled labor due to an ageing workforce and low interest from younger generations. Affects productivity, quality, and project timelines.	Padmasree & N (2023); Auhan and Rarasati (2022); Ibrahim et al. (2022)
Safety Risks	Non-compliance with safety protocols increases the risk of injuries, costs, and project delays—normalization of risk exacerbated by crises like COVID-19.	Ramli et al. (2022); Azil & Jabar (2022); Briggs et al. (2022); Adegboyega et al. (2021); Lee et al. (2024); Abdillah et al. (2022)
Miscommunication	Leads to misaligned goals, duplicated efforts, and delays. Improved through digital tools like BIM.	Abdelalim et al. (2024); Cui & Tai (2020)
Weather Disruptions	Adverse weather affects schedules, damages resources, and reduces labor productivity. Risk increases with climate variability.	Schuldt et al. (2021); Namuag et al. (2024); Usman et al. (2024); Oruç et al. (2024); Ballesteros-Pérez et al. (2018); Moothaldin et al. (2019); Alvanchi & Javadiaghdam (2019)

2.2 Methodologies and Technological Innovations for Enhancing Efficiency in Maintenance Operations

Multiple strategies have been introduced to minimize operational inefficiencies in maintenance operations. Lean manufacturing is the most popular optimization strategy, reducing waste and improving performance (Bhaskar 2020). Six Sigma enhancement strategies work parallel to quality control improvements by finding defective processes to remove errors and maintaining project compliance standards. Present-day organizations use Agile methodologies for project management because these approaches deliver flexible methods to effectively handle complex projects (Choi & Kang, 2019). Process reliability and quality control increase when organizations use data-based quality management approaches that reduce defects, process variations, and inefficiencies (Antony et al., 2020).

The DMAIC framework—Define, Measure, Analyze, Improve, Control—systematically enhances process efficiency and eliminates defects. Sprintzeal (2024) emphasizes its role in tackling operational inefficiencies, guiding businesses to make informed decisions and improve outcomes. In maintenance operations, Root Cause Analysis (RCA) functions within Six Sigma to eliminate recurring inefficiencies that produce project delays. The Error-Proofing approach, also called Poka-Yoke, offers systems that reduce human mistakes and assure compliance with safety principles. Process standardization is a central component for maintaining regular quality standards, leading to improved service delivery efficiency.

Agile methodologies introduce adaptability and responsiveness to the mix, which is particularly important in dynamic project environments. The Scrum Framework supports iterative task cycles, enabling teams to respond quickly to unexpected challenges (Think Lean Six Sigma, 2021). Kanban systems enhance transparency in task management by providing real-time visibility and tracking resources, ensuring workflows remain uninterrupted. Combining Lean, Agile, and Six Sigma methodologies creates a powerful organizational method to handle operational inefficiencies, specifically within construction and maintenance operations. These improvement frameworks focus on process optimization yet take distinct directions to achieve their goals. Lean practice

minimizes waste, but Agile brings adaptable project frameworks, and Six Sigma applies variance reduction mechanisms (Daniyan et al., 2022; Afriana et al., 2023). The collaborative application of these operational strategies enables organizations to develop an expanded approach which yields more efficient operations while reducing financial expenses and delivering superior project success.

Digital technology has become integral to modern maintenance operations, driving efficiency, precision, and coordination advancements. Microsoft Project, alongside Trello and Asana, has become popular due to its functionality, which allows for better task scheduling and resource optimization. The platforms provide hassle-free tracking functions that shorten project timelines by eliminating unnecessary interaction issues and information duplication. Predictive analytics has emerged as a game-changing innovation, empowering organizations to foresee potential problems and optimize asset performance. IoT-enabled sensors and AI-driven models predict equipment failures before they occur, reducing downtime and maximizing operational productivity. Furthermore, BIM (Building Information Modelling) creates more observable projects and encourages continuous teamwork and collaboration when integrated with cloud-based systems. The obtained technologies enable maintenance teams to monitor live infrastructure, leading them toward adopting proactive maintenance procedures (Sprintzeal, 2024).

