1st World Congress on Industrial Engineering and Operations Management
October 9-11, 2024
Publisher: IEOM Society International, USA DOI:10.46254/WC01.20240024
Published: October 09,2024,

Optimization of the Processes in the PAI 1.75lts Palletizer of the Coca-Cola Bottling Plant

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Abstract

The Coca-Cola bottling plant in Cayey, founded in 1995, initially manufactured 5 products. Today, it produces more than 500 different flavors, making it the largest production line bottler in Puerto Rico, operating 24/7. Since 2018, the main problem reported in the PAI 1.75 Lts palletizer has been downtime due to embedded pallets, which accounted for 31.60% of the total downtime in 2022 and 18.51% in 2023. In October 2023, we started our continuous improvement university degree completion project using the Six Sigma methodology (DMAIC) to address this problem. During the "Define" phase, it was observed that the palletizer suffered the most downtime during shift B (52.44% in 2023). We evaluated the entire process, identifying suppliers and inputs, and mapping the stages from the arrival of the product at the palletizer to its exit. A SIPOC diagram detailed the process's inputs, outputs, and customers. Additionally, we analyzed the conditions of the conveyor chains and personnel training to ensure a continuous and safe flow at the station. The goal of the project is to reduce downtime in the PAI 1.75 Lts palletizer to a target of 125 minutes per month, optimizing the process to increase productivity and safety. After completing all stages, we present short- and medium-term solutions to be implemented in the PAI 1.75 Lts palletizer, including the creation of an SOP, maintenance, and troubleshooting guide. According to the results obtained and the ROI analysis, an increase of 66% in production could be achieved after implementing the improvements suggested by our study.

Keywords:
DMAIC, efficiency, palletizer, production, distribution, Lean Six Sigma, downtime

Introduction
Coca-Cola is one of the largest and most recognized beverage companies worldwide, producing and distributing a wide range of beverages including sodas, bottled waters, juices, and other non-alcoholic beverages. The Coca-Cola bottling plant in Cayey, founded in 1995, started with 5 products and has grown to over 500 different products. It is the largest production line bottler in Puerto Rico, operating 24/7. In 2020, the Cayey bottler received the "Quality Excellence Award" among all other Coca-Cola plants in the United States and Canada.

In mid-October 2023, we initiated a Capstone Project of continuous improvement using the Six Sigma DMAIC methodology. In our first meeting, we identified key stakeholders, determined their level of influence, and established a clear understanding of the production department's challenges. A confidentiality agreement was signed by both parties, ensuring that sensitive company information would not be disclosed and that all collected data would be discussed with Production Manager José Lefevre and Process Engineer Giancarlo Sánchez before publication.

Since 2018, the production department reported that the main cause of downtime in the PAI 1.75 Lts palletizer was due to pallets getting embedded in different stations. In 2022, these "embedded pallets" accounted for 11,267 minutes of downtime, representing 31.60% of total downtime. From January to November 2023, they reported 5,157 minutes, representing 18.51% of the total downtime. Over the past five years, “embedded pallets” remained the main issue for the PAI 1.75 Lts palletizer. In 2022, 37.07% of downtime was reported in shift A and 63.93% in shift B. In 2023, shift A reported 47.56%, and shift B 52.44% of the total downtime.

1.1 Objectives

The purpose of this project is to undertake a continuous improvement initiative for the Coca-Cola bottling plant in Cayey, leveraging the Six Sigma DMAIC methodology. Our primary goal is to reduce the downtime on the PAI 1.75 palletizer to a target of 125 minutes per month, optimizing the process in the palletizer. Additionally, during our project, we aim to reduce waste and increase safety for both the operator and the end customer.

2. Methods

For this study, we formulated a data collection plan, and established variables based on observations. Data collection began in late November 2023 and continued until mid-January 2024, at the Coca-Cola bottling plant in Cayey, specifically in the PAI 1.75L palletizer. Our population was the pallets from CC Pallets Puerto Rico, with each pallet counting as a unit. Considering a 90% confidence level, a 5% margin of error, and a monthly output of 4,000 to 4,500 pallets, our sample size varied between 250-270 data points. To establish an effective time study, we divided the palletizer process into five phases or stations: (1) Exterior Conveyor A, (2) Fork-car, (3) Product / Cardboard, (4) Wrapping, (5) Exterior Conveyor B. Each station was chosen for its functional change within the palletizer and frequent points of failure or "Downtime." We collected numerical data in time intervals (minutes - continuous quantitative data) per pallet, considering color (cream, blue, or red), weight (70lb-110lb), and state (new or remanufactured). During our investigation, external offenders were also considered for our final data findings using stratified and systematic sampling.

