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The Effect of Lean Manufacturing on Production / Operation for the Small and Medium Enterprise in Malaysia

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ABSTRACT

At the start of 2022, the government announced its focus on supporting the development of small and medium enterprises (SMEs) to improve living standards following the COVID-19 pandemic. SMEs contribute significantly to the national economy, with the clothing industry playing a major role. This research applies lean manufacturing techniques to enhance the performance of SMEs in the clothing sector, specifically in T-shirt printing. Therefore the first objective was to collect, analyze processing times and recording of all issues encountered during production. The second objective involved using value stream mapping (VSM) to analyze the T-shirt printing process from raw material supply to finished product packaging. We also employed a why-why analysis to pinpoint the underlying causes of inefficiencies and devise specific solutions. The last objective focused on process improvement using VSM, along with the Kanban system, 5S and Make to Stock (MTS) to optimize block preparation and T-shirt printing. We selected Flexsilk Printshop as the case study. The findings showed a 66.59 % reduction in waiting time, a 30.77 % improvement in lead time, an increase in overall equipment effectiveness (OEE) from 93.3 to 97.45 % and a 50.41 % increase in efficiency.

1. Introduction

Lean manufacturing has garnered considerable attention in recent years as a strategic method to enhance efficiency and production across diverse manufacturing sectors. The use of lean principles into manufacturing and operations within small and medium firms (SMEs) in Malaysia can significantly enhance overall performance. The integration of lean processes is a pivotal aspect in the effective execution of lean manufacturing within Malaysian SMEs. Questionnaire-based research have indicated that management commitment, staff involvement and continuous improvement are essential in influencing the lean manufacturing environment within these firms. The findings indicate

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that SMEs in Malaysia have acknowledged the advantages of lean production and are actively integrating these principles into their operations [1,2].

The correlation between manufacturing sustainability and lean production within the Malaysian industrial sector has been examined. The findings demonstrate that industrial sectors in Malaysia exhibit a pronounced degree of sustainability in social competency, succeeded by economic and environmental competency. The study indicated that the implementation of lean production significantly impacts the sustainability of manufacturing processes, affecting both efficiency and the creation of ecologically sustainable and socially responsible products [3,4].

This research investigated the use of lean manufacturing tools and strategies to minimize waste in production. These tools were aimed to eliminate unnecessary processes while enhancing operational reliability, hence increasing the efficiency and productivity of industrial systems. Lean approaches are especially beneficial for SMEs, which are vital for fostering economic growth and creating employment opportunities [5,6]. SMEs frequently deliver specialized products and services that larger corporations may be unable to provide, becoming them essential participants in both local and global economies.

The researcher focused on printing T-shirt activities by SMEs. The reason is based on an empirical update in the Malay youth entrepreneurship in Malaysia, which shows the major types of business graph involve the printing sector being the highest percentage business in Malaysia [7]. According to research from a Malaysian website, wearing personalised T-shirt is a trend that is driving the industry for T-shirt printing to expand. For example, a Malaysian "print on demand" textile firm saw a 200 % increase in revenues year over year to reach RM8 million in 2020. So, that statement proved the printing T-shirt business is most profitable business in Malaysia.

The specific research location was focused on the printing T-shirt SMEs in Kuantan, Pahang. Kuantan was chosen to collect the data due to Kuantan is a large city on the East Coast of Peninsular Malaysia. Besides, Kuantan is the nearest city of University Malaysia of Pahang Al-Sultan Abdullah (UMPSA). The data of the printing T-shirt SMEs was then easily to collect.

The researcher decided to focus on silkscreen printing services due to the result on survey form from several printing shops in Kuantan. The printing shop that only focused on silkscreen printing was the highest percentage of T-shirt printing services with 50 % of printing services. Another printing shop provided services for silkscreen printing and dtf sticker with 25 % of the overall printing services. Most of printing shop focuses on silkscreen printing due to silkscreen printing used low cost to start the business or SME business.

2. Methodology

2.1 Phase 1: Data Collection

This phase corresponds to the define phase in the research. The researcher contacted 3 to 5 printing establishments utilizing a survey instrument to collect preliminary data. Following the acquisition of consent from the printing shop proprietors, site visits were executed for firsthand observation. Data collection was conducted utilizing a stopwatch and a check sheet to document the duration of each method employed in the silkscreen printing process.

During the site visits, particular focus was given to the Flexsilk Printshop. The flowchart is depicted in Figure 1. Flexsilk Printshop was chosen for this study as it exemplifies the issues encountered by SMEs in the T-shirt printing sector, especially with constrained resources, labor and capital. Despite these limitations, Flexsilk Printshop attempts to satisfy substantial consumer demand while preserving product quality, rendering it an exemplary case for assessing the efficacy of lean manufacturing methodologies. The shop's functioning in a competitive market with a limited

workforce exemplifies typical SME characteristics in the region. Consequently, enhancements at Flexsilk may represent the implementation of lean principles in comparable SMEs, illustrating the scalability and adaptability of these procedures throughout the sector [8].

