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Improving Carton Packaging Yield in the Beverage Industry Using PDCA and Integrated Quality Tools

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Abstract

In operations and production management, material yield is one of the key indicators of process efficiency and cost effectiveness. This study aims to identify the root causes of low carton packaging yield, formulate improvement strategies based on the PDCA (Plan–Do–Check–Act) cycle integrated with 16 structured quality management tools, and evaluate the effectiveness of this approach in addressing inefficiencies in carton packaging. To achieve this, root causes were identified using a Fishbone Diagram (*4M1E*), further analyzed with the 5 Whys method, and validated through the *3G* approach (*Genba*, *Genbutsu*, *Genjitsu*). Key issues were prioritized using Failure Mode and Effects Analysis (FMEA). Improvement ideas were then generated using the SCAMPER technique and selected using a PICK Chart. The selected solutions were implemented using the 5W2H framework and scheduled with a Gantt Chart. To ensure sustainability, *poka-yoke* mechanisms and process standardization were applied. The implementation of targeted improvement strategies at one of Indonesia's leading beverage companies led to a notable increase in carton packaging yield—from 99.44% to 99.75%—effectively closing the performance gap. This improvement was accompanied by a reduction of over 50% in measurable negative impacts across all PQCDSME dimensions (Productivity, Quality, Cost, Delivery, Safety, Morale, and Environment), reflecting enhanced process stability, operational efficiency, and cross-functional performance. This study demonstrates that integrating structured, data-driven problem-solving tools with the PDCA (Plan–Do–Check–Act) cycle can significantly improve manufacturing performance. The approach proved effective in reducing waste, increasing yield, and supporting continuous improvement within a production environment
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Keyword: PDCA Cycle, 7 QC Tools, FMEA, Packaging, Defect, Yield

INTRODUCTION

Effective quality management remains a critical concern in modern manufacturing, particularly in high-volume packaging processes where small inefficiencies can result in substantial losses (Agbejule & Lehtineva, 2022; Blieck et al., 2020; Nabokikh et al., 2020; Ross, 2017; Tonjang & Thawesaengskulthai, 2022). More broadly, the manufacturing industry faces unique challenges due to variability in material quality, equipment conditions, and stringent efficiency targets. Optimizing packaging yields—especially in the use of cartons—has emerged as a pressing issue for manufacturers seeking to balance operational excellence with cost competitiveness and environmental sustainability.

This challenge is also experienced by PT XYZ, a beverage manufacturer that has faced persistent inefficiencies in its carton packaging process. One of the main challenges encountered by PT XYZ is the high level of waste in carton packaging materials. As of September 2024, the average carton yield was recorded at 99.44%, which is below the company's target of 99.75%. In addition, carton yields are inconsistent and fluctuate throughout the year. While the yield differences may seem small, they have a significant impact, resulting in financial losses of carton material exceeding IDR 68 million in a year.

Furthermore, this also causes an average production downtime of 312 minutes per month, leading to a potential loss of product output of 56,320 units per year, equivalent to more than IDR 1 billion in lost sales and additional costs due to the downtime. As an illustration, the trend in carton packaging material yield for 2024 is shown in Figure 1.

Many studies have demonstrated the effectiveness of the Deming Cycle (Plan–Do–Check–Act, PDCA) combined with quality management tools in reducing waste and improving production yields (Sjarifudin & Kurnia, 2022). This approach has been widely applied across sectors such as automotive, electronics, and food processing. However, empirical research on the integrated application of PDCA and a comprehensive set of quality tools within the Indonesian beverage industry—particularly for optimizing packaging material yields—remains limited. Moreover, most existing studies focus on the use of only one or two quality tools, which often fails to address the full complexity of operational waste on the manufacturing shop floor.

