

APPLICATION OF PLAN-DO-CHECK-ACT PRINCIPLES IN MANUFACTURING INDUSTRY MOTORS IN THE PHILIPPINES: ENHANCEMENT OF FUNDAMENTAL PILLAR IN PAINTING PROCESS

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Abstract

The motors industry has encountered prolonged processing times, leading to inefficiencies and quality issues in the production of their products. This extended processing duration has become a significant factor contributing to decreased productivity and various challenges related to product quality. To address these issues, the researcher used a Lean Manufacturing strategy to improve quality and service, eliminate waste, reduce time and costs, and enhance overall organizational effectiveness. With Plan-Do-Check-Act (PDCA) Principles, productivity increases, and the bottleneck in production is eliminated, thus increasing efficiency. The researcher limits focus on the production of the painting process of the eco PUV line since it is the most critical process among the five sections of PUV production. Painting Eco PUVs is the most tedious and longest process in the production stream, so it will affect the next section which is the Trimming Section and Final Inspection Section. In this study, PDCA Principles, five why analysis and the Fishbone diagram were also used to identify the root cause of problems in production and identify areas for improvement. The production cycle time decreased from 4,311 minutes to 3,427 minutes. Due to the significant increase in production capacity made possible by this efficiency gain, the number of units produced increased from 64 to 81. The study was applied by the company and resulted in a 20% improvement in its productivity and processing time was improved.

Keywords: Bottleneck, Cycle time, Long process time, PDCA, Process improvement.

1. Introduction

All companies strive to attain manufacturing efficiency by removing production bottlenecks, improve the productivity of the workers, and removing waste, and rejects. Efficient manufacturing processes lead to reduced costs, improved productivity, and enhanced quality of products [1] and efficient manufacturing operations enable companies to optimize resource utilization, minimize waste, and streamline production flows, thereby achieving higher output levels with lower input requirements [2].

Manufacturing companies can adapt more easily to all these forces through improving workflow. The flow being described may refer to a document, service, or product that is being transferred from one step to another. Enhancements in the fundamental aspects of a painting process can encompass various improvements in techniques, materials, technologies, and methodologies to achieve better results in terms of quality, efficiency, and sustainability [3, 4].

In the previous study of South Africa, the problems were defined, root causes identified, effects quantified, and concrete solutions provided to solve the problems. This was done to ensure that production processes were free from non-conforming products and to promote continual improvement across all functional areas [5]. To improve the process of aircraft manufacturing process, eliminates inconsistencies in the systems and processes, the previous study used the Deming PDCA quality management cycle and software interfaces [6]. Reduction of cycle and lead time to improve production efficiency and quality performance were inherent in different industries [7]. Some of the manufacturing companies focused on production and process improvement, quality improvement, and reducing the number of nonconformities. To address these problems, the Deming cycle and PDCA cycle were used as solutions to quality issues that occurred during the production process [8].

The researcher focused on several critical problems within the painting process. These issues included significant idle time and bottlenecks, which disrupted the workflow and slowed down production. Additionally, the study addressed the low productivity of labour, which was a key factor in the overall inefficiency of the process. The disorganized assignment of workers was another major concern, leading to confusion and a lack of coordination among the workforces. Furthermore, the researcher identified redundant activities performed by some workers, which wasted time and resources. Lastly, the non-availability of essential equipment for more efficient operations was highlighted as a significant obstacle.

PDCA is a quality management system that is used as a continual improvement tool that is widely used in the service and manufacturing sectors [9]. The researcher employed the PDCA (Plan-Do-Check-Act) principles as a structured approach to enhance the processing time of the ECO PUV line. Initially, the researcher meticulously planned the improvement process, identifying specific objectives and outlining the strategies to achieve them. Through this iterative PDCA principles, the researcher systematically addressed inefficiencies and iteratively optimized the ECO PUV line, resulting in reduced processing time and enhanced operational efficiency.

