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Improving Quality Control in Cup Beverage Production Using the Six Sigma Method

Deri Maryadi[1*]; Amrillah Azrin[2]; Suhendra Suhendra[3]

[1]*Industrial Engineering/Faculty of Engineering, Universitas Tridinanti, Indonesia*
[2]*Management/Faculty of Economics and Business, Universitas Tridinanti, Indonesia*
[3]*Industrial Engineering/Faculty of Engineering, Universitas Pelita Bangsa, Indonesia*

*Corespondent Author: derimaryadi@univ-tridinanti.ac.id

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ABSTRACT
Purpose: *This study aims to reduce defect rates and enhance operational efficiency in the cup beverage production process using the Six Sigma DMAIC methodology.* ***Methodology:*** *The research applies the DMAIC framework (Define, Measure, Analyze, Improve, Control) to identify key defect causes and implement process improvements.* ***Results:*** *The application of Six Sigma DMAIC significantly reduced defect rates, as evidenced by improved Defects Per Million Opportunities (DPMO) metrics.* ***Findings:*** *The study demonstrates the effectiveness of Six Sigma in improving process quality and reducing waste, leading to better operational performance and customer satisfaction.* ***Originality:*** *This research uniquely applies Six Sigma in the cup beverage production sector, showcasing its adaptability to this industry.* ***Novelty:*** *While Six Sigma has been widely used in various industries, its implementation in beverage production remains underexplored, making this study a valuable contribution.* ***Conclusions:*** *The Six Sigma DMAIC methodology effectively reduces defects, enhances process efficiency, and increases customer satisfaction.* ***Type of Paper:*** *Empirical research paper.*

INTRODUCTION

Quality serves as an indicator of how well a product or service aligns with consumer needs and expectations (Lee et al., 2021). This multifaceted concept encompasses various dimensions such as durability, reliability, aesthetics, and the capacity to satisfy consumer demands. Within the business realm, quality extends beyond the mere technical specifications of a product to include the perceptions customers have of that product (Tripathi et al., 2018). A product of superior quality not only adheres to defined specifications but also achieves maximum customer satisfaction (Maryadi et al., 2024). Quality is a crucial determinant of a business's success or failure (Azhari et al, 2024). Products of exceptional quality are more likely to be preferred by consumers, thereby enhancing the company's sales and profitability (Maryadi et al., 2024).

Quality control is a methodical strategy aimed at ensuring that produced goods or services conform to predetermined quality standards. This process includes activities such as inspection, testing, and process regulation to identify and eliminate defects (Neave, 2019)(Juliani & de Oliveira, 2021). It also involves utilizing statistical tools to monitor and analyze the performance of production processes (Widjayanto et al., 2021). Effective quality control enables companies to produce consistently high-quality products, which can increase customer satisfaction and loyalty. The role of quality control is Condense repetitive sections to improve readability. High-quality products provide several benefits to a company (Alarcón et al., 2023). Firstly, superior quality can enhance the company's reputation. Customers tend to trust and remain loyal to companies that consistently deliver high-quality products. Secondly, superior quality can improve operational efficiency. Reducing defective products can save production costs and minimize waste. Thirdly, superior quality can enhance a company's competitiveness in the market. In a highly competitive environment, high-quality products can provide a competitive edge that differentiates a company from its rivals. Finally, superior quality can improve customer satisfaction and loyalty (Maryadi et al., 2023). Customers satisfied with product quality are more likely to make repeat purchases and recommend the products to others (Sony et al., 2020;Sam et al., 2021).

In the globalization and complicated competition, quality has emerged as a key factor in determining business success. Companies that do not cover their product quality face the risk of losing customers and market share (Dhinar et al., 2023). On the other hand, companies that effectively maintain and improve their product quality will gain lasting competitive advantages. Consequently, quality control should not be seen as solely the responsibility of the quality department; it must be embedded within the company's overall business strategy. Every employee in the organization needs to recognize the significance of quality and play an active role in sustaining and enhancing product quality (Maryadi, 2021).

