Streamlining Manufacturing Operations Through Lean Six Sigma and Industrial Automation

Author: Yaití Rivera Sánchez
Advisor: Dr. José A. Morales Morales
Polytechnic University of Puerto Rico Graduate School

Abstract

This pharmaceutical packaging design project integrates Lean Six Sigma principles and industrial automation to optimize a manual-intensive process. Focused on loading/unloading, visual inspection, and palletizing, the improvements include automated systems, such as cameras for inspections and robotic lifts for loading and palletizing. The study reveals a substantial reduction in cycle time, from 93 to 72 minutes, showcasing a 20% improvement. Statistical analysis indicates significant results ($p < 0.001$), validating the effectiveness of the enhancements. The streamlined process aligns with Lean principles, emphasizing efficiency, waste reduction, and improved quality control. The project contributes to operational excellence, offering a competitive edge in the pharmaceutical industry.

Introduction

Optimizing packaging processes in today's dynamic pharmaceutical manufacturing landscape is paramount for ensuring operational efficiency and product quality. The complexities inherent in pharmaceutical packaging, compounded by stringent regulatory requirements and market demands, necessitate a meticulous approach to process enhancement. This research addresses the challenges faced by pharmaceutical packaging lines, particularly in streamlining manual interventions, improving operational efficiency, and enhancing quality assurance mechanisms. By integrating principles of Lean Six Sigma and industrial automation, this study aims to revolutionize traditional packaging processes, paving the way for enhanced productivity, reduced errors, and heightened competitiveness in the pharmaceutical industry. Through a comprehensive analysis of the existing shortcomings and the strategic implementation of innovative solutions, this research seeks to establish a foundation for a more efficient and agile pharmaceutical packaging sector.

Background

In the quest for operational excellence, industries have turned to methodologies like Lean Six Sigma to optimize production processes; Lean Six Sigma integrates Lean principles aimed at waste reduction and flow enhancement with Six Sigma methodologies, which target process variation and defect reduction. This hybrid approach empowers organizations to deliver high-quality products or services efficiently. With its widespread adoption across industries, Lean Six Sigma has become synonymous with operational excellence and continuous improvement.

Problem

The packaging process at a manufacturing facility is beset by inefficiencies, leading to extended cycle times and resource wastage. These inefficiencies are primarily caused by manual handling during loading and unloading, as well as the reliance on visual inspection for quality control. Addressing these challenges is crucial to improving productivity and streamlining operations. Thus, the research objectives focus on implementing Lean Six Sigma principles and automation to optimize the packaging process, reduce cycle times, and enhance overall efficiency.

Methodology

In streamlining manufacturing operations through Lean Six Sigma and Industrial Automation, the methodology encompasses a structured process that integrates crucial principles and technologies to enhance efficiency and quality in the pharmaceutical packaging process.

Process Cycle time Study		
Task	Action	Time (min)
Manual Unloading from Forklift	Forklift unloads 14,000 bottles pallets, divided into cases of 400 bottles	8
Manual Loading onto Conveyor	Cases are manually placed on a conveyor	7
Turntable 1	Cases are push into Turntable 1	6
Conveyor Tunnel	Cases pass through a conveyor tunnel with a counting sensor for individual vial accountability	4
Turntable 2	Vials are transported to the Cartoner 1	5
Cartoner 1	Automated Process for putting the bottles into boxes	5
Wrapper	Boxes are wrapped together	8
Turntable 3 to QC Box	Turntable to QC station	5
QC Station	Visual inspection done by an operator	5
Cartoner 2	Four sets of wrepped boxes are packaged in Cartoner 2	12
Turntable 4 to labeler	The truntable takes boxes to the labeler	5
Labeler	Boxes go through a labeler, an automated process that sticks shipping labels	3
Batch Record Entry	Batch record data	5
Release Approval	Verification of data realise batch for shipping	5
Final Conveyor to Pallet	Boxes are manually loaded onto the final conveyor, which leads to pallet loading	10
Cycle Time		93

Figure 1. Process Cycle Time Study

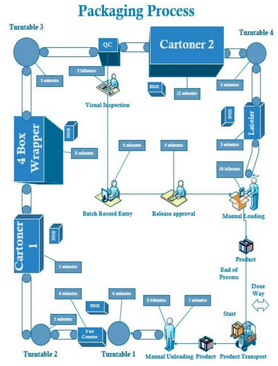

Figure 2. Packaging Process Cycle Time

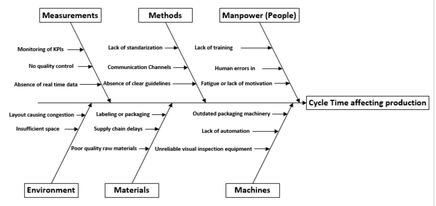

Figure 3. Packaging Process Cause and Effect Diagram

The fishbone diagram was pivotal in pinpointing the root causes of inefficiencies in the pharmaceutical packaging process. Organizing potential factors contributing to delays and bottlenecks provided a structured framework for analysis. This visual tool helped identify critical areas for improvement, guiding targeted solutions to streamline operations and boost efficiency.