The study aims to improve the long process time of Painting Eco PUV line using PDCA Principles at the Industry Motors. It sought to achieve the following objectives:

- To determine the present status of production output and process of the Eco PUV line.
- To identify the problems encountered in the current production of the Eco PUV Line and implement measures to reduce the lengthy processing time.
- To evaluate and check the effectiveness and efficiency of recently introduced techniques or procedures.
- To assess the impact of enhanced workflow through lean manufacturing in the Painting Eco PUV Line.

To achieve the objectives the researcher used the PDCA (Plan Do Check Act) principles to enhance and advance the aspects of the painting process, in the motor sector in the Philippines. The PDCA cycle, a known iterative management approach for managing and enhancing processes and products continuously offered a framework for the research. Through planning, execution, assessment and refinement of the painting process the researcher aimed to uncover inefficiencies implement measures and ensure lasting enhancements.

Improved painting process was highly relevant because it had broad applicability across the entire motors industry in the Philippines. By refining the painting process, the industry achieved higher quality standards, reduced production costs, and minimized waste.

2. Plan-Do-Check-Act Approach

The data collection procedure employed in this study adhered to the fundamental principles of Lean Six Sigma [10], with a specific focus on the PDCA principles as shown in Fig. 1, which stands for Plan, Do, Check and Act. This structured approach was integral to enhancing the efficiency of the Eco PUV line.

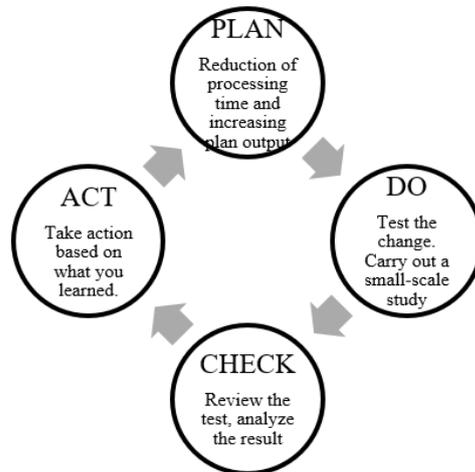


Fig. 1. PDCA principles.

2.1. Plan phase

The researcher's objective is to evaluate the present state of production in order to minimize processing time and enhance planned output. This entails conducting a

comprehensive analysis of the existing production processes, identifying inefficiencies, and implementing strategic measures to streamline operations. By identifying areas for improvement and implementing targeted interventions, the aim is to optimize production efficiency, reduce processing time, and ultimately increase the output of the production plan. It is necessary to identify the problem, analyse the causes affecting it, generate solutions, and develop a plan of implementation [11].

2.2. Do phase

After analysing the workflow, the researcher identifies the problems occur in the production process. More observations were carried out which is integrated in the overall result of the study. In this phase, it is vital to prioritize the elimination of the root causes of problems. By addressing these underlying issues. It can effectively enhance efficiency and productivity [12].

The researcher utilized the "Why-Why" analysis and fishbone diagram to conduct an in-depth investigation into the root causes of the identified problem. The five why analysis involves iteratively asking "why" questions to uncover underlying factors contributing to the issue. A five why analysis is conducted to identify solutions to a problem that address its root causes [13]. Fishbone diagram was created with the goal of identifying and grouping the causes which generate a quality problem [8] and it is visually map out potential causes across different categories such as people, processes, equipment, materials, and environment. This comprehensive framework allows for a structured exploration of possible causes, facilitating a holistic understanding of the problem's origins.

2.3. Check phase

In this step, the researcher review, test, and conduct a further analysis on the recommendations provided by the team. Drawing from the insights gained during this process, the researcher evaluates the results and assesses their broader applicability within the actual painting process setting of the Eco PUV Line. This comprehensive approach ensures that the proposed solutions are thoroughly scrutinized and aligned with the specific requirements and challenges of the painting process, ultimately facilitating informed decision-making and effective implementation strategies. The findings point out the importance of breaking the idle time and improve the overall workflow and efficiency of the workforce.

