

Core Problem Solving with the Kepner-Tregoe Approach for Aerospace Quality Performance

Erwan Nofrianto^{1*}, Mursyid Hasan Basri²

Institute Technology Bandung, Jawa Barat, Indonesia^{1,2}

erwan_nofrianto@sbm-itb.ac.id^{1*}, mursyid@sbm-itb.ac.id²

ARTICLE INFO

Received: 9 June 2024;

Revised: 27 June 2024;

Revised: 13 July 2024;

Accepted: 12 August 2024;

Volume 1, Number 2

2024, pp 119-138

<https://doi.org/10.61401/rmaps.v1i2.133>

Corresponding author:

Erwan Nofrianto

Institute Technology Bandung, Jawa Barat, Indonesia

E-mail: erwan_nofrianto@sbm-itb.ac.id

ABSTRACT

Purpose: This study examines whether Core Problem Solving (CPS) integrated with the Kepner-Tregoe approach can improve quality performance at PT UTC Aerospace System Bandung (UTAS Bandung), an aerospace parts supplier, by reducing the percentage of scrap, rework, and reject (%SRR) from 0.73% in 2022 toward the company's five-year target of 0.5% by 2027.

Methodology: A single case study was conducted using Systems, Applications, and Products (SAP) in data Processing quality-notification data. The CPS approach, comprising the Define, Investigate, Verify, and Ensure (DIVE) stages, was integrated with Pareto charts, Ishikawa (fishbone) diagrams, and Five Whys analysis to identify the primary source of the Cost of Poor Quality (CoPQ) and evaluate corrective actions through a before-after comparison.

Results: The prismatic cell accounted for 61% (approximately USD 154,000) of the USD 254,300 total CoPQ in 2022. Root-cause analysis linked recurring drill-tool failures on part number 340902-110 to low tool rigidity and the absence of a coolant channel. Replacing the finishing tool reduced failure costs from USD 12,000 to USD 3,200 (73%), saving USD 8,800 annually, while total CoPQ decreased by USD 37,223 to USD 217,077 in 2023.

Conclusions: CPS combined with Kepner-Tregoe problem analysis provides an effective and replicable approach for reducing CoPQ and achieving the targeted %SRR through data-driven root-cause analysis.

Limitations: The study is limited to 2022 SAP records from one site and excludes customer returns and supplier-caused rejects.

Contributions: The study provides a practical framework for integrating CPS and Kepner-Tregoe analysis in aerospace manufacturing.

Keywords: *Cost of Poor Quality, Fishbone Diagram, Kepner-Tregoe, Pareto Diagram, Root Cause Analysis*

How to Cite: Nofrianto, E., & Basri, M. H. (2024). Core Problem Solving with the Kepner-Tregoe Approach for Aerospace Quality Performance. *Review of Multidisciplinary Academic and Practice Studies*, 1(2), 119-138.

1. Introduction

Commercial aviation is recovering from the disruption caused by the Covid-19 pandemic, and passenger travel volumes have climbed steadily as airlines rebuild capacity. That recovery has renewed confidence among the manufacturers that supply the aviation value chain. PT UTC Aerospace System Bandung (UTAS Bandung), part of the Collins Aerospace group, is one such supplier, producing machined parts for Airbus and Boeing programs. Because the aerospace supply base is intensely competitive, sustaining and improving quality performance, understood within the broader theoretical development of quality management by [Koskela, Tezel, and Patel \(2019\)](#), is not optional for a tier supplier such as UTAS Bandung; it is a condition of continued participation in original-equipment-manufacturer programs.

Quality performance is the primary lever through which UTAS Bandung protects customer satisfaction and market position, consistent with evidence that structured quality-related action programs improve both quality and firm performance ([Curkovic, Vickery, & Droge, 2000](#)) and that total quality management practice strengthens organizational performance more broadly ([Pambreni, Khatibi, Azam, & Tham, 2019](#)). One of the operational indicators the plant tracks is the percentage of scrap, rework, and reject parts, abbreviated %SRR, a widely used proxy for conformance quality in discrete manufacturing. Over the three years preceding this study, %SRR performance had generally tracked below target, and the 2022 result of 0.73% was comfortably inside the 1.1% ceiling that management had set for that year. Even so, UTAS Bandung's leadership set a more ambitious five-year target of 0.5% for 2027, signaling that historical compliance with a looser target was not sufficient and that a structured improvement effort would be required to close the remaining gap.

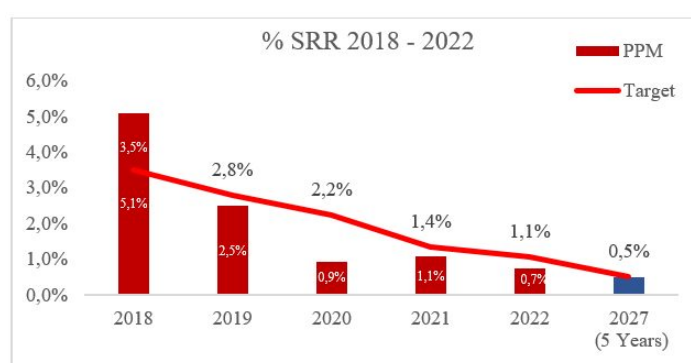


Figure 1. %SRR period 2018-2022

Figure 1 traces %SRR performance for the five years from 2018 through 2022 and shows that, despite year-to-year fluctuation, the plant consistently operated under the internal ceiling. The chart establishes the performance baseline from which the five-year improvement trajectory toward 0.5% is measured.

The Scrap, Rework, and Reject (%SRR) indicator was calculated by comparing the Cost of Poor Quality (CoPQ), which consists of scrap, rework, and reject costs, with the total value of parts sold to customers during the same period. The %SRR was determined using Equation 1.

$$\%SRR = \frac{\text{Cost of Poor Quality (CoPQ)}}{\text{Value of Parts Sold}} \times 100\% \quad (1)$$

Based on Equation 1, the total Cost of Poor Quality (CoPQ) recorded at UTAS Bandung in 2022 was USD 254,300, while the total value of parts sold to customers reached USD 34,637,000. Substituting these values into the equation resulted in an %SRR of 0.73%, indicating that quality-related losses represented 0.73% of the company's total sales value during the reporting period. This result exceeded the company's long-term quality target and highlighted the need for continuous

improvement initiatives to reduce quality-related costs. Both the numerator and denominator were expressed in US dollars because the SAP system records the value of disposed parts in monetary units, thereby ensuring consistency and reliability in the measurement of the %SRR indicator.

To improve quality performance, the company established a target of reducing the %SRR to 0.5% by 2027. Using the 2022 sales value as the baseline, the maximum allowable Cost of Poor Quality (CoPQ) was determined to be USD 173,185. This value represents the highest level of quality-related losses that can be tolerated while still achieving the targeted %SRR. Consequently, maintaining the CoPQ at or below this threshold is essential to ensure that quality losses remain within the company's acceptable performance level.

A comparison between the actual CoPQ in 2022 (USD 254,300) and the maximum allowable CoPQ (USD 173,185) indicated that the company must reduce quality-related losses by a total of USD 81,115. This amount represents the cumulative improvement required over the five-year implementation period to achieve the desired quality objective. The improvement target provides a quantitative benchmark for monitoring progress and evaluating whether the implemented corrective and preventive actions effectively reduce the Cost of Poor Quality over time.

