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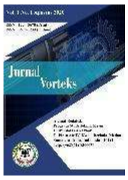

10 IMPROVING THE QUALITY of MSME PRODUCTS USING LEAN SIX SIGMA: A Case Study of Plastic Ball Production at UD. Billa Bola

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Abstract

The implementation of Lean Six Sigma (LSS) has been widely adopted as an effective methodology to enhance quality and productivity in manufacturing and service sectors. By integrating
9 Lean principles and Six Sigma tools, LSS provides a structured
11 framework to minimize defects and eliminate non-value-added activities [1], [2], [3], [4].This study applies the LSS methodology within a small-to-medium enterprise (SME), UD. Billa Bola, which manufactures plastic balls, aiming to improve production performance and reduce defect rates. Using the DMAIC (Define, Measure, Analyze, Improve, Control) approach, the research identifies dominant defects, analyzes process stability through control charts, measures sigma level improvements, and maps value stream efficiency. Results indicate a reduction in defect rate from 4.6% to 2.8%, an improvement of sigma level from 3.2 to 3.5, and a decrease in production lead time by 19%. These findings confirm that LSS not only enhances product quality but also increases operational efficiency in resource-constrained SMEs, highlighting its broader applicability beyond large-scale manufacturing [5], [6], [7]

Kata Kunci: *Lean Six Sigma, DMAIC, UMKM, Kualitas Produk, Bola Plastik*

Abstrak

Penerapan Lean Six Sigma (LSS) telah banyak diadopsi sebagai metodologi yang efektif untuk meningkatkan kualitas dan produktivitas di sektor manufaktur maupun jasa. Dengan mengintegrasikan prinsip Lean dan alat Six Sigma, LSS menyediakan kerangka kerja terstruktur untuk meminimalkan cacat dan menghilangkan aktivitas yang tidak bernilai tambah [1], [2], [3], [4].. Penelitian ini menerapkan metodologi LSS pada usaha kecil dan menengah (UKM), UD. Billa Bola, yang memproduksi bola plastik, dengan tujuan meningkatkan kinerja produksi dan mengurangi tingkat cacat. Dengan menggunakan pendekatan DMAIC (Define, Measure,
4 Analyze, Improve, Control), penelitian ini mengidentifikasi cacat dominan, menganalisis stabilitas proses melalui peta kendali, mengukur peningkatan level sigma, dan memetakan efisiensi aliran nilai. Hasil penelitian menunjukkan penurunan tingkat cacat dari 4,6% menjadi 2,8%, peningkatan level sigma dari 3,2 menjadi 3,5, serta penurunan lead time produksi sebesar 19%. Temuan ini
5 menegaskan bahwa LSS tidak hanya meningkatkan kualitas produk tetapi juga meningkatkan efisiensi operasional pada UKM dengan keterbatasan sumber daya, sekaligus menyoroti aplikasinya yang lebih luas di luar manufaktur skala besar [5], [6], [7]

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INTRODUCTION

Lean Six Sigma (LSS) is a quality management approach that integrates lean and six sigma principles to achieve process efficiency while maintaining product quality. Previous studies have shown that this methodology can produce tangible results, including reduced production costs, faster process cycles, and increased customer satisfaction. For small and medium-sized enterprises (SMEs), the application of LSS is particularly relevant as it can support competitiveness amid limited resources and an increasingly dynamic market environment.

However, practical experience shows that the application of LSS in SMEs is not without challenges. Common obstacles include financial and labor constraints, inadequate technical expertise and understanding of LSS concepts, and weak management commitment. These conditions often result in improvement initiatives that fail or do not achieve their expected goals [1], [2]

In response to these challenges, this study seeks to examine the extent to which Lean Six Sigma can be effectively implemented in SMEs, with a particular focus on improving product quality. Furthermore, this study aims to identify the main obstacles that can hinder successful implementation and propose strategies to overcome them. These findings are expected to provide practical insights for SMEs in optimizing Lean Six Sigma practices, thereby promoting operational excellence and sustainable competitiveness.

