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Improving productivity of production line using lean manufacturing

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ABSTRACT
Reducing waste, cutting production costs, and raising productivity are the most important objectives for fast-moving consumer goods manufacturing to maintain competitiveness in the global market and aim for stable and long-term development. Lean manufacturing is a set of tools, processes, and concepts for implementing continuous improvement and eliminating operations that do not bring value to the business. This study emphasizes defining and evaluating overburden, monitoring process efficiency, and formulating improvement plans using the DMAIC framework in terms of lean implementation. Lean techniques such as 3M (Muda, Muri, Mura), and NVA (non-value-added) analysis are used to eliminate waste, reduce cost, and increase line productivity. After applying Lean Manufacturing with the suggested DMAIC framework, the packing system automation will replace the current system. The advantages of this innovation will increase the productivity of the production line. In addition, it can also improve industrial safety and ergonomic work conditions for workers and reduce labor.

Keywords: *Lean manufacturing, 3M, DMAIC, NVA analysis*

1. INTRODUCTION

Globalization is an inevitable trend in the world. The huge changes in labor productivity, needs, psychology, and habits of users and the new production and business models that are being formed show globalization's huge role and impact on social life and all professions today. This poses new challenges in promoting the manufacturing sector and improving competitiveness and production capacity. Faced with competitive pressures, manufacturers are required to have a strategy to develop sustainable production through activities to improve productivity, quality, and flexibility of products and services at more competitive prices.

Fast-moving consumer goods manufacturing is one of the oldest industries in the world. The demand of this market is always fluctuating, so businesses that produce fast-moving consumer goods all the time must be flexible and seek changes in production models. The nature of the fast-moving consumer market is a short production life cycle, high volatility, low pre-dictability, high level of purchasing, rapid market response, and today's fast-moving consumer goods industry faces even greater challenges. To remain competitive, businesses must be able to respond quickly to changes in customer demand by improving productivity and production efficiency.

Lean Manufacturing is a combination of methods applied to eliminate waste and unreasonable steps in the production process [1]. Applying lean production will maximize cost savings and improve competitiveness compared to competitors. In addition, lean production also increases the ability to flexibly respond to constantly changing and increasingly demanding customer requirements. Lean includes a set of tools, techniques, and principles to implement continuous improvement, helping to eliminate activities that do not add value to the business [2].

While numerous lean tools, such as VSM, 5S, and Kaizen, have been proven effective individually, there is a lack of comprehensive studies that evaluate the synergistic impact of combining

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multiple lean tools on production line capacity. The majority of existing research focuses on lean manufacturing in specific sectors, like automotive and electronics. This research applies lean manufacturing with the DMAIC framework to improve production line capacity, and sharing best practices from FMCG industries offers valuable insights for practitioners and researchers. In the first six months of 2023, the FMCG company has reviewed its ability to meet the target output and proposed production schedule. Looking at the production capacity of the lines, it was found that the majority of production lines did not meet the target output. According to a report from the IE department, not meeting enough output will delay orders, leading to a recent average profit reduction of 10 - 15% (according to data in the first 6 months of 2023). The research identifies the company's low-productivity lines, analyzes data, and finds the root causes. The integration of advanced technology, such as robot automation and lean manufacturing principles, is used to increase productivity line and improve the safety and ergonomics of labor.

2. LITERATURE REVIEW

Lean Manufacturing provides methods for eliminating waste and delivering value to customers more efficiently. Popular tools include value stream mapping (VSM), 5S, total productive maintenance (TPM), single minute exchange of dies (SMED), just in time (JIT), and Kaizen, 3M. This section provides a comprehensive review of the literature on lean tools employed in this study, focusing on their role in minimizing waste and enhancing production line capacity.

2.1. Lean manufacturing

Lean Manufacturing, also known as Lean Production, originating from the Toyota Production System, was implemented throughout Toyota Company's activities since the 1950s [3]. Lean focuses on identifying and eliminating activities that do not add value (Non-Value-Added). Lean is not just about eliminating and preventing waste. It takes a value mindset to be able to find streamlining opportunities, thereby increasing value [2, 4, 5]. The main benefit of this system is to reduce production costs, increase output, and shorten production time [6].

