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USING LEAN MANUFACTURING TO IMPROVE PROCESS EFFICIENCY IN A FABRICATION COMPANY

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Abstract:
This article presents a case study on improving process efficiency in a mining equipment part fabrication company. The company was facing issues concerning communication, organisation, and workflow processes. This study investigated that ineffective communication among departments was the major weakness which was responsible for the long lead or idle time. This lead time was a waste that affected the company's productivity. A great amount of time was spent on non-value-added processes. The Kanban Centralised Communication System was implemented. Time study and value stream mapping were also used. A significant improvement in process efficiency from 34% to 85% was achieved by reducing lead time from 4200 minutes to 1680 minutes after streamlining the communication in the company using Kanban.

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1. INTRODUCTION

The twenty-first-century industrial scenario has changed the international marketplace significantly due to the accelerated requirements of high product quality and short process time [1]. Thus, forcing all spheres of manufacturing and assembly to fulfil such requirements. Lean Manufacturing plays a role in improving processes that pertain to production and promotes employee job satisfaction [2]. Lean fundamentally means minimizing or removing waste and facilitating the correct utilization of resources, which, therefore, contributes value to the customer without compromising product quality and/or process time [3]. There are eight types of waste identified in Lean, which mainly include [4]:

a) Overproduction- waste created from making more production than the customer demands or faster than the customer needs.
b) Defects- Flaws in materials, parts, or products that make them unsuitable for intended use or application, as quality standards are not met.
c) Inventory- extra inventory requires higher inventory cost and/or additional space.
d) Transportation- transfer distance for product, semifinished product or materials between warehouse and production station or the distance between two production stations is unnecessarily long, which could cause increased transfer time, waiting, potential damage during transport and increased number of logistics operators being used.
e) Waiting- when time is not spent productively, standing by and/or waiting for a bottleneck to be resolved or a delivery to arrive.
f) Motion- workers' inefficient or unnecessary movement may cause increased production time.
g) Over-processing- when unnecessary or additional alterations are done to the product that the client will not notice.
h) Unused talent is wasted due to the underutilization of people's talents, skills, and knowledge.

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Lean Manufacturing has three established pillars that are universally used. These three pillars include [3-5]:

a) Respect for people: This entails considering the workers/employees of the company. Factors like workplace environment, tasks that are not beneath their capabilities, and job security play a role in how a company respects their manual workforce.
b) Eliminating waste: wastes can come in many forms, but they are generally identified as activities that do not add value to a company. These wastes must be identified and dealt with in a manner that reduces or eliminates them.
c) Continuous improvement: utilizes processes that allow for flexibility and are adaptable to meet the demands and requirements of the industry to stay relevant.

It is important here to mention *Jidoka* and *Just-in-time*, which are also considered pillars of Lean manufacturing. Jidoka refers to automation with a human touch, which is capable of detecting abnormalities, stopping operations automatically, and preventing future occurrences. Just-in-time refers to producing or supplying only those products which are required and in the correct amount and at the right time.

The five Lean principles are Define Value, Map Value Stream, Create Flow, Establish Pull System, and Pursue Perfection [6]. The environment that Lean manufacturing creates for the workforce of the company is well constructed and safe, positively impacting productivity, which in turn makes the company more equipped to compete in its respective industry [7]. However, there are scenarios where manufacturing companies do not see the benefits of Lean manufacturing because of its incorrect implementation, the main reason being the lack of knowledge around this concept as well as the culture that comes with Lean manufacturing. With little understanding, companies are susceptible to using the wrong tools to solve the problem at hand, as well as repetitively using the same tool in different scenarios that require unique solutions [8].

Cellular manufacturing systems found in Lean manufacturing group products into product families to be produced on groups of machines that have been categorized into manufacturing cells on the floor plan [9]. The correct application and implementation of cellular manufacturing produce advantages that correlate to the reduction of machine setup times, material handling, and work-in-progress inventory while simultaneously enhancing the throughput and quality of the product. A relevant reason to adopt cellular manufacturing in high-variety and low-throughput industries is to reduce machine setup times, which is considered the accumulation of time spent on preparation activities that need to be carried out before producing the product. These preparation activities are regarded as non-value-added activities or wastes in Lean Manufacturing [6,9]. *Kaizen* is an important tool used in Lean manufacturing. Kaizen can be defined as a continuous improvement that is conducted daily and at every moment of that day at any job level in the company. Everyone in the company is involved in the improvement; this improvement can range from micro-scale to macro-scale. The larger improvements are regarded as breakthroughs and innovations [10]. *Work-In-Progress (WIP) Inventory* refers to inventory that is undergoing the manufacturing process. This inventory cannot be considered as raw material nor finished product. In Lean manufacturing, reducing this type of inventory results in greater liquidity, better cash flow, greater customer service and fewer risks pertaining to the business [11]. Work-in-progress inventory has limits; if these are not applied, it will be difficult to manage the wasteful and inefficient processes across the floor plant. WIP limits help us to manage capacity, implement slack into the workflow and practice systems thinking [11]. *Value Stream Mapping (VSM)* is another important tool used in Lean manufacturing. It identifies and removes waste by ensuring that lead time is less than takt time. It is the process in which a visual map of the flow of product is shown. Moreover, it shows all the activities, from accepting raw materials from the suppliers to the final product being delivered to the customers [12]. All processing steps are shown to provide a bigger picture of the shop floor, with these improvements can be made to the production line. The value stream map includes all materials and information required in the manufacturing of the final product and how they flow through the manufacturing systems. Value Stream Mapping can be used in high-variety and low-volume companies [12]. *5S* is a method of organizing the work environment that falls under Lean manufacturing. The 5S's are Sort, Set in Order, Shine, Standardize, and Sustain [13]. This process involves analysing the current process and achieving greater production and throughput through small consistent improvements. *Kanban* translated to signboard or billboard, is a scheduling system that is very effective and useful in Lean manufacturing interventions. The role of Kanban is to minimize the amount of work in process and inventory. Overproduction or defects are regarded as waste and failure to meet production standards. Kanban is used in a production scenario to show ongoing production quantities and update employees on the work floor about already produced quantities and the number of products that still need to be produced [14]. Kanban, according to its basic understanding, is the use of a digital or physical board to display information. Through this Kanban board, progress can be tracked by everyone involved in the work process, allowing everyone to be a leader and keeping WIP limits and deadlines transparent. In general, Kanban enables employees to understand production through visualization. Kanban also allows employees to control the continuous flow in the floor layout between cells. As mentioned before, *Just-In-Time (JIT)* is a Lean manufacturing concept that focuses on the employee's talents and skills. Just-In-Time allows workers to display their knowledge and skills by giving them the responsibility to manage and improve their own workplace or cell. It also implements that the parts and components are delivered just as they are needed for production or when the customer requests the final product, and not before, to reduce inventory [15].