Assuming that the required improvement is distributed evenly across the five-year period, the minimum annual reduction is approximately USD 16,223. This annual target serves as the performance benchmark for assessing the effectiveness of quality improvement initiatives implemented during each year of the study. By establishing measurable annual milestones, management can systematically monitor progress, identify deviations from the planned target, and implement corrective actions when necessary. The distribution of the cumulative improvement target into annual milestones is illustrated in Figure 2.

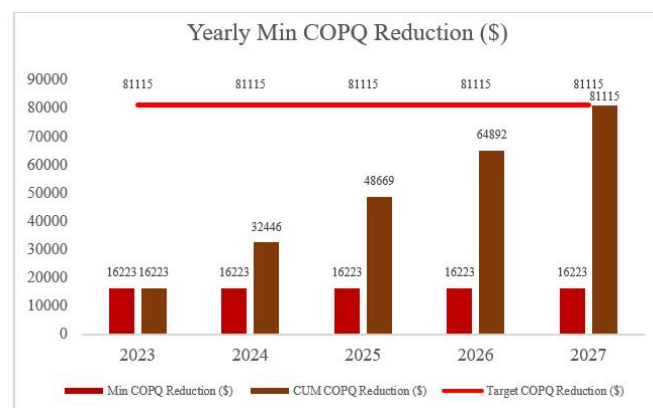


Figure 2. Yearly minimum target of CoPQ reduction

To meet this annual cadence, UTAS Bandung selected Core Problem Solving (CPS) combined with the Kepner-Tregoe problem-analysis approach as its primary improvement vehicle. The rationale for that choice, together with a review of the alternative root-cause methodologies it was weighed against, is developed in the literature review that follows. Pareto charting, Ishikawa (fishbone) diagramming, and five-why analysis were nested inside the CPS-Kepner-Tregoe structure as the specific tools used to trace the highest-value defect streams back to an addressable root cause and to translate that root cause into a countermeasure capable of moving %SRR performance toward the 2027 target.

2. Literature Review

2.1 Theoretical Foundation

Root-Cause Analysis (RCA) is not a single technique but a family of methodologies chosen according to the nature of the problem being investigated. In a widely cited classification, the United States Department of Energy grouped RCA approaches into five families: events-and-causal-factor analysis, typically used for major single-event failures such as an explosion; change analysis, applied when a system's performance has shifted noticeably from an established baseline;

barrier analysis, which examines which controls should have prevented or detected a failure and why they did not; management-oversight-and-risk-tree analysis, which uses a tree diagram to trace how and why an event occurred; and Kepner-Tregoe problem-solving and decision-making, which proceeds through situation analysis, problem analysis, solution analysis, and potential-problem analysis ([Latino, Latino, & Latino, 2019](#); [Okes, 2019](#); [Mahto & Kumar, 2008](#)). This classification is a useful frame because it makes explicit that recurring, dispersed nonconformances of the kind UTAS Bandung experiences with scrap and rework are better suited to change analysis or Kepner-Tregoe than to the single-event techniques designed for catastrophic failures.

Recent manufacturing-focused reviews reinforce this point. A scoping review of root-cause analysis practice across industrial manufacturing found that most published applications still rely on structured, human-facilitated tools such as Pareto charts and Ishikawa diagrams, even as data-driven and machine-learning-assisted methods expand the toolkit available to practitioners in high-volume or highly instrumented lines ([Pietsch et al., 2024](#)). A parallel review situates root-cause analysis within the broader Quality 4.0 movement, arguing that digitalization tends to accelerate rather than replace conventional RCA tools such as the fishbone diagram, the Pareto chart, and the affinity diagram by making the underlying defect data easier to collect and visualize ([Andrews, Emamjome, ter Hofstede, & Reijers, 2022](#)).

2.1.1 Kepner-Tregoe

The Kepner-Tregoe (KT) method, developed by Charles Kepner and Benjamin Tregoe, is used in this study to decide on the best course of action once a root cause has been identified. The approach proceeds through four sequential steps, illustrated in Figure 3.

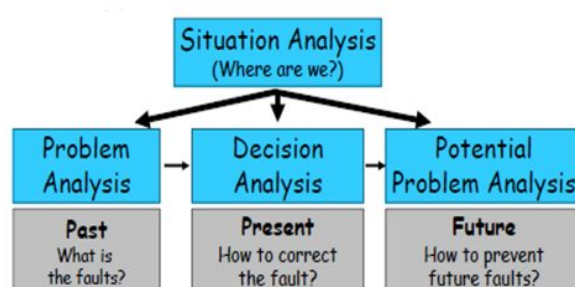


Figure 3. KT method approach

Situation analysis identifies which concerns or issues require attention and answers the question of where the organization currently stands. Problem analysis examines what has gone wrong in the past and why. Decision analysis generates and evaluates alternative solutions, including how a fault should be corrected in the present. Potential-problem analysis looks forward, asking how the outcome of the chosen solution can be protected and how similar faults can be prevented in the future. Empirical applications of KT decision analysis in manufacturing settings continue to appear in the recent literature; one study used Kepner-Tregoe decision analysis to fix a defective clamping pad in a leak-testing process, demonstrating that the framework transfers well from its original managerial context into shop-floor failure analysis ([Jhorar, Pathak, & Singh, 2020](#)).

2.1.2 PDCA Approach

The problem-solving model most familiar to practitioners is Plan Do Check Act (PDCA), originally developed by Walter A. Shewhart in 1939 and later popularized by W. Edwards Deming ([Isniah, Purba, & Debora, 2020](#)). PDCA is a well-known model for continuous process improvement that teaches organizations to plan an action, execute it, check how the result conforms to the plan, and act on what has been learned, and it remains a common backbone for kaizen events and Six Sigma DMAIC projects alike.

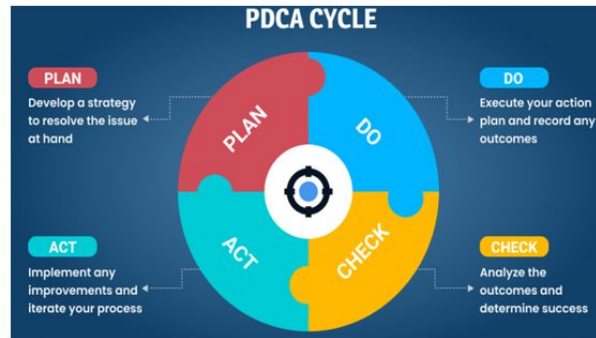


Figure 4. PDCA cycle

Figure 4 illustrates the PDCA cycle consists of four repeating steps. A study applying the PDCA cycle to reduce manufacturing defects in an automotive case demonstrated measurable reductions in reject rate once the cycle was run iteratively rather than as a one-time intervention, underscoring that the value of PDCA lies in repetition rather than in any single pass through the loop ([Realyvasquez-Vargas, Arredondo-Soto, Carrillo-Gutierrez, & Ravelo, 2018](#)).

2.1.3 Core Problem Solving (CPS)

Core Problem Solving (CPS) is the common problem-solving language and methodology applied at UTAS Bandung as part of a broader cultural change intended to build an internal community, or "army," of problem solvers. CPS is designed to help organizations solve problems with the people who are closest to the process and to help the organization learn from each cycle of improvement, echoing evidence that the quality of group problem-solving during kaizen events shapes improvement outcomes ([Franken, van Dun, & Wilderom, 2021](#)) and that lean, engaged problem-solving practices are associated with better firm-level results ([Galeazzo, Furlan, Tosetto, & Vinelli, 2024](#)). It is also intended to correct problems permanently rather than temporarily, with downstream benefits for safety, quality, delivery, cost, and workforce morale, and to accelerate improvement in a way that creates sustainable competitive advantage, a pattern also reported for kaizen-based cost-reduction efforts in other heavy-manufacturing settings ([Astuti, Rahman, & Wijaya, 2023](#)) and for hybrid lean-management approaches applied outside manufacturing ([Rizan et al., 2020](#)). In carrying out improvement using CPS, UTAS Bandung follows five sequential stages, shown in Figure 5.