External conditions to consider include:

- Shift in progress (Shift A or Shift B)
- Number of operators available to the palletizer
- Operators' experience with the palletizer
- Production season (high or low)
- Pallet conditions (new or remanufactured)
- Delays outside the palletizer affecting its production
- External human delays (warehouse or filling) not due to mechanical failure

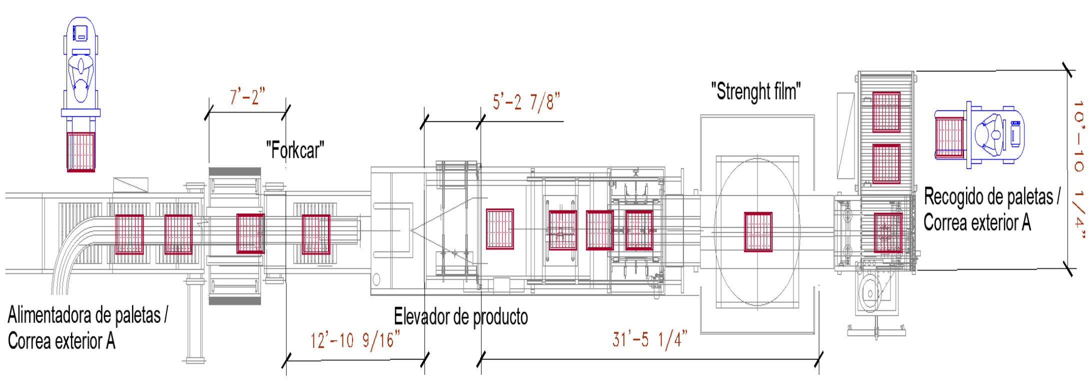

Figure 1. PAI 1.75 Lts Palletizer with all the five stations identified and the dimension of each one.

Quantitative data was collected using a stopwatch and documented in Microsoft Excel. We ensured consistency and accuracy by following the same data collection steps and using reliable measurement tools. Weekly quality checks identified and corrected potential errors, ensuring consistency in data collection to identify variations and trends over time.

2.1 Five Why Analysis

To analyze the root cause of the problem, we began by creating the Five Whys Diagram (Why do pallets jam in the PAI 1.75L palletizer?). The first answer was due to mechanical issues like faulty proximity sensors, worn or misaligned belts, or cycle disruptions. When we asked why these mechanical issues existed, we found that preventive inspections were lacking in adjusting or replacing parts before failure. Moreover, they did not inspect pallet quality or ensure compliance with the entry limit. Further questioning revealed that there was no SOP for the palletizer to guide these preventive procedures. Additionally, there was no operator training on equipment use, resulting in ad-hoc training by experienced operators. Finally, the lack of continuous control and improvement process for the palletizer was identified. Therefore, establishing a training process, documentation, and SOP for preventive inspections is crucial to avoid waiting for sensor failures or belt wear before replacement. The 5 Whys analysis revealed that mechanical problems, such as worn sensors and conveyor belts, were due to a lack of preventive inspections and the absence of a Standard Operating Procedure (SOP). This lack of preventive maintenance and training led to frequent jams. Observations and data collection showed that 37% of delays were mechanical and 63% were human errors.

2.2 Ishikawa Diagram

In the maintenance branch, we found two faulty proximity sensors on the input conveyor, causing pallets to jam when the sensor failed to stop them in time. Additionally, we observed two worn belts at the wrapping station, causing pallets to jam in the exit rail and requiring manual intervention to push the pallets forward. In the Forklift Operators section, we noted operators placing pallets in a zigzag pattern on the input conveyor, causing jams at the Fork-car station. Occasionally, operators placed more than six pallets in the input column, causing jams at the Fork-car station. For standardization, we found that Fork-car measurements and palletizer cycles were not standardized, leading to jams when the machine went out of cycle or did not meet Fork-car measurements. Regarding material, pallets varied in weight, ranging from 70 to 110 pounds. However, 80% of the pallets received at the station were remanufactured and sometimes did not meet standard weights and measurements. Therefore, creating an SOP to monitor measurements and conditions of palletizer parts is essential to avoid replacing them after causing production delays. Additionally, training operators on proper station use is crucial.

