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Relocation of the Fuel Fast Fill Unit on the Komatsu PC2000 from Beneath the Engine to the Unit Stairs as an Effort to Improve Safety, Refueling Efficiency, and Reduce Production Loss Time (Case Study of Quality Control Project Implementation in the AMM Pit Area, Mifa Jobsite, PT Putra Perkasa Abadi, 2025)

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Abstract
The Komatsu PC2000 excavator operating in the AMM Pit Area at the Mifa Jobsite was equipped with a fast-fill fuel system positioned beneath the engine, exposing its components to potential damage from boulder impacts and creating accessibility challenges during refueling operations. Maintenance records from February 2024 to July 2025 documented nine system-related incidents resulting in at least 25 hours of equipment downtime, of which 16.7 hours (66.8%) were attributed to structural damage. This study evaluated the relocation of the fast-fill fuel connection point from beneath the engine to the excavator stairway area using the eight-step Quality Control Circle (QCC) methodology integrated with the Plan–Do–Check–Act (PDCA) cycle. Data were collected through maintenance records, field observations, cross-functional team discussions, Pareto analysis, Ishikawa cause-and-effect analysis, and solution-selection matrices to identify the primary causes of equipment downtime and determine appropriate corrective measures. Following the relocation, no additional fast-fill system disturbances were recorded during the specified monitoring period. For seven Komatsu PC2000 excavators, the projected operational benefits included annual savings of 638.5 equipment operating hours, a reduction in fuel consumption of approximately 76,620 liters, and a potential productivity gain of 447,125 bank cubic meters (BCM). However, these estimates were based on projected operational scenarios rather than independently verified annual performance measurements. The reported implementation cost was IDR 34,815,899 per excavator. Overall, the modification improved access to the refueling connection and potentially reduced component exposure to mechanical impacts, although its long-term reliability, safety performance, and economic benefits required further evaluation. These findings demonstrated the potential of evidence-based maintenance practices and multidisciplinary QCC methodologies to support targeted equipment modifications, improve refueling efficiency, and minimize production-related downtime in mining operations.

INTRODUCTION

PT Putra Perkasa Abadi (PPA) operates heavy equipment at the Mifa AMM Jobsite, where Komatsu PC2000 hydraulic excavators play a critical role in material loading operations and maintaining production continuity. These excavators are equipped with a fast-fill fuel system designed to facilitate efficient refueling through a dedicated connection point without requiring conventional fuel tank cap removal. Reliable operation and accessibility of this system are essential for minimizing refueling delays, maintaining equipment availability, and preventing disruptions to production schedules and maintenance activities (Rahman et al., 2026).

In the existing equipment configuration, the fast-fill fuel connection point on the Komatsu PC2000 was positioned beneath the engine compartment. This location exposed fuel hoses, couplings, and mounting brackets to potential mechanical damage from falling rocks, boulders, and other materials encountered during mining operations (Anthony, 2025). Additionally, the restricted accessibility of the connection point complicated fuel hose attachment and disconnection, potentially increasing refueling time and exposing operators to additional operational hazards. Maintenance records collected between February 2024 and July 2025 documented nine fast-fill system disturbances, resulting in at least 25 hours of equipment downtime. Of this total, 16.7 hours were attributed to physical or structural damage, indicating that component exposure was a substantial contributor to recurring equipment failures.

These operational deficiencies presented significant implications for equipment reliability, occupational safety, environmental protection, and production efficiency. Restricted access to the refueling connection could prolong preparation and refueling activities, while damaged fittings and hoses increased the potential for diesel fuel leakage and environmental contamination. Furthermore, unexpected maintenance requirements reduced equipment availability and disrupted scheduled production activities. Consequently, improving the positioning and protection of the fast-fill fuel connection became an operational priority in the AMM Pit Area, where the existing configuration provided insufficient protection against mechanical impacts and limited safe, efficient access during routine refueling operations.