Some of the previous attempts at utilizing important Lean manufacturing tools and techniques are discussed below.

An interesting study reported the effectiveness of Kanban in reducing inventory costs by reducing storage from 13 to 5.5 days in a switchgear company [16]. It was highlighted that Kanban is also equally effective for vendors. In a labelling and packaging company, Kanban-based Lean manufacturing implementation resulted in quality enhancement and waste reduction [17]. Lead time and consumer complaint rates were reduced by 7.1 and 83%, respectively. In the latest investigation, a lead time reduction of 51 minutes was reported by authors when Kanban and value stream mapping were implemented in a foundry facility related to railway part manufacturing [18]. Not only physical facilities like plants, factories, and workshops but also online e-commerce services, etc., have availed Kanban benefits for improving operational activities, process efficiency, and profits [19].

Lean manufacturing was found effective in significantly reducing process time from approximately eighteen thousand to fifteen thousand minutes in an aircraft maintenance industry by identifying and eliminating non-value-added activities using plan-do-check-act, value stream mapping, and problem identification and corrective action [20]. With the help of value stream mapping, an improvement in waste identification and analysis and a reduction in non-value-added activities have been achieved in the case of the Palm oil processing industry [21]. Similarly, in a company, value stream mapping was found effective in reducing lead time at 81%, cycle time at 38%, and scrap at 90%, while production of rubber parts for automobiles [22]. In a metalworking company, with the application of Lean manufacturing, especially under 5S implementation, availability was increased by 17.36% and machine productivity by 10.37% [23]. A combination of the value stream map and Knaban successfully eliminated wastes in a chemical company in the form of a 6.74% reduction in non-value-added activities and a 67.25% improvement in process cycle efficiency [24].

Utilizing most of these tools and techniques of Lean manufacturing, many types of wastes, such as idle time and unnecessary motion, as well as defects during the production process, can easily be outlined and treated [25]. This significantly affects the production processes positively, hence increasing profit and leading to sustainability. Having this motivation, the current case study was conducted in a fabrication company that fabricates multiple parts for equipment and machines used in the mining sector. The company is located in Johannesburg, South Africa and has a permanent staff base of 52 employees. This includes managerial staff, directors, and the owner. The company lacks organizational structure and overlooks the benefits of systems that log all processes, hours spent working and materials. Because the company is small, only one member is designated to oversee processes, quality control, and inspections alongside their job descriptions and responsibilities. This makes for a 'juggling act' where the individual is overwhelmed with responsibilities, often leaving many issues overlooked or unnoticed. There are several tools that fall under Lean manufacturing, some of these tools will be examined and applied to highlight critical weak points in the company and formulate beneficial alternatives to the processes. This will include a reduction in processes that do not add value and wastes (as defined by Lean manufacturing) found in the company. In order to apply Lean manufacturing tools more efficiently, this project will focus on one process, which is the fabrication of the part shown in Fig. 1. This part is very common and can be found in the majority of job orders requested by customers; therefore there is merit in focusing on the process of fabricating the part selected.

The fabrication company produces several other parts; however, standardization will only be applied to this product as standardization of all parts will be a large and lengthy undertaking. The company faces long production lead time when compared to the processing time for the fork part due to negligence of the overall organization and lack of communication with the employees involved in producing the products alongside the departments of the company. Overall, this work aims to determine what areas of weaknesses can be found in the company and to optimise functioning using Lean manufacturing.

The specific objectives of this research are as follows:

- To identify the weaknesses in the organizational system under consideration and thereby waste in fabrication processes therein.
- To implement the Lean manufacturing technique Kanban to improve areas of weaknesses and minimize waste, i.e. lead time.
- To improve the efficiency of the processes involved in fabricating the part in focus.

It is expected that applying Lean manufacturing tools and techniques will optimize the function of this fabrication company by improving communication and reducing areas of waste.

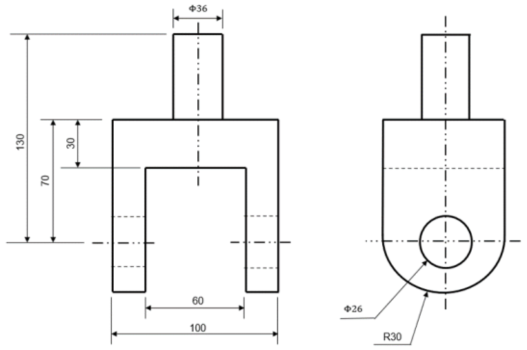


Fig. 1. Diagram of the part (fork) in focus

2. METHODOLOGY

The type of research study is a case study, as the data collection was done in this company alone. After the data was recorded through the time study technique, an evaluation of what areas were deemed as wastes, according to Lean manufacturing, was emphasized. The statistical method used was descriptive statistics, which focused on average cycle times. Descriptive statistics also outline the characteristics of the recorded data. This project focuses on the production and requirements of a fabrication company that specializes in the mining industry and may have to be adapted or adjusted if applied to other companies. The work part is processed and transferred in batches between stations as opposed to a one-piece flow. The reason is that the company does not solely focus on the fabrication of this part but on several other parts. The batch process favours larger quantities being fabricated faster, however, at the expense of creating potential excess inventory (which one-piece flow reduces). The company is regarded as a small to medium-sized enterprise, and although it fabricates a variety of parts, there are limitations in the available manual labour, machines and equipment needed to fabricate parts with a one-piece flow.

2.1 Study Setting

As previously mentioned, the company has a base of 52 permanent employees, making it a small to medium-sized enterprise (SME). The company is going to provide all data for the case study. The company is currently functioning and continues to fabricate products for customers that can be found across South Africa.

2.2 Sampling Methods

The product is a standard part produced by the company. The company follows standardization, which is a key aspect of Lean manufacturing. This part, as shown in Fig. 1, is a common product produced by the company; therefore, the sample size is adequate for this project. The sample size is the whole fabrication output for the parts produced in a month.

2.3 Data Collection

Before a design can be developed, background knowledge and data need to be collected. Therefore, a data analysis using a time study was carried out. This data analysis highlights average cycle time (ACT) and standard minute value (SMV), which were calculated as per Equations 1 and 2.

