The impact of lean production on operational performance: a case study

Memari, Ashkan; Panjehfouladgaran, Hamid Reza; Rahim, Abd Rahman Abdul; Ahmad, Robiah

Published in:
Asia-Pacific Journal of Business Administration

DOI:
10.1108/APJBA-04-2022-0190

The Impact of Lean Production on Operational Performance: A Case Study

Abstract

Purpose: This paper aims to investigate the impact of adopting lean manufacturing principles on operational efficiency by eliminating seven major lean wastes (or Muda) in a Malaysian stationery manufacturer.

Design/Methodology/Approach: Process Activity Mapping (PAM) was utilised to identify the potential for waste elimination. Since PAM is involved in every step of the production process, value-added and non-value-added are examined using PAM as a visual tool to assist in observing the hidden wastes and their sources.

Findings: Results revealed that the adopted lean principles significantly reduce the waiting times. This time reduction resulted in savings (reduction of cycle time) and, to a certain extent, can be a crucial driver in continuous improvement sustainability in the production process.

Research limitations/implications: the findings of this paper are limited due to the nature of the research and the company's size.

Practical Implication: results demonstrate that lean is still recognised as a powerful approach to improve operations in small and medium size companies.

Originality/Value: this paper reflects the application of lean in a real case study showing the impact of lean on a small and medium size company's performance.

Keywords: Lean Production; Operational Performance; Case Study; Malaysia Lean Practice

Paper Type: Case study

1. Introduction

Lean Manufacturing (LM) is among the initiatives that many leading manufacturers in Asia, especially in Malaysia (Nordin et al., 2010, Abu et al., 2021, Antony et al., 2021). This technique aims to reduce costs by removing non-value-added activities. LM identifies waste and eliminates it from every production step throughout the 'products' value stream (Sundar et al., 2014, Kovács, 2020). Many of the LM approaches and techniques (e.g., cellular manufacturing, Just-In-Time (JIT), production smoothing, Total Preventive Maintenance) have been broadly employed since the birth of the Toyota Production System (TPS). The main idea behind TPS is a systematic strategy to determine and remove waste activities through continuous improvement (Taj and Morosan, 2011, Costa et al., 2019, Inan et al., 2021).

Lean thinking has been adopted in both industry and service sectors, seeking to eliminate waste and help make organisations more efficient. This is mainly due to a diversified set of tools in Lean practising that could be employed individually or collectively, based on specific requirements in each organisation (Pinto et al., 2022). From simple tools like 5S (Sort, Set in order, Shine, Standardise, Sustain) to considerably more complicated methods such as Value Stream Mapping (VSM), engineers can identify and analyse different processes and ultimately find a way to run operations more efficiently. Nevertheless, the success of Lean's application usually means more awareness of potential room for improvement to top management; also, every employee is more focused on appropriately implementing these tools and adding value to the company's efficiency (Loyd et al., 2020). There are many success stories of Lean implementation in case studies in various sectors (Elkhairi et al., 2019); however, findings from these studies cannot be globally generalised (Marodin et al., 2019). Therefore, more practical studies are needed to show continuous improvement through adopting Lean approaches in various settings and regions.

Nevertheless, the lessons learned from such studies are crucial for successfully executing and implementing Industry 4.0 in various sectors. This study contributes to the body of literature by addressing the adoption of Lean manufacturing principles on operational efficiency in a stationery manufacturer, in which, to the best of our knowledge, the implementation of Lean in this manufacturing sector is scarce or even not existent. Also, the capability to persistently recognise exceptional operational performance from lean has been elusive (Aghajari and Senin, 2014, Hardcopf et al., 2021). Therefore, this study contributes to the literature by presenting more evidence of the impact of Lean on operational performance. The rest of this paper is structured as follows. In Section 2, a detailed review of relevant literature is presented. Section 3 describes the case study and the adopted method are discussed, respectively. Numerical results are discussed in Section 4, followed by presenting managerial insights in Section 5. Finally, the paper ends with concluding remarks and future research directions in Section6.

2. Literature Review

A comprehensive literature review is devoted to the LM (Bhamu and Singh Sangwan, 2014; Pagliosa. LM consists of a large number of tools and techniques. Shah and Ward (2003) discovered twenty-two LM practices that have been frequently addressed in the literature and classified them into four categories, namely JIT, Total Quality Management (TQM), TPM and Human Resource. Some other researchers grouped the lean techniques and tools based on the scope of implementation, for instance, internally and externally oriented lean practices (Nordin et al., 2010, 2014). Rahman et al. (2010) developed a model to evaluate the effect of lean implementation practices on the operational performance of Thai companies. They found that waste minimisation, flow management and JIT have positively correlated with operational performance. Nevertheless, they pointed out that the importance of the JIT practice for large companies is higher compared to small and medium-sized enterprises (SMEs). In contrast, waste minimisation influences more SMEs compared to large companies. Rahani and Al-Ashraf (2012) presented quantitative shreds of evidence that showed most of the lean techniques have a significant effect on waiting time reduction.

Karim and Arif-Uz-Zaman (2013) designed a method that examines the performance of LM, utilising continuous performance measurement. Their proposed method led to identifying relevant performance indicators as well as selecting the most appropriate lean tools. Furthermore, they concluded that the matrices for continuous performance measurement could be effectively used for the continuous evaluation of LM performance measurement. Lacerda et al. (2016) investigated the value stream mapping of the production process in an automotive company. Their proposed action plan improved the production process by reducing the cycle time and workforce level. Dadashnejad and Valmohammadi (2018) analysed the impact of the value stream on operational performance using the discovered pattern.

Regardless of the substantial positive aspects obtained through LM implementation outlined, in practice, few organisations are to employ this system successfully (Ballé, 2005, Papadopoulou and Özbayrak, 2005). Many different companies reported issues and challenges concernıng the malfunction of LM implementation. Several researchers concluded that the primary concern lies in the false impression of the actual concept and objective of LM (Ballé, 2005, Schonberger, 2007). Several researchers determined this false impression is triggered by cultural variations which arise while in translation or transition of LM (Herron and Braiden, 2007, James, 2006, Achanga et al., 2006, Sartal et al., 2020). This kind of misconception might result in far more critical problems, including misapplication of lean tools (Herron and Braiden, 2007, Pavnaskar et al., 2003), piecemeal adoption of lean tools and techniques (James, 2006, Iqbal et al., 2020) and insufficient development of the lean culture which helps the lean development (Jørgensen et al., 2007, Chaple et al., 2018). Puvanasvaran et al. (2009) highlighted that companies in the beginning phase of lean implementation should keep their attempts for more efficient communication procedures for all phases to succeed in implementing LM. Effective communication procedure facilitates lean practices in manufacturing. As a result, the transformation from a conventional manufacturing system to LM could simply not be achieved. Achanga et al. (2006) proposed that four fundamental aspects determine the accomplishment of LM implementation: management and leadership, skills and expertise, finance and supportive organisational culture. A few researchers also recommended that implementing the total lean principles and tools also leads to effective LM transformation (Herron and Braiden, 2007, James, 2006).