Previous studies have demonstrated the application of Quality Control Circle (QCC) methodologies and the Plan–Do–Check–Act (PDCA) cycle in addressing recurring operational problems, reducing process defects, and improving industrial performance (Adriantantri et al., 2023; Aliyudin & Setijadi, 2026; Erlian, 2020; Sari & Nurwathi, 2023; Setiawan et al., 2025; Sumasto et al., 2024; Wang et al., 2013; Yuliarty et al., 2024). Maintenance-related research has also highlighted the effectiveness of Pareto analysis and structured root-cause identification in prioritizing equipment failures and developing targeted corrective actions (Anshar & Nasution, 2025; Knights, 2001; Kovacevic et al., 2016; Rahman et al., 2025). These methodological approaches provided a systematic foundation for evaluating recurring fast-fill system disturbances, identifying their underlying causes, and selecting appropriate engineering modifications based on documented maintenance evidence rather than relying exclusively on reactive repairs.

Despite these methodological developments, previous studies cited in this research had not specifically examined the positioning of the fast-fill fuel connection on Komatsu PC2000 excavators as an interconnected source of mechanical damage, refueling accessibility constraints, and production-related downtime. Existing research primarily emphasized general maintenance improvement and failure reduction (Amanullah et al., 2026; Arsić et al., 2025; Li et al., 2023; Ucar et al., 2024), while limited attention was given to evaluating localized component relocation as a

preventive engineering intervention in mining equipment. Accordingly, the identified research gap concerned the systematic selection and evaluation of a component relocation strategy using maintenance records, structured root-cause analysis, and operational performance indicators to improve refueling system reliability within an active mining environment.

This study addressed the identified gap by implementing a site-specific Quality Control Project (QCP) using the Quality Control Circle (QCC) methodology to evaluate and improve the configuration of the Komatsu PC2000 fast-fill fuel system. The intervention involved analyzing equipment failure patterns, identifying dominant causes through cause-and-effect analysis, evaluating alternative corrective measures through cross-functional decision-making, and relocating the fast-fill fuel connection from beneath the engine to the excavator stairway area. The principal contribution of the study was the integration of maintenance breakdown analysis, engineering modification, and operational performance evaluation within a structured continuous improvement framework. Furthermore, the study assessed potential implications for equipment downtime, fuel consumption, implementation costs, productivity, and Quality, Cost, Delivery, Safety, and Morale (QCDSM) performance, while distinguishing projected operational benefits from directly observed post-implementation outcomes.

Accordingly, this study aimed to identify the primary causes of fast-fill fuel system disturbances on Komatsu PC2000 excavators, determine the technical feasibility and operational suitability of relocating the refueling connection, and evaluate changes in recorded system failures and relevant operational performance indicators following implementation. The findings were expected to provide practical recommendations for improving equipment maintenance strategies, enhancing refueling accessibility and occupational safety, and minimizing production-related downtime. Additionally, the study sought to establish a foundation for evaluating the long-term reliability and economic feasibility of similar engineering modifications across comparable mining operations and equipment configurations.

METHOD

This study employed a case study approach using the eight-step Quality Control Circle (QCC)/Quality Control Project (QCP) methodology, structured around the Plan–Do–Check–Act (PDCA) cycle (Deming, 1986). The research procedures comprised problem identification, root-cause analysis, solution selection, improvement planning, implementation, effectiveness evaluation, and standardization. The eighth step, identification of the next improvement theme, was optional under the QCP framework and was not included in the reported research procedures.

Data were collected from historical breakdown records of Komatsu PC2000 excavators retrieved from PT Putra Perkasa Abadi's maintenance information system for February 2024–July 2025, supplemented by field observations and cross-functional brainstorming sessions involving the Plant, Supply Chain Management (SCM)/Fuel Operations, and Safety, Health, and Environment (SHE) departments. Quality control techniques included data stratification and Pareto analysis to prioritize equipment failures, followed by Ishikawa cause-and-effect diagrams to identify root causes related to personnel, methods, machinery, and materials (Ishikawa, 1985; Kovacevic et al., 2016). Improvement targets were established using SMART criteria, while alternative solutions were evaluated through a decision matrix considering implementation feasibility, expected outcomes, time, cost, and effectiveness. The selected intervention was

subsequently organized into a structured 5W+1H action plan, incorporating implementation responsibilities, schedules, procedures, and estimated costs.