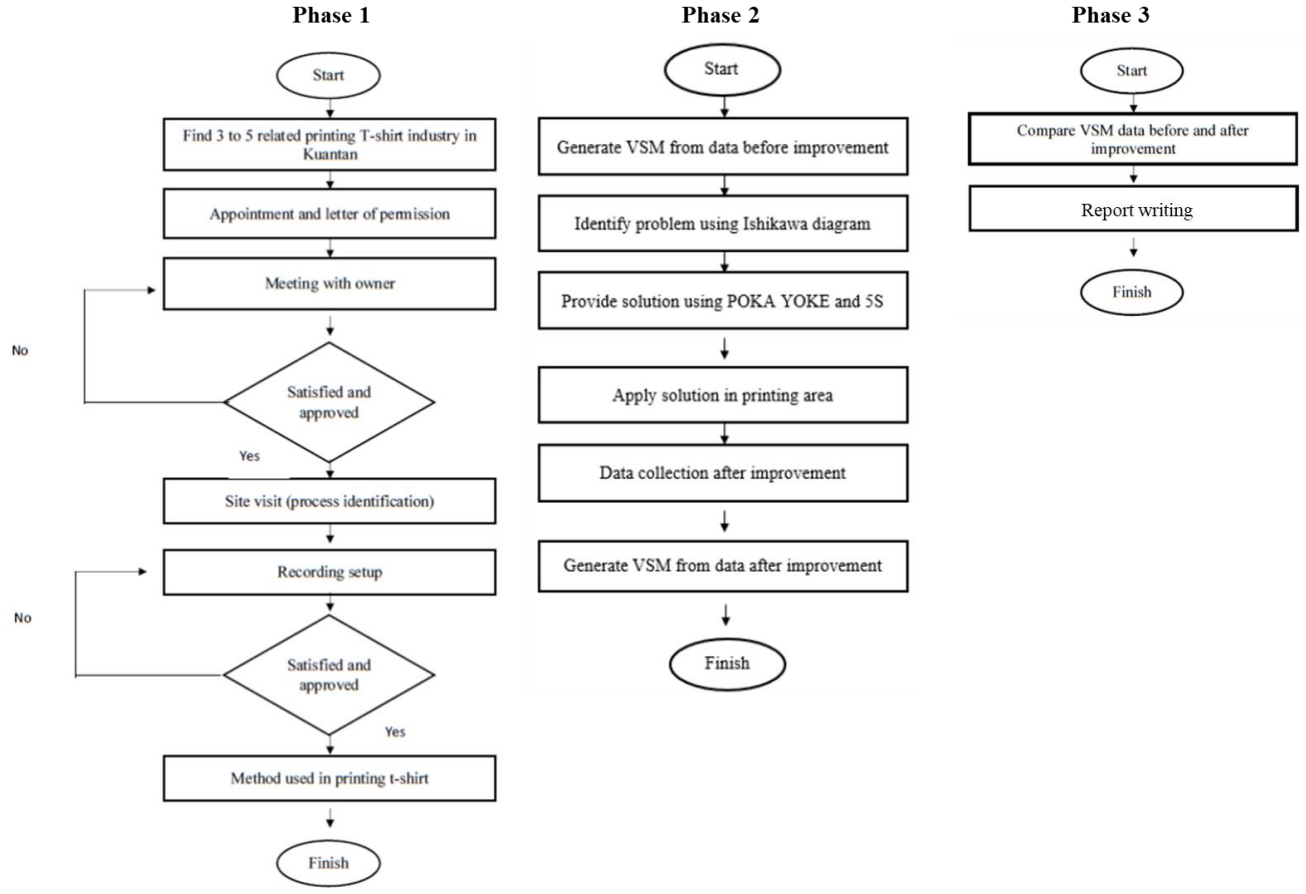


Fig. 1. Flow chart of this research

Figure 2 illustrates that the shop manufactured 100 T-shirts in one day with silkscreen printing. The principal data gathering equipment used was a defect concentration diagram, a variant of a check sheet. A check sheet is a systematically organized form intended for the collection and analysis of data in a consistent way [9,10]. It functions as a multifaceted instrument that may be tailored for many data gathering and analytical objectives. The emphasis of data collection was on the methodology employed for each procedure and the duration necessary for each task in the silkscreen printing process.