Generally, LM is an arrangement of tactics and actions for operating a production process or service (Rahani and Al-Ashraf, 2012). The LM methods and techniques would probably differ depending on the application (Rylands et al., 2016). However, LM principles have the same core: eliminating all non-value-added activities and waste from a process. There are seven main types of wastes (Muda) in LM: OverproductionWaiting, Over-processing, Transportation, Motion, Inventory, and Rework (Shah and Ward, 2003, Ghobadian et al., 2020, Thürer et al., 2017). Lean implementation is taken by five necessary steps beginning with determining the value of a process, determining the process value stream, concentrating on the process flow, configuration settings of the pull factors and working toward process excellence (Bhamu and Singh Sangwan, 2014, Rafique et al., 2019).

This study aims to eliminate waste to improve the production process of a Malaysian Stationary Manufacturer. A PAM approach was adopted to map the existing operating state of the investigated case study. The employed PAM identifies the waste sources. A later map is drawn after that to highlight the improvement.

3. Materials and Methods

The methodology processes of the current study are demonstrated in the following figure:

<<FIGURE 1 ABOUT HERE>>

3.1. Company and process background

ABC company is located in Johor Bahru in the southern part of Malaysia. ABC is a stationary manufacturer, and the main product that ABC produce are as follows:

- EK660- highlighter marker (6 colours)
- EK300-water colour pen (12 colours)
- ESA/HSA stamp pad ink (5 colours)

EK577/EK579-whiteboard marker

The products are distributed in South Asia, the Middle East, and Europe. In this study, we focused on the production process of the EK660 highlighter marker. Those parts come in six colours; pink, green, orange, yellow, blue, and purple. All of the EK660 highlighter markers components are made and produced in the factory itself, excluding the nip and the filter supplied by others. Parts that SPSB itself is producing for the EK660:

- Cap (cover of the highlighter-differ in colour depending on the ink colour) EK300-watercolor pen (12 colours)
- Body (main body part-all of the body part is produced in black colour)
- Plug (the end cover, which also differs in colour depending on the ink)

All three parts produced by the SPSB use the injection moulding process.

3.2. Process review and data collection

A process overview was performed prior to LM implementation to investigate the current approach to the actual assembly procedures of EK660. The primary information was collected from Standard Operating Procedure (SOP) and Operations Manuals of the actual manufacturing activities. The Processing Time or Cycle Time was calculated using Production In-process that was gathered during the past four months. A direct line observation was conducted to understand the existing practice of production procedure and determine different types of waste in the production line.

3.3. PAM - the mapping process

PAM is an efficient tool for the practice of LM. PAM approached the entire process flow in three steps (2003). In the first step, the actual materials and information flow are drawn. The purpose of this step is to depict the Current State of the existing processes' operations. This step was accomplished while walking down the production line. The second step is creating a Future State map to detect the origin causes of waste through identifying opportunities for process improvements. The third step deals with the Implementation Plan, which provides actions needed to gain the project objectives.

3.4. The layout of the process line

An improper arrangement of the machine caused extensive transportation needed in the production line of the EK 660 marker. The high frequency of in-house transportation is a source of waste where the existing layout is not crowded. The improper layout of a plant can add to the cost of processing due to increased throughput time, setup times and in-process inventories and reduce the overall inefficiency of operations. Transportation will increase the production time, but there is no value added to the product. Therefore, the arrangement of machines and layout should be improved so that the number of transportation will be reduced. Figure 2 shows the existing factory layout of ABC company.

<<FIGURE 2 ABOUT HERE>>

3.5. Observation

- The overall flow process for product EK 660 highlighter markers

Figure 2 shows the whole flow process for product EK 660 highlighter markers. The process started with producing parts of the body, cap and plug through the injection moulding. The company made the parts from raw materials to finished products. After injection moulding, the operation proceeds to body printing of the product.

In the following, we explain the tasks in each workstation. This will be followed by presenting PAM for each workstation.

1. Workstation 1: Injection Molding

<<FIGURE 3 ABOUT HERE>>

Three essential parts were made in this process: body, cap, and plug. These parts come in six colours: pink, green, orange, yellow, blue, and purple. Each machine must produce the same colour as the front and end caps. A single machine produces body parts. Samples of a cavity of injection moulding are taken for inspection by the quality inspector twice daily. The test is conducted by measuring the dimension using a calliper and visual examination by the naked eye. The air tester test is carried out to ensure the body parts do not have any air cavities. When all operations are completed, the parts will be stored in boxes and transported to the next workstation. Figure 4 shows the process flow of workstation 1.

<<FIGURE 4 ABOUT HERE>>

2. Workstation 2: Cutting Process - Manual Cutting

The cutting process deals with eliminating the runner of injection moulding. This process only emphasises body parts. The operation is done manually by an operator using a cutter. The process starts with collecting the boxes in the storage area. These parts are collected in the boxes and transported to the workstation. The PAM of this workstation is presented in Figure 5.

<<FIGURE 5 ABOUT HERE>>

3. Workstation 3: Printing Process

This process begins with arranging body parts appropriately to avoid printing the wrong surface. It is done manually by an operator. Then the printing automatically starts by machine. A worker has been allocated to this operation to monitor the operation and is on standby to set up the dye. Then the operation continues to dryer process for drying purposes and simultaneously avoids smearing by paint. Another operator is waiting to inspect the printing label. Rejects will pass to another worker for rework by removing the paint. Then the body will undergo the printing process again. If the part has already been reworked, body parts will be excluded. As the inspection approves the quality of the paint, the body part will be stored in boxes and again sent to workstation 4. Figure 6 shows the PAM of the printing process.

<<FIGURE 6 ABOUT HERE>>

4. Workstation 4: Assembly

In this workstation, the operation starts with ink injected into the filter. An operator arranged the body from boxes properly before the operation. The amount of ink is based on weight. The filter with ink will automatically be inserted into the body. Then plug and followed by the nip, are assembled with the body. An inspection occurs manually after the operation to eliminate those products whose nip does not immerse by ink colour. After that, the machine will automatically assemble the cap to the product. The operation continues with an operator inspecting the bar code on every product. Finally, the same operator will collect and arrange the product into boxes.

<<FIGURE 7 ABOUT HERE>>

5. Workstation 5: Packing

Packing is the last workstation where the products are packed into smaller boxes with 12 pieces; each box has the same colour. The operation is manually operated by 3 operators. Figure 8 shows the activities in this procedure.

<<FIGURE 8 ABOUT HERE>>

4. Results

4.1. Types of wastes

Since in lean manufacturing, the main idea is waste elimination, so for this project, we have identified the related waste and tried to eliminate it.

<<TABLE 1 ABOUT HERE>>

4.2. 'Activities' analysis

In this Section, we analyse value-added, non-value added and waste activities.