The time study was recorded by looking at how long it took to produce the sample/part (fork) from the time the raw materials (Stainless Steel 316) were ordered until the time the finished product was dispatched to the customer. The data shows the cycle times for each operation as well as the average and the standard minute value (SMV).

$$Average\ cycle\ time = \frac{Sum\ of\ cycle\ times}{Number\ of\ cycle\ times} \quad (1)$$

$$Standard\ minute\ value = Sum\ of\ cycle\ times \quad (2)$$

The time study as presented in Table 1, has shown the cycle times for each operation and where they can be improved.

The following observations were made after conducting the time study:

- Ordering new raw materials is only done when current raw materials are finished and not before then.
- A delay in ordering raw materials impacts the lead time as well as the operator responsible for dispatching raw materials to CNC machining is overwhelmed by other responsibilities.
- A delay from the inspection officer, as there is no formal system to notify the inspection officer when the CNC part is finished.
- A delay from the operator responsible for dispatching to welding as he is overwhelmed by all the other dispatches between workflows.

Table 1. Results of time study

Step No.	OPERATION	MACHINE	CYCLE TIME (DAYS)					ACT	SMV
			1	2	3	4	5		
1	Order raw materials	Manual	6	4	5	6	2	4.6	23
2	Dispatched to CNC	Manual	2	2	3	2	3	2.4	12
3	CNC maching	CNC manual	4	5	2	3	4	3.6	18
4	Inspection	Manual	2	2	3	2	2	2.2	11
5	Dispatch to welding	Manual	2	2	2	2	3	2.2	11
6	Welding	Arc welding machine	4	3	2	3	3	3	15
7	Inspection	Manual	2	3	2	3	2	2.4	12
8	Dispatch to painting	Manual	2	1	3	2	2	2	10
9	Painting	Air brush machine	4	5	4	6	5	4.8	24
10	Inspection	Manual	2	3	3	3	3	2.8	14
11	Dispatch to packaging	Manual	2	2	2	3	3	2.4	12
12	Packaging	Manual	4	3	3	3	4	3.4	17
13	Inspection	Manual	3	3	4	4	3	3.4	17
14	Inventory waiting to be dispacthed to customer	Manual	6	8	7	9	6	7.2	36
	TOTAL		45	46	45	51	45		

- A delay from the inspection officer, as there is no formal system to notify the inspection officer when the welded part is finished.
- A delay from the operator responsible for dispatching to painting is overwhelming, as he is the only operator responsible for dispatches.
- A delay from the inspection officer, as there is no formal system to notify the inspection officer when the paint job has been finished as well as the inspection officer having the responsibilities of inspecting this work part all though the processes flow.
- A delay from the operator with dispatching finished work parts to packaging for reasons previously mentioned.
- A delay from the inspection officer in inspecting the finished and packaged product for the reason mentioned previously.
- The finished work part contributes to idle time as well as inventory waste, as the department responsible for shipping and logistics experiences backlog due to poor planning and process control.

The time study shows that most operations are dependent on manual labour and the human factor. Operations that should take one or two days often exceed the cycle time. There can be several factors that contribute to this, including poor scheduling (or overscheduling) and lack of communication between different sectors of operations. The use of a system that would better understand and standardize operations to a simpler form, as well as include communication on work-in-progress, would be required to improve cycle time and decrease lead time.

2.4 Solution Design

There are three possible solutions to reduce process lead time and time waste that can be addressed. This is done by calculations and visual mapping. Fig. 2 illustrates the simplified fabrication floor plan layout (Fig. 2a) and its ArchiCAD drawing (Fig. 2b) before any design elements in terms of possible solutions were added to the fabrication processes.

2.4.1 Concept Generation

Solution 1: Kanban Centralized Communication System

Utilizing billboards implies that all processes are put on display and act as a form of communication. This concept deals with communication from management as well as the workers on the floor.

Solution 2: Inventory System for three types of inventories, i.e. raw materials, work-in-progress (WIP) inventory, and finished products inventory

Inventories play an important role, as intentional allocations of materials and products allow for better tracking of physical assets and processes.

Solution 3: Mainstream flow floor plan layout using spaghetti diagrams as rough models

The spaghetti diagram shows the paths taken. These paths show where they cross (which can be undesirable when crossing paths too often) and which paths are long in comparison to others.

2.4.2 Concept Evaluation

Solution 1: Kanban Centralized Communication System:

A newly designed Kanban system will improve the processes between departments and the time it takes to complete these processes. The improvements do not include work cell layout and transport to and from the company.

Solution 2: Inventory System:

A newly designed inventory system will improve the allocation/finding of raw materials, WIP parts, and finished products. This will reduce the number of reorders or reworks due to misplaced items and reduce dispatch times. This will, in return, reduce costs and lead times.

Solution 3: Floor Plan Layout:

The newly designed floor plan layout will rearrange work cells to improve the flow of operations and reduce process times. These improvements do not include time to order raw materials, operational times, time spent in inventory, and time spent delivering the product to the customer.

2.4.3 Concept Selection

Out of the three solutions, the Kanban centralized communication system has been used to develop a database that all members of the company have access to and can input information. This will allow workers to know which process has been completed and what processes still need to be undertaken. They can also gauge if they are behind schedule and if there are any bottlenecks in the process flow. The day of dispatch will be a deadline, which will be the goal the company will work towards completing the job on time. Because of the previously mentioned points, Kanban will provide improvements and will be the selected design system as the best solution.

