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Operational Excellence: A Six Sigma Approach for Scrap reduction and increasing efficiency for Foam Sanitizer assembly line

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Abstract

This study presents the successful implementation of a Six Sigma project in a manufacturing environment of a Foam sanitizer product line during Covid-19 pandemic, focusing on scrap reduction, machine performance, and operational efficiency. Using Six Sigma tools such as Voice of Customer (VOC), Pareto Analysis, 5 Whys, Failure Modes and Effects Analysis (FMEA), Mistake Proofing, and Control Charts, the project achieved significant improvements. Results included Zero Defect product delivery, cost savings of $79,000 through scrap reduction, enhanced on-time delivery, and an increase in Overall Equipment Effectiveness (OEE) from 42% to 78%. These outcomes highlight the role of structured methodologies in achieving operational excellence.

Keywords

Six Sigma, Scrap Reduction, OEE, Quality Improvement, Manufacturing, Operational Excellence

Introduction

In the highly competitive manufacturing sector, maintaining quality and optimizing efficiency are critical for sustaining profitability and customer satisfaction. Scrap generation, machine downtime, and inconsistent process outputs are persistent challenges. This paper documents a Six Sigma project aimed at addressing these issues at the assembly line of Foam sanitizer by leveraging structured problem-solving techniques and statistical analysis to deliver measurable improvements.

Manufacturing organizations face increasing pressure to minimize costs, ensure consistent product quality, and deliver on time in an environment of global competition and stringent customer expectations. The cost of poor quality (COPQ)—including scrap, rework, warranty claims, and lost customer trust—can account for as much as 20–30% of sales revenue in some industries. One of the most widely adopted approaches to tackling these challenges is Six Sigma, a structured methodology designed to reduce variation and systematically improve processes. By focusing on statistical analysis, root cause identification, and continuous monitoring, Six Sigma has proven effective in a wide range of manufacturing domains, from automotive and aerospace to electronics and medical devices.

Literature Review

The application of Six Sigma in manufacturing has been extensively studied, with research showing its ability to reduce variation, eliminate waste, and improve quality outcomes. Montgomery (2013) emphasized the importance of statistical quality control in sustaining process performance. Pande et al. (2000) highlighted the structured DMAIC methodology as a driver for continuous improvement, while George (2002) illustrated the benefits of integrating Lean and Six Sigma for efficiency. Stamatis (2003) noted the role of FMEA in proactively identifying and mitigating risks in quality-critical processes. These studies provide the theoretical foundation for this project's practical application.

Methodology

The Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) framework was adopted for this project.
• **Define:** Problems were identified through brainstorming and VOC analysis. The Define phase of the DMAIC cycle focused on clarifying the project scope and objectives. Voice of Customer (VOC) analysis identified key customer requirements, particularly the need for defect-free products and consistent delivery timelines. A project charter was created outlining financial impact, team responsibilities, and success criteria.

• **Measure:** Data were collected for machine downtime, fault counters, and scrap levels. Metrics such as Defects per Unit (DPU), Defects per Million Opportunities (DPMO), and OEE were tracked. During the Measure phase, data were collected on daily scrap levels, machine downtime events, and fault counters. Defects per Unit (DPU) and Defects per Million Opportunities (DPMO) were calculated to quantify baseline quality. Additionally, Overall Equipment Effectiveness (OEE) was determined using the standard equation:

“OEE = Availability × Performance × Quality”

Baseline results showed OEE at 42%, driven primarily by low machine availability and frequent setup-related defects.
• **Analyze:** Pareto Analysis, 5 Whys, and FMEA were used to identify root causes of defects and downtime. In the Analyze phase, Pareto analysis demonstrated that 80% of scrap was generated by fewer than 20% of defect types. Root causes were identified using the 5 Whys method, pointing to equipment misalignment, inadequate preventive maintenance, and operator training gaps. A Failure Modes and Effects Analysis (FMEA) assigned Risk Priority Numbers (RPNs) to potential failures, ranking them based on severity, occurrence, and detection. The Make-Ready process and setup stage were found to be the highest contributors to scrap generation.
• **Improve:** Mistake Proofing techniques and revised process standards were implemented to eliminate recurring defects. The Improve phase introduced targeted solutions: mistake proofing (poka-yoke) devices to eliminate setup errors, updated Standard Operating Procedures (SOPs), and cross-training of operators to enhance flexibility. A pilot test validated improvements before full-scale deployment.