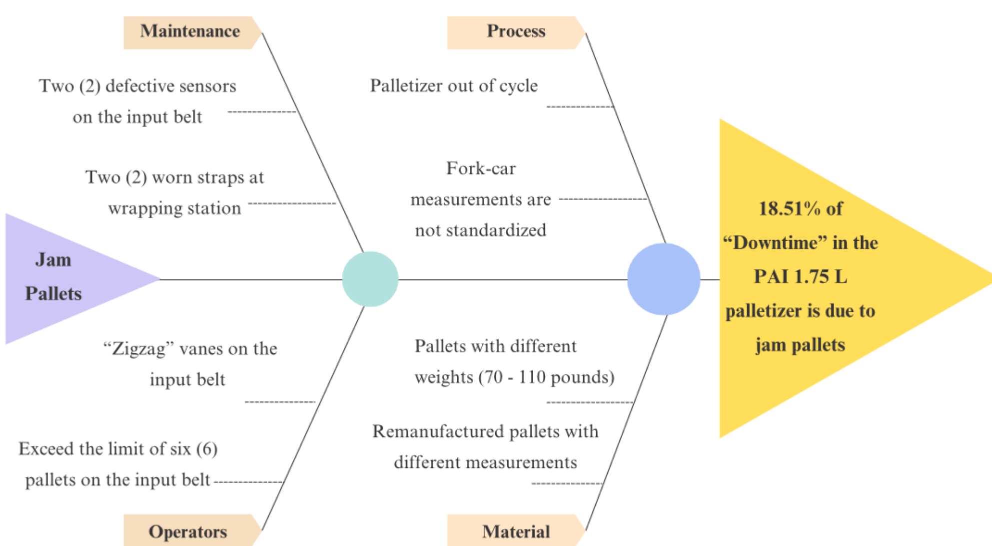

Figure 2. Fishbone diagram of the Jam Pallets at the PAI 1.75 Lts Palletizer

3. Statistical Analysis

We categorized the data according to the reasons why the production line stopped. Found that the maximum time per pallet (unit) was 60 minutes vs the normal time of 12-14 minutes. While the minimum unit time was of 11 minutes where a normal flow is documented without interruptions per station.

3.1. Pareto Analysis

This graph shows the variable of "Waiting for the Forklift at exit conveyor B" being the principal reason for downtime at the PAI 1.75 palletizer, representing 60% of the total downtime reported in our observations. The total minutes of this variable was of 1,500 minutes while the total of downtime observed was of 2,500 minutes.

Pareto of Variables and Downtime in Minutes at the PAI 1.75 Lts

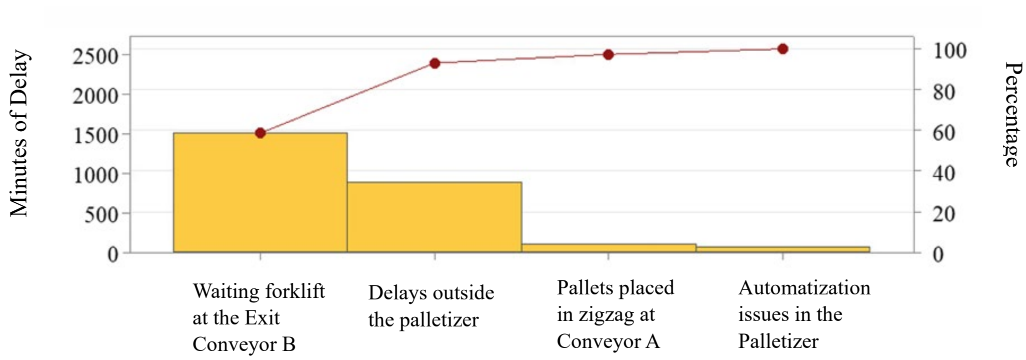

Figure 3. Pareto Diagram of the downtime in minutes for all the observed variables at PAI 1.75 Lts Palletizer

3.2. Marginal Plot Analysis

In this analysis, we found that the final station of the palletizer (variable named "Correa Exterior B") has a direct relationship with the downtime observed at the PAI 1.75 palletizer. This means that the exit station required more attention for improvement efforts since it is the bottleneck of the operation. These results suggest there is a correlation between downtime and the station of "Correa Exterior B".