Lean Six Sigma

LSS combines Lean principles, which emphasize waste elimination, with Six Sigma methodologies that focus on variation control and data-driven quality management [8], [9] Lean and Lean Six Sigma have proven effective in increasing productivity and reducing defects in SMEs, especially in the food and bakery sector [10], [11]

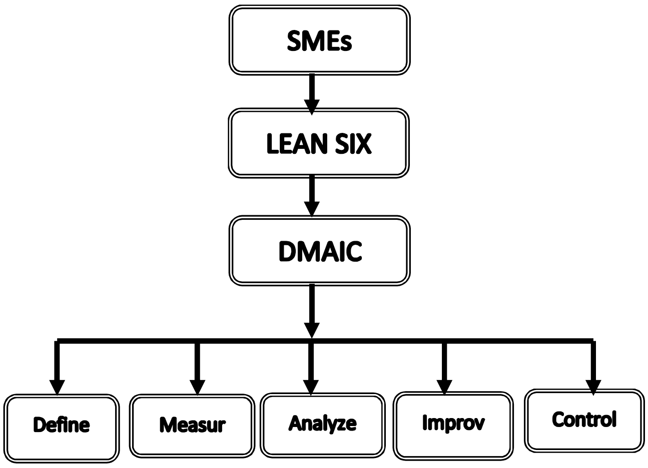

Figure 2. Conceptual framework of Lean Six Sigma (DMAIC) in addressing SMEs' problems

Although LSS has been widely implemented in large-scale industries, its adoption in SMEs remains limited due to resource constraints, lack of expertise, and resistance to change [12], [13], [14]. Although implementing Lean Six Sigma (LSS) in SMEs often faces various obstacles, recent research shows that companies that successfully implement it are able to achieve tangible benefits. These benefits not only include increased operational efficiency and reduced costs, but are also reflected in increased customer satisfaction, which is a key measure of business sustainability [15], [16], [17].Accordingly, adopting the LSS framework through the DMAIC cycle (Define, Measure, Analyze, Improve, Control) offers a viable solution to identify root causes, reduce defects, and improve process efficiency [18], [19]

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12 Figure 3. The DMAIC cycle (Define, Measure, Analyze, Improve, Control) in the Lean Six Sigma framework.

State of the Art

13 Lean Six Sigma (LSS) has been widely implemented in manufacturing and service industries as an integrated methodology for quality improvement [1], [2], [3], [4], [5], [6], [7], with evidence from large enterprises showing its success in achieving process stability, defect reduction, and customer satisfaction [10], [11], [12]. However, its application in SMEs remains limited due to resource constraints, lack of expertise, and organizational resistance [13], [14]. The effectiveness of LSS in SMEs depends heavily on management commitment, employee training, and the integration of a continuous improvement culture [20], [21], [22], yet many fail to sustain improvements because of weak supporting factors [23] .[24] While various tools such as Value Stream Mapping (VSM) [18], [19] control charts and sigma analysis [25], [26], and fishbone diagrams [24] have proven effective, empirical evidence on LSS effectiveness in SMEs, particularly in traditional manufacturing within developing countries, is still scarce [5], [6], [7][13], [14]. Therefore, this study applies the DMAIC-based LSS framework at UD. Billa Bola, an Indonesian SME producing plastic balls, to evaluate its impact on defect reduction, sigma level improvement, and process efficiency [15], [16], [17], [27], [28], [29]

Table 1. Research Gap on Lean Six Sigma (LSS) in SMEs

Dimension	Existing Knowledge (Literature)	Identified Gap	Research Focus
Enablers for LSS	Success depends on management commitment, employee training, and a culture of improvement [23–25].	Many SMEs fail to sustain improvements due to weak supporting factors .[26], [27]	Examine the role of management and employee engagement in sustaining LSS in SMEs.
Industrial Context	LSS has been effective in large enterprises for defect reduction, process stability, and customer satisfaction [10–12].	Empirical evidence in SMEs, particularly in traditional manufacturing, is limited [13], [14]	Case study of LSS application in a plastic manufacturing SME (UD. Billa Bola).
Benefits of LSS	SMEs adopting LSS show improved competitiveness and market performance [28–30].	Limited contextual evidence of measurable benefits in resource-constrained SMEs.	Assess the impact of LSS on defect reduction, sigma levels, and process efficiency.
Developing Economy Context	Most studies focus on developed countries with strong infrastructure [5–7].	Research on SMEs in developing countries remains scarce.	Extend empirical evidence of LSS in Indonesian SMEs.