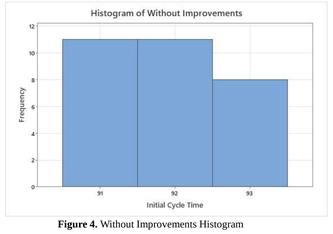

Figure 4. Without Improvements Histogram

Figure 4 illustrates the distribution of cycle times without improvements, ranging from 91 to 93 minutes. In this case, the histogram would likely show a peak around the average of 91 minutes, with fewer occurrences as the cycle time increases or decreases from this average. This visualization helps to understand the variation in cycle times and identify any trends or patterns in the data before implementing improvements.

Results and Discussion

This section presents the outcomes of the applied methodology to streamline manufacturing operations in the pharmaceutical packaging process. It also follows the logical order established in the Methodology, highlighting key findings and their implications.

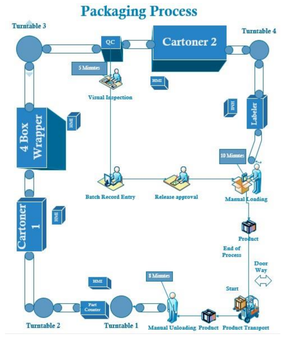

Figure 5. Packing Process Kaizen

Figure 5 shows the Kaizen methodology employed to drive principles; small incremental changes were systematically implemented to enhance continuous improvement in the loading/unloading and visual inspection areas.

Improvements Implementation	
Task Improved	Time (min)
Automated Unloading from Forklift	3
Automated Loading onto conveyor	2
Turntable 1 (No change)	6
Conveyor Tunnel (No change)	4
Turntable 2 (No change)	5
Cartoner 1 (No Change)	5
Wrapper (No change)	8
Turntable 3 to QC Box (No change)	5
Visual Inspection Station	1
Cartoner 2 (No change)	12
Turntable 4 to labeler (No Change)	5
Labeler (No change)	3
Automated Palletizing	5
Electronic Batch Recod Entry	4
Electronic Release Aproval	4
Cycle Time	72

Figure 6. Process Cycle Time Study After Improvements

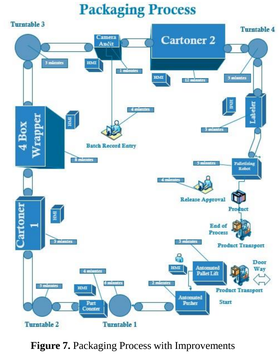

Figure 7. Packaging Process with Improvements

Figure 6 illustrates the implemented improvements in loading/unloading and visual inspection alongside the time allocated for each step in Figure 7.

Figure 8. With Improvements Histogram

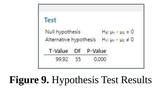

Figure 9. Hypothesis Test Results

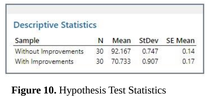

Figure 10. Hypothesis Test Statistics

Figure 6 displays the distribution of cycle times after implementing improvements, ranging from 69 to 72 minutes. The histogram shows a peak at the cycle time of 72 minutes, indicating that this is the most common cycle time after improvements. Figures 9 and 10 show the hypothesis test conducted to validate the significance of the improvements made in the process. The obtained p-value of 0.000 indicates that the average reduction achieved through the implemented improvements is statistically significant. This validation underscores the impactful nature of the enhancements made to the process.

Conclusions

The culmination of this design project signifies a significant stride in addressing the pressing challenges faced by the pharmaceutical industry in optimizing its packaging processes. The research was driven by meticulous examination and redesign of the manual aspects of the pharmaceutical packaging process, incorporating Lean Six Sigma principles and industrial automation technologies.

Figure 11. Cycle Time Comparison Without and With Improvements

Figure 11 shows the boxplot diagram comparison, which illustrates the distribution of cycle times before and after implementing improvements in the packaging process.

Future Work

As with any transformative project, avenues for future research emerge. Subsequent studies could further refine automation technologies, continuous improvement methodologies, and integration of emerging Industry 4.0 technologies.

Acknowledgements

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