The effectiveness of the intervention was evaluated by comparing pre- and post-implementation conditions across Quality, Cost, Delivery, Safety, Health, Environment, and Morale (QCDSM) performance dimensions. Additional economic assessments estimated potential equipment downtime reductions, fuel savings, and productivity gains based on operational data and projected performance scenarios. The improvement activities were conducted by the five-member QCP "Seger Waras" team, representing plant engineering, tracked equipment maintenance, maintenance planning, and SCM fuel operations. The team possessed relevant technical competencies in mining operations supervision, fuel handling, energy performance management, and rigging, supporting the implementation and evaluation of the proposed equipment modification.

RESULTS AND DISCUSSION

Problem Identification and Stratification

The stratification of the Fuel Fast Fill PC2000 trouble record data for the period February 2024–July 2025 is presented in Table 1. The Pareto diagram of the downtime data shows that physical/structural damage is the largest contributor, at 16.7 hours or 66.8% of the total downtime recorded, followed by fuel leakage (4.4 hours) and function/system disruption (3.9 hours or more). Referring to the Pareto principle of 80:20 (Knights, 2001), the focus of repair is directed to the cause of physical/structural damage as the top priority.

Table 1. Fuel Fast Fill PC2000 trouble record stratification (February 2024–July 2025)

Category Trouble	Field Evidence	Frequency	Downtime
Fisik/structural damage	Fast Fill exposed to boulder; bracket bent; Fast Fill falling/immovable	3 Occurrence	16.7 hours
Fuel leakage	Fast Fill leak; leakage in the hose and cylinder arm	3 Occurrence	4.4 hours
System/functional problem	Fast Fill can't go up; Fast Fill ladder is problematic	3 Occurrence	≥ 3.9 hours
TOTAL	Fuel Fast Fill system related disruptions	9 Occurrence	≥ 25.0 hours

Source: Maintenance records from the original project case study.

Based on the data in Table 1, a gap was identified in the form of "the existing Fast Fill position is not optimal for the need for reliability and effectiveness of refueling". In addition to the reliability aspect, the access of fuelmen to difficult filling points also causes delays in the refueling preparation stage, while Fast Fill leaks have the potential to cause environmental pollution due to diesel fuel spills. On this basis, a Specific-Measurable-Achievable-Relevant-Time based (SMART) target was set: reducing the frequency of Fuel Fast Fill damage by 100% (from nine incidents to zero incidents) and reducing the average refueling process time, which was evaluated within two months post-implementation (January-February 2026).

Cause-and-Effect Analysis and Determination of Dominant Causes

Cause-and-effect analysis was carried out using fishbone diagrams (Ishikawa, 1985) in four categories: Man, Method, Machine, and Material, followed by cross-departmental brainstorming to determine the dominant root cause (Table 2). The use of fishbone diagrams in the context of

mining heavy equipment maintenance is in line with the commonly used cause-effect analysis approach to unravel the contribution of human, method, machine, and material factors to failure in mining machinery (Kovacevic et al., 2016).

Table 2. Analysis of the dominant root causes by Man-Method-Machine-Material category

Category	Direct Causes	Root Causes	Priorities
Man	Fuelman has difficulty connecting/disconnecting the Fast Fill hose when refueling	The existing Fast Fill position is under the engine, making it difficult for the fuelman to reach	✓
Method	The refueling process requires hose handling and unit position adjustment which increases preparation time	Existing Fast Fill points do not yet provide effective access for refueling	✓
Machine	Fast Fill has repeated physical damage due to material exposure/impact during surgery	The Fast Fill position is under the engine so that high exposure to the material/boulder	✓ DOMINANT
Material	Fast Fill hoses, brackets, and fittings/couplings are damaged and potentially cause fuel leakage	Fast Fill components in the existing position have not been optimally protected against external impacts	✓

Source: Project-team cause-and-effect analysis reported in the manuscript.

The results of the analysis show that the dominant root cause lies in the Machine category, namely the position of Fuel Fast Fill which is under the engine so that it has high exposure to materials and impacts (boulder) during the unit operation. This finding is consistent with the largest downtime contribution in Table 1 (physical/structural damage), so that the root cause in the Machine category is set as the main priority of handling, without ignoring the other three interrelated root causes.