3. Proposed Solution

The maintenance and construction industry faces persistent challenges that hinder operational efficiency, including project delays, workforce shortages, safety risks, miscommunication, and weather-related disruptions. These inefficiencies increase costs, prolong schedules, and negatively impact industry-wide productivity. To mitigate these issues, organizations must adopt integrated methodologies that streamline processes and enhance adaptability. Combining Lean Manufacturing, Agile methodology, and Six Sigma provides a comprehensive solution that optimizes project execution and fosters sustainable improvements.

One of the most prevalent obstacles in industry is project delay, often caused by inefficient scheduling, resource mismanagement, and unpredictable disruptions. Lean principles focus on eliminating waste and optimizing production workflows to shorten project timelines (Alemu & Thakur, 2021). Through Lean implementation, organizations can identify inefficiencies and remove non-value-added processes, accelerating project delivery. Additionally, Agile methodologies provide flexibility in project planning, allowing teams to respond quickly to unforeseen delays through iterative adjustments and frequent feedback loops (Pinto, 2023). By incorporating Agile frameworks, companies enhance coordination and minimize risks of delays, ensuring greater adaptability in dynamic project environments. Six Sigma complements these efforts using data-driven insights to pinpoint the root causes of delays and implement corrective actions that refine scheduling precision (Akomah et al., 2020). Research indicates that a well-structured project schedule backed by Lean and Six Sigma strategies significantly reduces completion time (Alemu & Thakur, 2021).

Workforce shortages represent another challenge that impairs maintenance and construction efficiency. Organizations struggle to maintain skilled personnel due to an ageing workforce and declining interest in vocational careers. Lean methodologies promote workforce optimization by implementing standardized work procedures, ensuring consistency and operational efficiency (Lundberg et al., 2021). Agile further supports workforce adaptability by fostering continuous learning and iterative training programs that respond to shifting labor demands (Tai et al., 2021). Six Sigma plays a crucial role in workforce management by identifying skill gaps, refining recruitment strategies, and enhancing employee performance evaluations (Mashamba et al., 2023). Moreover, automation and robotic integration reduce dependency on manual labor while maintaining operational productivity (Lafhaj et al., 2023). The organization effectively creates sustainable employment structures that address labor shortages by aligning Lean, Agile, and Six Sigma principles with workforce development.

Safety hazards remain a critical concern in the maintenance and construction industry, with non-compliance often leading to injuries, increased insurance costs, legal penalties, and project shutdowns. Lean Manufacturing supports proactive hazard assessment and risk mitigation, embedding safety measures into operational workflows (Yahya et al., 2019). Agile methodologies improve real-time responses to safety incidents by collecting worker feedback and implementing immediate corrective actions (Choi et al., 2022). Integrating project management software and real-time dashboards further strengthens workplace safety by providing automated alerts and compliance tracking, ensuring adherence to safety protocols (Lundberg et al., 2021). Digital tools facilitate seamless safety communication, reducing risks and improving on-site accountability.

Miscommunication within project teams leads to delays, confusion, and compromised project outcomes. Lean principles establish standardized communication frameworks, ensuring transparent information flow across project phases (Adekunle et al., 2022). Agile reinforces these efforts by fostering collaboration and real-time coordination, eliminating stakeholder misalignment (Cui & Tai, 2020). Six Sigma refines communication strategies by implementing structured feedback mechanisms, minimizing misunderstandings and improving overall project efficiency (Shah et al., 2021). A well-integrated Lean-Agile-Six Sigma system enhances workplace cohesion, ensuring all team members remain aligned on objectives, expectations, and project milestones.

Weather disruptions have become increasingly prevalent due to climate change, affecting resource availability and delaying construction schedules. Lean Manufacturing supports predictive scheduling models, enabling organizations to anticipate and mitigate weather-related delays through strategic planning (Schuldt et al., 2021). Agile methodologies allow teams to swiftly adjust operations based on real-time weather data, facilitating resource redistribution and minimizing downtime (Namuag et al., 2024). Six Sigma contributes to weather risk management by analyzing historical climate patterns and developing contingency strategies to maintain project efficiency (Schuldt et al., 2021). The collective application of these methodologies improves resilience against environmental disruptions, ensuring continuous project progress.