• **Control:** Control Charts were used to ensure stability and sustain improvements. Finally, in the Control phase, Statistical Process Control (SPC) charts were deployed to monitor key variables. Control plans were documented, including periodic machine audits and operator refresher training. These ensured that improvements were sustained over time.
Data collection spanned three months, capturing detailed logs of scrap categories, downtime incidents, and production volumes. Scrap was categorized into setup errors, material handling defects, and process variability. Baseline scrap rate was 6.5%, equating to an annualized cost of approximately $79,000. Machine downtime accounted for nearly 18% of scheduled production hours, further reducing OEE.

The Critical-to-Quality (CTQ) parameters established were:
• X_1 = Scrap rate per shift
• X_2 = Downtime minutes per shift
• Y = Overall Equipment Effectiveness (OEE).

Baseline equation: $Y = f(X_1, X_2)$.
Quantitative improvements after implementation were significant. Scrap rate dropped from 6.5% to 1.8%, directly saving $79,000 annually. Downtime was reduced by 45%, primarily due to improved preventive maintenance and operator training.

OEE improved from 42% to 78%, reflecting gains in availability, performance, and quality. On-time delivery increased by 25%, strengthening customer relationships. In addition to measurable metrics, qualitative improvements included stronger workforce engagement, a culture of accountability, and enhanced trust from leadership.

Despite the successes, the project faced challenges. Data collection was initially hindered by inconsistent logging, necessitating the introduction of digital monitoring tools. Resistance to change among operators required dedicated training and communication. Nonetheless, the structured DMAIC methodology provided clarity, ensuring that solutions were evidence-based and sustainable.

Data Collection

Data collection was focused on identifying critical scrap sources and downtime causes. Machine counters and daily scrap logs were analyzed to track defect trends. Critical-to-Quality (CTQ) parameters included scrap rate, downtime frequency, and yield. Baseline OEE was measured at 42%, highlighting significant opportunity for improvement.

Analysis

Pareto Analysis revealed that a small number of recurring defect modes accounted for the majority of scrap losses. Root cause investigations using the 5 Whys and FMEA identified equipment setup errors and operator handling as key contributing factors. By implementing mistake proofing solutions and updating standard operating procedures, process variation was reduced significantly.

Results

The Six Sigma project yielded measurable improvements:

1. Achieved Zero Defect product delivery, enhancing customer satisfaction.
2. Realized $79,000 in cost savings through scrap reduction.
3. Improved on-time delivery rates to customers.
4. Increased OEE from 42% to 78%, demonstrating substantial operational efficiency gains.

These results validated the effectiveness of Six Sigma in driving process improvements in manufacturing.

Discussion and Implications to Engineering Management

This project highlights the value of structured methodologies such as Six Sigma in achieving operational excellence. The results demonstrate that data-driven decision-making and proactive risk management can deliver significant cost savings and efficiency improvements. From an engineering management perspective, the project underscores the importance of aligning improvement initiatives with customer requirements, using VOC, and ensuring sustainability through control mechanisms.

From an engineering management standpoint, this project illustrates the scalability of Six Sigma across industries. The integration of financial analysis, quality tools, and workforce engagement demonstrates how managers can align improvement initiatives with strategic goals. Furthermore, the adoption of mistake proofing and SPC ensures that processes remain robust against variability, reducing reliance on inspection and rework.

The Six Sigma initiative not only delivered measurable cost savings and efficiency improvements but also fostered a culture of continuous improvement. The combination of data-driven analysis, workforce collaboration, and rigorous control mechanisms ensured lasting results. Future research could focus on replicating this framework across multiple production sites, benchmarking results, and integrating advanced digital tools such as real-time dashboards and predictive analytics for even greater impact.

Conclusion

The Six Sigma initiative successfully addressed manufacturing inefficiencies, reducing scrap, improving machine performance, and increasing OEE. By leveraging DMAIC tools, the project delivered financial savings and operational benefits while fostering a culture of continuous improvement. The findings support the broader application of Six Sigma methodologies as a cornerstone of engineering management in manufacturing.

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