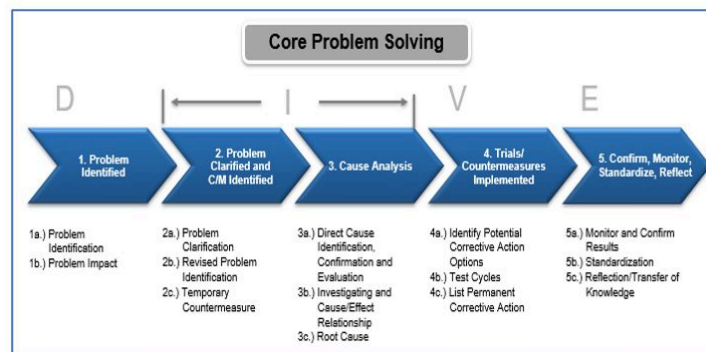


Figure 5. Core problem solving steps

The five stages, problem identification, problem clarification, cause analysis, countermeasure implementation and confirmation, and monitoring, standardization, and reflection, are abbreviated DIVE for Define, Investigate, Verify, and Ensure. Progress through these stages is tracked visually through Relentless Root Cause Analysis (RRCA) boards, illustrated in Figure 6.

RRCA Visual Management									
1) Problem Identification		2a) SW1H of Problem		2a) SW1H of Problem		2a) Containment Action		2b) Containment Action	
No.	Date	Problem Identification & Containment Action							
		3) Analysis		Fishbone Diagram		5 Why Analysis			
		4) Permanent Corrective Action		Permanent Corrective Action		Result Monitoring			

Figure 6. RRCA visual management

The RRCA structure captures problem identification, the 5W1H framing of the problem, containment action, analysis using the fishbone diagram together with potential-direct-cause and five-why techniques, permanent corrective action, and result monitoring, giving a single visual artifact that can be audited at any point in the improvement cycle.

2.1.4 Pareto Analysis

Vilfredo Pareto, an Italian economist, is credited with the observation that a small share of causes typically accounts for a disproportionate share of outcomes, an idea generalized into the rule that roughly 80% of a project's benefit or results are achieved from 20% of the work, or conversely that 80% of problems can be traced to 20% of causes ([Tague, 2023](#)). Pareto analysis is used to focus limited improvement resources on the small number of causes with the greatest potential impact rather than spreading effort evenly across all observed defects, an approach shown to concentrate Six Sigma DMAIC effort where it most reduces the cost of poor quality ([Prashar, 2014](#)) and to guide Pareto-based process-quality improvement in automotive forging operations ([Zgirskas, Ruzevicius, & Ruzele, 2023](#)). Figure 7 shows an illustrative Pareto chart of the type applied later in this study.

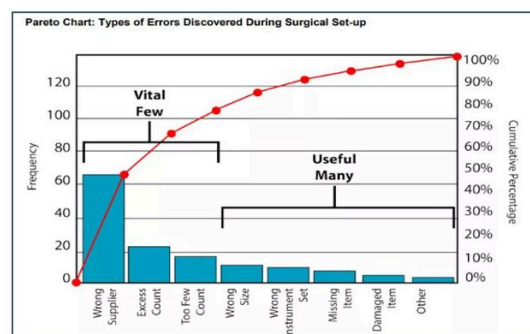


Figure 7. Example of pareto

2.1.5 Fishbone Diagram

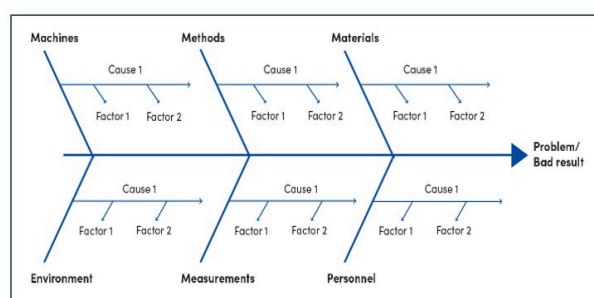


Figure 8. Fishbone diagram

Figure 8 presents the Ishikawa (fishbone) diagram developed to identify the potential root causes of recurring drill-tool failures in the prismatic cell. The identified causes were grouped into six categories: method, machine, manpower, material, measurement, and management (Ilie, & Ciocoiu, 2010; Tagaram, & Chen, 2024). This categorization enabled the improvement team to systematically examine all possible factors contributing to the defect and ensured that no major source of variation was overlooked. Based on the analysis, the machine category emerged as the dominant source of the problem, particularly the low rigidity of the drill tool and the absence of a coolant channel, which were identified as the primary causes of premature tool failure (Sakdiyah, Eltivia, & Afandi, 2022). These findings provided the basis for the subsequent Five Whys analysis and the development of corrective actions (Xhafka, Avrami, Canton, & Mazreku, 2024).

2.1.6 Mistake Proofing

Shigeo Shingo, one of the principal architects of the Toyota Production System, introduced the concept of poka-yoke, or mistake-proofing, as a mechanism for preventing defects at the source rather than detecting them after the fact (Lazarevic, Mandic, Sremcevic, Vukelic, & Debevec, 2019; Prabowo & Aisyah, 2020; Thareja, 2019). Three levels of mistake-proofing are commonly distinguished. Level I prevents an error from occurring at all, for example a fixture designed so that only one part orientation can physically be installed. Level II detects an error as it happens and prompts correction, for example a torque tool that signals red or green depending on whether the correct torque has been achieved. Level III captures errors that were made earlier in the process before the part moves to the next step, for example a standard-work checklist that walks an operator through every required action (Husar, Hrehova, Trojanowski, Wojciechowski, & Kolos, 2023). A recent systematic classification of poka-yoke thinking situates these levels within a broader Lean toolkit and notes that mistake-proofing continues to be extended into digital and Industry 4.0 contexts, including sensor-based detection and deep-learning-assisted inspection on assembly lines (Wolniak, 2024; Martinelli, Lippi, & Gamberini, 2022; Hussein & Mohammed, 2024; Uhanovita, Kato, & Parameswaran, 2023).

2.2 Conceptual Framework

The conceptual framework in Figure 9 explains the current situation of quality performance at UTAS Bandung as it relates to Scrap, Rework, and Reject (SRR) parts, mapping the direct and indirect factors that plausibly influence the creation of nonconforming parts.