- Value-added activities
  i. Injection moulding W1
  ii. Cutting process W2
  iii. Printing process W3
  iv. Ink injected to filter W4
  v. Filter inserted into body W4
  vi. Plug inserted into body W4
  vii. Nip insertion W4
  viii. Assemble cap W4
  ix. Packing process W5
- Non-value-added activities
  i. Body, cap and plug transport to assembly area W1
  ii. Samples for Quality inspection after the injection moulding process W1
  iii. Transport to printing W2
  iv. Arrangement before printing process W3
  v. Inspection for paint on body part W3
  vi. Paint rework W3
  vii. Transport to assembly process W3
  viii. Inspection on nip W4
  ix. Transport for packing W4
  x. Transport to warehouse W5
- Waste
  i. Waiting for cutting process W2
  ii. Waiting for printing W3
  iii. Inspection barcode W4
  iv. Waiting for packing W5

<<TABLE 2 ABOUT HERE>>

- Number of workers

Eleven workers are involved in the entire process for EK 660 Highlighter Marker, excluding two persons in charge of controlling the moulding process. Their tasks are as below:

Worker 1. Cutting the body from the moulding process.

Worker 2. Arrange the body from the box on the conveyor.

Worker 3. Set up machine and dye. Maintain the machine operation.

Worker 4. Inspection of paint quality if pass arranges in the box. If it fails, pass to rework by removing the paint.

Worker 5. Remove paint.

Worker 6. Arrange body need to be assembled.

Worker 7. Check the nip to determine ink flow within the filter to nip.

Worker 8. Check the barcode and arrange it into boxes.

Worker 9. Pack the finished product.

Worker 10. Pack the finished product.

Worker 11. Pack the finished product.

The cycle time for each process is as follows:

<<TABLE 3 ABOUT HERE>>

4.2. Process flow analysis

Figure 9. shows the sequences of the process to manufacture and assemble EK660. Each process uses a different area.

<<FIGURE 9 ABOUT HERE>>

Based on the input data (observation and historical data), relationships between sections, from-to chart and activity relationship analysis are performed. From-to-the-art quantitatively describes the degree of closeness between each work area. Flow analysis is defined based on three tables:

a) From-To chart – the estimated distance between sections (Table 4)

b) From-To chart – the estimated flow of goods per day (Table 5)

c) From-To chart – the estimated total distance travelled each day (Table 6)

<<TABLE 4 ABOUT HERE>>

<< TABLE 5 ABOUT HERE>>

<< TABLE 6 ABOUT HERE>>

4.3. Utilisation of equipment and space

We used the line balancing technique for this part. This method can help define the line's efficiency and come up with a solution to balance it. From this Yamazumi Board, we can identify the best number of idle workstations for the entire process line and predict and plan to meet customer demand.

<<FIGURE 10 ABOUT HERE>>

Based on the Yamazumi board for the existing process flow, it indicates that the process is imbalanced because there are two stations whose cycle time exceeds the Takt time. While the rest of the line is too far away from the Takt time value. This extremely indicates that there should be a change to rebalance the line back to the track to increase efficiency and performance. As for this project, the take time value is 10.03 seconds/unit, represented by the daily demand. It is hard to calculate the monthly demand since the market demand for the product has a wide range of differences. The Takt time is gained with the following condition (daily):

- 1-hour break
- 15% rest allowance
- Demand=17000 product/day

Figure 9 shows the pattern of the new line balance after revision. The cycle time for some stations is reduced (existing station 4 and station 5), and some are increased (due to the combination of station 1, station 2 and station 3). As for existing station 4, it is split into three substations, stations 2, 3 and 4 (refer to 1 in Figure 10), to balance the cycle time for each station. The existing station 5 is split into two substations, stations 5 and 6 (refer to Figure 11).

<<FIGURE 11 ABOUT HERE>>

The revised Yamazumi board clearly shows that the line is a bit balanced compared to the existing one because the cycle time for each station is near the Takt time. Below is the summarisation of the cycle time for each station:

Station 1 - 9.61s (the combination of existing stations 1,2 and 3)

Station 2 - 8.5s
Station 3 - 8.5s
Station 4 - 8.5s

The split from the existing station 4

Station 5 - 5.85s
Station 6 - 5.85s

The split from the existing station 5

Referring to the balancing theory, by applying the balancing approach, the efficiency of a process flow (line) will increase regarding the value of the new cycle time is approximate to the Takt time. Therefore, the company should implement the new workstation.

For this project, the company may not implement this concept since it involves a large amount of investment they may be capable of. This situation refers to splitting the existing stations 4 and 5, which requires the company to invest in a new machine and increase operators.

4.4. Inventory and demand

The main inventory for this company is due to the WIP (Work-In-Progress), especially in the cutting and printing processes. As for the WIP in the cutting process, the time needed for the printing process is slightly higher than the cutting process, which contributes to the high inventory. This is because the amount produced during the cutting process cannot be moved to the following process. The same goes for the printing process, in which both processes show significant differences in cycle time.

<<FIGURE 12 ABOUT HERE>>

4.4. Labor efficiency

Labour efficiency is calculated to determine how efficient the workers are. While loss shows, the percentage of workers is idle due to no work to be done. The less loss rate indicates that the workers use their working time properly. From the table below, we can see that certain workers have a higher loss rate. It shows that they have less workload compared to other people. Therefore, by combining the job number of workers will be reduced. Consequently, it is a waste to hire people to do nothing.

$$\text{Efficiency} = (\text{Productive Time}/\text{Available Time}) \times 100 \quad (1)$$

<<TABLE 7 ABOUT HERE>>

The ABC company implemented some lean techniques, but not all of them. The primary technique that can be identified in the company is the pull production system. Pull production in which the flow on the factory floor is driven by demand from downstream, pulling production upstream as opposed to traditional batch-based production in which production is pushed from upstream to downstream based on a production schedule. This means that no materials will be processed until there is a need (signal) from downstream. For example, in pull production, a customer order creates demand for the finished product, which in turn makes a demand for final assembly, which forms the demand for sub-assemblies, and so on up the supply chain. Pull production is the same as Just-in-Time (JIT), which means that raw materials or works-in-progress are delivered with the exact amount and ―just in time‖ for when the downstream workstation needs it.

ABC company produce the customers' parts based on their demand. Therefore, they will only provide the component according to the demand. There will be no waste due to the excess inventory because the finished parts will be shipped immediately after the packaging. Until today, pull production is the only lean technique adopted by the company.

There are several problems found in the ABC company during the observation: excess labour, inefficient layout and line balancing, WIP and transportation, which are considered waste. In general, there is an excess of labour compared to the process demand. Two persons are not required in the process flow as they contribute to a 16.67% loss of overall labour efficiency. The optimum labour for the process would be 9, despite 11 workers avoiding idle time for each employee. With optimum labour efficiency, the cost can be reduced and enhance the profit and performance of the company. The other problem is the imbalance line in which the cycle time for two stations in the flow line exceeds the takt time stated. Station 4 contributes 24.6s and station 5 11.7s, which exceeds the 10.03s required by the company to balance the line altogether.