RESEARCH METHODS

This study applies the Lean Six Sigma (LSS) framework using the DMAIC cycle (Define, Measure, Analyze, Improve, Control), a systematic roadmap for process improvement [1], [2]. Conducted as a case study at UD. Billa

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Bola, data were drawn from 12 months of production records, observations, and interviews, supported by literature [3], [4], [5], [6]. Defects were measured through DPU, DPO, DPMO, control charts, and sigma levels [7,8], while root causes were identified using Pareto charts, fishbone diagrams, PAM, and VSM [9], [10] Improvement actions included standardized procedures, preventive maintenance, in-line quality control, and training, with sustainability ensured through audits, monitoring, and SOP reinforcement.

Conceptual Framework

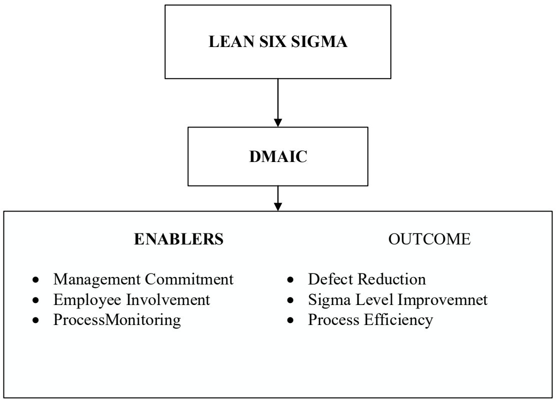

Figure 4 Conceptual Framework

The conceptual framework illustrates the role of Lean Six Sigma (LSS) as an integrated methodology for quality improvement in SMEs. At the core of the framework is the DMAIC cycle (Define, Measure, Analyze, Improve, Control), which provides a structured, data-driven approach to identifying problems, analyzing root causes, and implementing sustainable solutions.

The framework emphasizes two critical elements:

1. Enablers – Successful LSS implementation depends on management commitment, employee involvement, and systematic rocess monitoring. These enablers provide the necessary organizational support to ensure that process improvements are effectively implemented and sustained.
2. Outcomes – When the DMAIC cycle is executed with strong enablers, SMEs are expected to achieve tangible results such as defect reduction, sigma level improvement, and enhanced process efficiency. These outcomes contribute to better product quality, cost savings, and increased competitiveness.

In summary, the framework demonstrates how Lean Six Sigma, operationalized through DMAIC and supported by organizational enablers, can drive measurable improvements in SMEs' performance and product quality.

Research Steps

This study identifies product quality issues, collects preliminary data, and observes processes before applying Lean Six Sigma through the DMAIC stages. The Define stage sets main problems and scope using SIPOC, while the Measure stage gathers data and creates the Current Value Stream Map. In the Analyze stage, root causes are explored with data analysis and cause-and-effect diagrams. The Improve stage designs solutions and develops the Future Value Stream Map, and the Control stage ensures sustainability through monitoring and standard procedures.

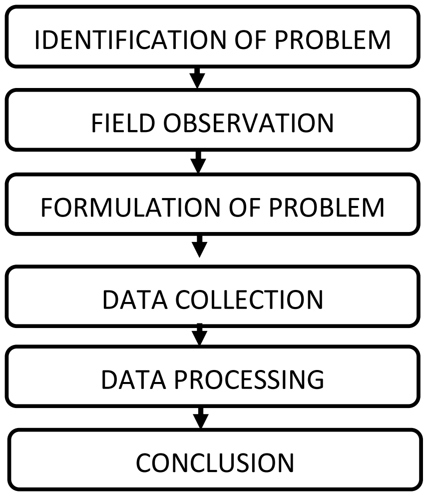

Figure 5 Illustrated the Research Flow

he figure illustrates the research flow adopting the Lean Six Sigma (LSS) methodology to improve quality in SMEs, presented from problem identification to conclusion:

1. Problem Identification – Identifying key issues such as high defect rates or production inefficiencies.

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2. Field Observation – Observing workflows to detect waste and quality variations.
3. Problem Formulation – Structuring the research focus within the DMAIC cycle as the LSS framework.
4. Data Collection – Gathering quantitative data (defect counts, cycle times, sigma levels) and qualitative data (employee input, machine condition).
5. Data Processing (DMAIC):
   - Define: Clarify problems and scope (SIPOC).
   - Measure: Assess performance with defect data and Current VSM.
   - Analyze: Identify root causes using cause-and-effect, Pareto, and control charts.
   - Improve: Develop solutions and map Future VSM.
   - Control: Standardize procedures to sustain improvements.
6. Conclusion – Summarizing solutions to reduce defects, raise sigma levels, and enhance process efficiency.

