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Lean Methodology and Operational Excellence: A Framework for Process Optimization and Cycle Time Reduction in Productivity Enhancement

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ABSTRACT

This research examines the integration of Lean Methodology and Operational Excellence as a strategic framework for improving the organization's productivity. The global market is becoming increasingly competitive, and it is a challenge for the sector to ensure good quality standards and to reduce lead times.

This study investigates the effect of the synergy between Lean's waste reduction tools and the cultural element of Operational Excellence with its long-term continuous improvement approach for the development of a solid methodology for operational efficiency.

A quantitative descriptive-comparative design was used in the study to evaluate the current and proposed reel receiving processes through a time and motion study. This study provides the main drivers to eliminate non-value-added operations and increase throughput. It presents a systematic approach to improving workflows and increasing output through Lean techniques such as Value Stream Mapping (VSM), Kaizen, and 5S. The methodologies reduced the cycle time by 28.47% and increased productivity by 39.32%. These results highlight the power of these tools to create cultures of continuous improvement and optimization.

The research provides a practical, data-driven strategy that the organization will implement to reduce waste and achieve sustainable growth.

Keywords – Lean Methodology, Operational Excellence, Optimization, Cycle Time Reduction, Continuous Improvement (Kaizen)

INTRODUCTION

In today's competitive global market, organizations are under increasing pressure to create higher value with fewer resources. According to the World Economic Forum (2023), more than 70% of organizations cite productivity improvement as a top strategic priority, but only a small margin of them are able to achieve sustained operational improvements. The studies indicate that sectors implementing Lean practices can reduce operational costs by up to 30% and cycle times by 20-50% (McKinsey & Company, 2022). Additionally, Deloitte (2021) found that the systematic implementation of process optimization strategies results in significant improvements in efficiency and customer satisfaction. These benefits are critical, but still many sectors use traditional management systems that limit agility and responsiveness. Lean Methodology and its application to Operational Excellence is studied in this project as a systematic framework for process optimization and cycle time reduction. The aim is to show that a data-driven implementation of Lean can be an impulse for measurable productivity improvement.

The study is beneficial for a wide range of stakeholders across industries. Businesses can implement these results especially in the manufacturing and service sectors to improve operational efficiency and eliminate

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waste in their processes. A clearer framework, connecting strategic objectives with operational execution, will be helpful to managers. The employees will also benefit from more organized workflows, reduced inefficiencies and better working conditions. The structured approach to Lean integration and empirical evaluation may be of interest to academic researchers and students. Insights can also be used by policymakers and industry leaders to inspire productivity-led economic growth. The study contributes to the practical and theoretical fields and supports continuous improvement at different organizational levels.

While Lean literature is extensive, a significant research gap exists regarding integrated statistical analysis. Most previous works focus on isolated tools, such as Value Stream Mapping or 5S, and lack comprehensive statistical validation of their combined effects. Current research often provides descriptive results with insufficient quantitative analysis, which restricts the ability to generalize the findings. There is also no focus on cycle time reduction as a measurable variable that is directly correlated to productivity improvement. This study provides a more systematic statistical approach than previous studies with measurable indices such as process efficiency, lead time and throughput. The study aims to fill these gaps and provide more data-driven evidence of Lean's effectiveness. This strengthens the academic and practical relevance of lean implementation strategies.

This study aims to help organizations remain competitive in rapidly changing industries. The presence of inefficiencies, delays and waste in real world processes points to the need for systematic approaches to improvement. Many organizations use Lean tools, but don't know how to integrate the tools into a cohesive framework resulting in sub-optimal results. This research was selected to bridge that disconnect and offer a more holistic, structured solution. It also hopes to contribute to the increasing body of knowledge by underscoring measurable and statistically backed results. Finally, the research aims to prove that the Lean Methodology can convert processes into efficient and high-performing systems, if used correctly. This is in line with the big picture of sustainable productivity increase through Operational Excellence.