To fill this gap, the present study proposes a structured improvement framework that integrates the PDCA cycle with a broad set of quality and management tools, including the 7 QC Tools (stratification, flowchart, fishbone diagram, and graphs), SMART target setting, *3G* analysis (*Genba–Genbutsu–Genjitsu*), and PQCDSME (Productivity, Quality, Cost, Delivery, Safety, Morale, and Environment) evaluation. The framework also incorporates Failure Mode and Effects Analysis (FMEA), SCAMPER for creative ideation, PICK Chart for prioritization, the 5W2H technique for problem exploration, Gantt Chart for scheduling, 4W2H for reporting, as well as *poka-yoke* mechanisms and standardization practices. Additionally, it includes participatory methods such as brainstorming and focus group discussions (FGDs) to generate and validate improvement ideas.

This study aims to identify the root causes of low carton yield, formulate improvement strategies using the PDCA cycle integrated with structured quality tools, and evaluate the effectiveness of the approach in enhancing yield performance and operational efficiency.

METHOD

This study was conducted at PT XYZ over six months (October 2024–March 2025). Primary data were gathered through observations, interviews, brainstorming, and FGDs with key personnel from Production, Quality, Engineering and Operational Excellence department. the company's performance database and Corrective and Preventive Action (CAPA) records. All data were analyzed using Microsoft Excel to support evaluation and decision-making.

This study adopts an action research approach by applying a PDCA-based framework integrated with quality tools, ensuring that improvement efforts are both systematic and grounded in real-world practice. The complete PDCA cycle—from problem identification through solution implementation to evaluation—was carried out to facilitate continuous learning and drive operational improvements. As noted by Kocik (2017), the PDCA cycle is a flexible and practical methodology, applicable across organizations of varying sizes and sectors in the pursuit of continuous improvement. Within this framework, root causes are identified, analyzed, and collaboratively resolved by a cross-functional team consisting of personnel from the Production, Engineering, Quality and Operational Excellence departments. The primary objective is to minimize material waste, reduce production downtime, and mitigate broader operational inefficiencies, all viewed through the lens of PQCDSME (Productivity, Quality, Cost, Delivery, Safety, Morale, and Environment) performance.

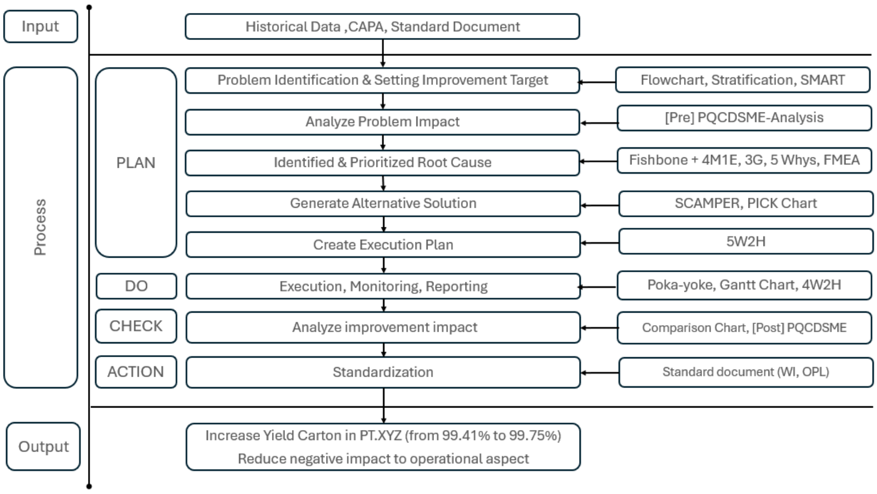

Figure 2. Conceptual Framework

Figure 2 presents a conceptual framework structured around the PDCA (Plan-Do-Check-Action) cycle to improve carton yield in PT. XYZ from 99.41% to 99.75% and minimize operational disruptions. The framework begins with inputs such as historical data, CAPA records, and standard documents. In the Plan phase, problems are identified and targeted using tools like flowcharts and SMART goals, followed by impact analysis, root cause prioritization (via 5 Whys, Fishbone, etc.), alternative solution generation (e.g., SCAMPER, PICK Chart), and execution planning using 5W2H. The Do phase involves implementing, monitoring, and reporting solutions through Gantt Charts, 4W2H, and error-proofing methods. In the Check phase, improvement impacts are evaluated using comparison charts and post-PQCDSME analysis. Finally, the Action phase standardizes successful changes using documented work instructions (WI) and one-point lessons (OPL), ensuring sustainable improvement outcomes.