ANALYSIS AND EVALUATION

The results of this study are presented according to the DMAIC framework (Define–Measure–Analyze–Improve–Control), which serves as the structured methodology of Lean Six Sigma**.**

Define Phase

To provide a high-level overview of the production system, a SIPOC diagram was constructed (Figure 6). This mapping highlighted the flow from suppliers to customers, clarifying the scope of improvement initiatives.

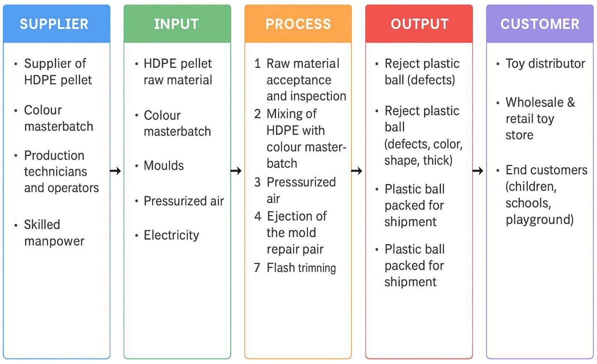

Figure 6 SIPOC Diagram of plastic ball production process

This SIPOC confirmed that suppliers, raw materials, and production stages must all be considered to improve both defect reduction and process efficiency.

In the Define phase, the critical-to-quality (CTQ) characteristics were identified as product roundness, wall thickness uniformity, and color consistency. These defects were confirmed as the most frequent causes of product rejection.

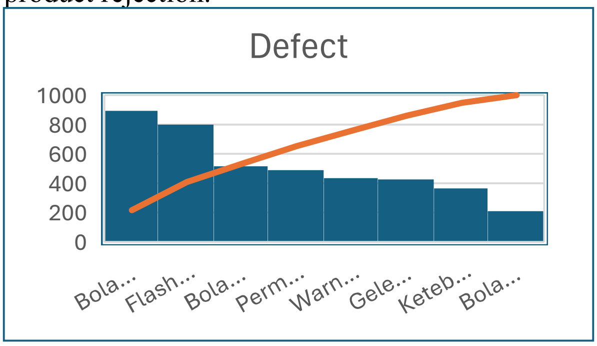

Figure 7. Pareto Diagram

Production data from UD. Billa Bola between January aDiand December 2024 showed that the average defect rate was 4.6% of total output. The dominant defects identified included non-round shapes (38%), uneven wall thickness (27%), and inconsistent color (20%). A Pareto chart confirmed that these three categories contributed to more than 80% of total defects,

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indicating a critical focus area for improvement [2]

Measure Phase

In the Measure phase, production and defect data were collected from January to December 2024. The summary is provided in Table 1

Table 2. Monthly production and defect count.

Month	Total Production	Weighing & Mixing	Melting	Blow Molding			
January	56,532	47	75	96			
February	56,107	42	66	98			
March	56,008	65	85	110			
April	56,99	52	63	106	[illegible]	[illegible]	[illegible]
May	56,375	50	76	99	98	75	398
June	56,893	32	80	96	55	37	300
July	56,727	54	74	105	65	47	345
August	56,631	60	75	88	56	39	318
September	54,841	72	65	120	76	54	387
October	57,051	51	68	110	69	53	351
November	55,047	58	84	128	74	49	393
December	56,51	55	78	92	54	36	315
Total	**675,712**	**638**	**889**	**1248**	**802**	**573**	**4150**

Table 2. indicates that a total of 4,150 defects were recorded in 2024 from 675,712 units produced, yielding an average defect rate of 0.61%. The majority of defects originated from Blow Molding (30.1%), Melting (21.4%), and Mold Release (19.3%), which together accounted for over 70% of all defects. This confirms the need to prioritize improvement efforts in these critical workstations.

Process Stability and Sigma Level

The p-chart analysis revealed that the monthly defect proportion largely fell between the Upper Control Limit (UCL = 0.012) and the Lower Control Limit (LCL = 0.001), with a Center Line (CL = 0.0063). This indicated that the process was statistically stable, although the defect proportion remained above the desired target of zero defect [1].