Besides that, there are stations that too below away from the Takt timeline, such as station 1 (2.5s) and station 2 (2.11s) of cycle time. Therefore, the line should be upgraded and rebalanced to enhance the line performance and increase its efficiency. To improve the company's overall performance, serious attention should be given to implementing lean techniques since it has been proven that lean can enhance overall performance with proper implementation of lean. But lean cannot be implemented in total at one time; it must follow the step-by-step procedure.

4.5. Recommended action plan

Reducing time and tossing well to determine the exact time of rest for workers is extremely valuable for accelerating the production process. As a result, times more to throw waste in the factory transfers are detected.

Part of a palette that can be assembled in the factory to produce it, and half-made components for storing the pallets SAVE them, increasing the available space and easy access to materials and components, can be remarkably effective.

Storage systems (manner of entry and exit of goods, easy access, reduced time encoding and controlling all materials and parts available) and inventory control system (Economic Order Quantity ordered each time – Model EOQ), before forecasting materials required, expected future orders, took orders, order value) and create incentive systems for workers and a statistical quality control system.

We combine jobs from workers 1 and 2 because the activity setup machine is less frequent. Arranging the body only needs to be done after the machine setup is completed. Worker 7 is required in this area because the machine makes the arrangement automatically. They need to ensure the body is adequately inserted into the socket. Therefore, we eliminated worker 7. Worker 8 will be responsible for inspecting the arrangement of the body.

4.5.1 Proposed worker tasks

Worker 1. Cutting the body from XXX

Worker 2. Arrange the body from the box on the conveyor. Set up machine and dye. Maintain the machine operation.

Worker 3. Inspection of paint quality if pass arranges in the box. If fail or pass to rework by removing the paint. Worker

4. Remove paint.

Worker 5. Remove paint 33

Worker 6. Arrange body need to be assembled. Check the nip to determine ink flow within the filter to nip.

Worker 7. Check the barcode and arrange it into boxes.

Worker 8. Pack the finished product.

Worker 9. Pack the finished product.

Worker 10. Pack the finished product.

After improvement is made, labour efficiency is recalculated to get the new efficiency of each worker. The loss for each worker has been reduced. It shows that workers have less idle time because they have more work to be done.

<<TABLE 8 ABOUT HERE>>

4.6. Layout improvement

Data from flow process analysis can be used to study the relationship between each process, while an activity relationship chart shows the link and their significance in each Section. The improvement of the layout will focus on the production area only. The closeness of each segment is based on the quantity of flow, cost of material handling, the number of travels every day and flow of the process. Figure 13shows the activity relationship chart of ABC company.

<<FIGURE 13 ABOUT HERE>>

<<TABLE 9 ABOUT HERE>>

The next step is to develop a graphical representation of the activity relationship chart. The higher closeness must be prioritised, followed by lower closeness. Figure 14 shows the relationship diagram and Space relationship diagram for ABC company, respectively. From this relationship diagram, a new layout of High-Risk areas can be designed.

<<FIGURE 14 ABOUT HERE>>

4.6.1 Proposed layout

This improvement only involves the manufacturing and assembly areas. Therefore, the position of the office and toilets will be the same as before. Figure 15 shows the proposed layout of the factory. This layout may look the same as before because there are only minor changes made. However, a minor change is seen to reduce the number of transportations, one type of waste in manufacturing. Furthermore, this innovative design layout does not require excessive cost because only the cutting process is a move to the packing area.

<<FIGURE 15 ABOUT HERE>>

4.6.2 Validation of the proposed layout

After redesigning the layout, validation is made using flow process analysis to compare total distance before and after improvement. Flow process analysis for the new layout is defined using three tables:

d) From-to chart – the estimated distance between sections (Table 10)

e) From-to chart – the estimated flow of goods per day (Table 11)

f) From-to chart – the estimated total distance travelled each day (Table 12)

<<TABLE 10 ABOUT HERE>>

<<TABLE 11 ABOUT HERE>>

<<TABLE 12 ABOUT HERE>>

$$\text{Total travelling distance} = \text{Distance} \times \text{Flow of products} \qquad (2)$$

<<TABLE 13 ABOUT HERE>>

After analysing the process flow, the total distance travelled each day for a new layout is 84009 meters, and the current total travel is 140012 meters. With the recommended layout and proposed to use of a conveyor, total travelling is decreased by 40%. Lowering the total travelling distance will reduce travelling costs and improve production output.

5. Managerial Implications

Our paper contributes to the managers and practitioners of small and local companies who intend to apply Lean Manufacturing (LM) to their operations and improve operational performance. The result of the study demonstrates even limited application of the lean techniques will positively impact the company's performance. Despite shreds of evidence from the literature (Rossini et al., 2019), the results of this study confirm that LM implementation is successful within small-size companies and leads to improvement. In some cases, such as the current study, the lean application does not require huge capital investment. Therefore, managers and practitioners could plan to implement LM within their operations. However, the appropriateness of the lean tool would vary from one company to another. Besides operational performance improvement, layout improvement optimises the workflow and reduces cost and lead time. These lateral advantages help small enterprises to prevent excessive investment in productivity improvement activities (Inan et al., 2021)

6. Conclusion

While the elimination of waste may seem a simple and straightforward subject, it is noticeable that waste is often very conservatively identified. This then hugely reduces the potential of such an aim. The elimination of waste is the goal of Lean, and Toyota defined three broad types of waste: Muda, Muri and Mura; it should be noted that for many Lean implementations, this list shrinks to the first waste type only with corresponding benefits decrease. To illustrate the state of this thinking Shingo observed that only the last turn of a bolt tightens it—the rest is just movement. This ever-finer clarification of waste is key to establishing distinctions between value-adding activity and waste and non-value-adding work. Non-value-adding work is waste that must be done under the present work conditions. One key is to measure, or estimate, the size of these wastes, to demonstrate the effect of the changes achieved and the movement toward the goal.

By using PAM, hidden waste in the production of EK660 was revealed. A significant amount of this waste relates to waiting time and non-value-added activities, which influence the productivity of the EK660 production. The results from quantitative analyses performed by this study showed that the adopted lean principles could significantly reduce the waiting time in the production system. More precisely, the evaluation of cycle time highlights the economic benefits that would be gained through implementing considered lean tools. In other words, applying LM could be a fundamental key driver for continuous improvement in sustainability.

This study has several limitations, which bring opportunities for future research. Since the study was limited to a mall-to-medium enterprise, care should be taken to generalise the results. More precisely, the case study's observed improvements in operational efficiency in this research might be due to the company's size. Further research is needed to compare the performance indicator for different sizes of companies. In addition, further research needs to examine more closely the links between implementing Lean and the characterisation of the implementation of Industry 4.0. Also, it is interesting if future studies address new types of waste, such as unused employer creativity, for further development of this study. Another interesting area for further investigation could be the consideration of digitalisation, i.e. (Martins, 2022) on operational performance in SMEs.