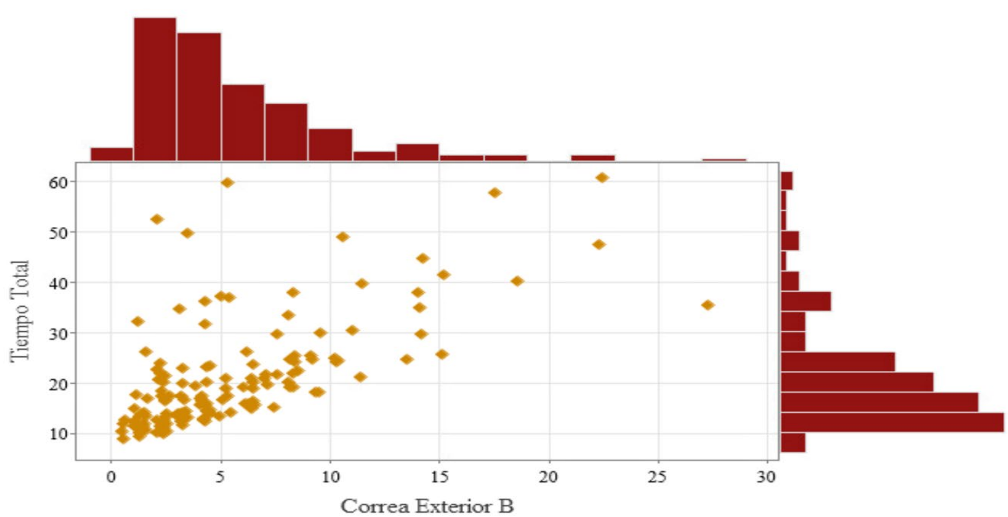

Figure 4. Marginal Plot of the total downtime in the external conveyor B

3.3. Hypothesis Testing:

We conducted hypothesis testing with data from November 2023 to January 2024 at the PAI 1.75L palletizer at the Coca-Cola bottling plant. We considered stakeholder and operator opinions and numerical data for our hypothesis analysis.

First Hypothesis:

Initial hypothesis: The primary cause of "Downtime" is pallet quality.
Alternate hypothesis: The main causes affecting palletizers are human error, material shortages, and mechanical failures.
The alternate hypothesis was accepted, as our data from November 2023 to January 2024, showed that 54.69% of "Downtime" was due to human error, while pallet quality (both remanufactured and new) did not significantly impact palletizer performance. Moreover, the new pallets were affected by the downtime in higher proportions than the remanufactured ones.

Second Hypothesis:

Initial hypothesis: Forklift waiting caused the most "Downtime" in the palletizer.
Alternate hypothesis: Forklift waiting caused significant "Downtime," but not the main offender due to its variability.
The alternate hypothesis was accepted, as forklift waiting accounted for 54% of "Downtime," but mechanical and automation failures caused the highest cycle times, with variations from 45 to 60 minutes. Mechanical and automation failures had a 53.66% process variation with potential special causes.

Third Hypothesis:

Initial hypothesis: The process is not directly affected by seasonal changes.
Alternate hypothesis: The process is affected by seasonal changes.
The alternate hypothesis was accepted, as high production seasons increased pallet cycle times by 10-15 minutes, exceeding normal station times. Seasonal hiring of less experienced operators contributed to this impact.

4.Results and Discussion

We identified the root cause of jammed pallets in the PAI 1.75L palletizer, confirming that human error, material shortages, and mechanical failures were the primary offenders. All of these could be corrected with a structured plan for improvement implementation, including leadership commitment, Lean training, performance audits, documentation, and monitoring. The results were presented and discussed with the stakeholders and after consultation, the following specific improvement actions were identified:

- Organize manual controls by function and label them correctly.
- Replace input conveyor sensors with proximity sensors to prevent jams.
- Standardize Fork-car measurements using parallel palletizer guidelines.
- Standardize pallet entry and exit procedures, ensuring compliance with established limits.