LITERATURE REVIEW

The Role of Lean in Throughput and Productivity

Recent research has indicated that Lean Manufacturing results in increased productivity and throughput through waste reduction and improved process flow. Most researchers agree the effects of Lean implementation are positive; however, they disagree about the primary mechanisms by which these improvements are achieved. Some studies emphasize workplace organization and labor efficiency as the key drivers of performance improvement, whereas others highlight technological advancements and process optimization. For example, Gunananthan and Singh (2023) recorded a 30% productivity improvement results of optimization of the workplace and task allocation, while IJRASET (2021) experienced a 7.02-minute reduction in cycle time and a 45% increase in monthly production due to line-balancing techniques and technological advancements.

Although both studies reported productivity improvements, they have approached different perspectives on the main source of productivity improvement. Gunananthan and Singh (2023) focused on the organization of the workplace and labor efficiency, whereas IJRASET (2021) emphasized technological improvements and process balancing. These perspectives indicate that Lean improvements can be achieved, is it either by a human-centered, or technology-centered approach, depending on the operational context. The findings suggest that there are multiple ways to increase productivity through Lean, but reducing cycle time is common to all performance improvements.

Macro VS Micro Optimization Trends

Another trend in literature is the scale of Lean interventions. Some researchers propose macro-level improvements, while other researchers focus on detailed process-level optimization. Ashiq et al. (2022) applied Lean tools in redesigning facility layouts to improve the overall operational responsiveness. On the other hand, Kumar et al. (2024) have taken a micro-level approach using time-and-motion analysis to identify

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inefficiencies within individual work elements. Both approaches aim to enhance operational performance, but they differ in scope and implementation. Macro-level improvements address organization inefficiencies. Alternatively, micro-level analysis focuses on the activities of the operators and the performance of the tasks. This distinction emphasizes the need to choose improvement strategies based on the type of operational problem. The present study is more related to the micro-level perspective, in that it investigates specific operator motions and process activities that contribute to cycle time variation.

Research Gap and Contribution of the Study

Although the literature documents the benefits of Lean implementation, several gaps remain. Many studies show that productivity, throughput, or operational performance can be improved, but the reduction of cycle time is often just a side effect of the analysis rather than the main goal. In addition, some studies emphasize qualitative improvements without providing specific time-based metrics to back up their results. Tortorella et al. (2023) pointed out the importance of standardization and variability reduction to sustain Lean improvements, but few studies have targeted cycle time as the key performance indicator with detailed time-and-motion analysis.

To address this gap, the present study focuses specifically on cycle time reduction through the elimination of motion waste and repetitive activities. The study provides quantitative evidence that process-level improvements can increase productivity and operational efficiency through a structured time-and-motion methodology. In so doing it extends the prior research by demonstrating the link between motion reduction, cycle time reduction, and productivity performance.

METHODOLOGY

Research Design

A quantitative descriptive-comparative research design based on the tenets of Lean Methodology, Time and Motion Study, and Operational Excellence was implemented in this study. The descriptive element of the study involved the analysis of the current reel receiving system in the In-Process Quality Assurance (IQA) section, with emphasis on identifying waiting, repetition and extra motions that contributed to low productivity. The comparative part sought to establish the comparison between the existing and proposed new process after the lean interventions.

This study design was considered suitable because the study aimed to produce quantitative evidence about system performance. The researchers compared the current process and the improved process by observing and measuring the current cycle time and output and comparing them to the proposed potential benefits. The research focused on process performance improvement rather than subjective measures, therefore, the use of quantitative performance measures (reels per hour, percentage of improvement).

The study also adopted the continuous improvement philosophy (Kaizen) by examining small but important changes in the process that may lead to significant productivity gains. Rather than suggesting costly equipment and additional manpower, the study focused on removing waste without investing in additional resources.

Research Settings

The research was conducted in the IQA Reel Receiving Section of the production operations department of the company. This section receives reels, scans material identification barcodes, verifies the information on a tablet computer, unloads reels, and prepares the materials for the next step in production.

The IQA Reel Receiving area was chosen as it is a critical part of the production process. Any delay in the receipt and verification of reels can impact on production planning, machine set-up and material flow. The process involves both manual handling and interaction with the computer system, therefore it was a perfect opportunity to apply lean process improvement techniques.