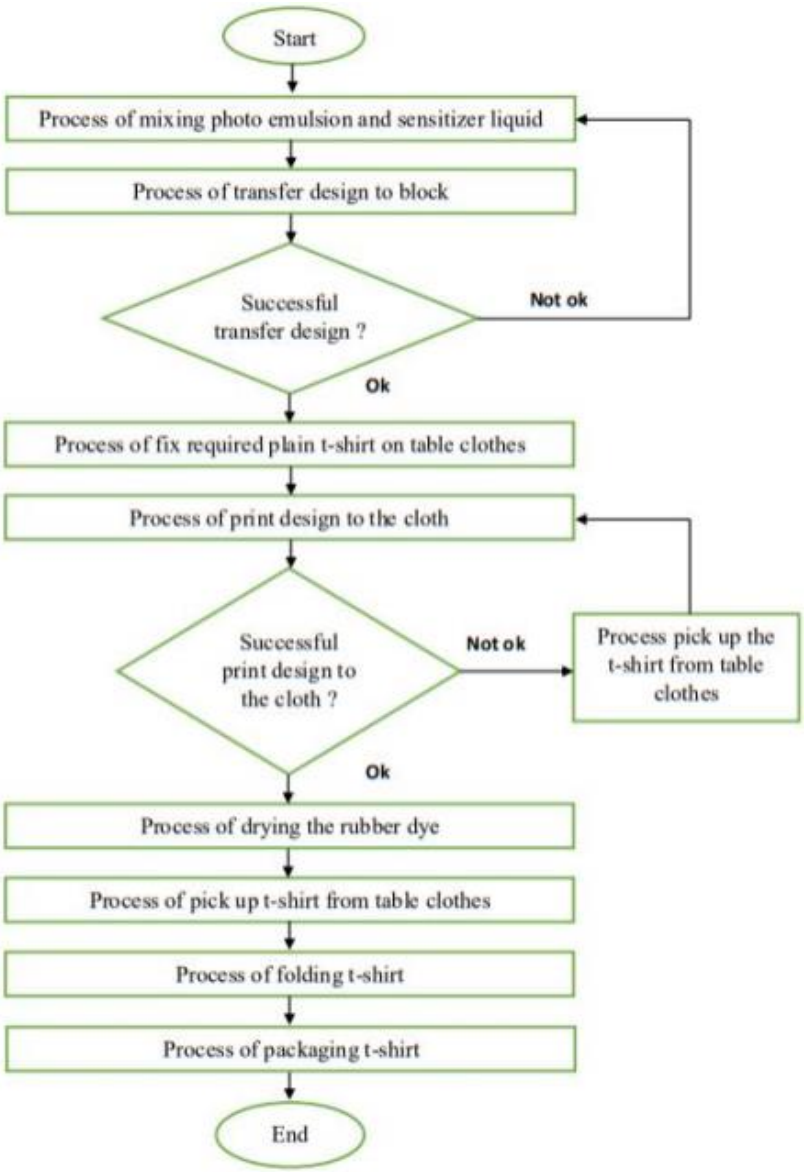


Fig. 2. Silkscreen printing process flowchart

2.2 Phase 2: Data Analysis

This phase corresponds to the measure phase. The data collected from the silkscreen printing process was input into a Value Stream Mapping (VSM) tool to visually represent the overall process [11] (shown in Figure 3), starting from the receipt of raw materials from suppliers to the final production of printed T-shirts. VSM, a key tool in lean manufacturing, helps identify and eliminate waste by providing a comprehensive view of the entire production process. It maps out critical attributes such as inventory levels, operator involvement, production output, time per product, transition times and total working hours [11].

The why-why analysis technique was utilized to discover specific problems and inefficiencies in the process. This lean tool identifies the fundamental causes of production issues by persistently inquiring "Why?" for each recognized problem. This investigation identified the fundamental issues contributing to waste or inefficiency, providing a foundation for developing remedies to enhance the process [12,13].

This study employed a why-why analysis at Flexsilk Printshop to ascertain the core causes of inefficiencies in its production process. The investigation identified wasteful practices, including excessive material use, production delays and recurrent rework. Through the iterative inquiry of "Why?" for each issue, underlying problems were revealed, such as chaotic processes, absence of established protocols and insufficient employee training.