Solution Risk Determination and Analysis

Based on the dominant root causes, the team developed three alternative solutions that were assessed against the criteria of opportunity for results, time, cost, and effectiveness (Table 3).

Table 3. Alternative selection matrix of repair solutions

Alternative Solutions	Outcome Opportunities	Time	Cost	Effectiveness	Verdict
Repositioning of Fuel Fast Fill from under the engine to the unit ladder	Height	Fast	Medium	Height	Selected
Installation of protective guards on existing Fast Fill	Medium	Fast	Medium	Low	No
Repositioning of Fuel Fast Fill from the bottom of the engine to the arm unit	Medium	Medium	Height	Medium	No

Source: Project-team evaluation of alternative solutions.

The alternative repositioning of Fuel Fast Fill to the unit stair area was chosen as the best solution because it has a high chance of results, can be implemented relatively quickly through minor modifications during scheduled unit maintenance, as well as costs that can still be controlled. Further risk analysis shows that this solution addresses several root problems while reducing material exposure while facilitating access to refueling and supporting the implementation of the Fuel Management System (FMS) required by IUP Owners. On the other

hand, alternative repositioning to the arm unit area risks causing longer routing hoses so that it has the potential to cause physical damage to new types, while the installation of protective guards does not solve the problem of fuelman access.

Improvement Plan and Implementation

The improvement plan was prepared using a 5W+1H approach equipped with cost estimates (Table 4), implemented in the period August 2025–February 2026 by the cross-functional teams of GL Fuel, GL Plant, Mechanic, SCM, and SHE.

Table 4. 5W+1H based improvement plan

Factors	Action Plan	Person in Charge	Cost
Man	Socialization/toolbox meeting regarding the position of the new Fast Fill, filling method, and safety aspects of refueling	GL Fuel / Plant	IDR0
Method	Review and adjustment of refueling SOP/IK: fuel truck positioning, connecting–refueling–disconnecting, and FMS application	GL Fuel / SHE / Plant	IDR0
Machine	New point determination, mounting/bracket fabrication, Fast Fill repositioning, hose rerouting, fitting installation, functional test	GL Plant / Fuel / Mechanic / SHE	IDR0
Material	Identification of specifications, procurement/fabrication of hoses, fittings, couplings, and brackets, installation, and leak checking	Plant / SCM / Mechanic	IDR 34,815,899/unit

Source: Project improvement plan and cost records reported in the manuscript.

The implementation stage is carried out through four main activities: (1) survey and determination of Fast Fill repositioning points through analysis of actual conditions (ANAKONDA) in the stairwell area of the PC2000 unit; (2) preparation of hose components, adapters, and Fast Fill components by MTU vendors; (3) repositioning and installation of Fuel Fast Fill in the stairwell area of the unit with verification by the Track Plant team; and (4) inspection, including leak check, ground test, and trial actual refueling as well as testing the function of the Fuel Management System (FMS) by the Track Plant and SCM Fuel teams. The total installation cost was recorded at Rp34,815,899 per unit, so that for the population of seven PC2000 units at the Mifa AMM Jobsite, a total investment of Rp243,711,293 is required. Picture of fast fuel installation (Figure 1.)



Figure 1. Fast Fuel Installation

Source: Field documentation supplied with the original manuscript.

Evaluation of Improvement Results

Monitoring of the frequency of Fast Fill breakdowns was carried out on a quarterly basis from Q1-2024 to Q3-2026. Data shows that in the period before implementation (Q1-2024–Q2-2025) there were nine cases of Fast Fill damage, with the peak of occurrence in Q2-2024 (3 cases) and Q1-2025 (3 cases). After the repositioning was implemented, no more cases of damage/trouble were found in Fast Fill PC2000 until the reporting period (Q3-2025 to Q3-2026), as presented in Table 5.