Quality control also includes preventive measures, which means that companies focus not just on detecting and correcting defects but also on preventing them from occurring initially. This approach is referred to as preventive or proactive quality control. Through preventive quality control, companies can identify and resolve potential problems before they affect product quality. This can be accomplished through multiple strategies, such as employee training, product design enhancements, improvements in the production process, and the adoption of advanced technology. Moreover, quality control should encompass a sustainable approach. This implies that companies must consistently monitor and assess their quality performance, striving for continuous improvement. This method is known as Continuous Quality Improvement (CQI). With CQI, companies are never content with maintaining the status quo; instead, they continually look for ways to improve the quality of their products and processes. CQI engages all levels of the organization and includes a range of activities such as data collection and analysis, problem identification, solution development, and the implementation of improvements.

The Six Sigma methodology is composed of five phases known as DMAIC: Define, Measure, Analyze, Improve, and Control. In the Define phase, the organization sets project goals and identifies the issues to be resolved. The Measure phase involves collecting data and evaluating the production process to understand current performance levels. During the Analyze phase, the data is scrutinized to determine the root causes of defects or variations. In the Improve phase, solutions are crafted and put into practice to address the identified causes of defects. The Control phase ensures that the improvements made are monitored and maintained to achieve the desired results. Extensive research has been conducted to evaluate the effectiveness of Six Sigma in various industries, including the beverage sector. Here are six previous studies that focus on the application of Six Sigma in quality control within the beverage industry and other manufacturing case. conducted their research at a soda beverage manufacturing facility. (Lopes et al., 2015) Through the implementation of Six Sigma methods, the company achieved a 50% reduction in product defects. This study illustrates that Six Sigma can substantially improve both product quality and operational efficiency in the soda beverage production process. (Dutta & Jaipuria, 2020) carried out their study at a packing material for beverages product. The results demonstrated enhancements in both product quality for packing material and production process efficiency after adopting Six Sigma practices. The study underscores the importance of data analysis and process control in achieving ongoing improvements in quality, and most important things this research can improve sigma level. (Elfanda, 2021) employed the Six Sigma methodology in a food and beverages manufacturing facility. The use of Six Sigma statistical tools led to a reduction in production costs and an enhancement in customer satisfaction. This study highlights the critical role of employee training and management engagement in effectively implementing Six Sigma. And the sigma level 3.8 with the possibility of damage/ defects to the product up to 11,760 pcs in a million chance of production (DPMO). The last, based one research (Purba et al., 2021) demonstrated that Six Sigma effectively decreased defect rates and boosted employee satisfaction. This study shows that Six Sigma not only improves product quality but also enhances the work environment and fosters greater employee involvement.

Six Sigma is a data-driven quality management methodology designed to minimize process variation and enhance operational efficiency across various sectors (Antony et al., 2018). In the beverage industry, particularly within the cup beverage sector, unique challenges such as maintaining product quality consistency, mitigating contamination risks, and managing waste necessitate a systematic approach to ensure adherence to high-quality standards (Aadil et al., 2019). Furthermore, the intense market competition and the imperative to comply with international standards, such as ISO 22000, underscore the importance of implementing Six Sigma within this domain.

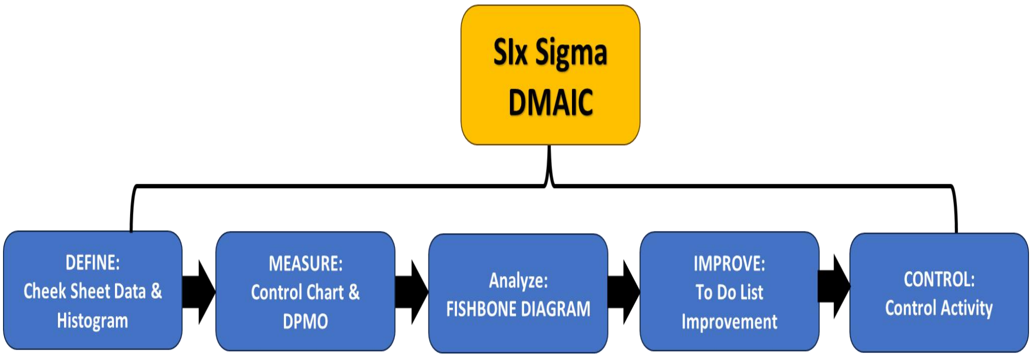
This Research aims to examine the application of Six Sigma in addressing these specific challenges, focusing on defect reduction, efficiency enhancement, and operational sustainability. This was carried out at a cup beverage packaging company situated in Palembang. The company encountered several quality challenges, such as elevated defect rates and unstable production processes. These problems led to higher production costs, decreased customer satisfaction, and a weakened market position. To tackle these issues, the company opted to use Six Sigma as its main quality control strategy. The purpose of the study is to assess the effectiveness of Six Sigma in lowering product defect rates and improving operational efficiency at the cup beverage manufacturing.