2.2. Value added and non-value added analysis

The value stream is an ordered set of activities of every department in the organization related to providing products/services, from input raw materials to production, until the finished product is delivered to the customer. Each activity of the production process can be classified into one of the following types (value-added- VA and non-value-added- NVA) [7]. Value-added activities are those that directly transform raw materials and inputs to create the correct products that customers require and that customers are willing to pay for. Non-value-added activities are those that are not required or necessary to create the product customers require and for which customers are not willing to pay [8]. Activities that do not create value consume resources and should be eliminated or minimized. Activities that do not create value but are necessary are activities that customers do not accept to pay for, but are necessary for the organization or business to meet customer requirements. These activities are difficult to eliminate in the short term, usually only eliminated when there is a change in production methods or changes in process capacity. D. Klimecka-Tatar presents the possibilities for improving the production process using lean production tools, which will enable the identification and reorganization of areas within the process that need enhancement [9]. A. R. Rahani and M. al-Ashraf found that the application of VSM helped to reduce obvious waste and risks in production, and that changes in the production process led to actual work savings [10].

2.3. Muda, Mura, Muri

Lean Manufacturing has introduced the 3M concept, which is 3 types of waste: Muda (waste), Mura (unevenness), and Muri (overburden) [1, 11]. To increase profits for businesses, in addition to increasing output and revenue, minimizing costs is always a top priority. Muda in Japanese means wasteful, useless, and without value. The seven types of waste (Muda) in Lean manufacturing are often abbreviated as TIMWOOD. These include Transportation, which involves the unnecessary movement of materials. Inventory refers to excess stock of goods and raw materials. Motion denotes unneeded movements by workers or machines. Waiting occurs when there's an imbalance in the production process's timing. Additionally, Overproduction is producing more than needed, Overprocessing refers to adding more features or work than required by the customer, and Defects are products that fail to meet quality standards. By recognizing and addressing these wastes, companies can streamline their processes, enhance efficiency, and reduce costs, thereby improving overall productivity and customer satisfaction [11 - 13].

Mura refers to inconsistency or irregularity in processes. In Lean Manufacturing, Mura is seen when there is an imbalance in workflow, leading to inefficiencies. For example, if a production line has stages where some workstations produce faster than others, it causes bottlenecks and idle times, creating waste in the form of waiting or excessive inventory. Lean aims to achieve a balanced workflow where each stage of production operates smoothly in sync with the others. Implementing systems like Just-In-Time (JIT) helps minimize Mura by ensuring that materials and components are supplied in the correct quantities exactly when needed, thus reducing fluctuations and ensuring a steady flow of production. Addressing Mura is crucial for reducing overall waste and improving the efficiency and reliability of manufacturing processes [11, 13, 14].

The third type of waste, Muri, means overburdening or exceeding the capacity of a person. Muri is connected to the other three types of waste and can result from eliminating too much Muda from the process. Muri occurs when machines or people are used beyond their sustainable capacity, leading to stress, injuries, and breakdowns. In the long run, Muri can cause employees to take sick leave or machinery to malfunction [11, 13, 14].

Understanding and addressing Mura and Muri, along with Muda, is essential for creating a smooth, efficient, and sustainable production process, ensuring the well-being of workers and the longevity of equipment [14, 15].

3. METHODOLOGY

The steps of approaching a problem and implementing an improvement project are carried out in the DMAIC methodology: Define, Measure, Analyze, Improve, and Control. DMAIC is a structured procedure for a problem-solving approach [16]. The content of the DMAIC steps is detailed as follows:

Define: This is the first stage of the DMAIC method. This phase aims to define the scope and goals of the project, the problems, and the customer requirements. At this stage, it is necessary to determine basic factors such as: Who are the customers and what do they need? What is the current operational process diagram? What percentage of productivity and quality indicators need to be improved, what departments or processes does the scope of the project involve, and what resources are required?