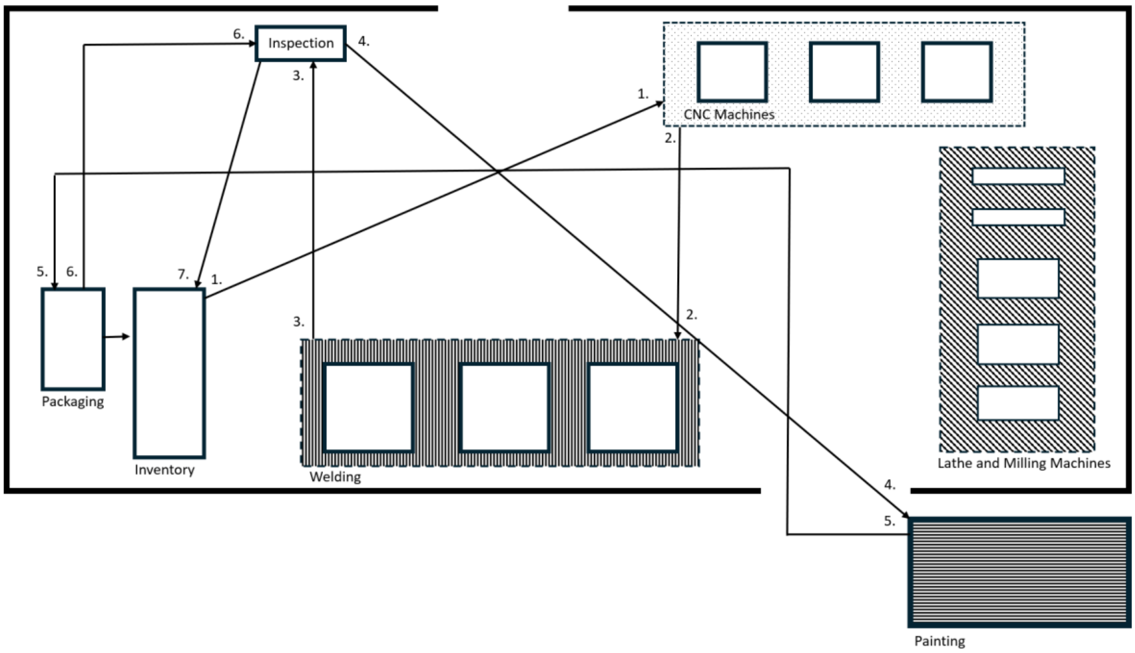
2.4.4 Detailed Design Solution

Kanban's primary function is to improve communication between all processes and members of the company. In turn, it facilitates the flow of parts, acts as a pull system, and reduces inventory.

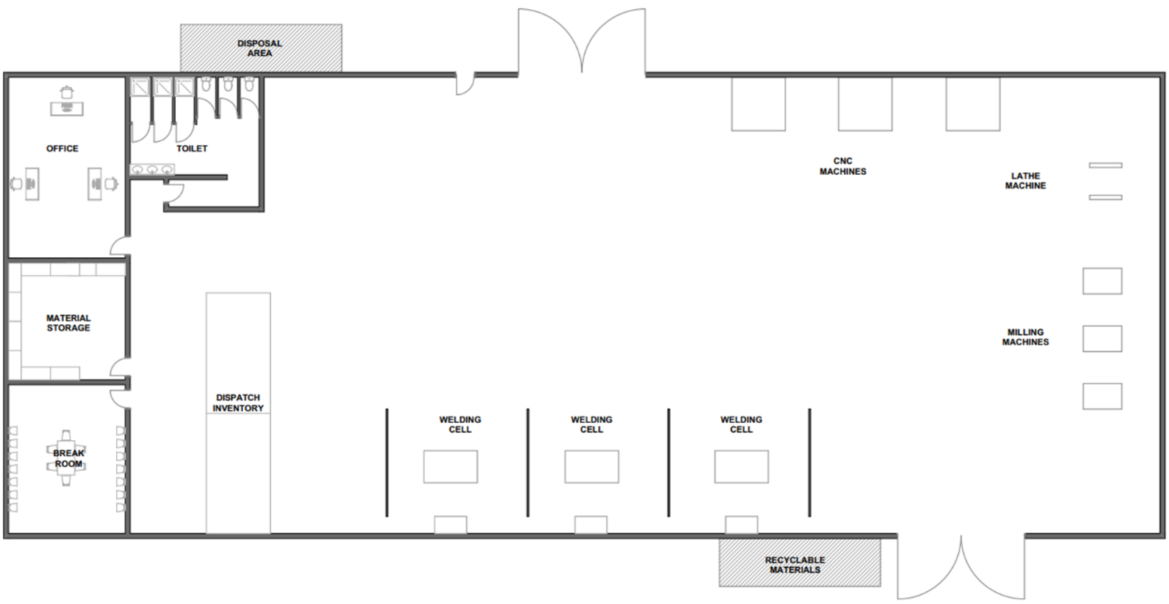
There are several areas of concern:

- Workers do not have a clear understanding of how many jobs must be completed.
- Workers do not have a clear understanding of how many jobs are still in progress.
- All members of the company do not have a clear outline of which processes require more time to complete than required. Thus, causing bottlenecks.

As per the selected methodology, the Kanban centralised communication system will utilise three boards that are placed on the floor at respective departments. Here, reports of the required tasks that need to be completed will be posted at the beginning of each workday. An appointed Kanban communication officer will be responsible for generating and posting these reports. At the end of the workday, the same officer will collect the reports with all the jobs completed, still in progress, or not started (with their justifications or reasons for not completing) and update the system responsible for generating the next batch of reports for the next workday. Because these reports go through the Kanban communication officer at the beginning and at the end of the workday, it is regarded as a centralised system. It was advised to use electronic boards/TV screens; however, such equipment would be susceptible to damage and theft. More industrially used electronic boards that could withstand wear and tear were regarded as costly to consider. Therefore, to address this, reports were printed physically and filled in manually by respective operators. This was a choice by this company, making it custom to their case. In the case of other companies where funding is sufficient, and security is not an issue, such equipment could be considered.



(a) Simplified drawing with material flow



(b) ArchiCAD drawing

Fig. 2. Fabrication floor plant layout

Further, the software ATLASSIAN Trello has been utilized on a computer located on the floor plant. Fig. 3 presents the interface of Trello. This software specializes in developing Kanban systems that are interactive with a user-friendly interface. Specific points have been included in the layout of the Kanban system:

- Customer Order Number: here, the customer order number from the invoice will be filled in beforehand from the company's invoice to keep track of the customer and the date the job is due for completion.
- Invoice Number: here, the operation manager will have the ability to cross-reference the invoices and the Kanban system.

- Description of Job: here workers on the floor will have a more comprehensive understanding of the job and the part they are fabricating to identify the part with ease.
- Inspected By: here, an operator will fill in their name, confirming the raw materials from the supplier have been inspected in order to ensure that the raw materials can be processed and not create rejections for the company.
- CNC Machine Completion Date: Here, the operator of the CNC machine will input the date they have completed this job process.
- Welding Completion Date: Here the welder will input the date they have completed this process of the job.
- Inspection Date: here, the quality assurance officer will inspect the CNC machining and the welding to determine whether they are up to the standard; if not, the inspector will send it back to the respective department to avoid rejects.
- Painting Completion Date: Here, the painter will input the completion date of this job process.
- Packaging Competition Date: Here, the packager will input the completion date of this job process.
- Inspection Completion Date: Here, the quality assurance officer will inspect the completed job/part to ensure that the final product meets the standards of the customer. If not, the inspector will send it back to the department that needs to rectify the errors.
- Dispatch Date: This date will be filled in beforehand to set a goal for when the job must be completed by the latest. Here, all members will have a gauge if the processes of certain departments are lagging behind schedule.