METHOD

This study is designed to evaluate the implementation of Six Sigma methodology in enhancing quality control at a cup beverage packaging company located in Palembang. Employing a case study approach, the research provides an in-depth examination of the company's quality control processes before and after the adoption of Six Sigma. This method allows for a thorough assessment of the significant changes in product defect rates and operational efficiency resulting from Six Sigma implementation.

Data collection is carried out through several stages. Initially, historical data on defect rates, is gathered to establish a baseline prior to Six Sigma implementation. Subsequently, the existing production processes are mapped to identify areas needing improvement. Six Sigma is then applied through the DMAIC framework—Define, Measure, Analyze, Improve, and Control. In the Define phase, the project scope will be outlined based on an analysis of identified defect categories, utilizing check sheets and data histograms. During the Measure phase, data will be collected over a specified period to calculate the Defects Per Million Opportunities (DPMO) value. Subsequently, in the Analyze phase, root cause analysis will be conducted using Ishikawa diagrams or the 5-Why technique to systematically identify the underlying issues. Proposed solutions in the Improve phase will include measures such as adjusting machine settings and conducting operator training. Finally, the Control phase will involve the application of control charts to monitor continuous improvements and the updating of standard operating procedures (SOPs) to ensure the sustainability of the implemented changes. This approach enables a comprehensive evaluation of changes in defect rates, production costs, operational efficiency, as well as customer satisfaction and employee engagement. And for DMAIC model will use in this research can see at figure 1 below.

Figure 1. DMAIC Model for this Research.



RESULTS AND DISCUSSION

RESULTS

Define Phase

The initial phase of implementing Six Sigma in the beverage industry focused on understanding the current state of the production process and identifying key areas for improvement. Data collection during the Define and Measure phases revealed several critical insights. The primary metrics analyzed included defect rates, production efficiency, and customer complaints. During the Define phase, both quantitative and qualitative data were gathered from the company to identify the types of product defects occurring in the production process at Manufacturing process using a Check Sheet. Observations of the production process provided data on production and product rejections categorized by defect type start from july to december, as shown in Table 1 below.

Tabel 1. Check Sheet for Define Phase

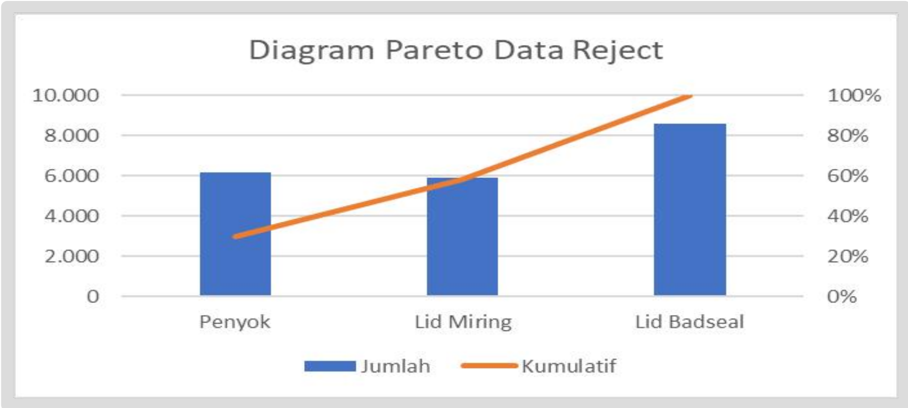
Month	Total Production	Deform	*Lid* Miring	*Lid* Bad seal	Total Reject	*Reject (%)*
July	264000	1082	*828*	*1182*	3097	4.81%
August	276000	980	*827*	*1311*	3118	4.56%
September	264000	994	949	1328	3271	5.01%
October	288000	904	1010	1378	3292	4.57%
November	252000	922	1057	1347	3326	5.43%
December	360000	1266	1210	2009	3422.064	4.75%
Total	1.703,000	6.148	5.881	8.555	20.589	