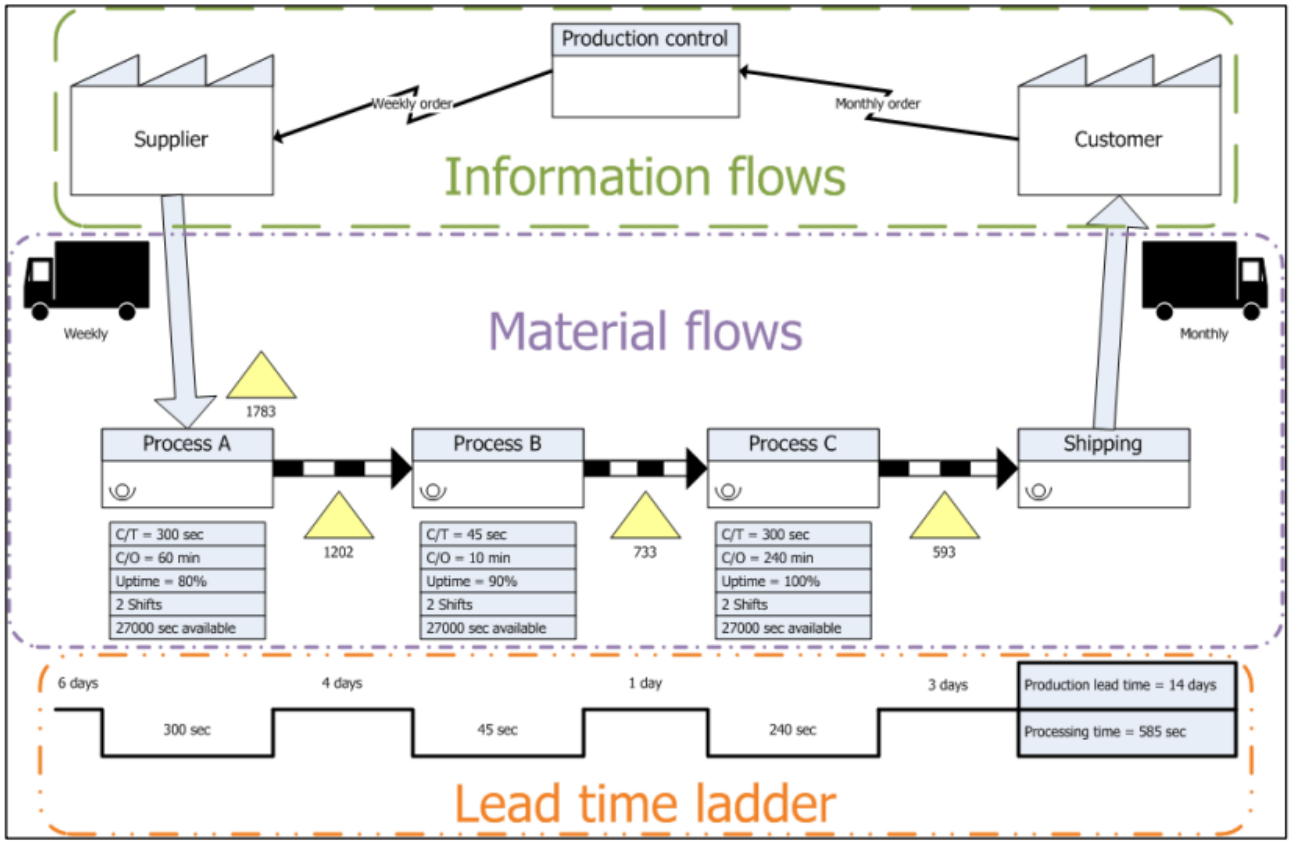


Fig. 3. Value stream mapping (VSM)

2.3 Phase 3: Process Improvement

The third phase correspondings to the improve phase, focuses on implementing and assessing process improvements in the printing shop's performance. This phase discusses the improvements made in lead time and other performance metrics based on the comparison of pre- and post-improvement data.

The lead time improvements were analyzed using VSM, which allowed for the identification of waiting times and bottlenecks in the production process [14]. The final percentage improvements in lead time were calculated based on the reduction of waiting times and the overall lead time efficiency.

Kanban, a lean technique meaning "signal card" in Japanese, was employed to manage inventory more efficiently. By prompting replenishment only when items were running low, Kanban helped reduce waste and inventory costs, ensuring that only necessary items were ordered, and that production was aligned with customer demand. This approach also helped minimize errors and ensured that defective goods were not passed to downstream operations, thus improving profitability [15].

Additionally, the 5S methodology was applied to improve workplace organization and efficiency [16]. The 5S principles include:

1. Sort (Seiri): Classifying items as necessary or unnecessary, and removing the unnecessary items.
2. Set in Order (Seiton): Organizing necessary items in a way that allows for easy and efficient use.
3. Shine (Seiso): Cleaning and maintaining the workplace to detect any irregularities or system errors.
4. Standardize (Seiketsu): Establishing standards to maintain the first three S's.
5. Sustain (Shitsuke): Creating a culture of discipline to sustain these practices over the long term [10].

Process improvements also included ordering more inventory of favorite T-shirt colors (white and black) to better meet forecasted demand and ensure smoother production. The improvements ultimately led to a reduction in waiting times and an increase in production efficiency, with tangible benefits observed in lead time and production quality.