Therefore, this study proposes the following exploratory proposition: “Integrating the PDCA cycle with structured quality tools can significantly improve carton packaging yields by systematically identifying and eliminating root causes of operational inefficiencies.” This hypothesis is based on previous research (Sjarifudin & Kurnia, 2022), which has shown that PDCA and quality tools are effective in optimizing performance. This proposition provides a conceptual basis for evaluating the practical effectiveness of structured improvement cycles in real-world manufacturing settings and supports the broader adoption of quality management practices across industries.

RESULTS AND DISCUSSION

The Plan Stage

At the beginning of the planning phase, an improvement team was formed, consisting of experienced personnel from the Production, Quality, Engineering and Operational Excellence departments. Each member was selected based on their technical skills and in-depth knowledge of production and machining operations. This cross-functional team structure is in line with findings from (Zavala 2024) that functional diversity and domain expertise significantly increase the effectiveness of work teams in implementing continuous improvement initiatives in a manufacturing context.

The team began problem identification using flowcharts and data stratification tools. Stratification helps to pinpoint problems through more specific categorized data. Flowcharts help visualize process steps and are effective in finding inefficiencies (Kustikova & Pankova 2023). These tools enabled the team to quickly identify defect-prone areas, specifically in the packaging and palletizing processes. Once the critical problem areas were identified, the team proceeded to define a structured improvement target using the SMART framework to guide continuous improvement. As emphasized by Ogbeiwi (2017), SMART goals—Specific, Measurable, Achievable, Relevant, and Time-bound—are vital for effective planning and evaluation. The team set a goal to improve carton yield from 99.44% to 99.75% by March 2025.

To assess the wider impact, the team conducted a PQCDSME analysis. The findings showed that carton material waste negatively affected Productivity (P), Quality (Q), Cost (C), Delivery (D), Safety (S), Morale (M), and Environment (E). In this study, the impact of the improvement efforts—in the PQCDSME framework—was measured as quantitatively as possible. This approach will help the team to conduct a more objective evaluation of the results and provide measurable evidence of operational improvements resulting from the implemented interventions. A summary of the impact before improvement can be seen in Table 5.

The root cause analysis process begins with the team brainstorming several possible proximate causes using a Fishbone Diagram based on the 4M1E (Man, Machine, Method, Material, and Environment) framework. As illustrated by Tantri et al. (2024), a fishbone diagram systematically categorizes and examines potential causes across key dimensions, allowing for comprehensive root cause identification in a manufacturing setting. The team successfully identified 11 potential proximate causes of carton defects. Based on this study, it is critical to communicate with the team and ensure that all factors contained in the Fishbone Diagram accurately represent proximate causes that directly impact the occurrence of defects only. Proximate causes are usually phenomena that can be clearly observed on the shop floor (genba), so they can be empirically verified as a direct contributor to defects. For example, “cartons falling or colliding” can be categorized as a proximate cause because they cause direct physical damage to the packaging. In contrast, factors such as “misaligned conveyor position” are considered indirect causes—although they may cause the carton to fall, they are not the direct trigger of the defect itself.

The confirmed causes varied in nature, originating from different sources such as human behavior, materials, methods, and machines. This diversity enabled the study to explore how each category of cause responded to specific improvement tools, offering insight into the relative effectiveness of different interventions. A detailed discussion of these cause categories is provided later in the study.