Kaizen, a continuous improvement philosophy, complements Lean, Agile, and Six Sigma by fostering a culture of systematic refinement and proactive adaptation. Organizations integrating Kaizen establish long-term strategic structures that respond quickly to emerging challenges, such as supply chain disruptions and unpredictable weather conditions (Tofan & Breesam, 2018). Through continuous improvement initiatives, businesses enhance operational efficiency, reduce costs, and ensure sustained project success.

The adoption of digital technologies, including AI-driven forecasting, project management platforms, and real-time analytics, further enhances the effectiveness of Lean, Agile, and Six Sigma in modern maintenance operations. These technologies facilitate automation, optimize resource allocation, and improve communication, allowing organizations to achieve greater efficiency while reducing operational risks.

Highlighting the integration of Lean, Agile, and Six Sigma provides a transformative framework for addressing persistent inefficiencies in the maintenance and construction industry. These methodologies complement each other by enhancing process optimization, improving workforce adaptability, reinforcing safety standards, and ensuring streamlined communication and risk mitigation strategies. Organizations implementing these approaches concurrently experience improved project execution, cost reduction, and enhanced stakeholder satisfaction. Future research should explore how these methodologies can integrate with emerging digital technologies to optimize maintenance operations further and improve industry resilience.

4. Conclusion

This concept paper introduces the maintenance and construction industry's main operational challenges, including persistent operational inefficiencies, project delays, workforce shortages, safety risks, communication breakdowns, and weather-related disruptions. These challenges hinder project efficiency, escalate costs, and negatively impact performance. This paper reviews existing methodologies -Lean Manufacturing, Agile Methodology, Six Sigma, and continuous improvement frameworks- that offer systematic solutions to these enduring issues.

This paper highlights a holistic approach to reducing operational inefficiencies that emerges when these methodologies are applied collectively. Lean Manufacturing emphasizes waste minimization and process optimization, enhancing workflow performance and time efficiency (Alemu & Thakur, 2021). Agile methodology fosters adaptive development and iterative problem-solving, ensuring rapid response to evolving challenges while strengthening teamwork and addressing inefficiencies, addressing systematic weaknesses with precision to improve operational consistency (Akomah et al., 2020). Kaizen's continuous improvement philosophy further reinforces long-term resilience, proactively addressing emerging challenges such as weather disruptions and resource shortages.

These methodologies collectively provide a multi-dimensional strategic framework for practitioners in maintenance and construction. By integrating Lean, Agile, Six Sigma, and continuous improvement, organizations can systematically address delays, optimize workforce allocation, enhance safety compliance, and streamline communication, ultimately leading to higher project success rates and improved client satisfaction. Furthermore, leveraging digital technologies, such as real-time dashboards, project management software, and predictive analytics, can augment these methodologies, making operations even more responsive and efficient.

Despite the extensive literature supporting these methodologies, further empirical studies are needed to explore their combined effects across maintenance and construction settings. Future research could examine how emerging technologies, including Artificial Intelligence (AI) and the Internet of Things (IoT), can integrate with these frameworks to optimize project performance further and enhance industry-wide resilience.

In conclusion, this paper has explored the key operational challenges in maintenance and construction and reviewed integrated methodologies to resolve inefficiencies in project delivery. The combined application of Lean, Agile, Six Sigma, and continuous improvement frameworks offers a structured approach to achieving timely, cost-effective, and high-quality project execution, making it a valuable strategy for industry advancement.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the paper's publication.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Noor Aslinda Abu Seman; **analysis and interpretation of results:** Mohd Shahrulnizam Ab Rahim, Noor Aslinda Abu Seman; **draft manuscript preparation:** Mohd Shahrulnizam Ab Rahim. All authors reviewed the results and approved the final version of the manuscript.*

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