Measure: The main goal of this phase is to collect data and information to evaluate the current status of the process. It is necessary to prepare a data collection plan with the following contents: details about data type, sampling frequency, and measurement method. Collect necessary data on the production line, such as the number of stations, cycle time of each station, working time per day, and productivity. It is necessary to ensure the correctness and suitability of the measurement system data collection system.

Analyze: This step is the process of studying the symptoms of the problem and determining potential causes. Some potential causes can be validated by statistical analysis of data collected from the process, while other potential causes must be confirmed only by observing the process.

Improve: The goal of the improvement phase is to find and implement solutions that eliminate the cause of the problem, reduce variation in the process, or prevent the problem from recurring. Research needs to develop ideas to eliminate root causes, test solutions, standardize solutions, and measure results. From the identified causes, this step selects, evaluates, and prioritizes solutions to solve the problem.

Control: The goal of this step is to develop a control and operation plan. Once improvements have been made and the results achieved have been recorded, it is necessary to continue to measure process performance regularly and adjust process performance. Evaluation standards need to be established to maintain performance and overcome problems that occur.

4. CASE STUDY

4.1. Define

The overall process of the FMCG factory is presented in Figure 1. The FMCG manufacturing process begins with storing raw materials and packaging materials. These materials are then accurately measured and transferred to the mixing area, thoroughly blended using agitators. Then the mixture is transferred to the packing line, where bottles are filled, capped, and sealed to prevent contamination. Labeled bottles are then packaged into cartons for distribution. The final products are stored in a warehouse, ready for timely distribution to the customers.

4.2. Measure and analyze

The packing line of the FMCG factory is divided into 6 processes, including manual case packing, manual bottle putting, case sealing, manual bottle feeding, filling, and manual cap feeding. Figure 2 shows the cost breakdown of the packing line, the manual case packing, and manual bottles putting consume the most costs in the production. Reducing the cost of work by eliminating losses arising from the organization of work leads to a reduction in operating costs.