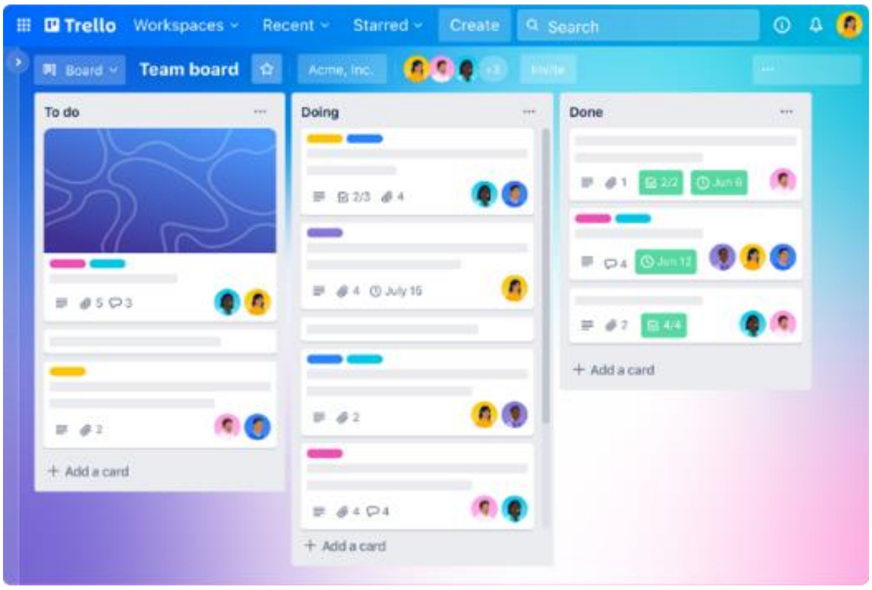


Fig. 3. Example of Trello Interface

Fig. 4 is an illustration of an ArchiCAD drawing of the fabrication floor plan layout. All items in blue highlight added features that will be included in the Kanban centralized communication system. There is one computer that will run the Trello software and three boards that will post daily report sheets generated and printed from the software. These boards are located per department: CNC Machining, Welding, Painting and Lathe/Milling machining. These sheets will be filled out throughout the working day by employees and returned to an appointed Kanban communication officer who will be hired as an additional staff member. The individual job description includes:

- To see overall operations are recorded on the Kanban system.
- Employees are logging their progress on their daily printed sheets.
- Employees return these printed sheets at the end of the working day.
- The officer is using and feeding the data from the returned printed sheets to be able to print the next day's report sheet with previous days' updates for the floor employees.
- Reports are generated for employees on the floor to acknowledge their progress or lack of progress during team meetings in the break rooms at the end of the month.

- Reports are generated for upper management to understand the efficiency of the company as well as using these reports for additional data to make future decisions.

An inspection table is being utilized by the Kanban communication officer to approve completed jobs while ensuring the quality of the product is up to standards of the company's production standards.

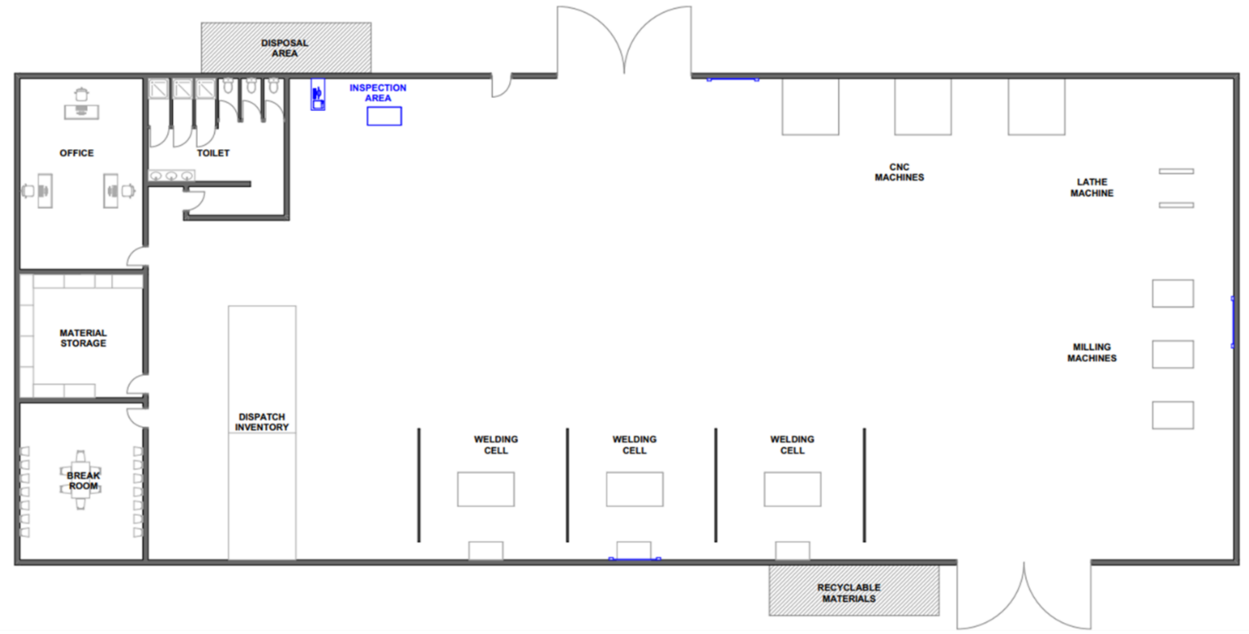


Fig. 4. Fabrication floor plan layout with kanban centralised communication features

3. RESULTS AND DISCUSSION

Fig. 5 presents the VSM analysis of these processes before the Kanban centralized communication system was implemented.

The workers on the floor have a 9-hour shift with an hour break in between the working day, adding up to eight hours of work. Considering that, the total production lead time, which represents how long an operator/worker must wait for the previous job, was calculated as:

$$Total\ production\ lead\ time = 8.75\ days \times 8\ hrs \times 60\ min = 4200\ min \quad (3)$$

A total of 8.75 days was spent on workers waiting for the previous process and, in turn, being idle. Therefore, the process efficiency was calculated as:

$$Process\ efficiency = \frac{Processing\ time}{Production\ lead\ time} = \frac{1430}{4200} = 34.05\% \quad (4)$$

The process efficiency shows that 34.05% of the total lead time was adding value to the product and the remainder of the time was not utilized on this product. Fig. 6 presents the VSM analysis of these processes after implementing the Kanban centralized communication system. The initial VSM showed a production lead time of 8.75 days, whereas after the Kanban design, the production lead time was reduced to 3.5 days. Activities that contributed to production lead time noticeably took less time to achieve with the aid of communication and improved workflow. The lead time and process efficiency after Kanban implementation are as follows:

$$Total\ production\ lead\ time = 3.5\ days \times 8\ hrs \times 60\ min = 1680\ min \quad (5)$$

$$Process\ efficiency = \frac{1430}{1680} = 85.12\% \quad (6)$$

An increase in process efficiency from 34.05% to 85.12% shows that the total lead time is adding value to the product; this is credible as a production lead time is dedicated to parts that were rejected by the inspector and needed reprocessing.