4.1 Cycle Time Comparison

The production team of Coca-Cola decided to implement several solutions discussed with the engineering team. Selected improvements included replacing two proximity sensors on the input conveyor, improving cycle times, and enhancing visual controls for manual operations. We collected 30 samples to verify the implemented improvements' effects on palletizing cycle times and conducted a Kaizen for continuous improvement implementation. The cycle time after the improvements shows a reduction of 50% of the downtime. Before the improvements were made the maximum time for a pallet was 60 minutes, after the improvements the total maximum time observed was 16 minutes.

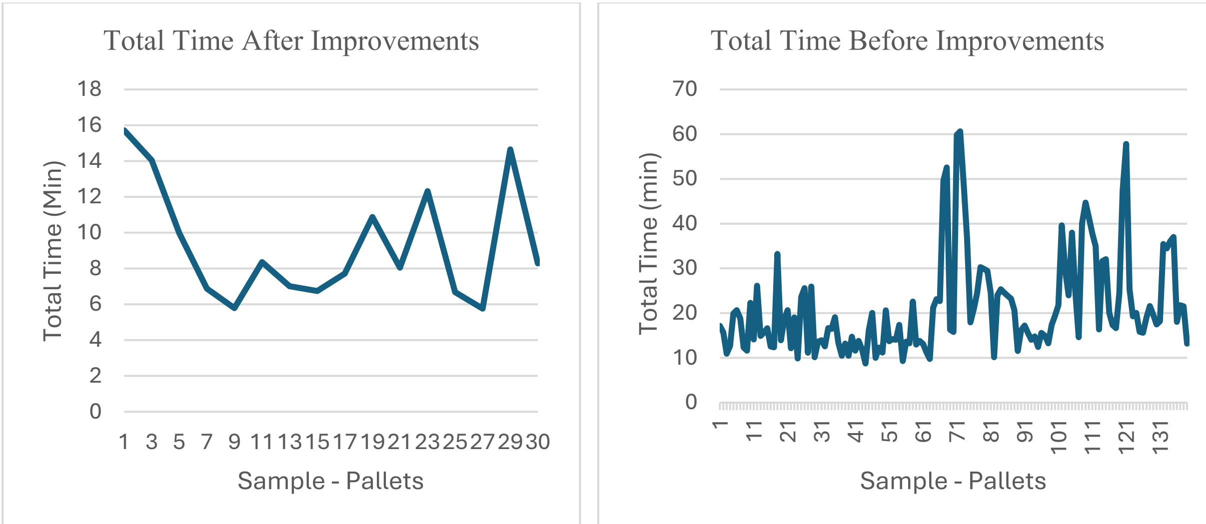

Figure 5. Time graph before and after the improvements in the PAI 1.75 Lts palletizer

Following a critical meeting with stakeholders, we presented data and highlighted analysis points, demonstrating that pallet quality was not the main palletizer offender. We emphasized operator training urgency, as 54% of "downtime" was related to material handling by forklift operators. Stakeholders expressed concerns about pallet quality but agreed to continue with the proposed improvements. Lastly, we developed an SOP for the company evaluation and implementation taking into consideration the continuous monitoring of the improvements' impact to ensure the alignment with business objectives and for them to make the necessary adjustments. We suggested constant communication and feedback at all organizational levels for acceptance and success.

4.2 Economic Analysis

The total investment proposed was $100,000.00, covering material costs, implementation costs, continuous training costs, operational costs, and SOP and additional costs. The projected additional production was 10,556 pallets per year, with annual savings of $13,722.80. The ROI was calculated to be 7 days, ensuring cost recovery within the first year.