References

ABU, F., SAMAN, M. Z. M., GARZA-REYES, J. A., GHOLAMI, H. & ZAKUAN, N. 2021. Challenges in the implementation of lean manufacturing in the wood and furniture industry. *Journal of Manufacturing Technology Management,* 33(1), 103-123.

ACHANGA, P., SHEHAB, E., ROY, R. & NELDER, G. 2006. Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management,* 17**,** 460-471.

ANTONY, J., PSOMAS, E., GARZA-REYES, J. A. & HINES, P. 2021. Practical implications and future research agenda of lean manufacturing: a systematic literature review. *Production planning & control,* 32**,** 889-925.

AGHAJARI, N., & SENIN, A. A. (2014). Strategic orientation and dual innovative operation strategies: Implications for performance of manufacturing SMEs. *Asia-Pacific Journal of Business Administration,* 6(2), 127-147.

BALLÉ, M. 2005. Lean attitude [considering attitude in lean production]. *Manufacturing Engineer,* 84**,** 14-19.

BELEKOUKIAS, I., GARZA-REYES, J. A. & KUMAR, V. 2014. The impact of lean methods and tools on the operational performance of manufacturing organisations. *International Journal of Production Research,* 52**,** 5346-5366.

BHAMU, J. & SINGH SANGWAN, K. 2014. Lean manufacturing: literature review and research issues. *International Journal of Operations & Production Management,* 34**,** 876-940.

CHAPLE, A. P., NARKHEDE, B. E., AKARTE, M. M. & RAUT, R. 2018. Modeling the lean barriers for successful lean implementation: TISM approach. *International Journal of Lean Six Sigma,* 12(1), 98-119.

COSTA, F., LISPI, L., STAUDACHER, A. P., ROSSINI, M., KUNDU, K. & CIFONE, F. D. 2019. How to foster Sustainable Continuous Improvement: A cause-effect relations map of Lean soft practices. *Operations Research Perspectives,* 6**,** 100091.

DADASHNEJAD, A.-A. & VALMOHAMMADI, C. 2018. Investigating the effect of value stream mapping on operational losses: a case study. *Journal of Engineering, Design and Technology,* 16(3), 478-500.

ELKHAIRI, A., FEDOUAKI, F. & EL ALAMI, S. 2019. Barriers and critical success factors for implementing lean manufacturing in SMEs. *IFAC-PapersOnLine,* 52**,** 565-570.

GHOBADIAN, A., TALAVERA, I., BHATTACHARYA, A., KUMAR, V., GARZA-REYES, J. A. & O'REGAN, N. 2020. Examining legitimatisation of additive manufacturing in the interplay between innovation, lean manufacturing and sustainability. *International Journal of Production Economics,* 219**,** 457-468.

HARDCOPF, R., LIU, G. J. & SHAH, R. 2021. Lean production and operational performance: The influence of organisational culture. *International Journal of Production Economics,* 235**,** 108060.

HERRON, C. & BRAIDEN, P. 2007. Defining the foundation of lean manufacturing in the context of its origins (Japan).

INAN, G. G., GUNGOR, Z. E., BITITCI, U. S. & HALIM-LIM, S. A. 2021. Operational performance improvement through continuous improvement initiatives in micro-enterprises of Turkey. *Asia-Pacific Journal of Business Administration,* 14(3), 335-361.

IQBAL, T., JAJJA, M. S. S., BHUTTA, M. K. & QURESHI, S. N. 2020. Lean and agile manufacturing: complementary or competing capabilities? *Journal of Manufacturing Technology Management,* 31(4), 749-774.

JAMES, T. 2006. Wholeness as well as Leanness. *Manufacturing Engineer,* 85**,** 14-17.

JØRGENSEN, F., MATTHIESEN, R., NIELSEN, J. & JOHANSEN, J. 2007. Lean maturity, lean sustainability. *Advances in Production Management Systems*. Springer.

KARIM, A. & ARIF-UZ-ZAMAN, K. 2013. A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organisations. *Business Process Management Journal,* 19**,** 169-196.

KOVÁCS, G. 2020. Combination of Lean value-oriented conception and facility layout design for even more significant efficiency improvement and cost reduction. *International Journal of Production Research,* 58**,** 2916-2936.

LACERDA, A. P., XAMBRE, A. R. & ALVELOS, H. M. 2016. Applying Value Stream Mapping to eliminate waste: a case study of an original equipment manufacturer for the automotive industry. *International Journal of Production Research,* 54**,** 1708-1720.

LOYD, N., HARRIS, G., GHOLSTON, S. & BERKOWITZ, D. 2020. Development of a lean assessment tool and measuring the effect of culture from employee perception. *Journal of Manufacturing Technology Management*, 31(7), 1439-1456.

MARODIN, G. A., FRANK, A. G., TORTORELLA, G. L. & FETTERMAN, D. C. 2019. Lean production and operational performance in the Brazilian automotive supply chain. *Total Quality Management & Business Excellence,* 30**,** 370-385.

MARTINS, A. (2022). Dynamic capabilities and SME performance in the COVID-19 era: the moderating effect of digitalisation. *Asia-Pacific Journal of Business Administration*.

NORDIN, N., DEROS, B. M. & WAHAB, D. A. 2010. A survey on lean manufacturing implementation in Malaysian automotive industry. *International Journal of Innovation, Management and Technology,* 1**,** 374.

PAPADOPOULOU, T. & ÖZBAYRAK, M. 2005. Leanness: experiences from the journey to date. *Journal of Manufacturing Technology Management,* 16**,** 784-807.

PAVNASKAR, S., GERSHENSON, J. & JAMBEKAR, A. 2003. Classification scheme for lean manufacturing tools. *International Journal of Production Research,* 41**,** 3075-3090.

PINTO, C. M., MENDONÇA, J., BABO, L., SILVA, F. J. & FERNANDES, J. L. 2022. Analysing the Implementation of Lean Methodologies and Practices in the Portuguese Industry: A Survey. *Sustainability,* 14**,** 1929.

PUVANASVARAN, P., MEGAT, H., HONG, T. S. & RAZALI, M. M. 2009. The roles of communication process for an effective lean manufacturing implementation. *Journal of industrial engineering and management,* 2**,** 128-152.

RAFIQUE, M. Z., AB RAHMAN, M. N., SAIBANI, N. & ARSAD, N. 2019. A systematic review of lean implementation approaches: a proposed technology combined lean implementation framework. *Total Quality Management & Business Excellence,* 30**,** 386-421.

RAHANI, A. & AL-ASHRAF, M. 2012. Production flow analysis through value stream mapping: a lean manufacturing process case study. *Procedia Engineering,* 41**,** 1727-1734.

RAHMAN, S., LAOSIRIHONGTHONG, T. & SOHAL, A. S. 2010. Impact of lean strategy on operational performance: a study of Thai manufacturing companies. *Journal of manufacturing technology management,* 21**,** 839-852.