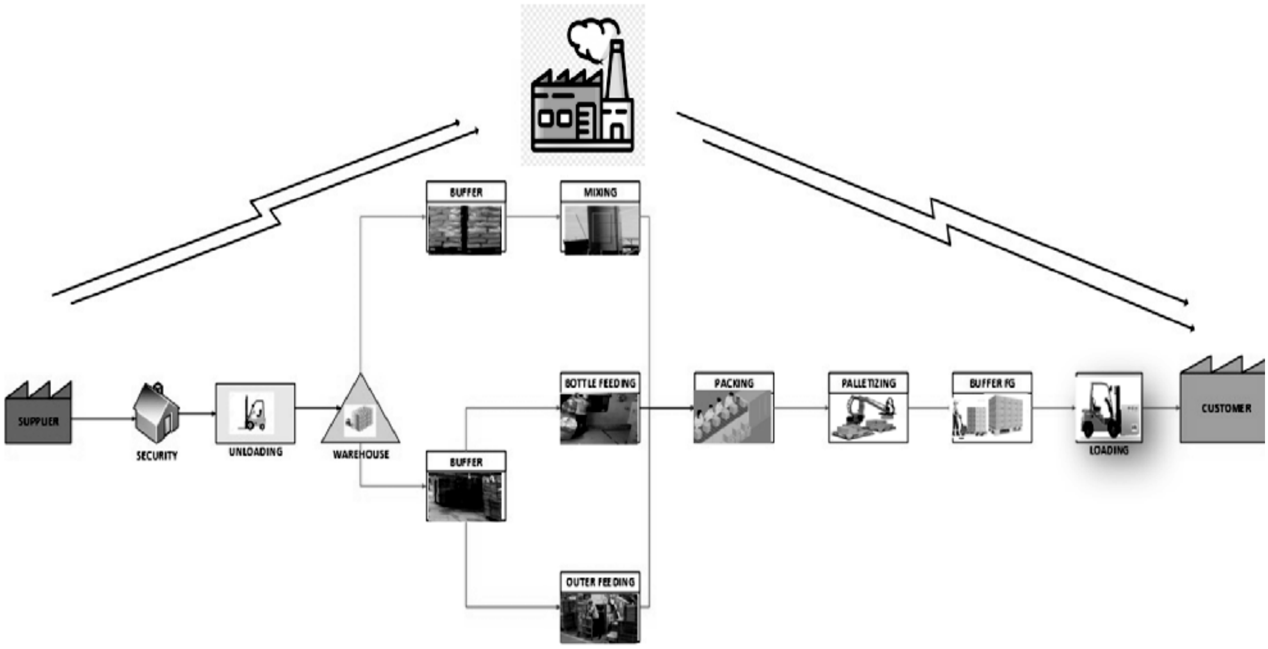

Figure 1. Overall process of the FMCG factory

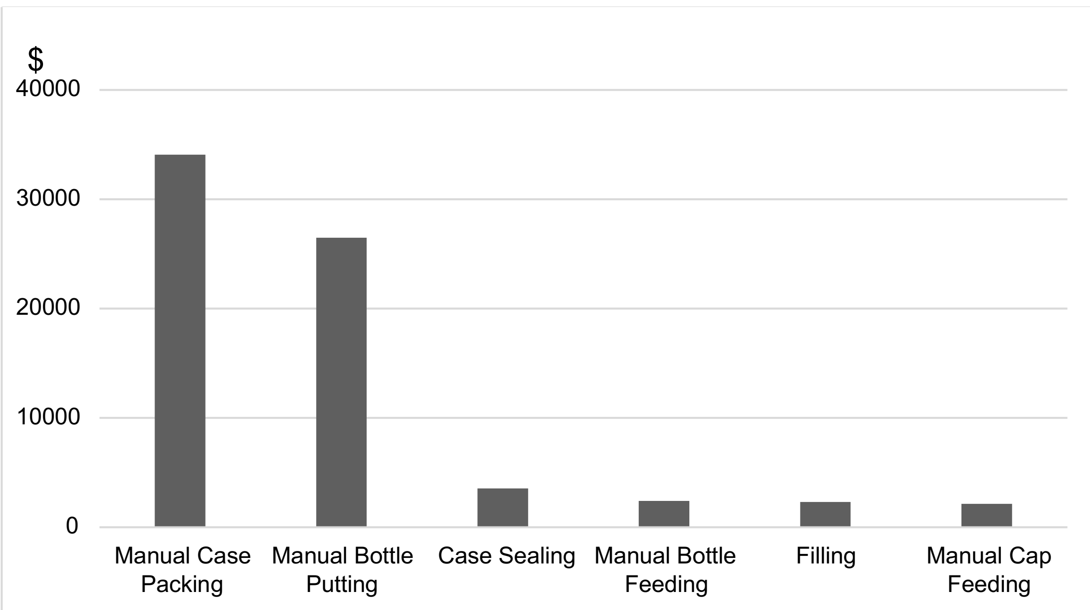

Figure 2. Cost breakdown of the packing line

A major issue with the packing process is that many of the steps are still done by hand, which is inefficient and results in a lot of waste. First of all, there is the packing area and a manual case packer station. We recorded tasks here in 1 shift and did 3M analysis. There were 6 tasks, including folding the outer box, inserting the divider, collecting bottles, supplying them to the outer box, waiting for bottles, pushing the outer box to the conveyor, and idle time. The result shows that 86% is NVA, including 14% idle time and 72% NNVA (necessary non-value-added) (Figure 3). We do in-depth analyses for each task. When the outer box is folded, the operator must flex their waist at an angle greater than 15° in order to retrieve the box, which is known as yellow muri. When inserting the divider, the operator must raise their arm above their shoulder in order to reach the red muri. In order to complete tasks of gathering bottles and both first others, the operator must rotate their body to cover a working range of greater than 90°. Red muri moving appears in this area. An operator must also have a greater than 15° waist flexion angle to perform tasks like suppling bottles to boxes and pushing boxes onto conveyors. It's the yellow muri.