The section observes ongoing material flow and involves repetitive tasks for the operators, and these tasks can result in considerable productivity loss over time if any inefficiencies are present.

Population and Sample

The population of the study consists of all cycle time performances of the reel handling process under both current and proposed conditions in the IQA section.

The sample consisted of five (n = 5) paired cycle time observations for both the current and proposed processes. Each observation represents one complete execution of the process performed by a single trained operator under controlled conditions. A purposive time study approach was used to ensure consistency and comparability of measurements.

Research Instruments

Several instruments were utilized to ensure accurate and objective data collection:

1. Stopwatch / Digital Timer

Used to measure the time consumed in each activity step such as lifting, scanning, unloading, and confirming transactions.

2. Observation Sheet

Used to record sequence of activities, unnecessary motions, waiting periods, delays, repeated walking, and interruptions.

3. Process Flow Chart

Used to visualize the current workflow and identify non-value-added steps.

4. Tablet System Transaction Logs

Used to validate the number of scans, confirmations, and digital interaction frequency.

5. Spreadsheet Software

Used for tabulation, calculation of averages, percentage increase, and comparative presentation of data.

6. Lean Waste Identification Checklist

Used to classify observed waste under categories such as motion waste, waiting waste, overprocessing, and inefficiency.

Statistical Treatment of Data

The data gathered in this study were analyzed using both descriptive and inferential statistics. Descriptive statistics were used to summarize the data, particularly:

- Mean cycle time per reel
- Productivity rate (reels per hour)

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- Percentage improvement between processes

To determine whether the difference between the existing and proposed processes is statistically significant, a Paired Samples t-test was employed.

The following hypotheses were tested:

Null Hypothesis (H_0). There is no significant difference between the current and proposed processes in terms of cycle time.

Alternative Hypothesis (H_1). There is a significant difference between the current and proposed processes in terms of cycle time.

The level of significance was set at $\alpha = 0.05$.

The decision rule applied was:

- Reject the null hypothesis if the p-value ≤ 0.05
- Fail to reject the null hypothesis if the p-value > 0.05

This statistical test was used to validate whether the improvements observed in the proposed process were statistically significant and not due to chance.

Paired T-test Formula

A paired samples t-test was computed using the following formula:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}}$$

Where:

$\bar{d}$= mean of the differences between paired observations

s_d= standard deviation of the differences

n= number of paired observations

df = n−1

Data Gathering Procedure

The data collection process began with an initial observation of the reel receiving operation to understand the existing workflow. The process was systematically documented, including the stages of getting the dampla, picking up the reels one by one, setting up the system, scanning the reels one by one, using the tablet, and unloading the reel.

A time study was conducted to measure the cycle time of each process element and to determine the average time required to complete one reel handling cycle. Multiple cycle observations were recorded under controlled conditions to ensure data consistency.

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Additionally, a motion study was performed to analyze the operational movements involved in the process. This included identifying non-value-added activities such as unnecessary walking, repetitive movements, and item handling.

Based on the findings, Lean improvement techniques were developed, focusing on reel batching and reducing tablet interactions to minimize motion waste and improve operational efficiency. The proposed method was then valuated and compared with the existing process in terms of cycle time and output performance.

Validity and Reliability

The study's validity was strengthened by direct observation and data collection from actual work operations in the IQA reel receiving department. The parameters measured were cycle time, production rate per hour, and motion-related activities, which are directly related to process performance evaluation. Based on real operational conditions, the process issues were identified and improvements implemented.

Reliability was maintained by using procedures such as same-time study, observation, and recording in all trials. All measurements were performed with the same timing technique, similar operating conditions, and one trained operator to reduce variability. Additionally, repeated observations of the cycles were conducted to increase the consistency of the results.

Ethical Considerations

The study complied with ethical standards when conducted in a workplace setting. The subjects were told that the observation would be used to improve processes and would not be used to evaluate or punish the workers. There was no documentation of any personal information. The research was conducted without disrupting work or putting employees at any risk.

Data Analysis

Descriptive and inferential statistics were used to analyze the collected data. The mean cycle time for the existing and the improved processes was calculated using descriptive statistics. Moreover, hourly production was calculated to determine the number of reels processed per hour for each condition.