Table 5. Comparison of QCDSM conditions before and after implementation

Aspect (QCDSM)	Pre-Repair Conditions	Condition After Repair
Quality	9 incidents of Fast Fill malfunction (Feb 2024–Jul 2025); downtime ≥25 hours	0 instances of Fast Fill corruption since the reposition was implemented
Cost	Potential for recurring losses due to Fast Fill repair/replacement	Investment IDR 243,711,293 (7 units); potential rental rate gain ≈IDR 462,560,000/year
Delivery	Unnecessary movement and preparation ±15 minutes each refueling per unit	Elimination of unnecessary movement; recovery of productivity ≈447,125 BCM/year
Safety/Health/Environment	Difficult fuelman access; risk of fuel leakage and environmental pollution	Easier and safer access to the fuelman; reduced risk of leakage
Morals	Refueling coordination is hampered due to the difficult reach of the Fast Fill position	Improved ease of work and coordination of the refueling process

Source: Pre- and post-implementation project observations and estimates.

Financial performance verification was carried out assuming the population of seven PC2000 units, elimination of unnecessary movement of 15 minutes (0.25 hours) per refueling per unit, fuel consumption ±120 liters/hour/unit, PC2000 rental rate of USD118/hour/unit, and productivity of 700 BCM/hour/unit. The calculation of potential loss time that can be eliminated is 7 units × 0.25 hours × 365 days = 638.5 hours per year. From this value, productivity

opportunities of 638.5 × 700 BCM = 447,125 BCM per year were obtained, potential rental rate gain ≈USD26,432 or equivalent to IDR 462,560,000 per year (exchange rate of IDR 17,500), and potential fuel savings of 638.5 × 120 liters = 76,620 liters per year. With an investment cost of IDR 243,711,293 for seven units, the potential annual benefits obtained show a relatively short period of return on investment, although the quantification of the payback period is formally beyond the scope of this article.

The positive impact of the implementation was also felt by various stakeholders (Table 6): The Production Department obtained an increase in the productivity of PC2000 through the elimination of unnecessary movement; The Plant/Track Equipment Department obtained an increase in the reliability unit that supports the achievement of the Mean Time Between Failure (MTBF) KPI; The SCM/Fuel Operation Department obtained the efficiency of the connecting-disconnecting process; and the Fuelman obtained an increase in safety and ease of work during refueling.

Table 6. Impact of implementation on relevant stakeholders

Stakeholders	Positive Influence
Production Department	Increased productivity of the PC2000, elimination of ±15 minutes of unnecessary movement and preparation with each refueling
Departemen Plant/Track Equipment	Increase unit reliability and support MTBF KPI achievement through reducing repetitive failure Fast Fill
SCM/Fuel Operation	Improve refueling operational efficiency through more accessible Fast Fill positions
Fuelman	Improve safety and ease of work; reduce the need to access the under-engine/counterweight area

Source: Project team's QCDSM assessment reported in the manuscript.

Discussion and Comparison with Previous Studies

The findings of this study strengthen the argument that the Quality Control Circle (QCC) approach combined with the Plan-Do-Check-Action (PDCA) cycle is effectively used across industrial sectors, not limited to manufacturing or healthcare as widely reported in the previous literature (Setiawan et al., 2025; Wang et al., 2013), but is also relevant to the problem of mining equipment reliability. When compared to the study by Setiawan et al. (2025) that succeeded in reducing the defect rate in vehicle lighting components through QCC-PDCA, this study shows a similar pattern of success, namely a significant decrease in the main indicator (frequency of Fast Fill damage) after the dominant root cause is intervened in a targeted manner. Similarly, Sumasto et al. (2024) studied the production of carousel wingboxes, QCC's success in this study was also supported by a combination of stratification table quality control tools, Pareto diagrams, fishbone diagrams, and solution selection matrices that consistently directed the team to one dominant root cause that could be directly intervened.

Compared to the conventional Pareto histogram approach, the use of trouble record category-based stratification in this study also considers the frequency and duration aspects of downtime simultaneously, in line with the recommendation of Knights (2001) that the downtime analysis of mining equipment should ideally not only rely on the frequency of failures, but also on the duration and impact of the costs incurred. The selection of repositioning solutions over the alternative of installing protective guards also reflects the principle of solving the root cause rather than symptom management, as emphasized in the cause-effect analysis approach to mine equipment failures (Kovacevic et al., 2016). Thus, the main contribution of this study is to demonstrate the application

of eight-step QCC integrated with quantitative downtime data and financial performance verification in the specific context of the reliability of mining heavy equipment refueling components, an area that has not been extensively discussed explicitly in the existing QCC literature.