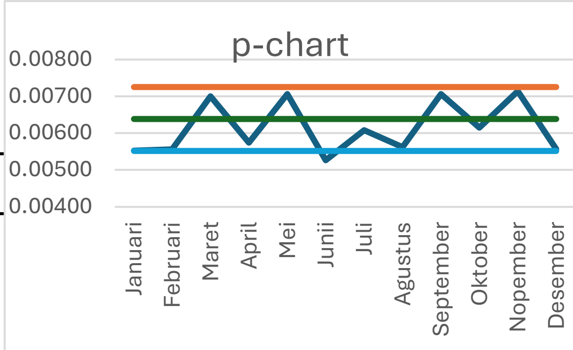

Figure 8. P-chart of monthly defect proportion.

Figure 8. Graphical visualization of monthly production quality performance, including Defects per Opportunity (DPO),

Current Value Stream Mapping (VSM)

In the context of Lean Six Sigma analysis, Current Value Stream Mapping (CVSM) is utilized to identify the flow of materials and information throughout the production process. This tool helps in visualizing both value-added and non-value-added activities, enabling the identification of bottlenecks and sources of waste. In order to illustrate the CVSM, a comprehensive recapitulation of process time values has been conducted, as presented in the

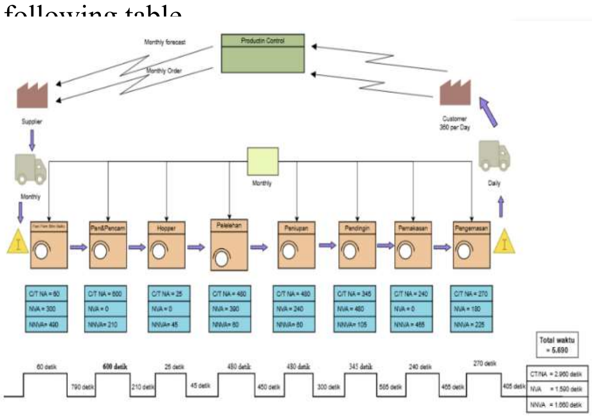

Figure 9 Current Value Stream Mapping

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The Current State VSM showed a total production lead time of 3,690 seconds, with non-value-added (NVA) activities dominating at 52% of the total. Process Activity Mapping (PAM) identified the highest waste at Cooling & Mold Release (660 seconds), Raw Material Receiving & Inspection (610 seconds), and Melting (450 seconds). After improvement initiatives, the Future State VSM indicated a reduced lead time of 2,980 seconds, with the Value-Added (VA) proportion increasing from 32% to 48% [4], [5].

Analyze Phase

The Analyze phase aims to identify the root causes of time waste and product defects in the plastic ball production process. Two main tools were applied, namely Process Activity Mapping (PAM) and the Fishbone Diagram.

The PAM results show that the total process time reached 5,690 seconds, with more than half spent on non-value-added (NVA) and necessary but non-value-added (NNVA) activities. The stations with the highest waste were Cooling & Mold Release, Raw Material Receiving & Inspection, and Melting. These findings indicate excessive waiting, transportation, and storage activities that reduce process efficiency.

The Fishbone analysis further revealed that defects are mainly caused by several factors: human (lack of training and accuracy), machine (unstable temperature, worn molds, blunt trimming tools), method (inconsistent or absent SOPs), material (moist or non-homogeneous raw materials), and environment (uncontrolled temperature, humidity, and cleanliness).

The most dominant defects are melted/deformed balls (21.57%) and flash/burrs (19.30%), which primarily occur during the Melting, Cooling, Blow Molding, and Trimming stages. Together, these two defects account for more than 40% of total rejects, making them the top priority for improvement.

4.4 Improve Phase

In the Improve phase, improvement proposals are developed with a focus on reducing process time and enhancing product quality based on the types of defects identified during the Analyze phase

Proposed Time Improvement Based on Process Activity Mapping (PAM)

From the Process Activity Mapping table (after improvement / Future State), the activities can be categorized as follows, VA (Value Added): activities that directly add value to the product (main operations such as mixing, molding, blow molding, trimming, and packaging), NVA (Non Value Added): activities that do not contribute any value, such as storage or waiting delays. NNVA (Necessary but Non Value Added): activities that do not add value but are still necessary, such as inspection and transportation.