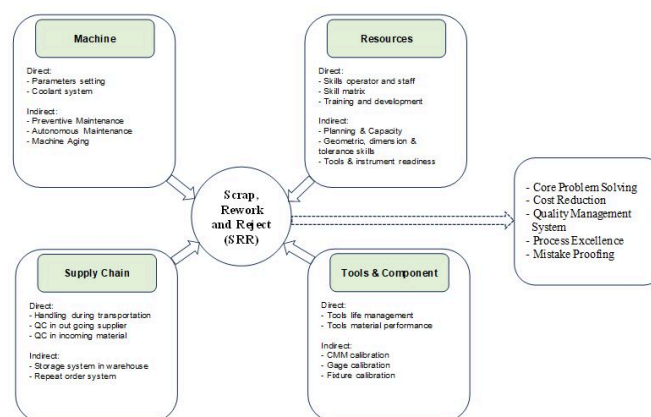


Figure 9. Conceptual framework of SRR

From the machine perspective, the direct items are parameter setting and the coolant system. An incorrectly set machining parameter can push the finished part's dimension outside specification, while a coolant system that does not flow correctly to the cutting zone risks overheating, which in turn produces unstable dimensions. Indirect items include preventive and autonomous maintenance activity, adherence to maintenance schedules, and any delay arising from constraints in the production schedule or shipment plan. Workforce resources, skills, and training also contribute to the creation of scrap, rework, and reject parts; ensuring that every employee is trained and certified

for the job they perform, that new hires, replacements, and internal movements are recorded against a skill matrix, and that machining operators pass and periodically refresh geometric-dimensioning-and-tolerancing assessments are all indirect but material contributors to conformance quality, a view consistent with evidence that workforce training and leadership-development programs shape operational outcomes ([Khalid et al., 2021](#)), that organizational culture and reward-and-punishment practices influence employee performance ([Aini, Shafitranata, Madyoningrum, & Octavia, 2023](#)), and that the work environment, discipline, and communication climate on the shop floor further condition how consistently employees execute their tasks ([Ananda, 2023](#)).

From the tooling and component perspective, tool-life management is a priority because a tool that fails before the end of its expected life directly produces scrap or rework. Tool life is itself linked to the material performance supplied by the tool vendor, so a decline in supplied material quality is a risk to part rework and rejection even before the tool physically breaks. Calibration of Coordinate Measuring Machines (CMM), gages, and fixtures is treated as an indirect factor because a dimensionally correct part can still be misjudged as nonconforming, or a nonconforming part passed as conforming, if the measuring instrument itself is out of calibration.

Supply-chain handling is a further contributor. Improper packaging or rough handling during transportation can damage parts before they ever reach the production floor, and quality inspection both before shipment by the supplier and on receipt at UTAS Bandung is a control point at which an undetected abnormality or a misinspection risks introducing bad material into the process. Storage handling within the warehouse likewise requires disciplined management to avoid damage or degradation prior to use.

Scrap, rework, and reject parts detected through this set of direct and indirect pathways are addressed through core-problem-solving events, in which root-cause analysis is used to identify the best available solution and thereby reduce rejection cost. Strengthening the quality management system across every process step, campaigning for process excellence, widening team engagement, and actively looking for opportunities to apply mistake-proofing at the point where a problem occurs are the mechanisms through which the conceptual framework is translated into day-to-day practice.

Taken together, the literature and the conceptual framework support the expectation that, at UTAS Bandung, a small number of cells and part numbers account for the majority of CoPQ, consistent with the Pareto principle, and that the root causes of the highest-value defect stream are traceable to specific, addressable machine or tooling factors rather than to diffuse or unmanageable causes, such that a CPS-Kepner-Tregoe intervention targeted at that root cause should produce a measurable reduction in CoPQ and a corresponding improvement in %SRR.

3. Methodology

3.1 Research Design

This study uses a single-case, action-research design carried out inside UTAS Bandung's own quality-improvement structure. The research follows the plant's standard five-stage CPS sequence: problem identification and problem clarification together with initial countermeasure identification (Define), cause analysis (Investigate), trial implementation of countermeasures (Verify), and confirmation, monitoring, standardization, and reflection (Ensure), collectively abbreviated DIVE. The Pareto diagram, the Ishikawa (fishbone) diagram, and five-why analysis were used as the principal tools for root-cause identification within this sequence. Figure [Figure 10](#) shows the overall flow of the research design, a visual approach to structuring investigative work that parallels process-mapping practice used to analyze root causes in service settings such as healthcare ([Antonacci, Lennox, Barlow, Evans, & Reed, 2021](#)).

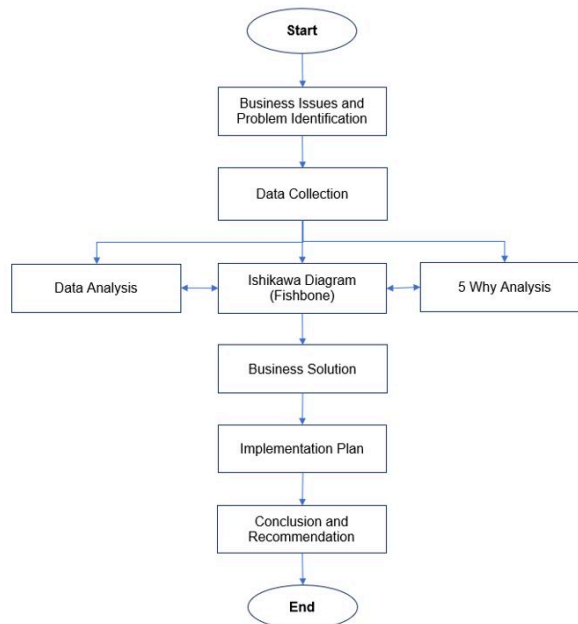


Figure 10. Research design

3.2 Data Collection Method

The data used in this study are primary data drawn from every nonconforming part recorded during the production process. Each nonconformance is logged as a Quality Notification (QN) inside SAP. Within a maximum of five working days, the quality engineer and the engineering function jointly disposition every rejected part into one of three outcomes: the part is released because, on closer inspection, it still meets the required specification; the part is reworked or repaired because the nonconformance is minor and correctable; or the part is scrapped because the issue is major and poses a risk to the customer if shipped. Every disposition is recorded in SAP, and the cost associated with rework or scrap constitutes the Cost of Poor Quality (CoPQ) used throughout this study. Because the data originate from a transactional enterprise-resource-planning system rather than from a sample survey, they represent a census of 2022 nonconformances rather than an estimate drawn from a subset of production.

3.3 Data Analysis Method

Four analytical methods were applied sequentially to transform raw nonconformance data into actionable corrective measures. The analysis began with Pareto chart analysis of SAP quality-notification data using a three-level disaggregation process. Data were first classified by production cell, then by defect category within the highest-cost cell, and finally by part number and issue type within the highest-cost category. This hierarchical approach enabled the improvement team to systematically identify the major contributors to the Cost of Poor Quality (CoPQ) and prioritize improvement efforts based on the principle of focusing on the most significant sources of defects.

After the dominant problem had been identified, an Ishikawa (fishbone) diagram was developed by a cross-functional team consisting of engineering, quality, production, maintenance personnel, and the responsible operator to identify potential root causes. The most probable causes were subsequently examined using Five Whys analysis, with each successive "why" supported by factual evidence and operational data until the underlying root cause was determined. Finally, a comparison matrix was employed to evaluate alternative corrective actions against criteria including resource requirements, investment, and implementation time, enabling the selection of the most feasible and effective countermeasure.

4. Results and Discussion

4.1 Analysis Result

4.1.1 Pareto Result

The 2022 cost of poor quality across scrap, rework, and reject parts totaled approximately USD 254,300, generated across five cell areas at UTAS Bandung. Figure Figure 11 presents the first-level Pareto chart of CoPQ by cell.



Figure 11. Pareto SRR (\$) in 2022 based on cell

The prismatic cell carries the highest Pareto value, at approximately USD 154,000, or 61% of the total 2022 CoPQ. Figure 12 breaks that amount down by defect category within the prismatic cell.