This study has a number of limitations that need to be considered in application and follow-up research. First, the post-implementation monitoring period used as the basis for evaluation (August 2025–September 2026) is relatively short compared to the life cycle of the Fast Fill component as a whole, so the sustainability of zero breakdown results needs to be continuously monitored in the next operational period. Second, the verification of financial performance in this study uses average rental rate assumptions, fuel consumption, and unit productivity assumptions (blanket assumption) for the entire population of seven PC2000 units, so that the variation in actual work front conditions between units has not been taken into account in detail. Third, this study focuses on one type of unit (Komatsu PC2000) in one work area (Pit AMM Jobsite Mifa), so the generalization of results on other unit types or mining conditions requires further study and adjustment, considering that the characteristics of the work front, material type, and operational patterns can differ from job site to jobsite.

Despite these limitations, the application of QCC in this case study emphasizes the importance of cross-functional team involvement from the problem identification stage to standardization. The simultaneous involvement of the Plant Department, SCM/Fuel Operation, and SHE ensures that the chosen solution not only solves reliability problems from a technical (Machine) point of view, but also considers the safety aspects of the fuelman (Man), adjustment of operational procedures (Method), and the availability of supporting materials (Material) as a whole. This kind of cross-functional approach is in line with the characteristics of QCC as a continuous improvement activity based on small group activities that involve workers at the operational level to solve problems in their own workplaces (Nemer & Vieira, 2018), while strengthening the team's sense of ownership of standardized repair results.

CONCLUSION

The implementation of the eight-step Quality Control Circle (QCC) methodology, integrated with the Plan–Do–Check–Act (PDCA) cycle, successfully identified the primary cause of recurring damage to the Komatsu PC2000 fast-fill fuel system, namely the original positioning of the refueling connection beneath the engine, which exposed its components to mechanical impacts from rocks and other materials during mining operations. Relocating the fast-fill fuel connection to the excavator stairway area was associated with a reduction in recorded system failures from nine incidents during the pre-implementation observation period to zero incidents during the post-implementation monitoring period. The modification also improved accessibility during refueling and potentially reduced the risk of fuel leakage and equipment downtime. For seven Komatsu PC2000 excavators, the projected annual operational benefits included 638.5 hours of equipment downtime reduction, fuel savings of approximately 76,620 liters, and potential productivity gains of 447,125 bank cubic meters (BCM), with a total reported implementation investment of IDR 243,711,293. However, these projected benefits represented scenario-based estimates rather than independently verified annual savings, and the observed reduction in failures required longer-term monitoring to establish sustained effectiveness.

Based on these findings, it was recommended that the modified fast-fill fuel connection configuration be standardized and progressively implemented across Komatsu PC2000 excavators at other jobsites with comparable operating conditions, subject to technical feasibility and safety assessments. Continuous post-implementation monitoring should also be conducted to evaluate component durability, detect potential new failure modes, and verify sustained improvements in refueling efficiency and equipment reliability. Furthermore, the QCP team should continue its structured improvement initiatives by identifying additional equipment reliability and operational efficiency challenges within the AMM Pit Area at the Mifa Jobsite. Future research should include a comprehensive economic evaluation to determine the investment payback period and validate projected cost savings using actual operational data. Additional longitudinal assessments of mean time between failures (MTBF) and mean time to repair (MTTR) were also recommended to establish the modification's long-term effects on equipment reliability, maintenance performance, and production continuity.

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CONFLICT OF INTEREST

The author states that there are no conflicts of interest, whether personal, commercial, or financial, that can affect the implementation and results of this study.

AUTHOR'S CONTRIBUTION

Johan Chrisna contributes to research design, data collection and processing, system development, result analysis, and article manuscript preparation.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

In the process of compiling this article, the author uses generative artificial intelligence (AI) as a tool in language refinement, writing structure, and grammar improvement. The use of AI is carried out on a limited basis and remains under the supervision of the author. All data, analysis, interpretation, and scientific substance in this article have been checked and verified by the author. The author is solely responsible for the accuracy, authenticity, and final content of the manuscript.

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