3. Results

3.1 Data Analysis

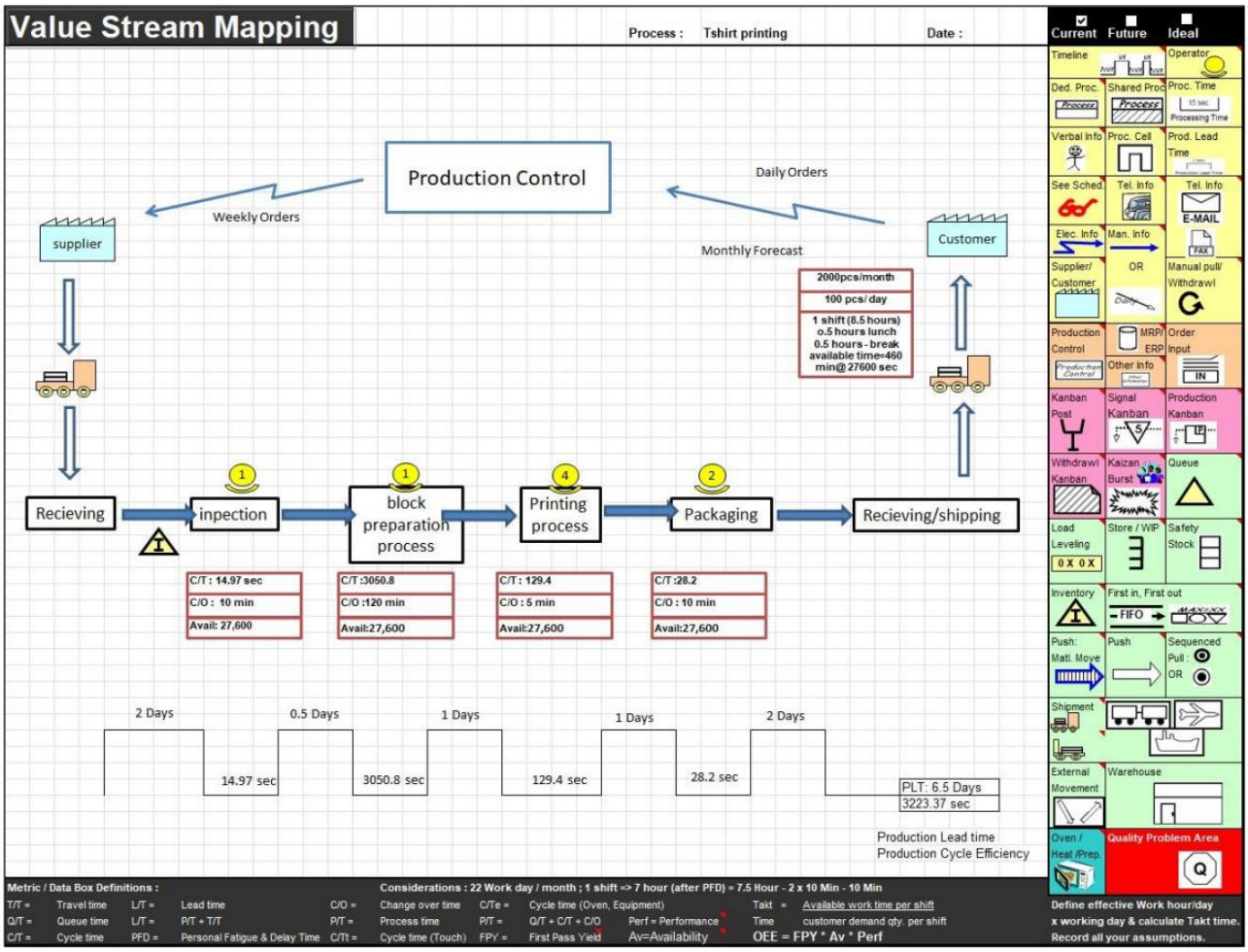
The data collection of silkscreen printing was inserted into VSM for mapping of the overall process of silkscreen printing, starting from supplier material to finishing of the T-shirt as shown in Figure 4 (a) and (b). The related problems were identified using why-why analysis. The problems were improved through lean manufacturing techniques. The data collection after improvement was done to generate future VSM. Lean techniques for processes have improved waiting times in marking block issues and motions (kaizen). An automatic stand heater was used to reduce the manpower for the drying process and eliminate the overheating dryer issue (kaizen).

3.2 Waiting Time Reduction

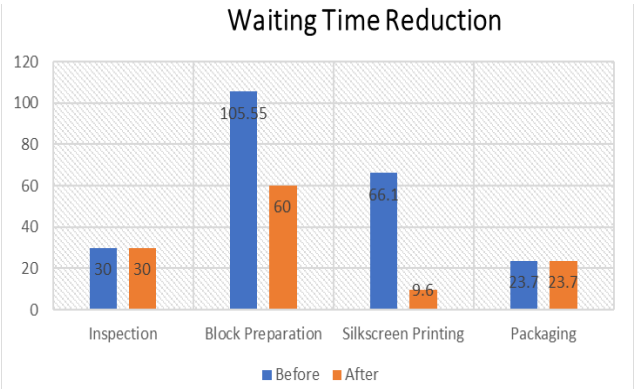
The waiting time before and after was used to calculate the percentage of waiting time reduction. After calculating the setup time, the waiting time reduction was determined using the following formula, Eq. (1):

$$\text{Waiting time reduction } (\%) = \frac{\text{Total average setup time before - Total average setup time after}}{\text{Total average setup time before}} \times 100\% \quad (1)$$