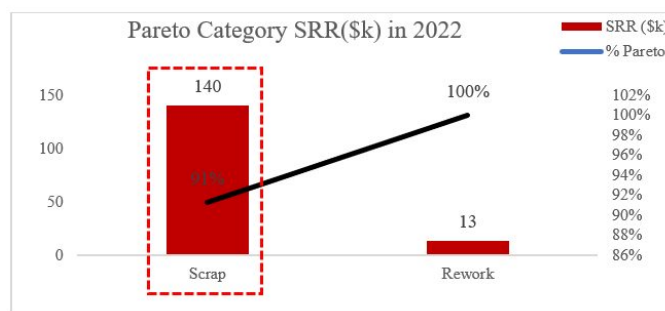


Figure 12. Pareto category in prismatic cell

Figure Figure 12 shows that scrap parts, not rework or repair, are the dominant category inside the prismatic cell, accounting for approximately USD 140,000. Improvement effort was therefore concentrated on reducing scrap in this cell. Figure 13 disaggregates prismatic-cell scrap cost a second level further, by part number.

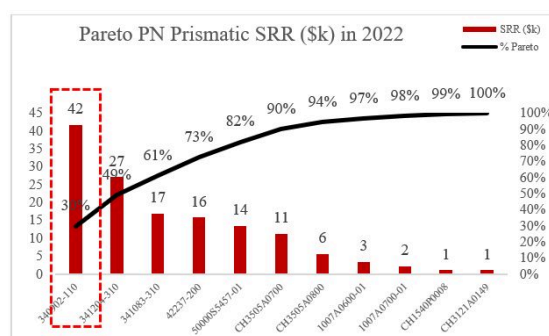


Figure 13. 2nd level Pareto based on Part Number (PN) in prismatic cell 2022

Part number 340902-110 has the highest Pareto value at this level, at approximately USD 42,000. Figure 14 carries the analysis to a third level, breaking down the scrap cost for part number 340902-110 by issue type and showing the five largest contributors.

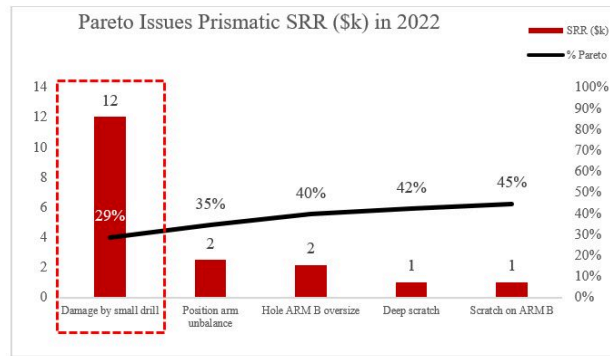


Figure 14. 3rd level Pareto based on issues in PN 340902-110

Damage caused by a small drill tool is the highest contributor at this third level, at approximately USD 12,000, and was selected as the focus of the improvement effort documented in this study.

4.1.2 Ishikawa Diagram (Fishbone Diagram) Analysis

The fishbone diagram in Figure 15 was used to map all plausible direct causes of small-drill damage across six categories: man, material, method, machine, mother nature, and measurement.

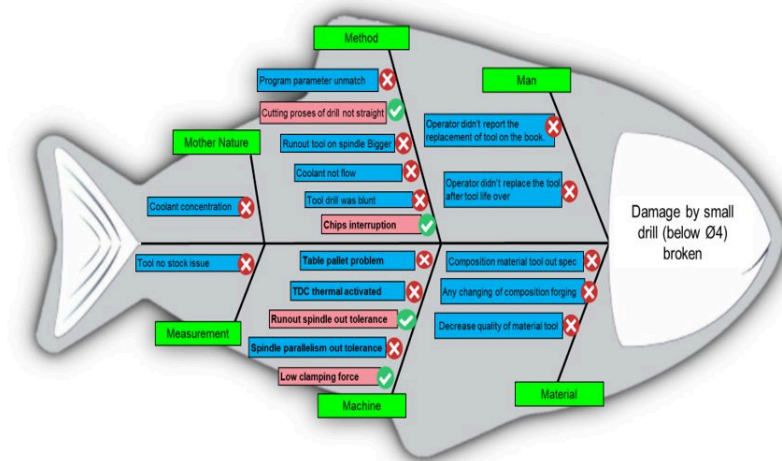


Figure 15. Fishbone of damage by small drill

Each candidate cause was verified and discussed by a team spanning quality, engineering, production, and maintenance, who reviewed the branches one by one to identify the direct causes most plausibly connected to the small-drill damage. The team narrowed the list to four candidate direct causes: the cutting process of the drill was not straight; chip or swarf interruption disrupted the cut; spindle runout was out of specification; and clamping force was insufficient.

Table 1. Impact and effort matrix

Potential Cause	Impact	Effort	Remark	Justification
Cutting process of drill not straight	High	Low	Trial simulation showed the remaining broken tool stuck in the hole.	Yes
Chips interruption	High	Low	The drill tool did not have a through coolant hole.	Yes
Runout spindle out of specification	High	High	Test bar inspection confirmed the spindle remained within the specification.	No

Potential Cause	Impact	Effort	Remark	Justification
Low clamping force	High	High	Clamping force measurement remained within the allowable standard.	No

Table 1 scores each of the four candidate causes on its estimated impact on the defect and the effort required to address it. Of the four candidates evaluated, only two, an unstraight drill cutting path and chip interruption, both traceable to the tool itself, scored as high-impact, low-to-moderate-effort items and were carried forward as potential root causes.

4.1.3 Five-Why Analysis

Table 2 reports the five-why analysis applied to the two potential root causes retained from the impact-and-effort matrix.

Table 2. Five-Why analysis of part damage

Potential Cause	Why Level	Question	Answer
Cutting process of drill not straight	Why #1	Why was the part damaged by the broken tool?	Because the cutting process of the drill was not straight.
	Why #2	Why was the cutting process of the drill not straight?	Because the drill deviated when inserted into the roughing hole.
	Why #3	Why did the drill deviate when inserted into the roughing hole?	Because the tool length was too long, resulting in excessive drill runout.
	Why #4	Why did the excessive tool length cause unacceptable runout?	Because the rigidity of the tool was insufficient.
Chips interruption	Why #1	Why was the part damaged by the broken tool?	Because chips (material fragments) interrupted the cutting process.
	Why #2	Why did chips interrupt the cutting process?	Because residual chips remained trapped inside the hole.
	Why #3	Why did the chips remain trapped inside the hole?	Because the drill did not have a through coolant hole.
	Why #4	Why did the drill not have a through coolant hole?	Because a standard HSS drill was used instead of a through-coolant tool.

The five-why chain converges on a single underlying root cause: the existing small drill tool suffers from insufficient rigidity in its material, which allows the tool to deviate from a straight cutting path, and the tool is a High Speed Steel (HSS) standard design that lacks an internal coolant hole, so chip material and cutting heat are not evacuated efficiently during machining.

4.2 Business Solution

Building on the five-why root cause, the team reviewed the existing drilling sequence and tool selection for the 4 mm diameter feature. Figure 16 documents the process as it stood before the improvement.