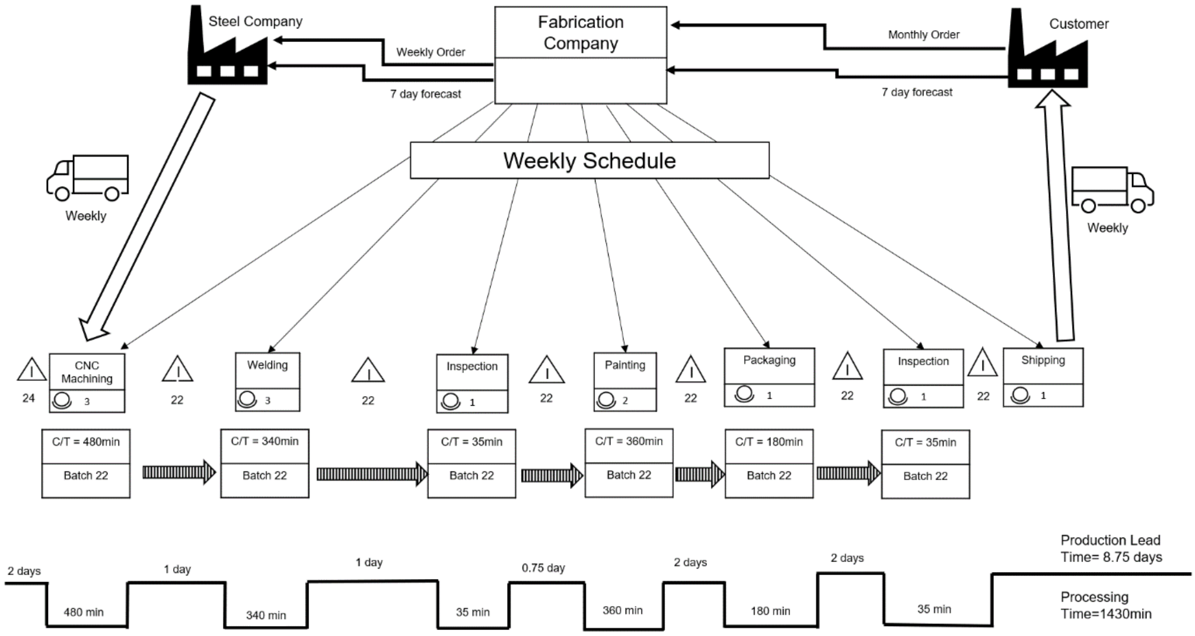


Fig. 5. VSM of fabrication company before implementing Kanban

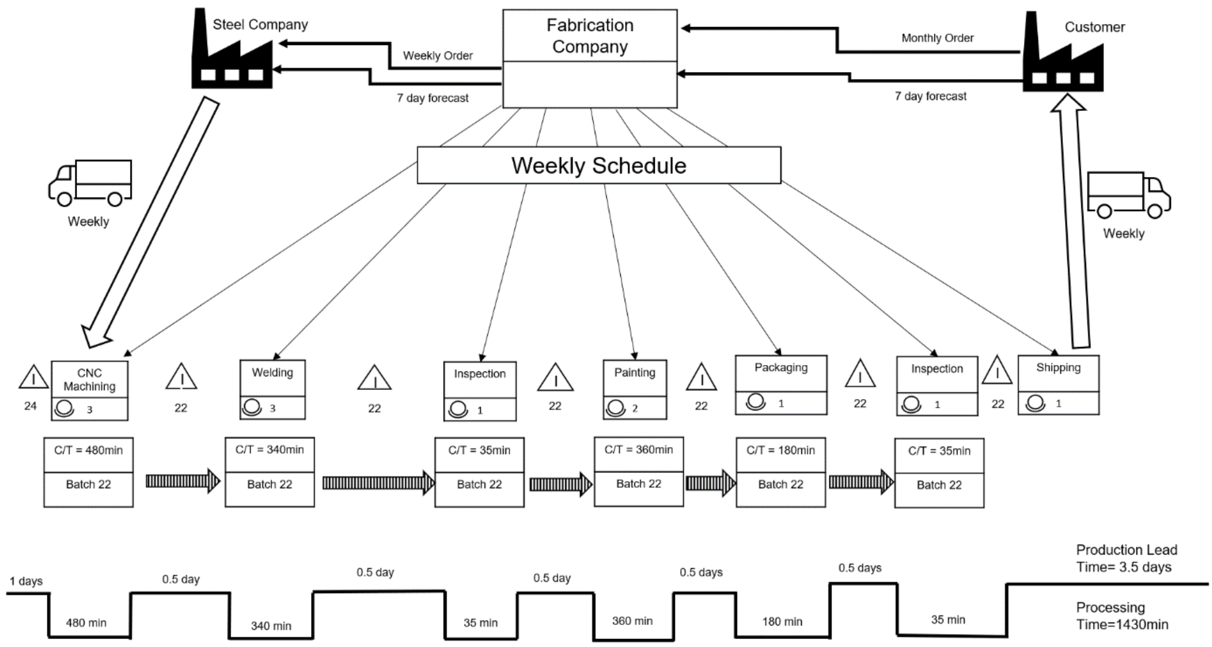


Fig. 6. VSM of fabrication company after implementing Kanban

Fig. 7 presents the graph illustrating lead times before and after Kanban implementation. Fig. 8 illustrates the difference in lead time and efficiency before and after Kanban implementation. After implementing the Kanban centralized communication system, the reduced lead time resulted in an improvement of 51.07% in time spent on value-added processes and, thus, an increment in process efficiency.

It is evident that the weaknesses were communication between departments and employees and the waste in terms of the lead time, as by introducing the Kanban centralized communication system, process efficiency was greatly improved. The Kanban-based Lean manufacturing technique proved to be a potential approach for significantly minimizing lead time and enhancing efficiency.