Based on the analysis of the was mentioned in figure 2, a Pareto diagram was utilized to identify the most significant causes that need to be addressed to reduce the rejection rate. A Pareto diagram is a bar chart that displays problems in descending order of frequency. The following table presents the calculations for the Pareto diagram.

Tabel. 2 Riject Ratio

No.	Item	Total	Reject	Total Percentage
1	Penyok	6.148	30%	30%
2	Lid miring	5.881	29%	58%
3	Lid badseal	8.555	41%	100%
Total		20.584	100%	

Figure 2. Pareto Diagram



Based on the Pareto Diagram above, the order of the rejection data percentages from highest to lowest is as follows: 41% of defects are caused by bad seals, which should be prioritized for improvement ,dented at 30%, and misaligned lid at 29%. It can be concluded that the largest cause of rejection is the lid bad seal, followed by dented and misaligned lids.

Figure 3. Classification of Riject

Measure Phase

In the Measure phase, the quality characteristics of the products produced in the manufacturing process at the Manufacturing Company were assessed using Control Charts. The P Control Chart was employed to depict the production process, evaluate its stability, and identify variations in the data. A control chart is a tool used to determine whether a manufacturing or business process is in a state of statistical control. It helps in identifying variations in the process and distinguishing between common cause variations and special cause variations Below are the processed data results using the P Control Chart, including the values for P, CL (Central Line), UCL (Upper Control Limit), and LCL (Lower Control Limit). To calculate the upper control limit (UCL) and lower control limit (LCL), the average proportion of defective parts must be determined using the following calculations:

$$P = \frac{Riject\ Ratio}{Production\ Total} = \frac{nP}{n} \text{ ....(1)}$$

Where: P: Defect Proportion
nP: Total Riject sub group
n: Total Checking sub group

$$CL = p = \frac{Jumlah\ reject\ total}{Jumlah\ total\ yang\ diperiksa} = \frac{\sum nP}{\sum n} \text{ ....(2)}$$

Where: $\sum n\mathrm{P}$: Total reject
$\sum n$: Total Checking/Total Output

$$UCL = CL + 3\frac{\sqrt{CL\ (1-CL)}}{n} \text{ ....(3)}$$

Where: CL: *Central Line*
N : Total Production
UCL: *Upper Control limit*

$$LCL = CL - 3\frac{\sqrt{CL\ (1-CL)}}{n} \text{ ....(4)}$$

Where: LCL: *Lower Control Limit*
CL: *Central Line*
n : Total Production

To determine the upper control limit (UCL) and lower control limit (LCL), as well as the reject proportion (P) and the Central Line (CL) for the data from June 19 to June 24, 2023 (the first week), the following steps will be implemented:

- $P = \frac{n\mathrm{P}}{n} = \frac{840}{5000} = 0{,}168$
- $CL = \frac{Jumlah\ reject\ total}{Jumlah\ total\ yang\ diperiksa} = \frac{21.589}{125.000} = 0{,}16471$
- $UCL = CL + 3\frac{\sqrt{CL\ (1-CL)}}{n}$
  $= 0{,}16471 + 3\frac{\sqrt{0{,}16471\ (1-0{,}16471)}}{5000} = 0{,}16786$
- $LCL = CL - 3\frac{\sqrt{CL\ (1-CL)}}{n}$
  $= 0{,}16471 - 3\frac{\sqrt{0{,}16471(1-0{,}16471)}}{5000} = 0{,}16157$

Based on the results of the calculations for the upper and lower control limits, the data can be represented using the P Control Chart as follows in figure 4 below.