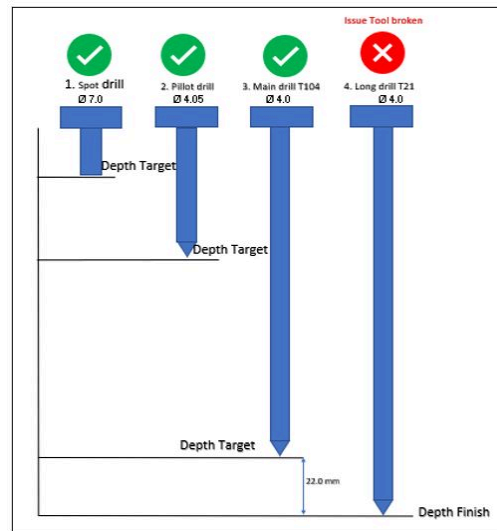


Figure 16. Current process diameter 4mm

The pre-improvement sequence to reach a finished 4 mm diameter proceeded through a spot drill at 7 mm, a pilot drill at 4.05 mm, a main drill at 4 mm using tool T104, and a final finishing pass at 4 mm using a long drill, tool T21. In a cross-functional brainstorming session involving engineering, quality, production, and maintenance, the team proposed eliminating the final finishing step performed with tool T21 and combining that operation with the earlier pass already performed by tool T104. The rationale was threefold: T104 already machines the same 4 mm diameter as T21 but is made of carbide rather than high-speed steel, giving it materially greater rigidity; T104, unlike T21, is supported by an internal coolant hole that clears chip material effectively during the cut; and removing a redundant step reduces cycle time and eliminates the ongoing cost of purchasing tool T21 altogether.

4.3 Implementation

Before the change was implemented, the team defined an implementation plan to ensure the modification introduced no new failure modes, summarized in Table 3.

Table 3. Implementation plan of improvement

No	Agenda	Owner	Due Date	Status	Result
1	Trial to remove Tool T121 and combine it into the Tool T104 process	Engineering	W1 Apr-23	Completed	OK
2	Dimension verification	Quality	W1 Apr-23	Completed	OK
3	Updating documents related to the improvement	Engineering	W2 Apr-23	Completed	OK
4	Review and final decision	Team	W3 Apr-23	Completed	OK
5	Start mass production	Production	W1 May-23	Completed	OK
6	Monitoring quality performance	Quality	W4 Jul-23	Completed	OK
7	Improvement result summary	Team	W1 Aug-23	Completed	OK

Post-implementation performance was monitored beginning in May 2023 to evaluate the effectiveness of the corrective actions implemented through the Core Problem Solving (CPS) and Kepner-Tregoe approaches. The evaluation focused on the quality losses associated with small-drill failures on part number 340902-110, which had previously been identified as one of the major contributors to the Cost of Poor Quality (CoPQ). Following the replacement of the finishing tool and the implementation of the selected countermeasures, the cost of rework, scrap, and rejection attributable to this failure mode decreased substantially from USD 12,000 in 2022 to USD 3,200 in

2023. This represents a 73% reduction, equivalent to an annual cost saving of USD 8,800. These results demonstrate that addressing the identified root causes not only reduced defect-related costs but also improved process stability and overall manufacturing performance. The comparison of quality costs before and after implementation is presented in Figure 17.

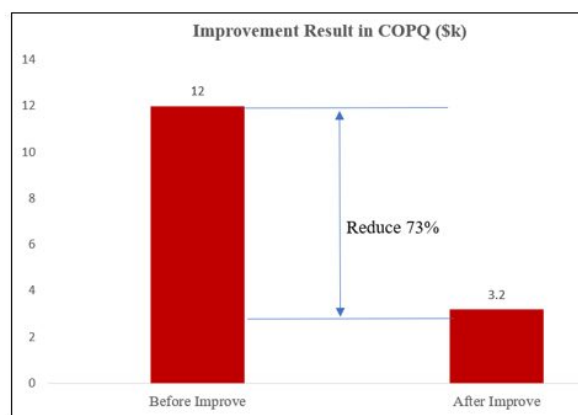


Figure 17. Improvement result in COPQ

Removing tool T21 and combining its operation into the T104 pass also reduced cycle time on part number 340902-110 by approximately 13 minutes, from 99 minutes to 86 minutes, an improvement of 13%. Because tool T21 is no longer purchased, an additional consumable saving accrues: the tool had previously been consumed at a rate of 48 pieces per year at USD 29.5 per piece. Table 4 summarizes the total quantified benefit of the single case documented here.

Table 4. Summary benefits of improvement

No	Item	Impact	Remark
1	CoPQ reduction	USD 8,800 per year	Reduced by 73%
2	Cycle time reduction	13 minutes faster	Improved by 13%
3	Tool cost savings	USD 1,400 per year	No longer requires new tool orders

Beyond this single case, the CPS-Kepner-Tregoe approach was extended to several other issues occurring across the production area during 2023. Total CoPQ for 2023 came to USD 217,077, a reduction of USD 37,223 relative to the USD 254,300 recorded in 2022, as shown in Figure 18, a reduction that also matters for the plant's broader financial standing, since disciplined operational cost control of this kind parallels findings that firm-level financial distress and resilience are closely tied to how well operating costs are managed (Budiman, 2023) and that downstream commercial outcomes, from purchasing behavior to share-price volatility, are sensitive to the operational and financial signals a company sends to its stakeholders (De Yusa, 2023; Harish & Amaroh, 2023).

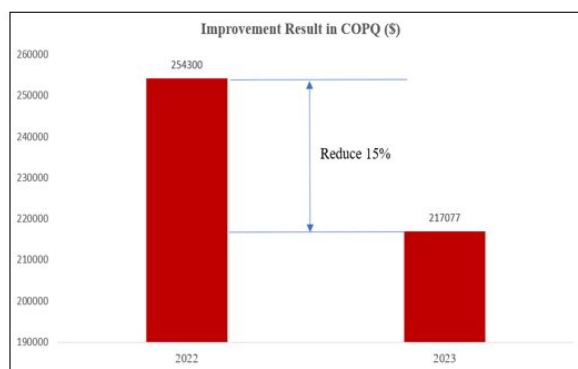


Figure 18. Total improvement result in COPQ

Against the minimum annual target of USD 16,223 established in Section 1, the small-drill-damage countermeasure alone contributed USD 8,800, or 54% of the annual minimum, while the full portfolio of 2023 CPS-Kepner-Tregoe activities delivered USD 37,223, or approximately 230% of the annual minimum target. These results are consistent with the Pareto-driven expectation set out in the literature review: concentrating effort on the single highest-value defect stream produced a return well out of proportion to the narrow scope of the intervention, and replicating the same disciplined sequence across additional problems compounded that return across the year.

4.4 Potential Problem Analysis

Consistent with the fourth phase of the Kepner-Tregoe approach, namely potential-problem analysis, the improvement team extended its evaluation beyond resolving the immediate root cause by identifying potential risks that could lead to similar failures in the future. This forward-looking assessment focused on anticipating possible recurrence, evaluating vulnerabilities within the production system, and defining preventive actions to minimize the likelihood of repeated defects. The objective was not only to eliminate the current problem but also to strengthen process reliability through systematic improvements in equipment, personnel, tools, and operational procedures. The resulting preventive and long-term improvement initiatives are summarized in Table 5, providing a structured roadmap for sustaining quality performance and supporting continuous improvement across the manufacturing process.