2.4. Act phase

Following the completion of the "Do" and "Check" phases, the researcher proceeds to act based on the outcomes observed. This action-oriented approach involves analysing the data collected during the "Check" phase, identifying any discrepancies or areas for improvement, and devising strategic interventions accordingly. By leveraging the insights gleaned from the assessment phase, the researcher formulates targeted action plans aimed at optimizing processes, rectifying deficiencies, and driving continual improvement. This proactive stance ensures that the research efforts are not only comprehensive but also result-oriented, ultimately leading to tangible enhancements in performance and efficiency.

3. Results and Discussion

The results and discussion were centre around the principles of the Plan-Do-Check-Act (PDCA) principles in the painting process.

3.1. Plan phase

In this phase, the researcher determines the present status of the production output (in units) of the Eco PUV line for the month of January to August 2020. Figure 2 shows the production output; the production output is illustrated graphically. Notably, in the month of January 2020, there was a notable shortfall of 11 Body Eco PUV units against the predetermined target. This pattern persisted, with each subsequent month's target being burdened by the accumulated shortfall from previous months. Over time, this cumulative backlog continued to grow, exacerbating the delays in meeting customer demand from January through August 2020.

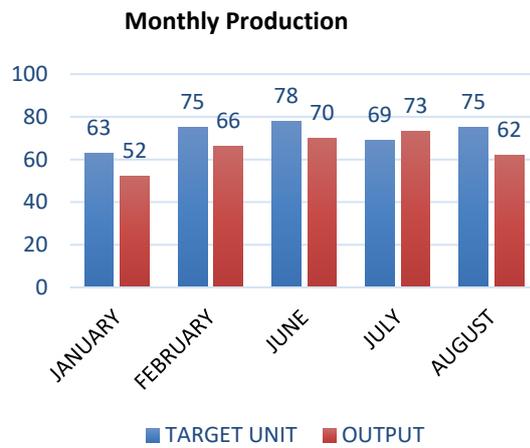


Fig. 2. Target unit (demand) vs output of eco PUV line in painting section at the industry motors.

Based on the findings, the target output for the months of January and August 2020 could not be met. The data collected was used to analyse the reasons behind the unfulfilled quotas or production output. The output has a direct influence on the functionality of the final product, and performance of a downstream process [14]. This analysis aimed to identify the factors that contributed to the shortfall and to understand the underlying issues that prevented the achievement of the production goals.

Figure 3 shows the production process layout of PUV line in painting process. Stage 1 Metal preparation by dry sanding all sides and the roof of the unit using sandpaper #120 then wet sanding of front and rear panel using arnox and sandpaper #120. Next is wiping and degreasing of metal (wiping dirt and grease using cloth, solvent naphtha/ wash thinner), air drying using air hose. Stage 2 includes wash and anti-corrosion primer application painting using spray gun, spray filler painting of front, rear panel, and wheel arc (fibre glass only, done at painting booth using spray gun), and application of undercoat on roof panel, side panel joints.

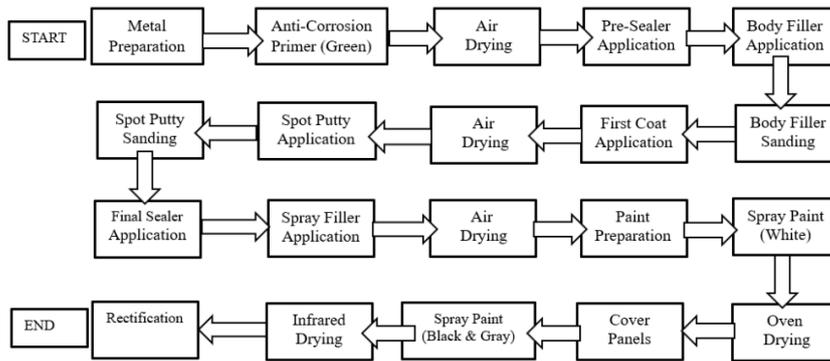


Fig. 3. Production process layout.