ROSSINI, M., COSTA, F., TORTORELLA, G. L. & PORTIOLI-STAUDACHER, A. 2019. The interrelation between Industry 4.0 and lean production: an empirical study on European manufacturers. *The International Journal of Advanced Manufacturing Technology*, 102**,** 3963-3976.

RYLANDS, B., BÖHME, T., GORKIN III, R., FAN, J. & BIRTCHNELL, T. 2016. The adoption process and impact of additive manufacturing on manufacturing systems. *Journal of Manufacturing Technology Management,* 27, 969-989.

SARTAL, A., VÁZQUEZ, X. H. & LOZANO-LOZANO, L. M. 2020. Organisational tools and cultural change in the success of lean transformations: Delving into sequence and rhythm. *IEEE Transactions on Engineering Management,* 69(5), 2205-2217.

SCHONBERGER, R. J. 2007. Japanese production management: An evolution—With mixed success. *Journal of Operations Management,* 25, 403-419.

SHAH, R. & WARD, P. T. 2003. Lean manufacturing: context, practice bundles, and performance. *Journal of operations management,* 21, 129-149.

SUNDAR, R., BALAJI, A. & KUMAR, R. S. 2014. A review on lean manufacturing implementation techniques. *Procedia Engineering,* 97, 1875-1885.

TAJ, S. & MOROSAN, C. 2011. The impact of lean operations on the Chinese manufacturing performance. *Journal of manufacturing technology management,* 22, 223-240.

THÜRER, M., TOMAŠEVIĆ, I. & STEVENSON, M. 2017. On the meaning of 'waste': review and definition. *Production Planning & Control,* 28, 244-255.

Table 1. Seven Types of Wastes

Wastes	Description
Overproduction	Is unnecessarily producing more than demanded or producing it too early before it is needed. Also, overproduction increases the cost of storage of production (keeping cost) So, in this case, there is no overproduction since the quantity of production is mainly referred to customer order and avoid—sparell production.
Waiting	Is there any idle time for workers or machine due to bottleneck or inefficient production flow on the factory floor? in this context, there is waiting time of the machines since the printing cycle time is longer compared to cutting. A balance of process line is one of the solutions to eliminate the bottleneck
Over-processing	Is unintentionally doing more processing work that the customer requires in term of product quality or features. In this case, there are over-processing, especially inspection in that does not have to be done more than once at each process. by implementing SPC and quality control principle the company can decrease the cost of inspection
Transportation	Includes any movement of material that does not add any value to the product. The materials or parts must move from one workstation to another. The most critical non-value-added work is transportation that in all factories is about 30% of the price of the finished production. By design the workstation with facility design techniques we can decrease the transportation
Motion	Includes unnecessary physical motions or walking by workers which diverts them from actual processing work. There is no waste in term of motion because the line was not really a long processing line. Especially using in the assembly line and use the techniques for assembling operator (right and left-hand techniques)
Inventory	Having additional high levels of raw material, work in progress and finish product. In this case, there is inventory waste since there are WIP in the process, especially waiting to be assembled. By adding more workstation or operator in the process line or equivalent the demand and supply.
Rework	Correction or reprocessing when something has to be re-do because it has not completed in the first place correctly. This type of waste also exists in the process, especially after the painting process. The improper print on the body will be rework and reprint again. It is done manually by the workers.

Table 2. Percentages Value Added, Non-Value-Added Activities and Wastes

List of activities	Frequency	Percentage (%)
Value-added activities	9	39.13
Non value-added activities	10	43.48
Wastes	4	17.39
Total	23	100

Table 3. Cycle Time

Workstation 1 (workstation)	Workstation 2 (cutting for one cavity)	Workstation 3 (printing)	Workstation 4 (assembly)	Workstation 5 (packing)
2.5s	2.11s	5s	25.6s	11.7s

Table 4. Estimated Distance Between Sections

From/To	C	D	E	F	G	H	I
C	-	0.6m	1.6m	1.65m	1.5m	1.3m	0.8m
D		-	.1m	1.1m	0.9m	1.3m	0.4m
E			-	0.7m	0.87m	0.6m	1.2m
F				-	0.4m	0.35m	0.95m
G					-	0.3m	0.7m
H						-	0.7m
I							-

Table 5. Estimated Flow of Goods Per Day

From/To	C	D	E	F	G	H	I
C	-	20	20,000	0	0	40,000	0
D		-	0	0	0	0	0
E			-	20,000	0	0	0
F				-	20,000	0	0
G					-	20,000	0
H						-	20,000
I							-

Table 6. Estimated Total Distance Travels Each Day

From/To	C	D	E	F	G	H	I	Total
C	-	12	3200	0	0	66,000	0	98,012
D		-	0	0	0	0	0	0
E			-	14,000	0	0	0	14,000
F				-	8,000	0	0	8,000
G					-	6,000	0	6,000
H						-	14,000	14,000
I							-	-
Total Distance								140,012

Table 7. Labor Efficiency (Available Time=21450)

Worker	Efficiency	Loss
1	77%	23%
2	75%	25%
3	42%	58%
4	97%	3%
5	98%	2%
6	98%	2%
7	75%	25%
8	90%	10%
9	98%	2%
10	98%	2%
11	98%	2%
12	98%	2%

Table 8 Labor Efficiency

Worker	Efficiency	Loss
1	77%	23%
2	93%	7%
3	97%	3 %
4	98 %	2%
5	98%	2%
6	96%	4%
7	98 %	2%
8	98 %	2%
9	98 %	2%
10	98 %	2%
1	77%	23%
2	93%	7%

Table 9 Activity Relationship Guideline

Key	Definition	Legend
A	Absolutely Necessary	
E	Especially Important	
I	Important	
O	Ordinary Important	
U	Unimportant	
X	Undesirable	

Table 10. Estimated Distance Between Sections

From/To	C	D	E	F	G	H	I
C	-	0.29m	0.54m	0.9m	1.04m	0.84m	1.4m
D		-	0.24m	0.6m	0.78m	0.6m	0.9m
E			-	0.38m	0.56m	0.44m	0.78m
F				-	0.2m	0.3m	0.7m
G					-	0.2m	0.48m
H						-	0.28m
I							-

Table 11. Estimated Flow of Goods Per Day

From/To	C	D	E	F	G	H	I
C	-	0.29m	0.54m	0.9m	1.04m	0.84m	1.4m
D		-	0.24m	0.6m	0.78m	0.6m	0.9m
E			-	0.38m	0.56m	0.44m	0.78m
F				-	0.2m	0.3m	0.7m
G					-	0.2m	0.48m
H						-	0.28m
I							-

Table 12. Estimated Flow of Goods Per Day

From/To	C	D	E	F	G	H	I
C	-	20	20,000	0	0	40,000	0
D		-	0	0	0	0	0
E			-	20,000	0	0	0
F				-	20,000	0	0
G					-	20,000	0
H						-	20,000
I							-