Next, the calculation of Defects Per Million Opportunities (DPMO) will be conducted, followed by converting the sigma values based on the sigma table. This process will continue with the calculations for the data over a period of six months. The steps involved are as follows:

DPU *(Deffect Per Unit):*

$$DPU = \frac{Total\ Cacat\ Produksi}{Total\ Produksi} \text{ :..(1)}$$

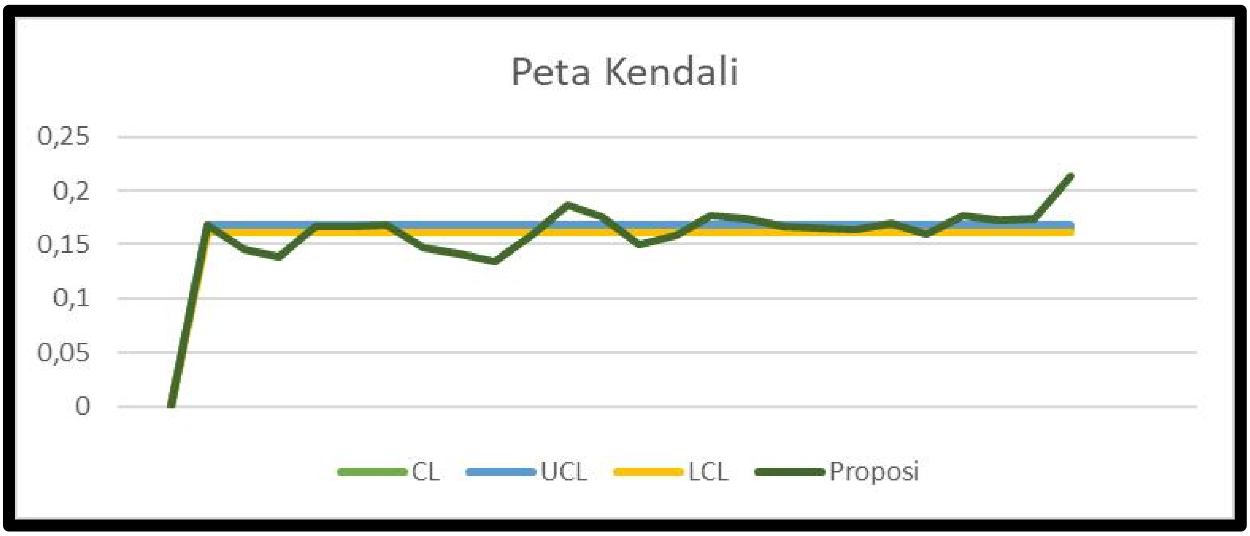
Data 1, DPU = $\frac{840}{72.000}$ = 0,011666
Data 2, DPU = $\frac{728}{48.000}$ = 0,015166

$$DPMO = \frac{Total\ Cacat\ Produksi}{Jumlah\ Produksi} \times 1.000.000 \quad \text{.......(2)}$$

Data 1, DPMO = $\frac{840}{72.000}$ x 1.000.000 = 11666,6667
Data 2, DPMO = $\frac{728}{48.000}$ x 1.000.000 = 15166,6667

From the analysis of the data above, it can be concluded that the production of "Kopikap" has a sigma level of 3.75, which corresponds to a condition of 2 sigma, with a defect probability of 1,224.252 per million production processes, means to a 12.2% Defects Per Million Opportunities (DPMO).

Figure 4. Control Chart



Analyze Phase
At this stage, an analysis was conducted on the production data of Manufacturing Process using the Fishbone diagram, also known as the cause-and-effect analysis. Based on the identification process, the factors influencing and causing product defects can generally be categorized into four main areas: People, Material, Machine, and Method.