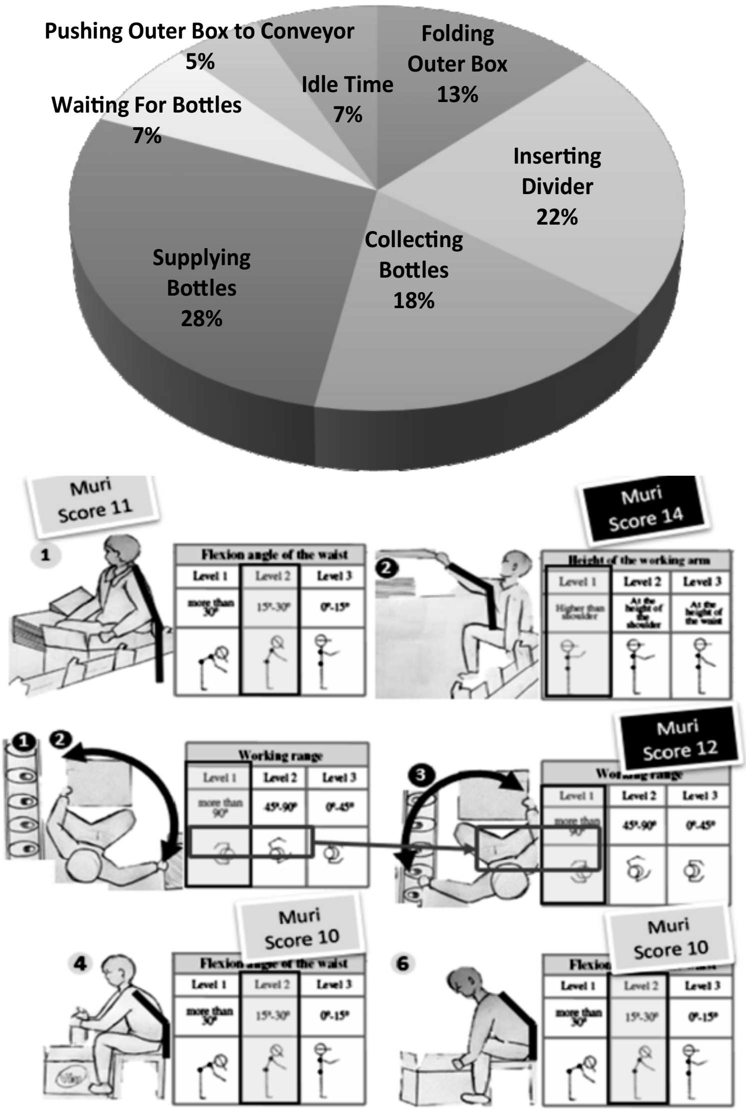

Figure 3. The task of manual case packer station

The next station is manual bottle putting. There were 4 tasks, including collecting bottles, bottle transfer, cleaning bottles, waiting for bottles, and idle time. We recorded time for tasks in this station, with 100% is NVA, including 33% idle time and 67% NNVA (Figure 4). There were two tasks with red muri, including bending down to gather bottles and rotating the waist to move them to another conveyor.