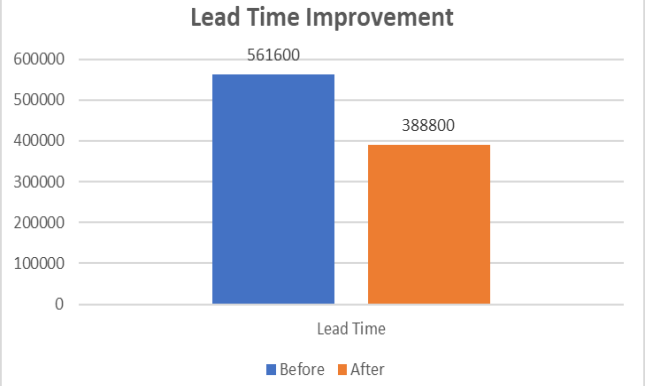
Figure 5 (a) compares the setup time before and after improvements that were made to the block preparation and silkscreen printing processes. The Kanban technique, which involved adding dryers to the drying block process, was used to improve the block preparation process. Next, the inventory system prepared a stock of blocks with emulsion coaters in the block preparation area. The enhancement in block preparation resulted in a reduction in setup time, particularly when the shop had a stock of blocks with emulsion coaters. The silkscreen printing process was improved by implementing the Kanban technique, which involved switching from a straight printing table to a rotating printing table. The improvement resulted in a reduction in the setup time required for loading and unloading T-shirts from the platen table and drying.


Value Stream Mapping
Process : Tshirt printing
Date :
Current
Future
Ideal
Production Control
Daily Orders
Weekly Orders
Monthly Forecast
supplier
Customer
2000pcs/month
100 pcs/ day
1 shift (8.5 hours)
0.5 hours lunch
0.5 hours - break
available time=460
min@27600 sec
Recieving
inpection
block preparation process
Printing process
Packaging
Recieving/shipping
C/T : 14.97 sec
C/O : 10 min
Avail: 27,600
C/T :3050.8
C/O :120 min
Avail:27,600
C/T : 129.4
C/O : 5 min
Avail:27,600
C/T :28.2
C/O : 10 min
Avail:27,600
2 Days
0.5 Days
1 Days
1 Days
2 Days
14.97 sec
3050.8 sec
129.4 sec
28.2 sec
PLT: 6.5 Days
3223.37 sec
Production Lead time
Production Cycle Efficiency
Timeline
Operator
Ded. Proc.
Shared Proc
Proc. Time
Verbal Info
Proc. Cell
Prod. Lead Time
See Sched.
Tel. Info
E-MAIL
Elec. Info
Man. Info
FAX
Supplier/ Customer
OR
Manual pull/ Withdrawl
Production Control
MRP/ ERP
Order Input
Other Info
IN
Kanban Post
Signal Kanban
Production Kanban
Withdrawl Kanban
Kaizan Burst
Queue
Load Leveling
0 X 0 X
Store / WIP
Safety Stock
Inventory
First in, First out
FIFO
Push: Matl. Move
Push
Sequenced Pull :
OR
Shipment
External Movement
Warehouse
Oven / Heat /Prep.
Quality Problem Area
Metric / Data Box Definitions :
Considerations : 22 Work day / month ; 1 shift => 7 hour (after PFD) = 7.5 Hour - 2 x 10 Min - 10 Min
T/T = Travel time
L/T = Lead time
C/O = Change over time
C/Te = Cycle time (Oven, Equipment)
Takt = Available work time per shift
Q/T = Queue time
L/T = P/T + T/T
P/T = Process time
P/T = Q/T + C/T + C/O
Perf = Performance
Time customer demand qty. per shift
C/T = Cycle time
PFD = Personal Fatigue & Delay Time
C/Tt = Cycle time (Touch)
FPY = First Pass Yield
Av=Availability
OEE = FPY * Av * Perf
Define effective Work hour/day
x working day & calculate Takt time.
Record all your assumptions.

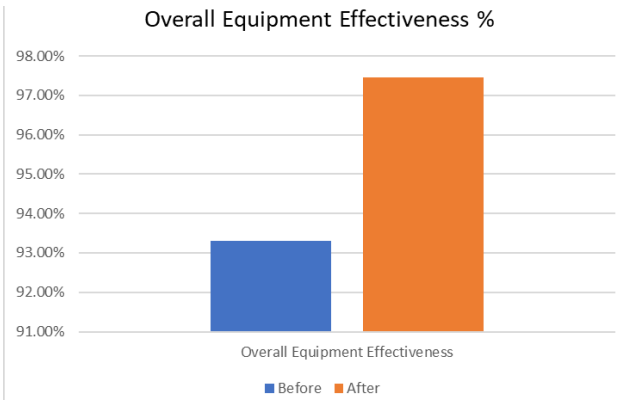
(a)


Waiting Time Reduction
120
100
80
60
40
20
0
105.55
60
66.1
9.6
30
30
23.7
23.7
Inspection
Block Preparation
Silkscreen Printing
Packaging
Before
After