Stage 3 is a body filler and putty application. The application of body filler uses “pallet” on portions (1 gal tack 8000 body filler: 1 tube fast acting creamer hardener for plastic body filler, dry sanding using “khatam” sandpaper #36 (stick-it) and steel brush, wet sanding using sandpaper #120, air drying, spraying with anti-corrosion primer on portion with body filler, acrylic putty application (spread using pallet, straight aluminium board.), then wet sanding on places using #240 and another round of air drying. Stage 4 includes first coat painting, painting of spray filler on portions with putty. (Done at a painting booth using a spray gun). First coat painting all over the body, send the PUV to the oven and set 60 degrees Celsius for 1 hour or let it dry overnight.

Stage 5 spot putty application, application of putty on uneven spots, sanding the portion with putty using sandpaper #240, installation of aluminium half-moon rub rail on side skin joints, spray filler painting on portions with spot putty. Application of sealer on upper facial and rear panel joints. (Done using sealer gun), QC inspection before topcoat, rectification of defects identified by QC inspector.

Stage 6 is a base colour painting wet sanding (sandpaper #360) and air drying. Stage 7 stripe put masking tape on portion, put fine line tape using the transferred lines as guide then paint stripe, send the PUV to the oven and set to 60 degrees Celsius for 1 hour again after that removing tape and newspaper. Stage 8 is top-coating and air and over drying. Stage 9 Lid cover and baggage compartment painting. Stage 10 This is the final touch up and QC inspection prior to transfer to the trimming line, final touch up of painting defects identified by QC inspector and then the unit is ready for transfer to the trimming line.

Based on the findings each stage includes steps to ensure quality, such as sanding, primer application, and QC inspections. This thorough process helps maintain high standards and reduces the likelihood of defects. The detailed stages and use of specific tools and materials (e.g., sandpaper grit sizes, primer types) indicate a streamlined process designed to optimize production efficiency. Anti-corrosion primers, body fillers, and topcoats contribute to the vehicle's long-term durability, protecting against environmental factors and wear. Attention to detail in painting and finishing stages ensures both the visual appeal and functional quality of the final product. By adhering to these stages, the production process aims to achieve consistent output, which is essential for meeting production targets and

customer satisfaction. The aim of this paper is to improve and developed the new process for the manufacturing industry motor in the Philippines. Production process is necessary to develop a planning guide for the electric motor production to reach economic production and quality [15].

3.2. Do phase

For The researcher observed some problems on the current production system, particularly on the painting process of the Eco PUV line.

Lean implementation such as improvement in production lead time, processing time, cycle time, set up time, inventory, defects and scrap, and overall equipment effectiveness [16], improve productivity [17], meet customer demand [18]. Bottleneck is a point of congestion in a production system that occurs when workloads arrive quickly for the production process to handle. A backlog of work-in-progress (WIP) and slowing down the overall production flow [19] and identifying bottleneck in the production line is important to improve productivity [20]. The inefficiencies brought about by the bottleneck often create delays [21] and higher production costs [22]. In painting Eco PUV in the sanding process the corner of the body is not reachable by orbital sander so they do it manually with sandpaper to accomplish the sanding process and it takes a long time to finish the process which causes the delay or waiting time of the next process.

The researcher analysed the current process of painting Eco PUV Line, they perceived that the long lead time contributed to the large amount of time in processing the body units because they have eight to nine days before they transfer the body unit to the trimming line. Figure 4 shows the standardized work combination table, which outlines the sequence of tasks in the process alongside their respective target times and the actual time taken. In this instance, the target time for completing the process is set at 3,840.00 minutes. However, upon evaluation, the current time taken to complete the process is recorded at 4,311.00 minutes. This discrepancy between the target time and the actual time indicates that the process has not met its intended time goal.