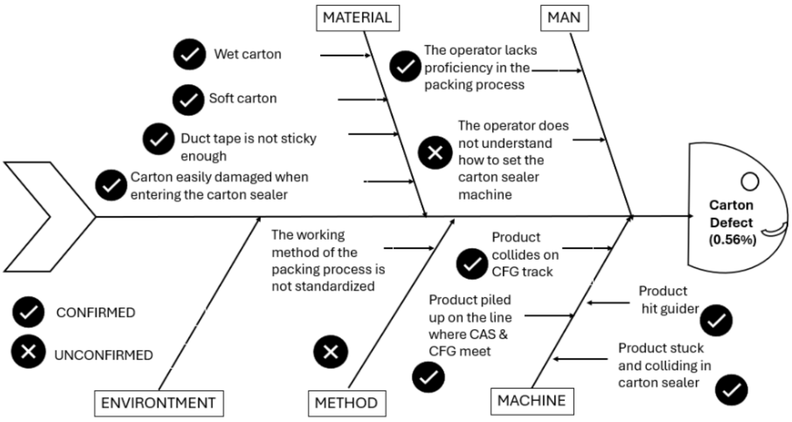

Figure 3. Fishbone Diagram (with 3G analysis)

Each confirmed cause was then examined using the 5 Whys technique to trace back to its root cause. As noted by Nguyen et al. (2020), this method promotes deeper investigation by encouraging teams to move beyond surface-level symptoms. It is important to note that the "5 Whys" serves as a flexible guideline rather than a rigid rule—teams may uncover the root cause in fewer than five questions, or they may need to go beyond five, particularly in complex situations. The primary objective is to identify the true root cause, not to simply fulfill a numeric target. Through this analysis, the team identified 8 (eight) critical root causes: (1) the control panel between the Conveyor After Sealer (CAS) and the Conveyor for Finished Goods (CFG) was not integrated, (2) no standard existed for carton stacking height on the packing table, (3) the position of the bottom sealing tape was difficult to visually inspect, (4) the CAS and CFG were misaligned, (5) incoming quality control relied solely on sampling, (6) there was no structured training for new operators, (7) packaging materials were stored under poor conditions, and (8) pusher handles on the conveyor belt were worn out. The complete 5 Whys analysis is presented in Table 1.

Table 1. (Example) 5 Whys Analysis

Direct Cause	Why 1	Why 2	Why 3	Why 4	Why 5
Wet cardboard	Contaminated by broken product contents	Product breaks when it hits the conveyor hard	Distance between the push start point (carton stack) and landing point (conveyor) is too high	Cartons are stacked too high (>30 cm) by the operator	No standard for carton stacking height on the packing table

Source: Data processed

To prioritize corrective actions, the team utilized the Failure Mode and Effect Analysis (FMEA) method. Through a Focus Group Discussion involving expert opinions and referencing available historical data, each root cause was assessed against three key criteria: Severity (S), Occurrence (O), and Detection (D). These criteria represent the potential impact of a failure, the likelihood of it occurring, and the probability of detecting it early, respectively. The scores for each criterion were multiplied to generate a Risk Priority Number (RPN), which served as the basis for determining the urgency of corrective actions. This structured and quantitative approach ensures that efforts are focused on the most critical issues, those with the highest potential risk, thereby maximizing the impact of improvement initiatives. The root cause with the highest RPN was prioritized for immediate resolution. This approach aligns with findings by Hii et al. (2024), which confirmed that the FMEA–PDCA framework is effective in identifying, ranking, and addressing high-risk failure modes in a timely and precise manner. The detailed results are presented in Table 2.

Table 2. Determination of Priority Root Causes

No	Root Cause	S	O	D	RPN	Priority
1	The control panel between the Conveyor After Sealer (CAS) and the Conveyor for Finished Goods (CFG) was not integrated	8	9	9	648	1
2	There was no defined standard for the stacking height of cartons at the packing table	7	9	8	504	2
3	The bottom sealing tape position was difficult to visually inspect	7	9	7	441	3
4	Misalignment between CAS and CFG conveyors	6	9	7	378	4
5	Incoming quality control relied solely on sampling methods	7	6	9	378	5
6	Absence of structured training for new operators	7	5	7	245	6
7	Poor storage conditions for packaging materials	7	6	4	168	7
8	Worn-out pushing grips on the conveyor belt	4	6	4	96	8