Table 13. Estimated Total Distance Travel Each Day

From/To	C	D	E	F	G	H	I	Total
C	-	9	17000	0	0	33600	0	50609
D		-	0	0	0	0	0	0
E			-	10400	0	0	0	10400
F				-	8000	0	0	8000
G					-	4000	0	4000
H						-	11000	11000
I							-	-
Total Distance								84,009

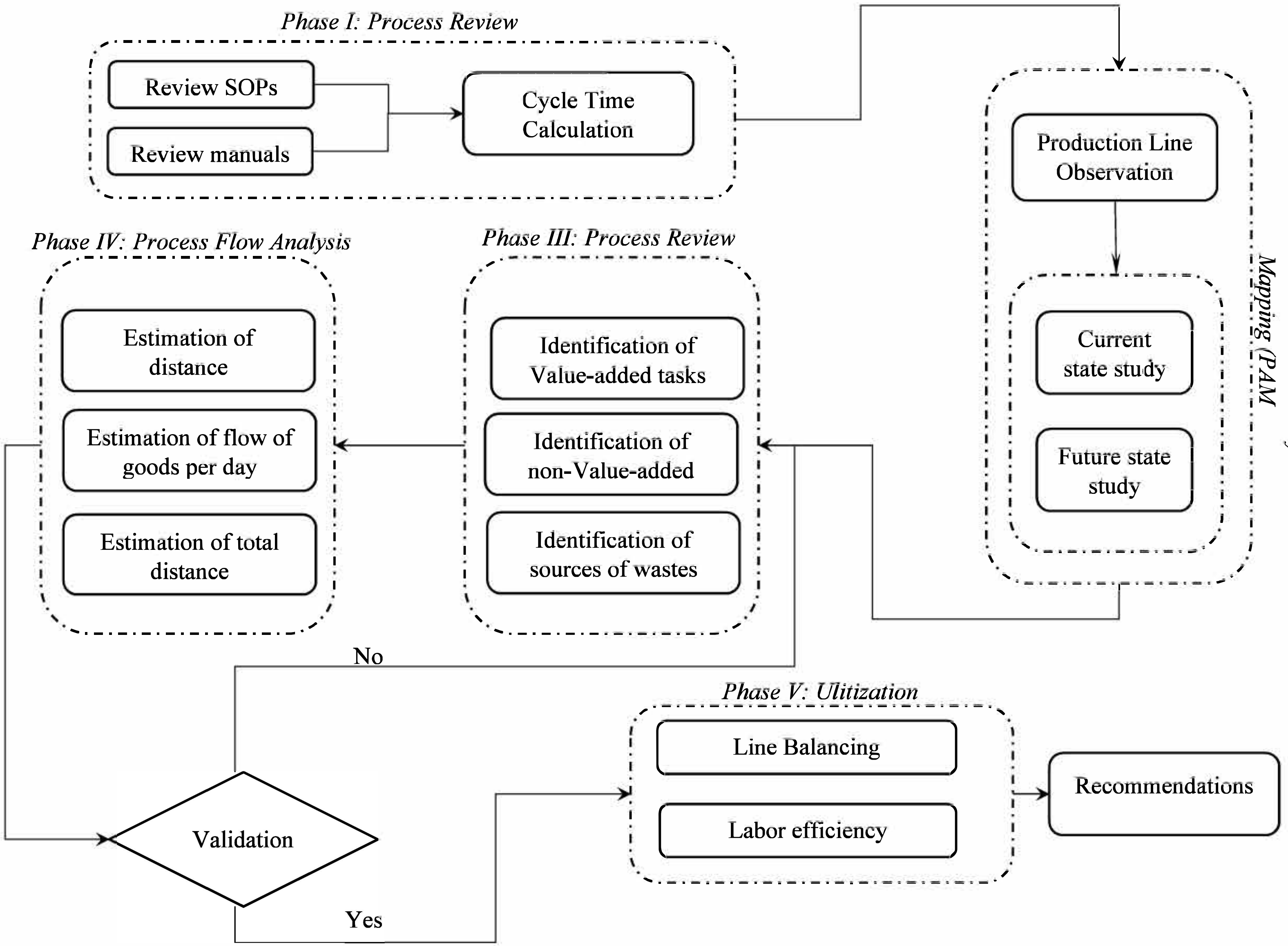

Figure 1: Research Methodology Processes

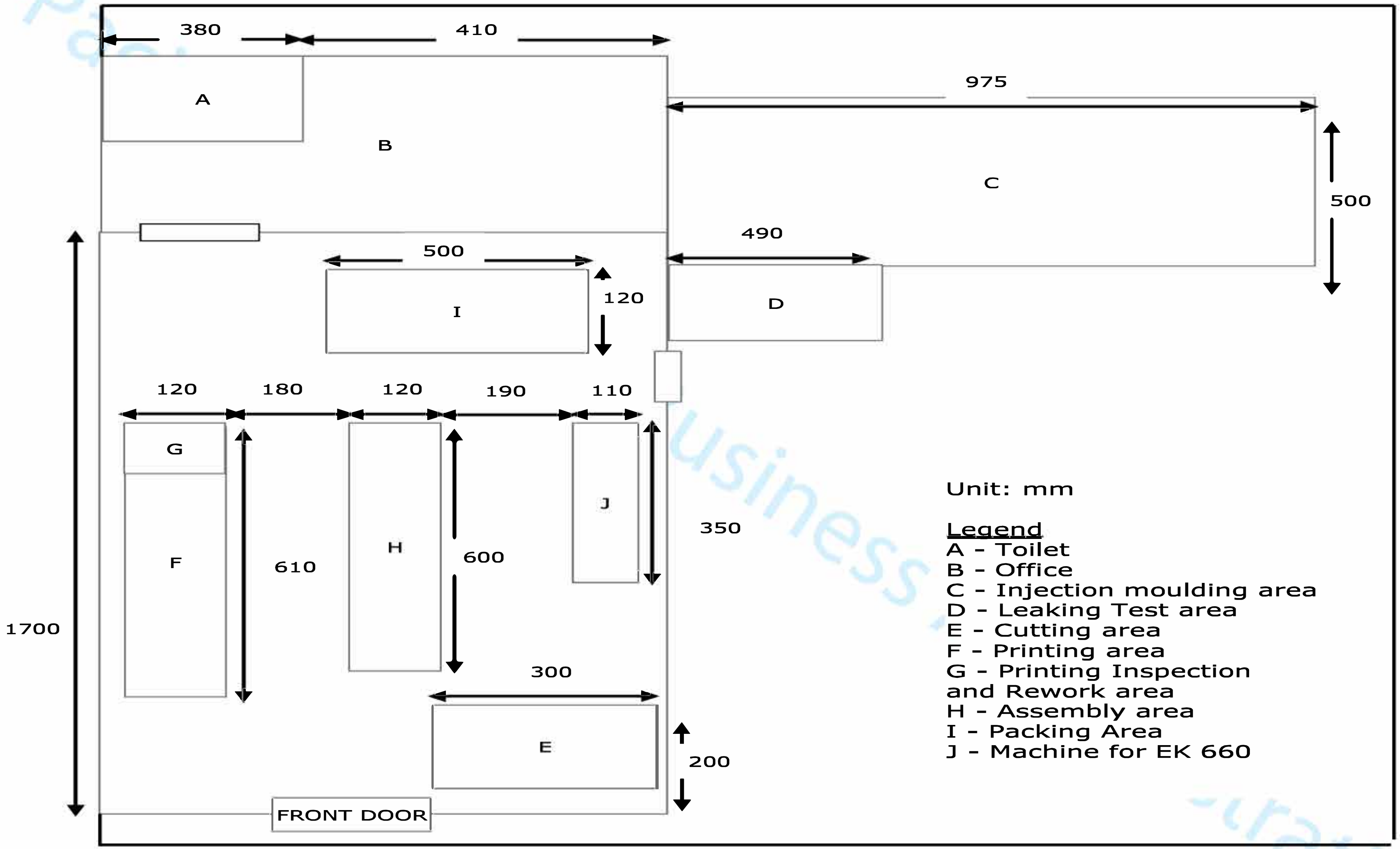