Based on the findings, the extended processing time presents a significant challenge that must be addressed urgently by the industry. If this issue remains unresolved, it could have far-reaching implications for overall productivity and efficiency. The prolonged lead time in the sanding process, particularly due to the manual effort required to sand the corners, not only delays the entire painting process but also causes a bottleneck that affects the subsequent steps. This inefficiency can lead to increased operational costs, reduced throughput, and potential delays in delivery schedules, thereby impacting customer satisfaction and competitiveness in the market. Additionally, the inability to meet target processing times can hinder the industry's capacity to scale up production and meet growing demand, ultimately affecting its profitability and long-term sustainability.

In the previous study, the elimination of waiting, unnecessary work, failures, unnecessary movements, unnecessary transportations, and additional costs was deemed necessary to improve various aspects of different businesses [20]. Adjusting the operation time of each process through various methods was very important to determine the overall production efficiency of the production line.

This optimization aimed to ensure that the operation time of each process was balanced and tended to be uniform [23].

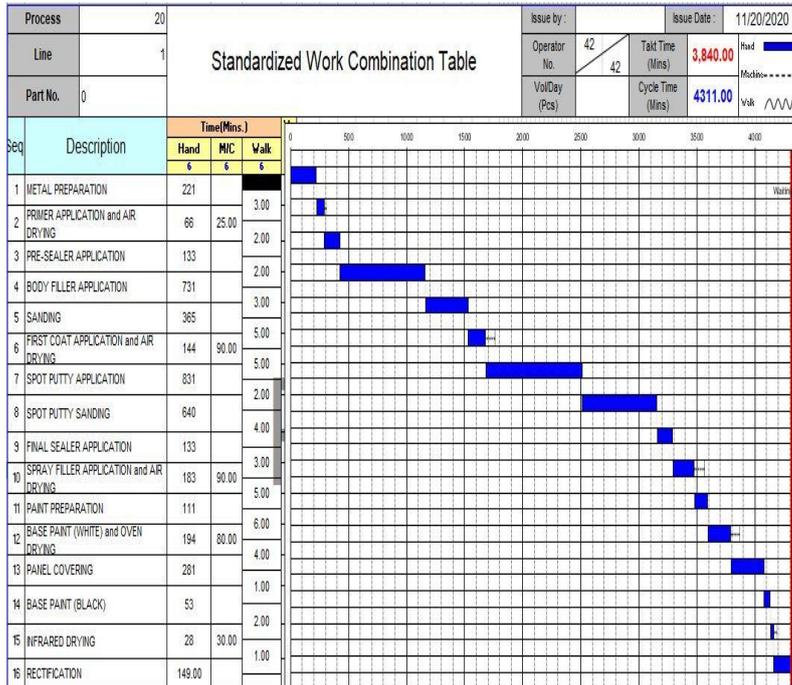


Fig. 4. Time study of current process.

Figure 5 shows the fishbone diagram for the possible causes and effects of the problem, to know the idle time within the process. Based on this method, the main problem is long production process time caused by the idle time in the three main stages of the painting process (spot putty application, body filler application, and spot putty sanding). Some of the main causes of this problem are the disorganized activities that led to some idle time for some workers which further delayed the painting process completion. Other causes include the lack of equipment, untrained manpower, workers unmindful of company’s production standards, and unfavourable working conditions.

The researcher used the Cause-and-Effect Diagram and 5 Whys analysis as complementary tools to leverage the problem-solving potential. While fishbone analysis is a diagram that helps to visualize and organize potential causes, the 5 whys technique starts with the main identified cause and digs deeper into each one of them explaining until finding out what was really happening as root problem.

Figure 6 shows the five why analysis of repeated activities, The why analysis supplements or augments other methods used in analysing the production problems. For this study, five why questions were posed and answered to establish the main problem and the root causes of the problem in painting processes of Eco PUV Line. Repeated tasks during painting frequently result in inefficiencies and decreased performance. Errors and inconsistencies could arise from repeating tasks without following a set protocol. Because of these inefficiencies, processing times could be

prolonged because one step might not flow into another smoothly. Further impeding overall productivity was the possibility of bottlenecks and delays in the absence of an optimized process flow.