The productivity difference between existing and improved processes was evaluated by comparing cycle time and output capacity. The proposed Lean improvements resulted in an efficiency gain, measured as the percentage improvement.

Lastly, a paired T-test was conducted to assess whether the difference in cycle times of the two processes was statistically significant.

RESULTS

This phase provides the results of implemented technical improvements, primarily based on lean manufacturing concepts, particularly the reduction of motion waste and the application of batch processing. A comparative evaluation between the current and proposed methods was performed using time-motion study data. Results are offered in terms of cycle time, element performance, and basic productivity to assess the effectiveness of the improvement.

Current VS Proposed Operational Process Flow

The current operational workflow of the production line is illustrated in Figure 1, that each process performed one reel at a time, resulting in repetitive movements and increased motion waste.

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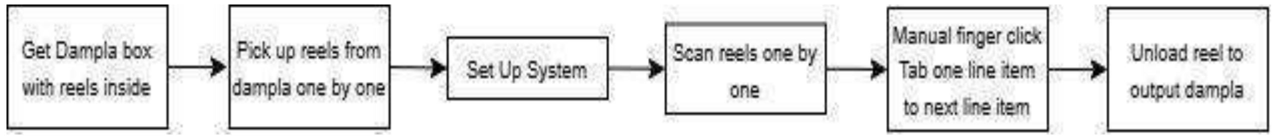

Figure 1. Current Operational Process Flow

While in Figure 2, which follows the same operational sequence; however, the second and fourth processes can handle reels in batches of ten instead of individually. This modification reduces repetitive movements and handling frequency, resulting in lower cycle time and improved process efficiency.

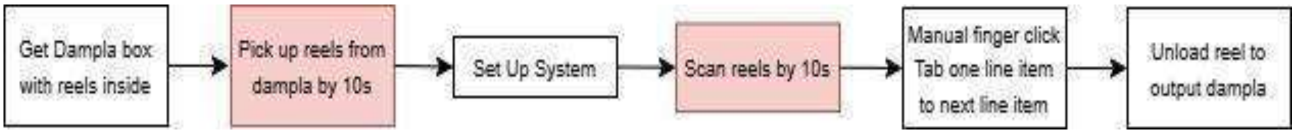

Figure 2. Proposed Operational Process Flow

Summary of Current VS Proposed Table

Table 1 summarizes the average processing time for the current and proposed methods and highlights the improvements in the second and fourth process steps. Detailed time-study observations are presented in Table 2.

Table 1. Summary of Process Improvements

Process Description	Average Time Current	Average Time Proposed	Difference
1. Get dampla box with reels inside	0.23	0.23	0
2. Pick up reels from dampla	4.18	0.42	3.76
3. Set-up system	8.63	8.63	0
4. Scan reels	4.78	0.48	4.3
5. Manual fingers click Tab one line item to next line item	5.98	5.98	0
6. Unload reel to output dampla	4.5	4.5	0
Average per Process Element	**4.72**	**3.37**	**1.34**

Table 2. Summary of Current and Proposed Process Flow

Process Description	Actual (one by one)					Average	Proposed (by 10s)					Average
	1	2	3	4	5		1	2	3	4	5	
Pick up reels from dampla	3.54	4.44	3.47	5.22	4.21	4.18	0.35	0.44	0.35	0.52	0.42	0.42
Scan reels	5.13	5.21	4.07	4.33	5.16	4.78	0.51	0.52	0.41	0.43	0.52	0.48

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Overall, the proposed workflow reduced repetitive movements and improved operational efficiency.

Cycle Time Improvement

The time-and-motion study showed a reduction in cycle time after implementing the proposed process improvements. The average cycle time decreased from 30.84 seconds under the current method to 22.06 seconds under the proposed method, representing a 28.47% reduction. This improvement indicates that the redesigned workflow reduced unnecessary operator movements and improved process efficiency.