The following table presents the recapitulation of the proposed improvements based on value categorization:

Table 3. Recapitulation of Proposed Activity Improvements Based on Value Categorization

Activity Category	Frequency (times)	Time (seconds)	Percentage (%)
VA (Value Added)	8	2,320	55.1%
NNVA (Necessary but Non Value Added)	14	1,160	27.6%
NVA (Non Value Added)	8	730	17.3%
Total	30	4,210	100%

These data can be illustrated in the following Future Value Stream Mapping (FVSM)

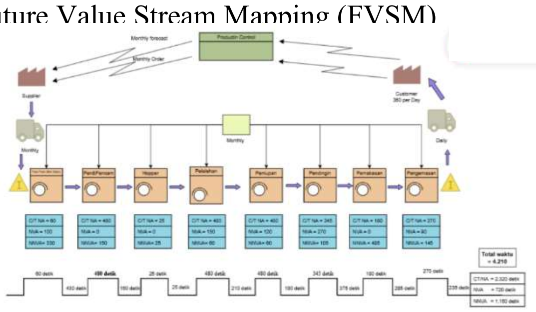

Figure 10. Future Value Stream Mapping

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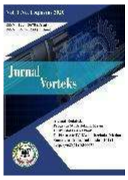

Proposed Improvements Based on 5W+1H and Quality Priorities

Using the **5W+1H framework**, key problems across production stages were identified and addressed through calibration, automation, SOPs, preventive maintenance, and operator training. Major issues included non-uniform mixing, unstable melting, flash defects, mold-related deformations, and poor trimming quality.

Based on Fishbone and Pareto Analysis, the top priorities are ball deformation (21.57%) from melting/cooling and flash defects (19.30%) from blow molding/trimming, together accounting for over 40% of defects. Subsequent priorities include dented balls, rough surfaces, and other minor defects. The main improvement focus should therefore be stabilizing melting and cooling processes, reducing flash, and strengthening operator skills and SOP standardization to achieve continuous quality enhancement.

Control Phase

The Control phase is the final step of DMAIC, ensuring the sustainability of improvements from the Improve stage. At UD. Billa Bola, controls focus on the main defect sources: Melting, Blow Molding, Cooling & Mold Release, and Trimming.

Routine inspections, preventive maintenance, QC sampling, control charts, and internal audits are applied to maintain stable processes. This ensures defects remain low, SOP compliance is consistent, and product quality is sustained.

Table 4. Countermeasures / Control Actions

No.	Subject Controlled	Frequency	Inspection Criteria	Responsible
1	Melting Process	Every shift	Stable temp. (±200–220°C), homogeneous melt	Operator & QC
2	Blow Molding Machine	Daily (start & end shift)	Air pressure & blowing time per SOP	Production Operator
3	Mold & Cooling	Daily + Weekly	Clean mold, stable cooling	Technician & Operator
4	Trimming	Every batch	Neat cut, flash ≤ 2 mm	Operator & QC
5	Raw Materials & Mixing	Each receipt & mixing	Calibrated scale, homogeneous mix	QC & Operator
6	Finished Products (QC Sampling)	1 per 500 pcs	Even color, round, smooth, no cracks	QC
7	Preventive Maintenance	Daily–Monthly	No unexpected downtime	Technician
8	P-Chart & Sigma Level	Monthly	Defects ≤ 0.65%, Sigma ≥ 4.20	QC & Management
9	Internal Audit	Every 3 months	SOP compliance ≥ 90%	QA / Management

CONCLUSION

The application of Lean Six Sigma (LSS) at UD. Billa Bola demonstrated significant improvements in product quality and process efficiency. The defect rate was reduced from 4.6% to 2.8%, sigma level improved from 3.2 to 3.5, and production lead time decreased by 710 seconds. The proportion of value-added activities increased from 32% to 48%, while production capacity rose by 15%. Root cause analysis confirmed that human factors, machine instability, material variability, and inadequate quality control methods were the dominant contributors to defects, all of which were mitigated through standardized procedures, preventive maintenance, operator training, and in-line inspection.

These findings reinforce the applicability of LSS in SMEs, proving that structured quality improvement can be achieved even in resource-

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constrained environments [1], [2], [3] For practitioners, the study provides practical insights into implementing LSS within small-scale manufacturing, while for academia, it contributes to the limited empirical evidence on LSS in SMEs. Future research may focus on expanding LSS applications across other SME sectors and evaluating long-term sustainability of implemented improvements.

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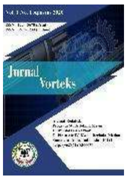

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