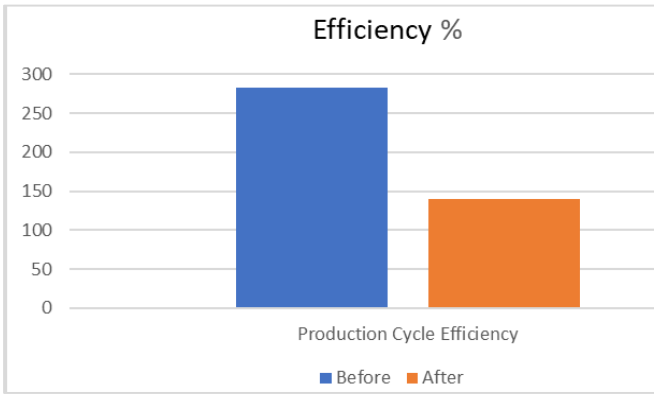
(a)


Lead Time Improvement
600000
500000
400000
300000
200000
100000
0
561600
388800
Lead Time
Before
After

(b)

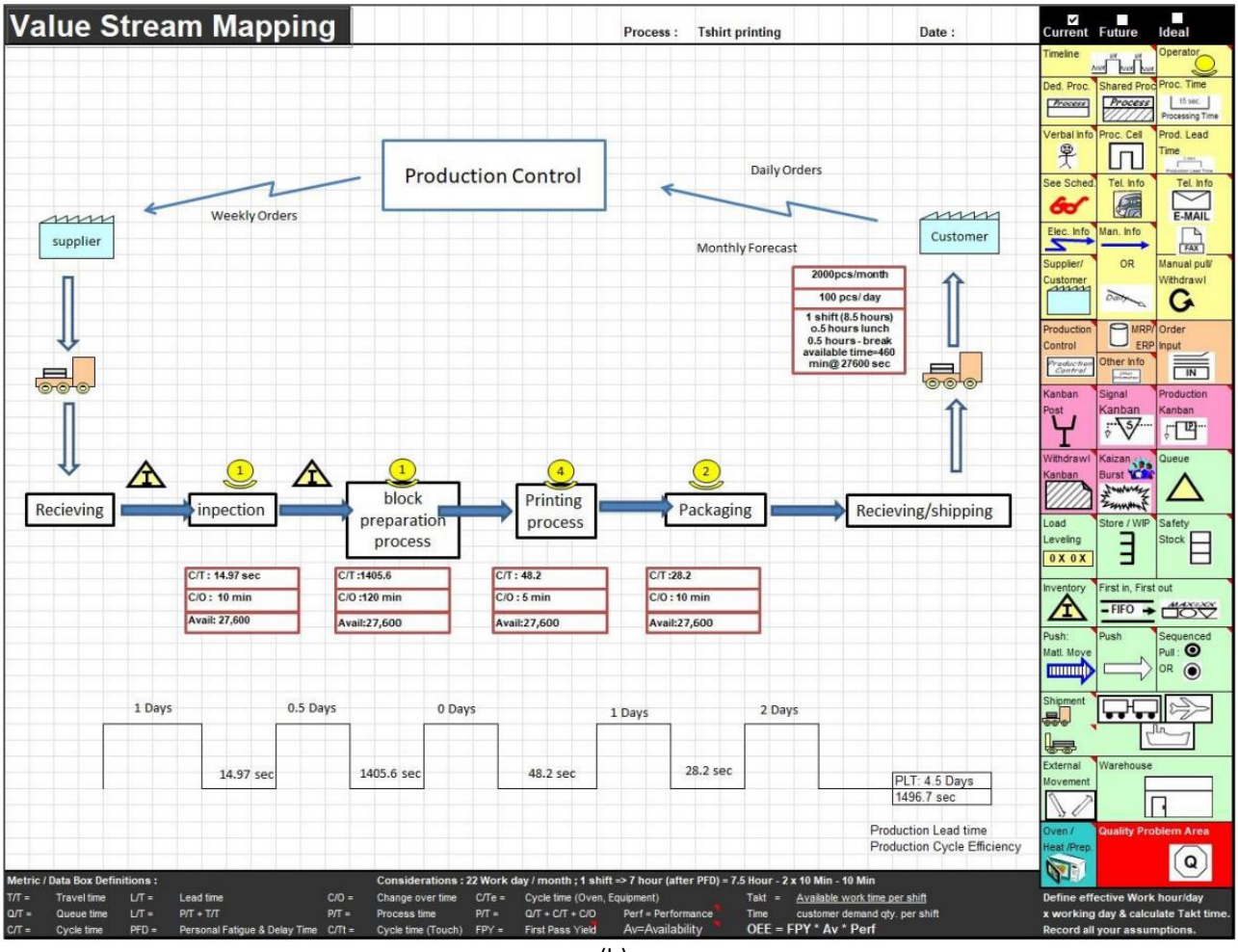


(c)



(d)

Fig. 5. (a) Waiting time reduction, (b) Lead time improvement, (c) Overall equipment effectiveness and (d) Efficiency



(b)

Fig. 4. VSM before and after improvement

3.3 Lead Time Improvement

The VSM provides the lead time. In this study, two VSM were prepared for before and after implementing the lean technique. Finally, the lead time improvement (%) was calculated using the following formula as in Eq. (2):

$$\text{Lead time improvement (\%)} = \frac{\text{Previous average lead time - Current average lead time}}{\text{Previous average lead time}} \times 100\% \quad (2)$$

Figure 5 (b) shows the lead time improvement from 561.6 to 388.8 seconds to finish the printed T-shirt. The improvement in lead time was achieved by implementing an inventory system. So, the T-shirt from the supplier, which takes 2 days to arrive at the printing shop, was decided to make a stock for the favorite color (white and black). The time it took for the shirt to arrive was reduced to 1 day. The result of the improvement of lead time percentage was increased by 30.77 %.