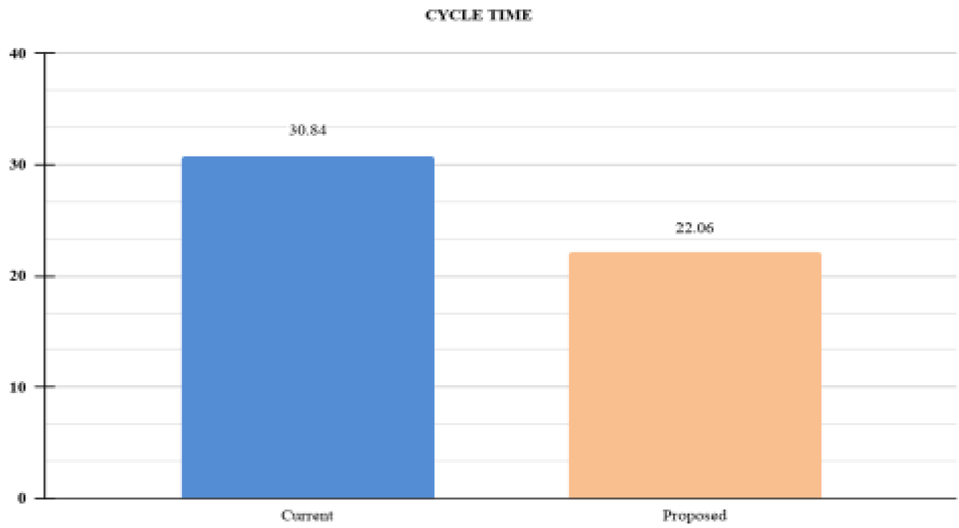

Figure 3. Cycle Time Comparison of Current and Proposed Method

Element-Level Time Reduction

A detailed analysis of individual process elements reveals that the most significant time reductions occurred in activities characterized by high levels of manual motion and repetition.

Specifically:

- Pick up reels from dampla: reduced from 4.18 seconds to 0.42 seconds
- Scan reels: reduced from 4.78 seconds to 0.48 seconds

These reductions represent an 85–90% decrease in execution time, indicating that these activities were the primary contributors to inefficiency in the original process. The dramatic decrease in time is basically due to implementing batch processing have been treated, which has exponentially reduced the total amount of required movements

In contrast, other elements such as:

- Get Dampla box with reels inside
- Set Up System
- Manual finger clicking (tablet interaction)
- Unload reel to output dampla

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Minimal or no measurable change showed in execution. This indicates that both of those steps are inherently necessary, already optimized, or restricted by the use of system or process requirements. As a result, they present limited opportunities for further development under current conditions.