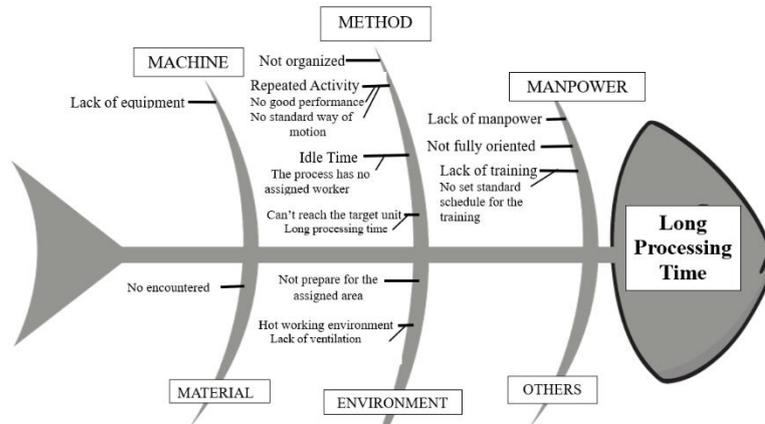


Fig. 5. Fishbone diagram.

These problems were further compounded by improper combinations of processes. Inadequate integration of steps could result in needless iterations or inconsistencies, leading to delays and possibly jeopardizing the quality of the finished product. To overcome these obstacles, the workflow had to be streamlined, processes had to be standardized, and every painting step had to reinforce and improve the efficiency of the preceding one.

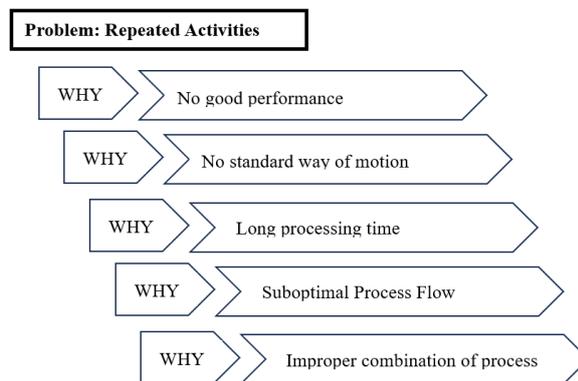


Fig. 6. Five why analysis.

3.3. Check phase

To address the idle time and overall production inefficiency problem, the researcher provides the improved production process of painting Eco PUV Line shows in Fig. 7.

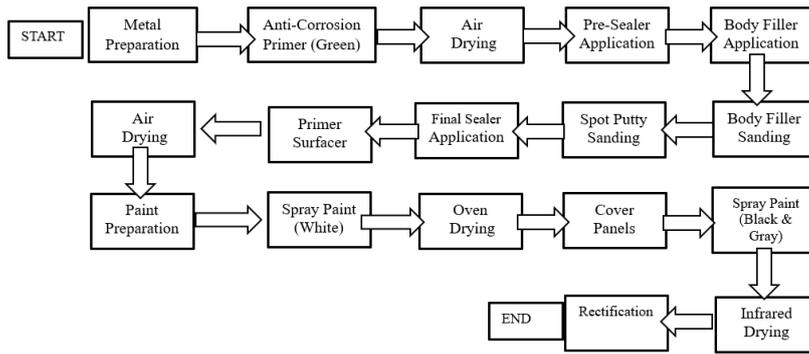


Fig. 7. Improved production process of painting eco PUV line.

Changing some key painting methods. Based on the understanding of the existing process of PUV painting, the researchers suggest using a guide coat and rectangular sander. First coat application can be changed into guide coat to easily identify the uneven surfaces. Guide coat is better, it easily dry and thus will no longer need air drying before the spot putty application. It can reduce the time needed in manual sanding. Reduced the steps/Combining some of the painting processes. To remove idle time, some of the painting process is recommended to be combined. From a total of 20 steps, it is now reduced to 17.