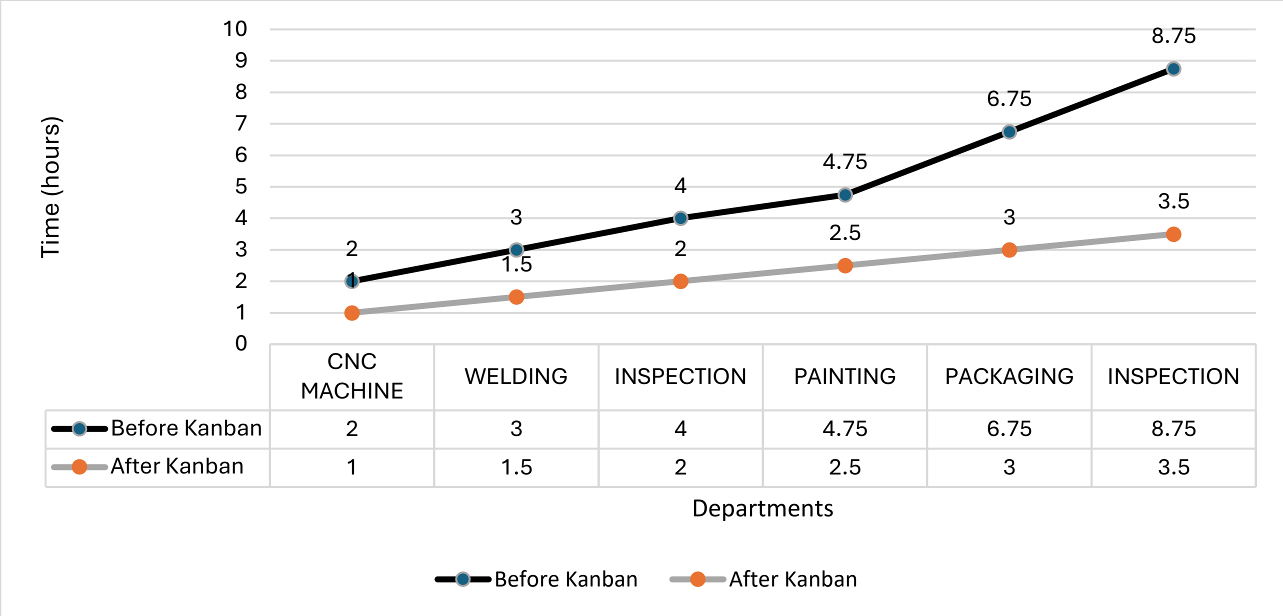


Fig. 7. Production lead times before and after Kanban implementation

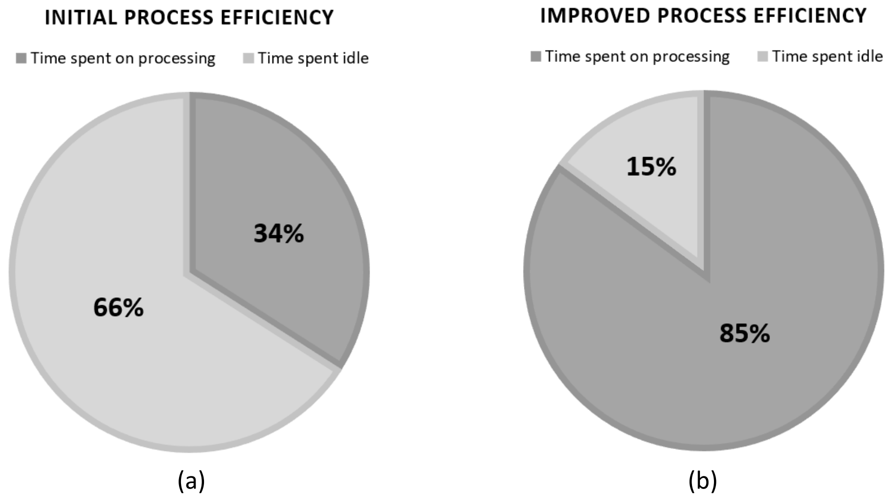


Fig. 8. Lead/Idle time and process efficiency (a) before, and (b) after Kanban implementation

4. CONCLUSION

In this work, with Lean manufacturing tools and techniques, i.e. time study, value stream mapping, and Kanban, it became evident that production lead time and processing time did not correlate. There was a great amount of time spent on non-value-added processes/time spent idle due to a lack of direction and communication. Using a centralized Kanban communication system as one of the design and solution strategies, lead time was successfully reduced, and efficiency improved after developing a new VSM. The value stream map and time study showed that most operations are dependent on manual labour and the human factor. Operations often used to exceed the prescribed cycle time. Poor scheduling (or overscheduling) and lack of communication between different sectors of operations were the factors that were responsible. The use of the Kanban system reduced the time between operations spent idle and improved communication between work cells/departments. When the members of the company input their relevant data, then other departments can see where too much time or idle time is spent and, therefore, could hold workers liable. This also allows managers to make corrections on time spent on processes and operators to carry out those adjustments. After the Kanban system was implemented, a noticeable reduction of 2520 minutes in lead time was achieved, and process efficiency improved from 34% to 85%.

The implications are that the study is limited to the particular part considered in this work, and not all processes are related to the fabrication of various other parts and their production. Other processes may have other wastes that may contribute negatively to the company and require further investigation. Limitations also include the companies' size; because the company is regarded as a small to medium-sized enterprise, there was not a willingness to invest largely into new infrastructure without a guarantee that process efficiency would be improved. Employees also had to adapt to a certain level of accountability and autonomy, as they were responsible for completing reports throughout the working day. For some, this was a difficult activity to adopt; however, after clarifications at several meetings where roll call was taken, operators were portrayed to be more confident with updating reports.

The long-term effect on competitiveness includes the companies' ability to complete tasks in a timely manner and provide an overview of issues that arise during the fabrication process. Some of these include waiting longer than expected for previous stations, lack of materials to proceed with the current task, and unforeseen absences of manual labour where escalations must made to compensate for such cases, for completing tasks and sustainability. The Kanban centralized system developed and used in this company could be scaled up to other companies to improve process efficiency.

It is recommended that this company pays full attention to communication throughout the organization. This can be achieved by adopting further systems and tools that enhance transparency at every level of production, which can be done in the future. Furthermore, it is recommended that changes in the fabrication process for employees in the company be considered. The human factor of such changes in the fabrication process does play a role in process efficiency. The ability of employees to accept and adopt the Kanban centralised system impacts the effectiveness of the design. Feedback should be taken from employees based on how this system impacts the value they add to each process or task they are responsible for carrying out, both positively and negatively. As well as where they would see changes best suited to improve the effectiveness of the Kanban centralised system.

Conflicts of Interest

The author declares no conflict of interest.