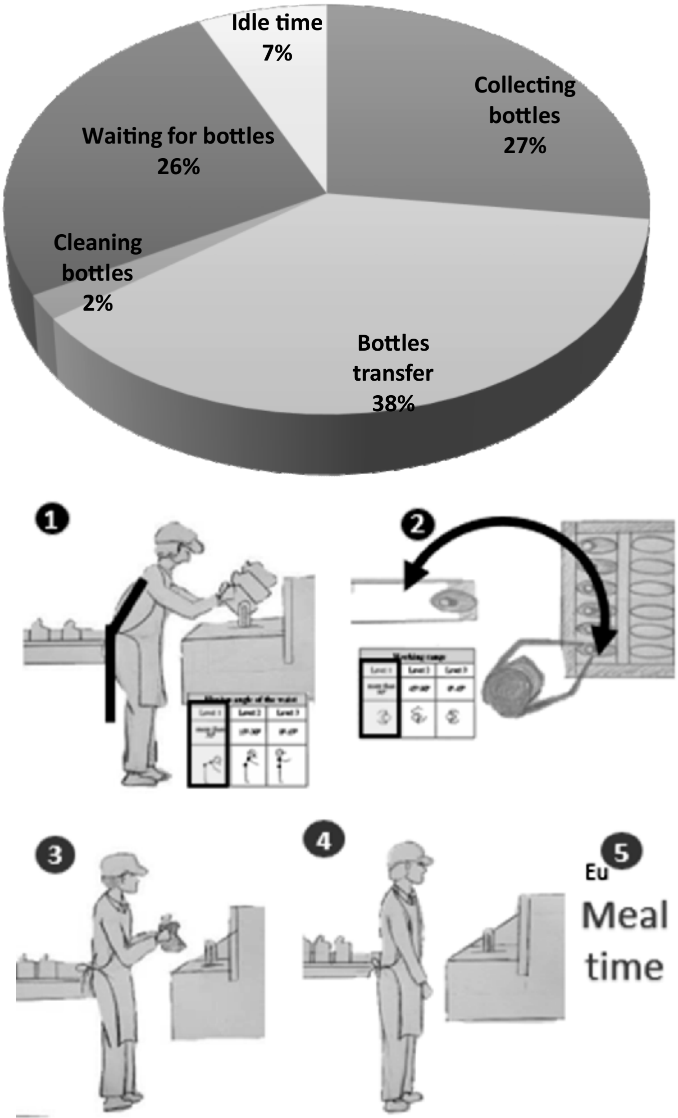

Figure 4. The task of the manual bottle putting station

4.3. Improve and results

After identifying all the stations in the packing process having opportunities for improvement, the following phase was executed. At the manual case packer station, in order to address Muri, the first step was to provide a suitable high shelf for storing outer boxes when the operator bends down to get the box and reach the divider. Thus, the operator can just grab them and is spared from further bending down and reaching. This action also reduces 0.3 seconds for each task cycle. Next, we moved the shelf and bottle conveyor in order to remove the operator's rotating body. So the operator just stays and gets simple. This action shortens task cycles by 0.2 to 0.3 seconds. Then we raise the conveyor's height in order to eliminate the waist bend. About 0.3 seconds are saved each task cycle with this action. As a result, we eliminate 100% of the red and yellow muri by using four better actions. In the end, we achieve a 9% cycle time reduction and lower NNVA. The analysis of Mura comes next. Task-by-task analysis revealed that each task has a small average cycle time, with deviations ranging from 0.3 to 1.4 seconds. Nothing to be done about this. We keep analyzing Mura according to the operator (two operators work a shift, for a total of six operators a day). After analyzing everything, it was shown that operator 2 and 5 had varied times (19 and 25 seconds). A thorough investigation revealed that the main cause of the difference in bottle collection per time is different (four pieces per time and one per time). New SOP was released to collect 4 pieces at a time in order to standardize. This also reduces NNVA by 4% (Figure 5).

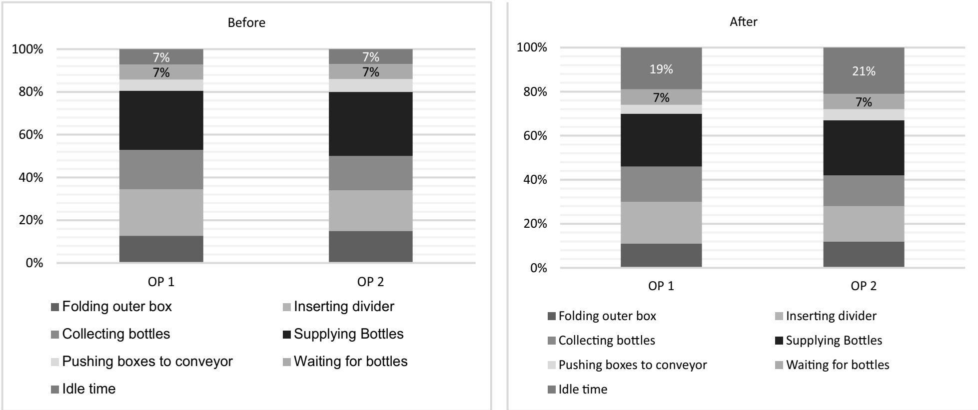

Figure 5. NVA analysis in the case packer station

At the manual bottle putting station, we lift up and one lose the space between the two conveyors, the NVAA reduces 6% (Figure 6). Mura analysis demonstrates that no action is required.