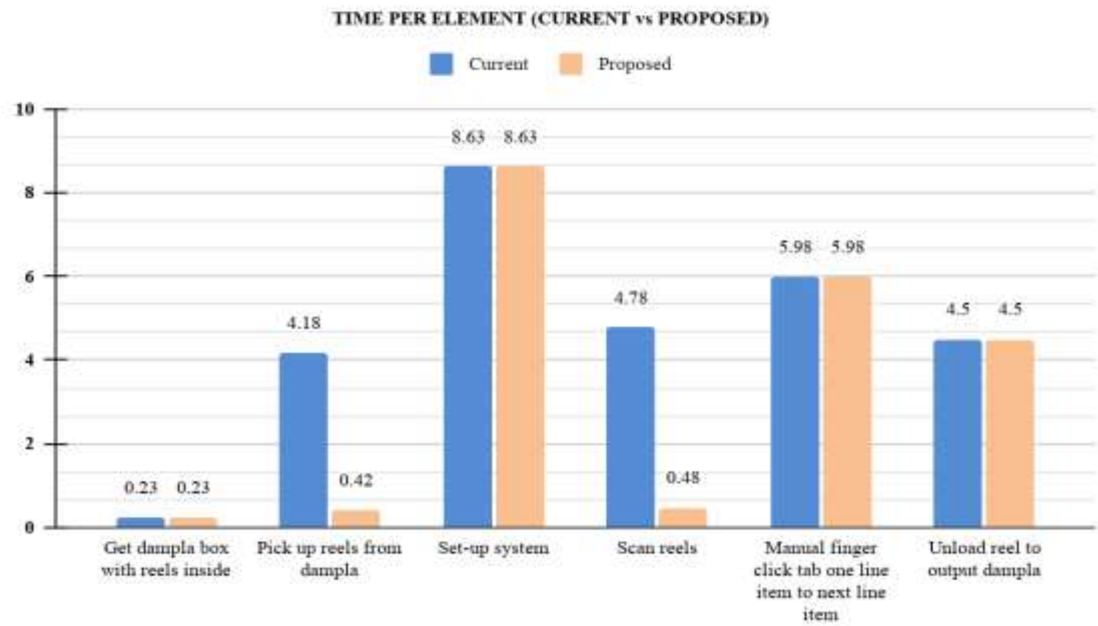

Figure 4. Element-Level Time Comparison

Productivity Improvement

The reduction in cycle time directly contributed to an improvement in process productivity. Based on system calculations, productivity increased from approximately 117 pieces per hour (PPH) under the current method to 163 PPH under the proposed method. This represents an increase of 46 PPH, equivalent to a 39.32% improvement in productivity.

The increase in productivity demonstrates the effectiveness of reducing motion waste and implementing batch-processing techniques. By minimizing unnecessary operator movements and repetitive handling activities, the process achieved higher throughput while utilizing the same manpower, equipment, and operational resources.

Figure 5 illustrates the productivity improvement achieved after implementing the proposed method.

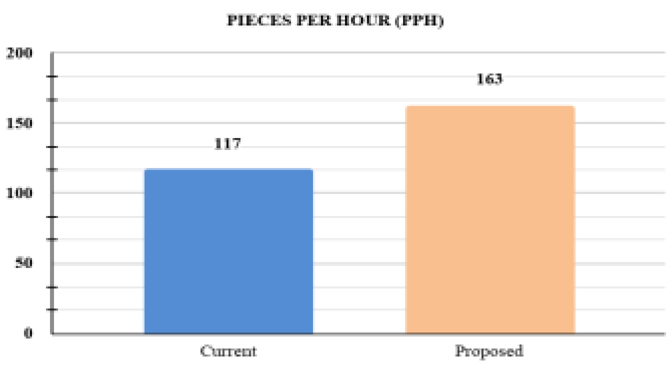

Figure 5. Productivity Comparison Before and After Improvement

From a resource utilization perspective, this productivity gain was achieved without additional manpower, equipment, or capital investment, indicating an improvement in system efficiency. The optimized workflow

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allows operators to perform their duties more effectively, reduce idle time, and maximize output per labor hour.

Overall, the results verify that reducing motion waste and optimizing performance not only improves efficiency at the micro level but also leads to huge gains in macro-phase performance markers with throughput, potential, and labor productivit

Statistical Rigor

A paired samples t-test was conducted to determine whether there was a significant difference between the current and proposed processes in terms of cycle time.

For Process 2, "Pick up reels from dampla," the current method recorded a mean cycle time of 4.18 seconds, while the proposed method recorded a mean cycle time of 0.42 seconds. A paired-samples t-test revealed a statistically significant reduction in cycle time, $t(4) = 13.01$, $p < .001$, Cohen's $d = 5.81$, with a mean reduction of 3.76 seconds and a 95% confidence interval ranging from 2.96 to 4.56 seconds.

The results showed a statistically significant difference between the current and proposed methods. Since the p-value was less than the significance level of $\alpha = 0.05$, the null hypothesis was rejected. These findings confirm that the proposed batch-processing method significantly improved process efficiency and reduced cycle time.

DISCUSSION

The findings confirm that operator motion significantly affects process efficiency and productivity performance. The original workflow included repetitive activities including picking, scanning, and system interaction performed on a one-by-one basis. These repeated micro-movements accumulated throughout the process cycle, resulting in longer processing times and limited throughput capacity that can create significant operational inefficiencies.

The implementation of batch processing greatly reduced the unnecessary movement of operators and repetitive handling activities. This allowed multiple reels to be processed in one cycle, greatly reducing repetitive movements per unit, resulting in faster task execution and improved operational flow. The reductions observed in reel pickup and scanning activities indicate that motion waste was identified as one of the primary contributors to inefficiency in the original process. These findings validate the lean manufacturing principle to remove non-value-added activities to improve overall process and workflow efficiency.