3.4 Overall Equipment Effectiveness

Overall equipment effectiveness (OEE) can be found from the availability time of process to finish the T-shirt, performance of operation and quality output of the T-shirt. In this study, two OEEs were prepared for before and after implementing the lean tools. Finally, OEE percentage was calculated as follows in Eq. (3):

$$\text{OEE (\%)} = \frac{\text{Good count} \times \text{Ideal cycle time}}{\text{Planned production time}} \times 100\% \quad (3)$$

Figure 5 (c) shows the comparison between before and after improvement results of OEE. Prior to improvement, the printing shop's OEE percentage was 93.3 % for producing 100 pieces of T-shirt printed in a day. The good count was 95, and 5 pieces were rejected due to out-of-position block marking during silkscreen printing. After improvement, the OEE percentage was 97.45 % for producing 200 pieces of T-shirts printed in a day. The successful count amounted to 200 pieces, with no T-shirt rejects.

The lead time improvement as shown in the graph, demonstrates a significant reduction from completing the printing of T-shirts. Implementing an inventory system was primarily responsible for this improvement. By keeping stock of the most popular colors (white and black), we reduced the delivery time from two days to just one day. This led to a 30.77 % improvement in the lead time.

In contrast, the graph also shows the improvement in OEE before and after implementing lean manufacturing techniques. Initially, the OEE percentage was 93.3 % when producing 100 T-shirts per day, with 95 good pieces and 5 rejects due to out-of-position block marking during the silkscreen printing process. After improvement, the OEE rose to 97.45 %, with production increasing to 200 T-shirts per day, all of which were defect-free. We achieved this improvement by transitioning from a straight printing table with manual block marking to a rotational printing table with grip block marking. The use of Kanban, a lean manufacturing technique, helped eliminate the issue of rejected T-shirts caused by block marking misalignments, leading to higher production quality and efficiency. The two results reflect the effectiveness of lean manufacturing in enhancing production performance by reducing lead time and improving equipment effectiveness, thereby increasing overall efficiency.

3.5 Efficiency

VSM was found to be efficient. We prepared two VSMs in this study, one before and one after implementing the lean technique. We finally calculated the efficiency improvement (%) using the following formula as in Eq. (4):

$$\text{Efficiency (\%)} = \frac{\text{Previous production cylce efficiency} \times \text{Current production cycle efficiency}}{\text{Previous production cycle efficiency}} \times 100\% \quad (4)$$

Figure 5 (d) above also shows a comparison between before and after improvement efficiency. The efficiency before and after the improvement was 282.96 and 140.33, respectively. Using the formula above, we calculated the efficiency improvement percentage, which came out to be 50.41 %. The graph above illustrates the result, which was achieved by improving the setup and cycle time of the block preparation and silkscreen printing processes.

4. Conclusions

The objective of collecting the processing time for T-shirt printing at Flexsilk Printshop was successfully achieved. The key processes, including inspection, block preparation, silkscreen printing and packaging, were identified and recorded on a check sheet. The initial VSM was generated, showing a total lead time of 6.5 days, mapping the entire silkscreen printing process from material supply to the finished product. Problems within the process were identified and addressed using the why-why analysis, which led to significant improvements. After implementing lean techniques, a new VSM was created with a reduced lead time of 4.5 days.

By comparing the before and after data, we were able to improve the printing process through VSM. The results show a total waiting time reduction of 66.59 %, achieved by calculating the time saved across all processes in the silkscreen printing operation. Lead time improved by 30.77 %, calculated by comparing the lead times in both the initial and improved VSMs. Additionally, OEE improved from 93.3 - 97.45 %, calculated based on the good count of T-shirts, planned production time and ideal cycle time. Lastly, the production efficiency increased by 50.41 %, calculated by comparing the production cycle efficiency before and after the improvements.

While these results highlight the effectiveness of lean techniques in reducing waste and improving performance, further reflection on the scalability of these outcomes across different types of SMEs would provide valuable insights. Recommendations for SMEs include adopting lean tools like VSM, Kanban and the why-why analysis to systematically identify inefficiencies and optimize their processes. Additionally, SMEs should consider customizing these tools based on their specific operational challenges to maximize results. This study shows that SMEs can replicate significant performance gains by properly implementing lean techniques.

Acknowledgement

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