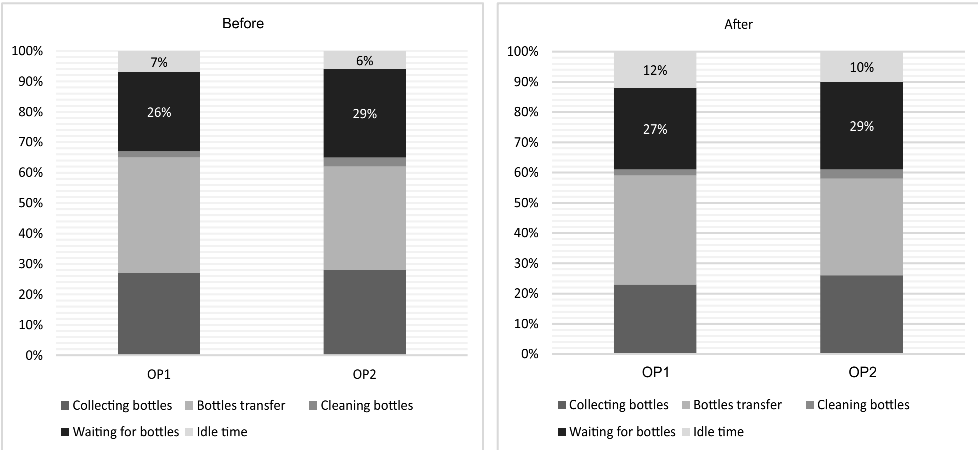

Figure 6. NVA analysis at the bottle putting station

Final result, the workload of workers after the Muri and Mura reduction is 54% (case packer station) and 78% (bottle putting station). Consequently, the line efficiency is also improved, but we can not release any labor.

Nowadays, autonomous robot technology helps increase productivity, revenue, and profits while allowing long-term use and flexibility in the face of changes in product variations. Furthermore, accidents workers can be minimized while working with high speed and precision, instead of needing many operators to work in this position without achieving high efficiency. Finally, we decided to do automation for the whole line by investing in 2 robots (Figure 7). Just invest 88,000 USD, and we release all 9 operators with a total saving of over 43,000 USD per year.