Figure 8 shows the improved time study, the target time allocated for the process, set at 3,840.00 minutes, and the actual time taken to complete it, which stands at 3,427.00 minutes. Importantly, the current time reflects a successful reduction, meeting the target goal for time efficiency in completing the painting process.

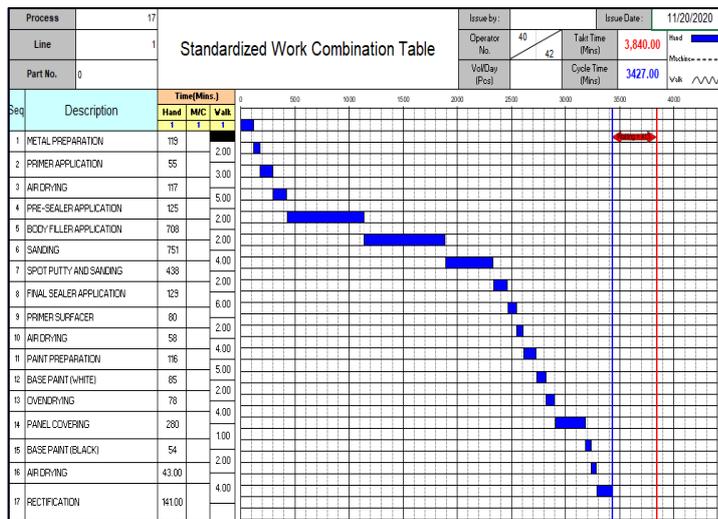


Fig 8. Improved time study.

Furthermore, the subsequent table below provides additional insight into the average time required to complete the enhanced painting process, which has

undergone optimization and refinement. This revised process now consists of 17 steps, streamlined from the original 20 steps. The average time calculated for completing the enhanced painting process serves as a testament to the successful implementation of measures aimed at enhancing efficiency and reducing unnecessary complexities within the process.

The achievement of meeting the target reduction in time to complete the painting process underscores the effectiveness of the implemented enhancements. This not only signifies improved operational efficiency but also holds implications for overall productivity gains and cost savings. The successful optimization of the painting process serves as a testament to the organization's commitment to continual improvement and its ability to adapt and refine operations to meet evolving demands and standards.

3.4. Act phase

The trials carried out to implement the improved process have yielded tangible results, showcasing a notable enhancement in the overall painting capacity of the Eco PUV Line. The empirical data gathered from these trials vividly illustrate the efficacy of the refined processes in driving efficiency and productivity gains. As depicted in Fig. 9, the total outputs generated from the enhanced process have surged significantly, marking an impressive 26% increase in painting capacity. This remarkable improvement translates to the successful completion of an additional 27 units, representing a substantial boost in production output.

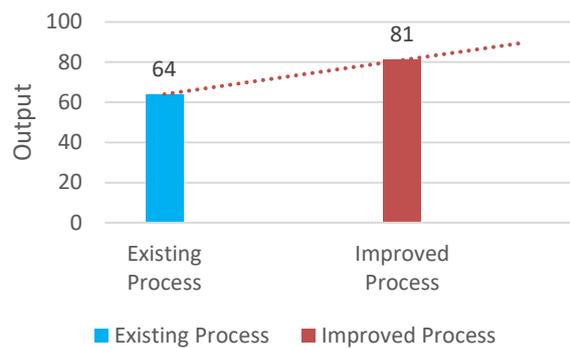


Fig. 9. Number of units produced per month.

Figure 10 illustrates a significant milestone achieved after the implementation phase, wherein the testing of the improved process was conducted. During the months of September to October, the company successfully met the target demand of the painting section without the need for overtime work. This achievement is indicative of the enhanced efficiency and productivity attained through the optimized process. Additionally, the surplus units produced during this period were strategically reserved for future months, demonstrating prudent inventory management practices.