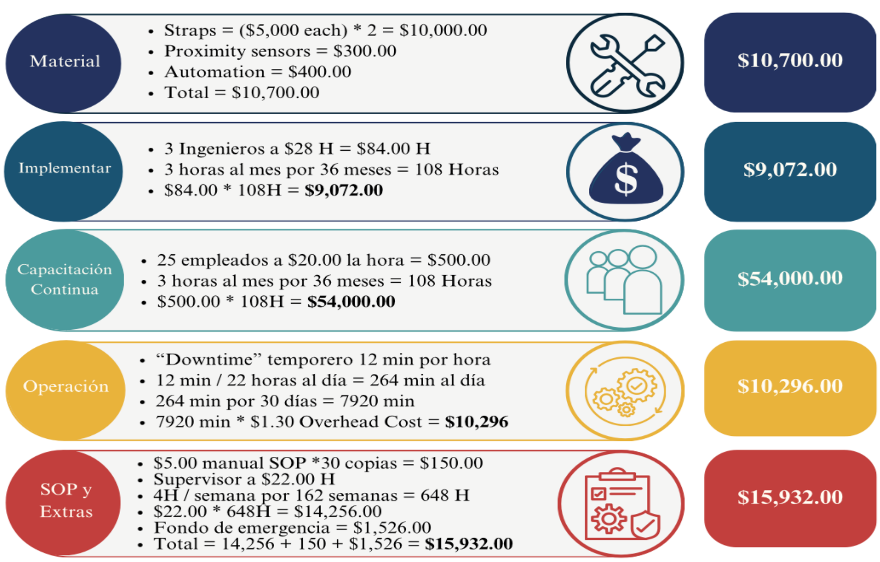

Figure 6. Details of the investments proposed at the PAI 1.75 Lts palletizer

The total investment over the three-year implementation period was calculated to be $100,000. An analysis of the return on investment (ROI) was prepared to explain to the project stakeholders the benefits of this investment. The current production rate was 3 pallets per hour, amounting to 1,800 bottles per hour, with pallets taking 20 minutes to pass through all the palletizer stations. With the proposed improvements, it was expected to achieve 5 pallets per hour, equating to 3,000 bottles per hour. This meant each pallet would take 12 minutes to pass through the palletizer stations, reducing production time by 16 minutes per hour. This reduction would result in an additional 352 minutes per day, totaling 29 extra pallets per day or 10,556 additional pallets per year. By multiplying the "Overhead Cost" factor by the additional pallets produced annually (10,556 pallets * $1.30), a yearly benefit of $13,722.80 was projected.

Total Investment	Current Production	Saving minutes	Projected additional production	Total Savings	ROI
$100,000.00	3Pallets/Hour = 1,800 bottles	16 min /Hour = 352 min per day	29 additional pallets per day = 10,556 pallets per year	10,556 additional pallets in one year * $1.30 "Overhead Cost" = $13,722.80	$100,000 investment / $13,722.80 savings = 7 days

Figure 7. Table with the ROI calculations

Considering the investment costs over three years, it was suggested to calculate the ROI using the first year's savings. The initial investment of $100,000 divided by the first year's savings of $13,722.80 yielded an ROI of 7 days. Thus, the investment costs for the three years would be covered by the savings from the first year alone. The following table summarizes these findings.

4. Conclusion

This project was an integral effort focused on continuous improvement using the Six Sigma DMAIC methodology. Throughout the project phases, we identified and addressed the primary causes of downtime, specifically jammed pallets, significantly impacting operational efficiency. In the "Define" phase, we clarified objectives and project scope, identifying key stakeholders and specific problems. During the "Measure" phase we quantified delays and analyzed contributing factors, revealing mechanical failures and human errors as primary causes. The "Analyze" phase used tools like the Ishikawa diagram and the 5 Whys to identify root causes, confirming the need for preventive maintenance, SOPs, and operator training. The "Improve" phase implemented targeted solutions, improving automation, training, and process standardization, reducing downtime, and increasing productivity. The "Control" phase established robust monitoring and feedback systems, ensuring sustained improvements, and fostering a culture of continuous improvement.

Overall, the project optimized the PAI 1.75L palletizer's performance, reducing downtime and enhancing productivity. Creating an SOP and continuous personnel training ensures long-term benefits, contributing to the sustained success of the Coca-Cola bottling plant in Cayey. Personally, both Amarilis Silva and Thais Sánchez strengthened our communication and teamwork skills, time management, and detailed analysis abilities to identify root causes. We thank our mentor and professor Luis Olivares for his continuous support and feedback and Giancarlo Sánchez, the process engineer at the Coca-Cola bottling plant, for his constant support and willingness to overcome project challenge

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