Table 5. Systemic improvement activities

No	Area	Improvement Item	Description
1	Machine	Daily autonomous maintenance	Machining operators perform routine inspections before production, including checking pressure, coolant level, and other basic machine conditions.
		Preventive maintenance	The maintenance department performs quarterly, semi-annual, and annual preventive maintenance using standardized checklists to ensure all inspection items are completed.
		Coolant control and replacement	Coolant is maintained within the specified minimum–maximum level and replaced when necessary by designated personnel.
		Machine refurbishment	Develop long-term refurbishment or replacement plans for aging machines that frequently cause quality issues.
2	Resources	Annual operator refresher training	Conduct annual training on geometric dimensioning, tolerancing, and inspection methods to maintain operator competency and address customer requirements.
		Operator certification	Machining operators must complete competency assessments and renew their certification every two years.
		Skills matrix	Maintain operator competency records to ensure replacement tasks are assigned only to qualified personnel.
3	Tools & Components	Tool life management	Engineering personnel monitor tool life and revise tool life standards if premature failures occur.

No	Area	Improvement Item	Description
Gage and CMM Calibration	Ensure all inspection gages and Coordinate Measuring Machine (CMM) equipment remain within their valid calibration period.		
Fixture Calibration	Schedule periodic calibration for critical fixtures based on historical quality issues.		
4	Supply Chain	Standard packaging	Suppliers must comply with packaging standards specified in engineering drawings or purchasing documents.
		Storage system	Store and handle raw materials according to warehouse work standards to prevent damage before production.
		Reorder Point (ROP)	Maintain minimum inventory levels for raw materials, coolant, and tools to prevent production interruptions and ensure stable machine performance.

To sustain core-problem-solving behavior at UTAS Bandung, the team also defined the steps needed to build a broader internal community of problem solvers. These steps are: provide core-problem-solving training to all employees; develop a dedicated core-problem-solving team in each cell area drawing on engineering, quality, and production personnel, including operators; develop at least one CPS case per cell area per month; have managers personally attend CPS events to confirm correct understanding and to treat each event as a learning-curve session; and track CPS activity, including the number of events run and the percentage of operators who participate, on a visual control tower. Together, these activities are intended to help the organization solve problems more quickly and take corrective action correctly the first time, rather than relying on a small number of specialists to carry the improvement burden indefinitely.

Read against the conceptual framework in Section 2.2, the root cause identified here, tool material rigidity and the absence of a coolant channel, sits squarely within the tool-and-component branch of that framework, and the fact that a single tooling change produced most of the measured benefit is consistent with the framework's premise that direct, close-to-the-process factors dominate the creation of scrap, rework, and reject parts at this stage of the plant's quality maturity. This suggests that, as the more visible tooling issues are resolved, subsequent CPS cycles will need to move progressively toward the indirect factors identified in the framework, workforce skill and training, calibration discipline, and supply-chain handling, if the plant is to keep closing the remaining gap toward the 0.5% target by 2027.

5. Conclusions

5.1 Conclusion

The single case study reported in this article demonstrates that Core Problem Solving combined with the Kepner-Tregoe approach, executed through a Pareto diagram, an Ishikawa (fishbone)

diagram, and five-why analysis, was able to detect the correct root cause of a problem concentrated in the prismatic cell, which was independently confirmed as the plant's largest source of cost of poor quality. After the resulting countermeasure was implemented, the cost of part damage on part number 340902-110 attributable to small-drill tooling fell to USD 3,200 in 2023 from USD 12,000 in 2022, an improvement of USD 8,800, or 73%, in a single year.

This single result already contributed 54% of the minimum annual target of USD 16,223. Across all improvement activities carried out in 2023, total CoPQ reduction reached USD 37,223, exceeding the annual target by a factor of more than two, at approximately 230% of the annual minimum. On the strength of these results, Core Problem Solving using the Kepner-Tregoe problem-analysis approach appears to be an appropriate method for reaching the specified 0.5% %SRR target. UTAS Bandung's management believes that maximizing the use of core problem solving together with Kepner-Tregoe analysis will achieve the 0.5% %SRR target set for 2027, and for that reason the plant is focused on building a broader internal community of core problem solvers spanning every level from manager to operator.

5.2 Research Limitations

First, the analysis is restricted to data available in SAP for the 2022 performance year and does not include return parts rejected by customers or reject parts caused by suppliers, both of which could materially change the composition of total CoPQ if included. Second, the study documents a single case in detail, drawn from one cell and one part number, so the magnitude of savings achieved should be read as illustrative of what the method can achieve under favorable conditions rather than as a guaranteed return applicable to every future CPS cycle. Third, because the research was conducted within a single site of a single corporate group, the transferability of the specific root cause and countermeasure to other sites, product families, or machining processes has not been empirically tested, even though the underlying method is designed to be general.

5.3 Suggestions and Directions for Future Research

Future research could extend this work in three directions. Internal teams could read across the same CPS-Kepner-Tregoe method to other part numbers and other cells that share similar tooling or process characteristics, testing whether the method generalizes within the plant before it is benchmarked externally. Researchers could also look for other tools with characteristics similar to the T21-T104 pairing documented here, since removing redundant or under-specified tooling steps may be a repeatable pattern rather than a one-off finding. Finally, continued implementation and tracking of core problem solving combined with Kepner-Tregoe analysis toward a %SRR below 0.5% by 2027 would allow future work to test whether the annual savings trajectory observed in 2023 can be sustained, and whether returns diminish as the most visible, highest-Pareto problems are progressively resolved and later CPS cycles must address the more indirect workforce, calibration, and supply-chain factors identified in the conceptual framework.

Acknowledgement

The authors thank the management of UTAS Bandung for facilitating access to the data and resources needed to complete this study, and thank their academic supervisor for guidance throughout the research process. The authors also thank their colleagues in the Blemba-67 MBA program at Institut Teknologi Bandung and their families for their support throughout this work.

References

- Aini, N., Shafitranata, S., Madyoningrum, A. W., & Octavia, R. (2023). Pengaruh reward, punishment, dan budaya organisasi terhadap kinerja mitra PT Hannas Fantastic Tour. *Reviu Akuntansi, Manajemen, dan Bisnis*, 3(2), 151-160.
- Ananda, F. R. (2023). Literature review pengaruh lingkungan kerja, disiplin kerja dan komunikasi terhadap karyawan CV. *Tidar Jaya. Studi Ilmu Manajemen dan Organisasi*, 4(2), 75-85.
- Andrews, R., Emamjome, F., ter Hofstede, A. H., & Reijers, H. A. (2022). Root-cause analysis of process-data quality problems. *Journal of Business Analytics*, 5(1), 51-75. <https://doi.org/10.1080/2573234X.2021.1974798>