Source: Data processed

After prioritizing the dominant root causes using Failure Mode and Effects Analysis (FMEA), the team proceeded to develop alternative solutions through the SCAMPER ideation method—Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate, and Rearrange. As noted by Ozyaprak (2016), SCAMPER creates an engaging and stimulating environment that promotes creative thinking across various age groups and disciplines. SCAMPER offers a structured yet flexible framework that fosters creativity, particularly effective when the problem and its root causes are well understood. Unlike conventional brainstorming, which can often be unfocused and yield unfiltered ideas, SCAMPER guided the team through targeted categories, resulting in more purposeful and actionable solutions. Through this process, the team successfully generated 16 proposed solutions. Each solution was labeled with a code (e.g., “1A”, “1B”) representing distinct ideas corresponding to specific root causes.

To prioritize these alternatives, the team applied the PICK Chart tools. The PICK Chart is is a decision-making tool that prioritizes ideas based on their potential impact and the effort required for implementation, thereby enabling teams to focus on solutions with the highest expected returns (Egan et al. 2021). The PICK Chart framework—Possible, Implement, Challenge, Kill—which evaluates ideas based on two criteria: magnitude of impact (ranging from small to large) and level of effort (including cost, time, and complexity). Its divided into 4 quadrant: The Implement quadrant (high impact, low effort) identifies top-priority solutions, The Challenge quadrant (high impact, high effort) includes feasible options requiring more resources, The Possible quadrant (low impact, low effort) contains low-priority but easy-to-implement ideas and The Kill quadrant (low impact, high effort) represents ideas not worth pursuing. Focus Group Discussion (FGD) was conducted, bringing in expert insights to evaluate the implications and feasibility of each proposed solution. Figure 3 presents the final mapping of all solutions, with check marks indicating 8 (eight) alternatives selected for implementation. These prioritized solutions formed the foundation for the next step: developing a comprehensive and detailed action plan.

The final activity of the planning phase is the development of a detailed improvement action plan, which serves as the foundation for systematic execution in the subsequent implementation phase. The selected solutions are structured using the 5W2H framework, a planning tool that ensures clarity and feasibility by addressing seven essential questions: What (the specific action), Why (the rationale or objective of the action), Where (the location of implementation), When (the timeline of implementation), Who (the responsible person or team), How (detailed description of the method or process of implementing the improvement), and How Much (the estimated cost or required resources to implement the action). This structured approach enhances accountability and facilitates effective execution and monitoring. As noted by Luo et al. (2024), the 5W2H framework promotes cross-functional communication and collaboration by clearly defining and assigning each strategic element, thereby improving organizational efficiency and team coordination. It should be clearly communicated to both the improvement team and management to ensure alignment, secure necessary resources, and maintain progress throughout the implementation of the action plan. The complete improvement plan is presented in Table 3.

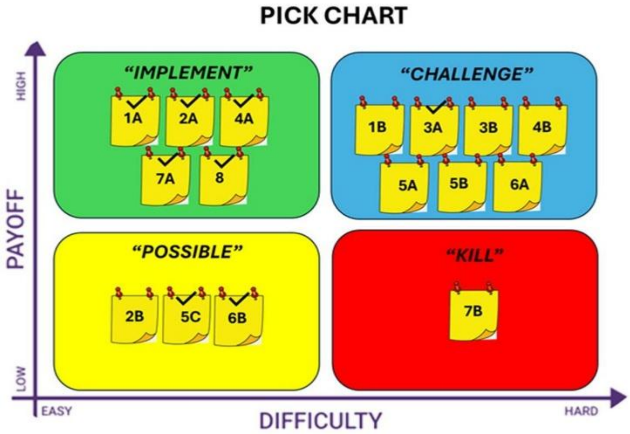

Figure 4. PICK Chart

Table 3. (Example) Improvement Plan in 5W2H approach

Root Cause	What	Why	How	Where-When-Who-How Much
No defined standard for the stacking height of cardboard at the packing table.	Installing "guide" structures on the packing table to limit the maximum allowable height of cardboard stacks.	To prevent excessively high stacks of cartons on the packing table, which causes a high push distance to the conveyor.	) Design adjustable metal guiders) Material purchase) Workshop process) Evaluation) Replication	Where: Packing Area, in packing table. When: W6-W8 Feb Who: Yonatan How Much: IDR 700k