1. **People Factor** The people factor refers to issues such as operators exhibiting a lack of discipline and motivation, being easily distracted, failing to comprehend existing work instructions, and not being diligent in monitoring the production process.
2. **Material Factor** This factor arises from raw materials that do not meet specifications, such as plastic cups that are leaking and lids that are not symmetrical.
3. **Machine Factor** The machine factor is attributed to issues during the sealing process, where the heater temperature is unstable, resulting in suboptimal sealing. Additionally, the driving motor may not function properly, and lids may not be accurately positioned in the center of the cups.
4. **Method Factor** The method factor pertains to the absence of training for employees, both before and after they begin working. Furthermore, production occurs simultaneously, leading to production overload.

Improve Phase

The Improve phase involves the action plan for implementing improvements and enhancing the quality of the products produced after identifying the causes of various types of defects. This phase entails developing recommendations or proposals for corrective actions aimed at reducing the defect rate of the products.

Tabel 3. Improvement for DMAIC phase

Main Factor	Cause Effect	Improvement Action
Human	Lack of discipline and lazy to work	Employees who are directly involved in the production process must be focused and disciplined in their work.
	Not careful in controlling the production process	control the work according to the specified standards Work.
	Lack of focus and fatigue	There is a need for training to motivate employee performance, along with providing bonuses for outstanding employees as a form of recognition and reward.
Material	Plastic cups that are leaking and do not meet the required size specifications.	It is advisable to conduct a thorough inspection of the cups to be used before utilizing the raw materials.
	Plastic raw materials do not meet specifications	Ensure that the machinery used during the production process maintains a stable temperature
Machine	Unstable heater temperature	Ensure that the machinery used during the production process remains stable
	Motor not operate as well in planning	Regular inspections and cleaning of the machinery should be conducted after production, along with repairs to any malfunctioning components
	Lid not in middle of the cup	Ensure that the core plate sensor is functioning properly
Method	Over Production	Production must adhere to precise size standards and be based on the available material composition.
	Production Schedule not Proper	Conduct production in a partial manner to ensure that the quantity of products produced aligns with consumer demand, adhering to the standard operating procedures established by the company

Control Phase

The Control phase represents the final analysis stage in the implementation of the Six Sigma method, focusing on the documentation and dissemination of the actions taken, which include:

- Conducting regular and continuous (sustainable) maintenance and repairs on factory machinery.
- Monitoring the raw materials and production employees to ensure the quality of the produced goods is improved.
- Recording all products daily by type and machine, as performed by employees during the production process.

- Reporting the recorded data on defective products categorized by type to the supervisor, with the total number of defects for the month included in the monthly manager's report.

DISCUSSION

The implementation of Six Sigma in the beverage production process at Manufacturing Company has effectively highlighted the importance of a systematic approach to quality control. The Define phase revealed significant insights into defect rates and production efficiency, allowing for the identification of critical areas that require improvement. Through the analysis of production data using tools such as the Check Sheet and Pareto Diagram, it became evident that the primary cause of product rejection was attributed to bad seals on lids, followed by dents and misalignment. In the Measure phase, Control Charts were utilized to assess quality characteristics, leading to the calculation of crucial metrics such as the Defects Per Million Opportunities (DPMO).

CONCLUSION

The results indicated a sigma level of 3.75, revealing a defect probability of 12.2%. This highlighted the necessity for targeted interventions to enhance production quality. The Analyze phase provided a deeper understanding of the root causes of defects, categorizing them into four primary factors: People, Material, Machine, and Method. By addressing issues such as operator discipline, material specifications, machine stability, and operational methods, the Improve phase proposed actionable recommendations aimed at mitigating defects and enhancing overall production quality. Finally, the Control phase emphasized the importance of sustaining improvements through regular maintenance, continuous monitoring, and proper documentation of production processes. By implementing these strategies, the Manufacturing Company can ensure that quality improvements are maintained, leading to a reduction in defects and an overall enhancement of production efficiency. In conclusion, the application of the Six Sigma methodology has proven to be an effective framework for improving quality control within the beverage production industry, ultimately contributing to higher customer satisfaction and operational excellence

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