- Antonacci, G., Lennox, L., Barlow, J., Evans, L., & Reed, J. (2021). Process mapping in healthcare: A systematic review. *BMC Health Services Research*, 21(1), 342. <https://doi.org/10.1186/s12913-021-06254-1>
- Astuti, D., Rahman, S., & Wijaya, K. (2023). Kaizen method for cost reduction and quality improvement in the cement industry. *Journal of Modern Project Management*, 11(1), 25. <http://doi.org/10.19255/JMPM03103>
- Budiman, L. S. (2023). Analisis financial distress pada perusahaan konstruksi selama PSBB-PPKM era Covid-19 di Indonesia. *Reviu Akuntansi, Manajemen, dan Bisnis*, 3(2), 123-150.
- Curkovic, S., Vickery, S., & Droge, C. (2000). Quality-related action programs: Their impact on quality performance and firm performance. *Decision Sciences*, 31(4), 885-902. <https://doi.org/10.1111/j.1540-5915.2000.tb00947.x>
- De Yusa, V. (2023). Pengaruh nilai hedonis dan nilai utilitarian terhadap niat pembelian tas lokal pada generasi Z wanita. *Reviu Akuntansi, Manajemen, dan Bisnis*, 3(2), 111-121.
- Franken, J. C., van Dun, D. H., & Wilderom, C. P. (2021). Kaizen event process quality: Towards a phase-based understanding of high-quality group problem-solving. *International Journal of Operations & Production Management*, 41(6), 962-990. <https://doi.org/10.1108/IJOPM-12-2019-0771>
- Galeazzo, A., Furlan, A., Tosetto, D., & Vinelli, A. (2024). Are lean and digital engaging better problem solvers? An empirical study on Italian manufacturing firms. *International Journal of Operations & Production Management*, 44(6), 1217-1248. <https://doi.org/10.1108/IJOPM-06-2023-0477>
- Harish, M. R., & Amaroh, S. (2023). Pengaruh dividen, pertumbuhan aset, dan volume perdagangan terhadap volatilitas harga saham JII70. *Reviu Akuntansi, Manajemen, dan Bisnis*, 3(2), 161-176.
- Husar, J., Hrehova, S., Trojanowski, P., Wojciechowski, S., & Kolos, V. (2023). *Perspectives of lean management using the Poka Yoke method*.
- Hussein, M. I. M., & Mohammed, M. A. (2024). The possibility of employing intelligent Poka-Yoke technology to reduce marketing risks: A study of the Iraqi oil refineries company. *International Journal of Financial Management and Economics*, 7(1), 101-106. <https://doi.org/10.33545/26179210.2024.v7.i1.266>
- Ilie, G., & Ciocoiu, C. N. (2010). Application of fishbone diagram to determine the risk of an event with multiple causes. *Management Research and Practice*, 2(1), 1-20.
- Isniah, S., Purba, H. H., & Debora, F. (2020). Plan do check action (PDCA) method: Literature review and research issues. *Jurnal Sistem dan Manajemen Industri*, 4(1), 72-81. <https://doi.org/10.30656/jsmi.v4i1.2186>
- Jhorar, R., Pathak, V. K., & Singh, P. (2020). Failure analysis and improvement of defective clamping pad during leak testing process using Kepner-Tregoe analysis. *Journal of Failure Analysis and Prevention*, 20(5), 1507-1515. <https://doi.org/10.1007/s11668-020-00950-6>
- Khalid, S., Dan, W., Sohail, A., Raza, W., Khalid, B., & Ur-Rehman, A. (2021). Empowering women at the higher institutional level: Analysis of business education and leadership training program. *Business, Management and Economics Engineering*, 19(1), 150-169. <https://doi.org/10.3846/bmee.2021.13716>
- Koskela, L., Tezel, A., & Patel, V. (2019). Theory of quality management: Its origins and history. Paper presented at In Proceedings of the 27th Annual Conference of the International Group for Lean Construction (IGLC), 1381-1390.
- Latino, M. A., Latino, R. J., & Latino, K. C. (2019). *Root cause analysis: Improving performance for bottom-line results (5th ed.)*.

- Lazarevic, M., Mandic, J., Sremcevic, N., Vukelic, D., & Debevec, M. (2019). A systematic literature review of Poka-Yoke and novel approach to theoretical aspects. *Strojniski Vestnik - Journal of Mechanical Engineering*, 65(7-8), 454-467. <https://doi.org/10.5545/sv-jme.2019.6056>
- Mahto, D., & Kumar, A. (2008). Application of root cause analysis in improvement of product quality and productivity. *Journal of Industrial Engineering and Management*, 1(2), 16-53. <https://doi.org/10.3926/jiem.v1n2.p16-53>
- Martinelli, M., Lippi, M., & Gamberini, R. (2022). Poka-yoke meets deep learning: A proof of concept for an assembly line application. *Applied Sciences*, 12(21), 11071. <https://doi.org/10.3390/app122111071>
- Okes, D. (2019). *Root cause analysis: The core of problem solving and corrective action (2nd ed.)*.
- Pambreni, Y., Khatibi, A., Azam, S., & Tham, J. (2019). The influence of total quality management toward organization performance. *Management Science Letters*, 9(9), 1397-1406. <https://doi.org/10.5267/j.msl.2019.5.011>
- Pietsch, D., Matthes, M., Wieland, U., Ihlenfeldt, S., & Munkelt, T. (2024). Root cause analysis in industrial manufacturing: A scoping review of current research, challenges and the promises of AI-driven approaches. *Journal of Manufacturing and Materials Processing*, 8(6), 277. <https://doi.org/10.3390/jmmp8060277>
- Prabowo, R. F., & Aisyah, S. (2020). Poka-Yoke method implementation in industries: A systematic literature review. *IOP Conference Series: Materials Science and Engineering*, 852, 012113. <https://doi.org/10.1088/1757-899X/852/1/012113>
- Prashar, A. (2014). Adoption of Six Sigma DMAIC to reduce cost of poor quality. *International Journal of Productivity and Performance Management*, 63(1), 103-126. <https://doi.org/10.1108/IJPPM-01-2013-0018>
- Realyvasquez-Vargas, A., Arredondo-Soto, K. C., Carrillo-Gutierrez, T., & Ravelo, G. (2018). Applying the Plan-Do-Check-Act (PDCA) cycle to reduce the defects in the manufacturing industry: A case study. *Applied Sciences*, 8(11), 2181. <https://doi.org/10.3390/app8112181>
- Rizan, C., Low, R., Harden, S., Groves, N., Flaherty, B., Welland, T., & Bhutta, M. F. (2020). A blueprint for streamlining patient pathways using a hybrid lean management approach. *Quality Management in Health Care*, 29(4), 201-209. <https://doi.org/10.1097/QMH.0000000000000268>
- Sakdiyah, S. H., Eltivia, N., & Afandi, A. (2022). Root cause analysis using fishbone diagram: Company management decision making. *Journal of Applied Business, Taxation and Economics Research*, 1(6), 566-576. <https://doi.org/10.54408/jabter.v1i6.94>
- Tagaram, S. D., & Chen, C. (2024). Quality tools and techniques (fishbone diagram, Pareto chart, process map). In *StatPearls*. StatPearls Publishing.
- Tague, N. R. (2023). *The quality toolbox (3rd ed.)*.
- Thareja, P. (2019). Poka Yoke: Poking into mistakes for total quality! SSRN. <https://doi.org/10.2139/ssrn.3475926>
- Uhanovita, A. C. N., Kato, T., & Parameswaran, A. (2023). Poka-yoke to minimise variations: A framework for building projects. *Construction Innovation*, 23(1), 137-154. <https://doi.org/10.1108/CI-12-2022-0343>
- Wolniak, R. (2024). The usage of Poka-Yoke in Industry 4.0 conditions. *Scientific Papers of Silesian University of Technology, Organization and Management Series*, 191, 613-628. <https://doi.org/10.29119/1641-3466.2024.191.39>

- Khafka, E., Avrami, E., Canton, G., & Mazreku, A. (2024). Applying the Ishikawa diagram and Pareto chart for defect reduction in the manufacturing industry: A case study from a textile-producing company. Paper presented at In Proceedings of the Joint International Conference ITC-ICEE 2023, Lecture Notes on Multidisciplinary Industrial Engineering. Springer.
- Zgirskas, A., Ruzevicius, J., & Ruzele, D. (2023). Quality improvement of the forging process using Pareto analysis and 8D methodology in automotive manufacturing: A case study. *Standards*, 3(1), 100-116. <https://doi.org/10.3390/standards3010008>