Source: Data processed

The Do Stage

The Do stage in the PDCA cycle marks the transition from planning to action, where improvement initiatives are executed based on the strategies and solutions developed during the planning phase. This stage emphasizes implementing the action plan in a controlled and systematic manner, ensuring that interventions are carried out as intended while progress is monitored and data is collected for subsequent evaluation. At this critical juncture, the 5W2H plan plays a pivotal role in maintaining clarity, consistency, and accountability throughout the implementation process.

To support effective monitoring, the team utilizes Gantt Charts to schedule and visually track all activities. While modern project management tools have continued to evolve, Gantt Charts remain a fundamental tool in planning and overseeing progress in continuous improvement projects (Ramachandran & Karthick, 2019). These charts enable both team members and management to understand how activities are interrelated—how delays in one task can impact the entire project timeline. Moreover, the visual structure of the Gantt Chart reinforces individual accountability, encouraging each team member to stay committed to completing their assigned tasks on schedule.

The progress of improvement activities is also greatly assisted by weekly review meetings between the improvement team and management. These review meetings encourage timely decisions when obstacles arise in the implementation of activities, strengthen accountability, and encourage team learning through input or corrections provided by management. This structured monitoring is in line with Pereira et al. (2022), who underline the importance of formal project evaluation in ensuring long-term success. Their study revealed that in the absence of structured performance reviews, organizations often miss important opportunities for reflective learning and continuous improvement in project management practices.

Equally important in the Do phase is ensuring thorough documentation of improvement activities, as this forms a critical foundation for future standardization efforts. All actions and outcomes are recorded using the 4W2H framework. This structured approach captures key details such as what was done (including before and after conditions), where and when the actions were taken, who was responsible, how the improvement was made, and the costs incurred for the activity. By providing a clear and comprehensive implementation report, the 4W2H format allows stakeholders to understand exactly what was implemented and how it aligned with the original plan. In addition, it facilitates knowledge transfer, replication of best practices, and internal benchmarking. 4W2H documentation also prepares the team for standardization by explicitly outlining the before and after conditions of implementation. An example of such a report is presented in Table 4.

Table 4. (Example) Implementation Report with 4W2H

Root Cause	How	What		Where, when, Who, How Much
		Before	After	
No defined standard for the stacking height of cardboard at the packing table.	Design and install a metal guider that can be adjusted according to the permitted carton height.	No standard of carton stacking height in packing 	Install metal guider to limit the height of carton's stacking 	Where: Packing Area, in packing table. When: W6-W8 Feb Who: Yonatan How Much: IDR 700k

Source: Data processed

A notable highlight of this phase was the implementation of poka-yoke as part of a critical improvement initiative—such as, the installation of a sensor that automatically halts the machine to prevent unsealed cartons from progressing to the next stage, along with a metal guider that limits the stacking height of cartons. Poka-yoke, a Japanese term meaning "mistake-proofing" or "error prevention," was introduced by Shigeo Shingo of the Toyota Production System. It refers to the design of tools, systems, or processes that either prevent errors from occurring or detect them early to avoid product defects. Unlike standardization, which promotes consistency through adherence to best practices, poka-yoke provides an additional automatic safeguard that mitigates the risk of human error. While both approaches are essential for sustaining process improvements, poka-yoke is especially valuable in repetitive or high-risk tasks where human oversight is more likely. In this case, the sensor and metal guider functioned as a fail-safe mechanism that enhanced the sealing process and significantly minimized the potential for defective cartons.