The impact of these improvements is profound, as evidenced by the remarkable 20% enhancement in the painting process efficiency within the Eco PUV

production line. This notable improvement not only contributes to the company's bottom line but also aligns with its overarching goal of delivering high-quality products in a timely manner. By consistently meeting customer demand without sacrificing quality or resorting to overtime, the company reinforces its reputation for reliability and customer satisfaction.

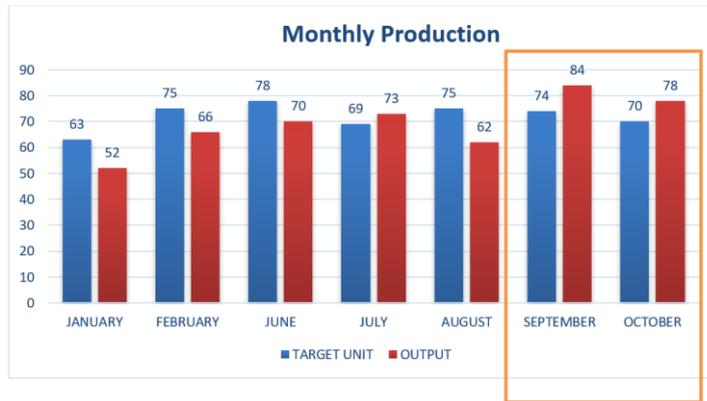


Fig. 10. Target demand vs. Output of eco PUV at painting section.

The successful implementation of the improved process in the Eco PUV production line not only enhances operational efficiency but also contributes to the company's overarching goals of profitability, customer satisfaction, and sustained growth in the marketplace.

4. Conclusions

The researcher used the PDCA (Plan-Do-Check-Act) application to methodically identify the problem's core causes. The researcher used a structured method to identify, evaluate, and resolve process inefficiencies by implementing PDCA. This approach worked well for both identifying the root causes and making sensible recommendations for fixing them. The results were especially pertinent to the Philippines' Manufacturing Industry Motors sector, which aims to reduce idle time during painting. In order to comply with industry standards and best practices, this strategy aimed to improve overall productivity, optimize resource utilization, and streamline operations.

After conducting a thorough study and analysis in painting Eco PUV Line, the arrived at the following conclusion:

- The researchers found that the existing painting process in the eco PUV line came short of delivering its targets based on customer's demand. The company is unaware that idle time exists which causes this delay, and it is possible to eliminate this kind of waste in the production. After determining the stages where improvement can be made, the process composed of 20 stages is reduced to 17. The long process creates idle time that result to the target or demand not being accomplished on time.
- After analysing the bottlenecks, the researchers saw in the stages where delay is huge and duplication of tasks or activities occur, thus the recommendation

to remove the two processes: first coat application and air drying and combining the spot putty application and spot putty sanding into one seamless workflow but with added engineering tools. Also, appropriate designation or assignment of manpower is key is reducing or removing the idle time and improving or increasing production.

- Eliminating waste enhances workflow and thus improves the pacing of the work. This is further enhanced by adding machines or equipment to make the work faster and efficient. The added equipment (rectangular sander) increased the enthusiasm and motivation of the workers as they were eager to learn new things and increased the quality of their work.
- The impact of these improvements is profound, as evidenced by the remarkable 20% enhancement in the painting process efficiency within the Eco PUV production line. This notable improvement not only contributes to the company's bottom line but also aligns with its overarching goal of delivering high-quality products in a timely manner. These improvements would be applicable for the motors industry in the Philippines.

The potential future research directions could include: Investigate additional stages in the painting process for potential reductions or improvements; implement and study the effects of Lean manufacturing principles beyond the initial improvements, focusing on continuous waste reduction; evaluate the potential for further technological integration, such as robotics or AI-driven quality control systems; study the effects of continuous training programs on worker efficiency and job satisfaction; research the impact of improved production efficiency on customer satisfaction and market demand; analyse how these changes influence customer perceptions and the company's market competitiveness; and study the environmental benefits of the streamlined process, such as reduced energy consumption and lower emissions.

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