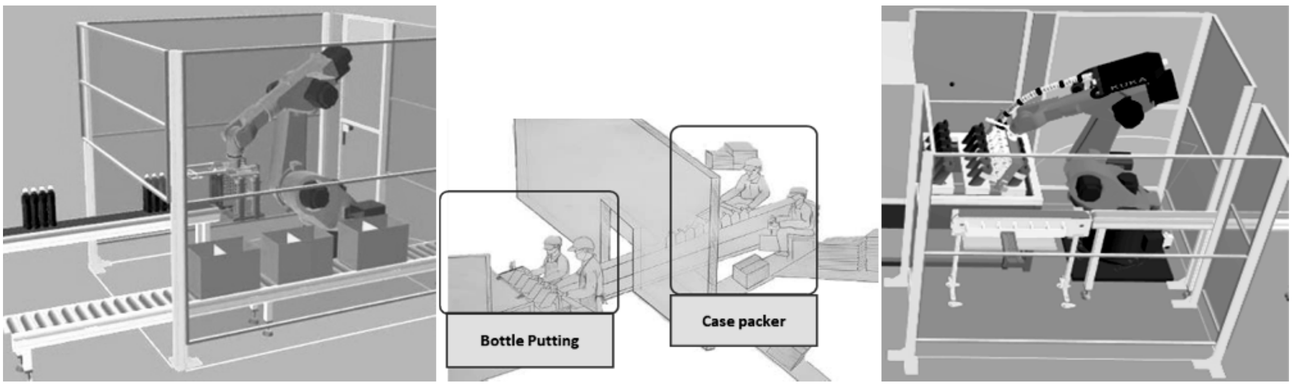

Figure 7. The automation packing line

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5. DISCUSSION

Waste is a main enemy in production systems, affecting the efficiency and effectiveness of production systems. 3M is often used in the determination and elimination of production wastes. Factories aim to increase the productivity of their production system rate throughout manufacturing processes as much as possible, but a lack of systematic methodology and a focus on the actual root causes prevent them from achieving the best solution [17]. This research aimed to improve the productivity of the line by integrating the DMAIC framework with lean tools such as VA/NVA analysis and 3M to identify and eliminate waste, thereby enhancing productivity. Similar to previous studies [7, 9, 18], this study shows that Lean Manufacturing significantly reduces waste in production, especially waste due to waiting time and unnecessary movement. The result also shows considerable impro-vements in workers' working operations, which aid in eliminating redundant movements and increase labor productivity while lowering the danger of occupational accidents due to proper workspace layout. This study also proposes that by implementing automation, the factory was able to release all nine operators, saving over 43,000 USD per year. However, this study also has certain limitations. Some workers have difficulty adapting to the new work process, leading to initial resistance. With such encouraging results, the team decides to continue doing more improvement projects for other production lines in the future.

6. CONCLUSIONS

Enterprises always develop positive and creative measures to stand firm in the market and increase their competitiveness, satisfying customers' requirements for higher profits. The application of lean manufacturing with the DMAIC framework helped improve the efficiency of a production line. The present work provided is a practical application of lean principles that helped reduce overall non-value-added activities time. Two processes of the packing production line, including bottle putting and case packing, were selected to demonstrate how the tools could be applied. The results presented show an improved workload for operators by using 3M analysis. The second solution is the use of autonomous robots for case packing and bottle placement, which improves ergonomics and lowers labor costs. In addition to the advantages, this study has significant drawbacks, including the high initial investment conversion cost of automated ma-chinery systems, maintenance costs, labor quali-fications, and the potential rise in low-skilled worker unemployment.

In future studies, the method will be implemented in the other production lines in the factory. Future studies should consider multiple lean tools (e.g., Value Stream Mapping, 5S, Kaizen, Kanban, Heijunka, Single-Minute Exchange or Die-SMED, ...) and their collective impact on production line capacity. On the other hand, research must identify factors that ensure maintenance and continuous improvement and prevent previous inefficiencies.

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Cải thiện năng suất dây chuyền sản xuất bằng sản xuất tinh gọn

Trần Quỳnh Lê

TÓM TẮT

Giảm lãng phí, cắt giảm chi phí sản xuất và nâng cao năng suất là mục tiêu quan trọng nhất của ngành sản xuất hàng tiêu dùng nhanh nhằm duy trì khả năng cạnh tranh trên thị trường toàn cầu và hướng tới phát triển ổn định, lâu dài. Sản xuất tinh gọn là tập hợp các công cụ, quy trình và khái niệm để thực hiện cải tiến liên tục và loại bỏ các hoạt động không mang lại giá trị cho doanh nghiệp. Nghiên cứu này nhấn mạnh việc xác định và đánh giá khối lượng công việc quá tải, giám sát hiệu quả của quy trình và xây dựng các kế hoạch cải tiến bằng cách sử dụng chu trình DMAIC để triển khai các kỹ thuật sản xuất tinh gọn. Các kỹ thuật tinh gọn như phân tích 3M (Muda, Muri, Mura) và NVA (hoạt động không tạo giá trị gia tăng) được sử dụng để loại bỏ lãng phí, giảm chi phí và tăng năng suất dây chuyền. Sau khi áp dụng kỹ thuật sản xuất tinh gọn với chu trình DMAIC được đề xuất, việc tự động hóa hệ thống đóng gói sẽ thay thế hệ thống hiện tại. Ưu điểm *của sự đổi mới này sẽ làm tăng năng suất của dây chuyền sản xuất. Ngoài ra, nó cũng có thể cải thiện điều kiện làm việc an toàn cho người lao động và giảm số lượng nhân công.*

Từ khóa: *sản xuất tinh gọn, 3M, DMAIC, phân tích NVA*

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