The Check Stage

After all improvement activities are implemented, the next step is the Check stage of the PDCA cycle. This stage is crucial for evaluating the effectiveness of the implemented actions in relation to the previously established objectives. The evaluation of material yield demonstrated a significant improvement in the efficiency of carton packaging materials, with results increasing from 99.41% to 99.85%, surpassing the initial improvement target of 99.75%.

As illustrated in Figure 5, the carton yield at PT XYZ had already begun to improve even before the formal improvement phase was initiated. This early positive trend was likely the result of emergency measures taken in response to recurring defects. However, these improvements proved to be unsustainable and inconsistent, and the results at that time had still did not reach the company's performance targets.

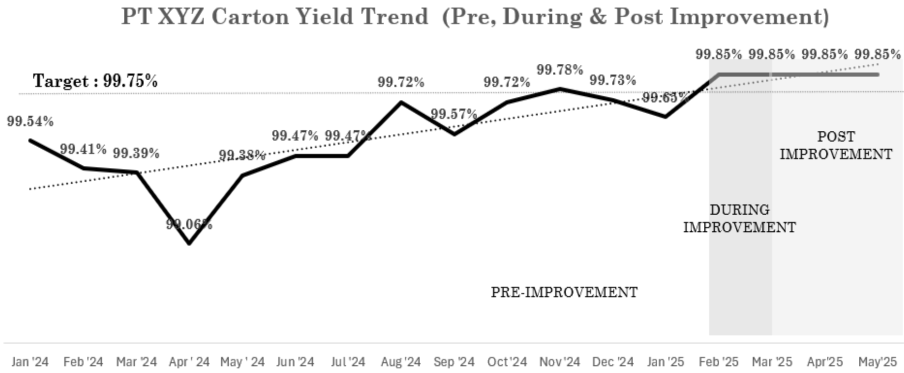

Figure 5. Carton Yield Tren (Pre, During & Post Improvement)

During the structured improvement phase, carton efficiency exceeded targets for the first time and remained consistently high, with post-implementation data showing a stable yield of 99.85%. This consistency reflects the effectiveness and sustainability of the solutions applied. The improvements were driven by the team's ability to systematically prioritize and address the most critical root causes through targeted, high-impact actions. Remarkably, even before full implementation, several initiatives had already shown positive results due to this strategic prioritization.

To assess the broader impact of these improvements, a post-intervention analysis was conducted using the PQCDSME (Productivity, Quality, Cost, Delivery, Safety, Morale, and Environment) framework. This comprehensive evaluation aimed to measure how the changes impacted key operational metrics and strategic performance dimensions.

Table 5. PQCDMSE Comparison

Aspect	Pre Improvement	Post Improvement
Productivity (P)	Carton yield achievement YTD: 99.44% (below target)	Carton yield increased to 99.85% (above target)
	Potential production output loss of 56,320 cs/year	Potential production output loss reduced to 27,180 cs/year
Quality (Q)	Carton defect = 0.56%	Carton defect = 0.15%
	Average carton defect = 4,020 pcs/month	Average carton defect = 917 pcs/month
Cost (C)	Average financial loss from carton defect= IDR 5,729,603/month	Average financial loss from carton defect = IDR 1,352,622/month
	Potential sales loss amounts to IDR 1,041,920,000/year	Potential sales loss decreased to IDR 502,380,000/year
	Average downtime is 312.89 minutes/month hindering	Average downtime reduced to 151 minutes/month (a 52% reduction)

Aspect	Pre Improvement	Post Improvement
Delivery (D)	product delivery to the next workstation	
	Average downtime frequency is 83 times/month	Average downtime frequency reduced to 39 times/month
Safety (S)	Potential risk of work accidents for operators when cleaning up carton defects due to machine breakdowns	Reduced risk of work accidents when cleaning leftover defective cartons due to machine breakdowns
Morale (M)	Operators feel fatigued when cleaning dirty areas caused by defective cartons	Operator fatigue is reduced, allowing for better work focus
Environment (E)	The work area becomes messier due to overflow and accumulation of defective cartons	The work area becomes cleaner and more organized due to no more carton overflows and reduced carton defects