REFERENCES

[1] A. Belhadi, F.E. Touriki, S. Elfezazi, Evaluation of critical success factors (CSFs) to implement Lean implementation in SMES using AHP: A case study. *International Journal of Lean Six Sigma*, 10(3), 2019: 803-829. https://doi.org/10.1108/IJLSS-12-2016-0078

[2] K.S. Minh, S. Zailani, M. Iranmanesh, S. Heidari, Do lean manufacturing practices have a negative impact on job satisfaction. *International Journal of Lean Six Sigma*, 10(1), 2019: 257-274. https://doi.org/10.1108/IJLSS-11-2016-0072

[3] K. Das, M. Dixon, Lean manufacturing and service. *CRC Press*, Boca Raton, 2024. https://doi.org/10.1201/9781003121688

[4] S. Gupta, P. Chanda, A case study concerning the 5S Lean technique in a scientific equipment manufacturing company. *Grey Systems: Theory and Application*, 10(3), 2020: 339-357. https://doi.org/10.1108/GS-01-2020-0004

[5] J.P. Davim, Progress in Lean Manufacturing. *Springer Cham*, 2018. https://doi.org/10.1007/978-3-319-73648-8

[6] L. Dubey, K. Gupta, Lean manufacturing based space utilization and motion waste reduction for efficiency enhancement in a machining shop: A case study. *Applied Engineering Letters*, 8(3), 2023: 121-130. https://doi.org/10.18485/aeletters.2023.8.3.4

[7] Y. Shi, X. Wang, X. Zhu, Lean manufacturing and productivity changes: the moderating role of R&D. *International Journal of Productivity and Performance Management*, 69(1), 2019: 169-191. https://doi.org/10.1108/IJPPM-03-2018-0117

[8] S. Sahoo, S. Yadav, Lean implementation in small- and medium-sized enterprise. *Benchmarking: An International Journal*, 25(4), 2018: 1121-1147. https://doi.org/10.1108/BIJ-02-2017-0033

[9] S. Caceres-Gelvez, M.D. Arango-Serna, J.A. Zapata-Cortes, Evaluating the performance of a cellular manufacturing system proposal for sewing department of a sportswear manufacturing company: A simulation approach. *Journal of Applied Research and Technology*, 20(1), 2022: 68-83. https://doi.org/10.22201/icat.24486736e.2022.20.1.1335

[10] H.H. Berhe, Application of Kaizen philosophy for enhancing manufacturing industries' performance: exploratory study of Ethiopian

chemical industries. *International Journal of Quality & Reliability Management*, 39(1), 2022: 204-235. https://doi.org/10.1108/IJQRM-09-2020-0328

[11] C. Hemalatha, K. Sankaranarayanasamy, N. Durairaaj, Lean and agile manufacturing for work-in-process (WIP) control. *Materials Today Proceedings*, 46(20), 2021: 10334-10338. https://doi.org/10.1016/j.matpr.2020.12.473

[12] J. Singh, H. Singh, A. Singh, J. Singh, Managing industrial operations by Lean thinking using value stream mapping and six sigma in manufacturing unit. *Management Decision*, 58(6), 2019: 1118-1148. https://doi.org/10.1108/MD-04-2017-0332

[13] C. Veres, L. Marian, M.S. Moica, K. Al-Akel, Case study concerning 5S method impact in an automotive company. *Procedia Manufacturing*, 22, 2018: 900-905. https://doi.org/10.1016/j.promfg.2018.03.127

[14] J.C-C. Chen, C.-Y. Cheng, Solving social loafing phenomenon through Lean-Kanban: A case study in non-profit organization. *Journal of Organizational Change Management*, 31(5), 2017: 984-1000. https://doi.org/10.1108/JOCM-12-2016-0299

[15] T. Bandoophanit, S. Pumprasert, The paradoxes of just-in-time system: an abductive analysis of a public food manufacturing and exporting company in Thailand. *Management Research Review*, 45(8), 2022: 1019-1043 https://doi.org/10.1108/MRR-04-2021-0262

[16] S. Gawande, J.S. Karajgikar, Implementation of Kanban, a Lean tool, In Switchgear Manufacturing Industry – A Case Study. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, July 26-27, 2018, Paris, France, 2335-2348.

[17] M.A. Habib, R. Rizvan, S. Ahmed, Implementing Lean manufacturing for improvement of operational performance in a labeling and packaging plant: A case study in Bangladesh. *Results in Engineering,* 17, 2023: 100818. https://doi.org/10.1016/j.rineng.2022.100818

[18] A.K. Das, M.C. Das, Productivity improvement using different Lean approaches in small and medium enterprises (SMEs). *Management Science Letters*, 13, 2023: 51-64. https://doi.org/10.5267/j.msl.2022.9.002

[19] P.A. Marques, D. Jorge, J. Reis, Using Lean to Improve Operational Performance in a Retail Store and E-Commerce Service: A Portuguese Case Study. *Sustainability*, 14(10), 2022: 5913. https://doi.org/10.3390/su14105913

[20] F. Khair, M. A. S. Putra, I. Rizkia, Improvement and analysis of aircraft maintenance flow process using Lean manufacturing, PDCA, PICA, and VSM for sustainable operation system. *IOP Conf. Series: Earth and Environmental Science*, 1324, 2024: 012071. https://doi.org/10.1088/17551315/1324/1/012071

[21] I. Rizkya, K. Syahputri, R.M. Sari, D.S. Situmorang, Lean Manufacturing: Waste Analysis in Crude Palm Oil Process. *IOP Conference Series: Materials Science and Engineering*, 851, 2020: 012058. https://doi.org/10.1088/1757-899X/851/1/012058

[22] A. Pradeep, K. Balaji, Reduction of lead time in an automobile rubber component manufacturing process through value stream mapping. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, 236(6), 2022: 2470-2479. https://doi.org/10.1177/09544089221094094

[23] D. Cabezas, I. Muelle, E. Avalos-Ortecho, Implementation of Lean Manufacturing to Increase the Machine's Availability of a Metalworking Company. *7th North American International Conference on Industrial Engineering and Operations Management*, June 12-14, 2022, Orlando, Florida, USA.

[24] W. Kosasih, I.K. Sriwana, E.C. Sari, C.O. Doaly, Applying value stream mapping tools and kanban system for waste identification and reduction (case study: a basic chemical company). IOP Conference Series: Materials Science and Engineering, 528, 2019: 012050. https://doi.org/10.1088/1757-899X/528/1/012050

[25] B.S. Patel, M. Sambasivan, R. Panimalar, R. Krishna, A relationship analysis of drivers and barriers of Lean manufacturing. *The TQM Journal*, 34(5), 2022: 845-876. https://doi.org/10.1108/TQM-12-2020-0296