The research findings are consistent with those of Tortorella et al. (2023), who noted that lean implementation leads to an improvement in operational performance through reducing process variability and unnecessary delays. Kumar et al. (2024) emphasized that time and motion analysis can help identify bottlenecks and inefficient operator movements that negatively affect productivity. The present study supports these theories in that cycle time can be drastically reduced through the reduction of repetitive handling activities and the optimization of task execution, while improving throughput performance.

Furthermore, the reduction in manual tablet interaction led to a more consistent and streamlined workflow. Operators experienced fewer interruptions caused by repeated system navigation, allowing smoother transitions between tasks and more stable execution of activities. This improvement increased efficiency by reducing operator fatigue and improving work consistency. These results are aligned with Lean and Operational Excellence concepts that highlight standardization, simplification of workflow, and continuous development as critical factors in maintaining productivity gains.

From an operational perspective, the improvements increased process responsiveness and manufacturing capabilities without additional manpower, equipment, or capital investments. This indicates better use of existing resources and improved labor productivity. The results also demonstrate that data-driven process optimization can lead to measurable operational efficiencies while maintaining cost efficiency.

However, improvements need to be properly implemented and continuously monitored for them to be sustainable. Operators must consistently follow standardized work procedures to maintain process stability and avoid performance variations. Additionally, system reliability must be maintained to minimize interruptions and ensure smooth workflow execution. Long-term operational improvement requires continuous evaluation and process monitoring to adapt to future production requirements.

One limitation of this study is the sample size (n = 5) used in the time and motion analysis. Although the results demonstrated a statistically significant reduction in cycle time and an improvement in productivity, the findings must be interpreted with caution due to the limited number of observations. In addition, the study was conducted within a specific production process and operating environment, which may limit the generalizability of the results to other manufacturing settings. Future studies could use larger sample sizes and compare multiple production lines to validate the effectiveness of the proposed improvements.

Future research may explore automation of scanning and system interaction activities to reduce remaining manual tasks. Lean tools such as poka-yoke, digital workflow integration, or automated material handling structures will also be considered to improve productivity and operational efficiency.

CONCLUSIONS/RECOMMENDATIONS

The study revealed that cycle time can be significantly improved by eliminating motion waste and non-value-added activities. As a result, the batch processing and workflow optimization, we have improved operations by eliminating repetitive tasks and simplifying the work.

The results support the use of lean manufacturing tools by improving productivity and resources utilization. The time-and-motion analysis revealed inefficiencies in the process, which were corrected to make the production process more efficient without the need for additional equipment. Likewise, the study focused on the importance of continuous improvement or being consistent in maintaining operational efficiency and supporting long-term process sustainability.

The improved process should be standardized and continuously monitored to achieve it. The future improvement measures the further automation and application of additional lean tools to reduce manual activities, and to increase productivity and operational performance.

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Engineer, where she leads initiatives focused on optimizing operations and driving organizational efficiency through automation. Her work centers on identifying opportunities to eliminate manual processes, implement innovative automation solutions, and deliver measurable cost savings and return on investment (ROI). Her professional interests include process improvement, operational excellence, and project management, with extensive experience in managing and implementing multiple automation projects that contribute to business transformation and sustainable operational performance.

Caryl M. Jerusalem is pursuing a Master of Science in Management Engineering. Currently employed in Taiwan as a Visual Inspector, with experience in quality control and manufacturing processes. Her interests include engineering management, process improvement, and industrial quality systems.

Sherry Rose D. Martin is a seasoned Lead Hardware Engineer at Allegro MicroSystems Philippines, Inc., with 15 years of extensive experience in the semiconductor industry. A graduate of Don Bosco Technical College in Mandaluyong City, she holds a Bachelor’s degree in Electronics and Communications Engineering. Throughout her career, she has specialized in hardware design and innovation, she contributes to the development and manufacturing of sensor and power integrated circuits (ICs) for which the company is globally recognized.