Source: Data processed

Following the implementation of structured improvements across productivity, quality, cost, delivery, safety, morale, and environmental aspects, significant performance gains were achieved. Productivity improved notably, with the carton yield rising to 99.85%, surpassing the target. The substantial reduction in machine downtime effectively minimized potential production and sales losses. In terms of quality, carton waste dropped from 0.56% to just 0.15%, leading to a meaningful decrease in material-related costs. Delivery processes became more efficient, with machine downtime reduced by 52% and the frequency of disruptions nearly halved. Operator safety improved due to fewer risks associated with handling defective cartons, while reduced fatigue allowed for better focus and performance. The work environment also transformed—from a cluttered space caused by overflowing defective cartons to a cleaner, more organized area—reflecting the success of the overall improvement efforts.

Overall, the post-improvement results demonstrate that the structured interventions not only addressed the root causes but also delivered sustainable improvements across all PQCDSME dimensions. This underscores the value of a holistic and data-driven approach in driving continuous operational excellence.

The Act Phase

Entering the "Act" phase of the PDCA cycle, standardization becomes a critical enabler for sustaining the improvements achieved. Among lean tools, standardized work is particularly effective, though often underutilized. By capturing and formalizing best practices, it provides a stable foundation for Kaizen and long-term operational enhancements (Mikva et al., 2016). In this phase, process standardization was carried out through the systematic development and revision of Work Instructions (WIs), the creation of One Point Lessons (OPLs) as concise visual training aids, the unification of machine operation and maintenance standards, and the delivery of structured on-the-job training for operators. These actions were designed to institutionalize previous improvements and ensure their consistent application in day-to-day operations. Embedding standardized procedures into workflows reduces process variability, minimizes human error, and promotes adherence to quality and safety standards.

Organizational Lessons Learned and Managerial Implications

The improvement project generated key organizational insights beyond technical achievements. As Haleem (2017) emphasized, systematically capturing and applying lessons learned strengthens long-term competitiveness and continuous improvement. Reliable historical data and genba (direct site observation) proved essential for fact-based decision-making. Involving frontline operators uncovered practical improvement ideas often overlooked by management, supporting Hsieh's (2016) findings on co-creating value. Cross-departmental collaboration accelerated problem resolution, while early stakeholder engagement reduced resistance and fostered trust (Einur et al., 2021). Regular management reviews and targeted training strengthened team capabilities and kept the project on track.

To sustain progress, management must complete pending actions such as optimizing packaging storage, upgrading sealing machines, and improving supplier quality for cartons and adhesives. This is expected to increase the impact of the intervention. Embedding genba in daily routines, improving data recording, and continuing staff training will further strengthen the improvement effort. These practices, when integrated into long-term planning, offer a practical model for similar industries aiming to reduce waste and increase efficiency.

CONCLUSION

This study demonstrated that implementing the Plan–Do–Check–Act (PDCA) methodology, integrated with quality improvement tools, effectively enhanced manufacturing performance by reducing waste and optimizing processes, particularly in minimizing carton defects and machine downtime. The adoption of eight targeted solutions led to notable improvements in carton yield, defect reduction, financial loss mitigation, and delivery performance, along with non-financial gains such as improved safety, employee morale, and workplace cleanliness—outcomes supported by accurate data, *genba*-based observations, stakeholder engagement, and cross-functional collaboration. However, as the research was limited to a single site and waste category, its generalizability may be constrained. Future research is suggested to apply the PDCA framework across multiple sites, various waste categories, and different manufacturing settings to assess its broader applicability and scalability. Additionally, expanding the investigation to include other waste forms—such as raw material usage, rework, and energy consumption—and exploring the institutionalization of PDCA in daily operations could further enhance operational efficiency and ensure sustainable, continuous improvement in manufacturing processes.

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