Figure 2. Existing Layout of the Factory

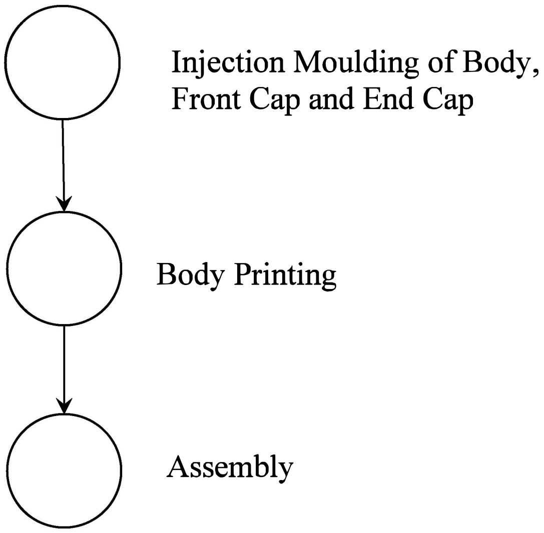

Figure 3. Overall Flow Process

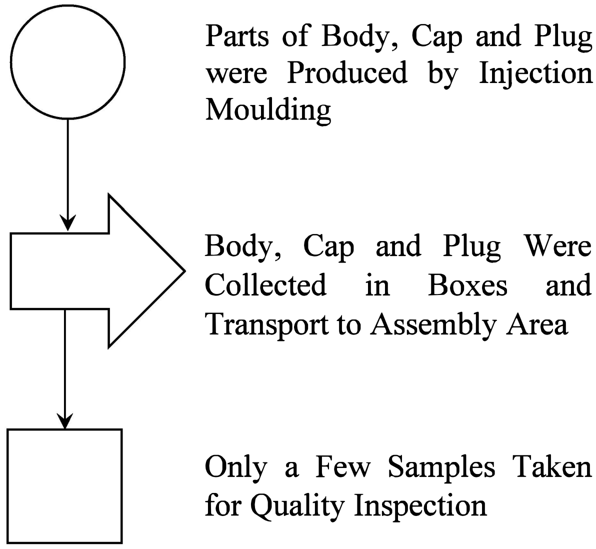

Figure 4. Process Flow of Workstation 1

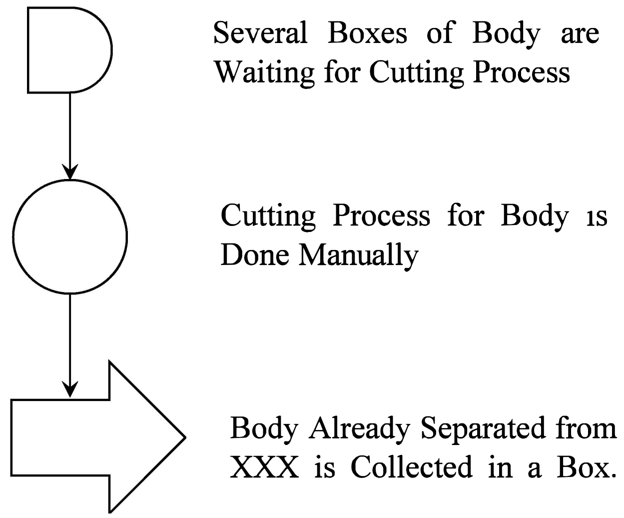

Figure 5. Process Flow of Workstation 2

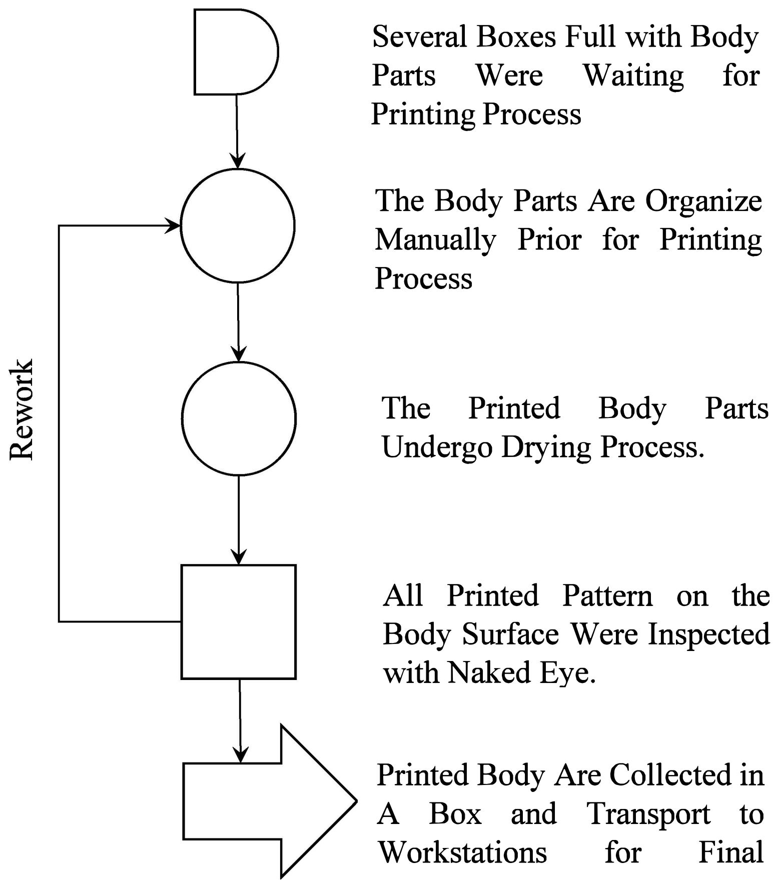

Figure 6. Process Flow of Workstation 3

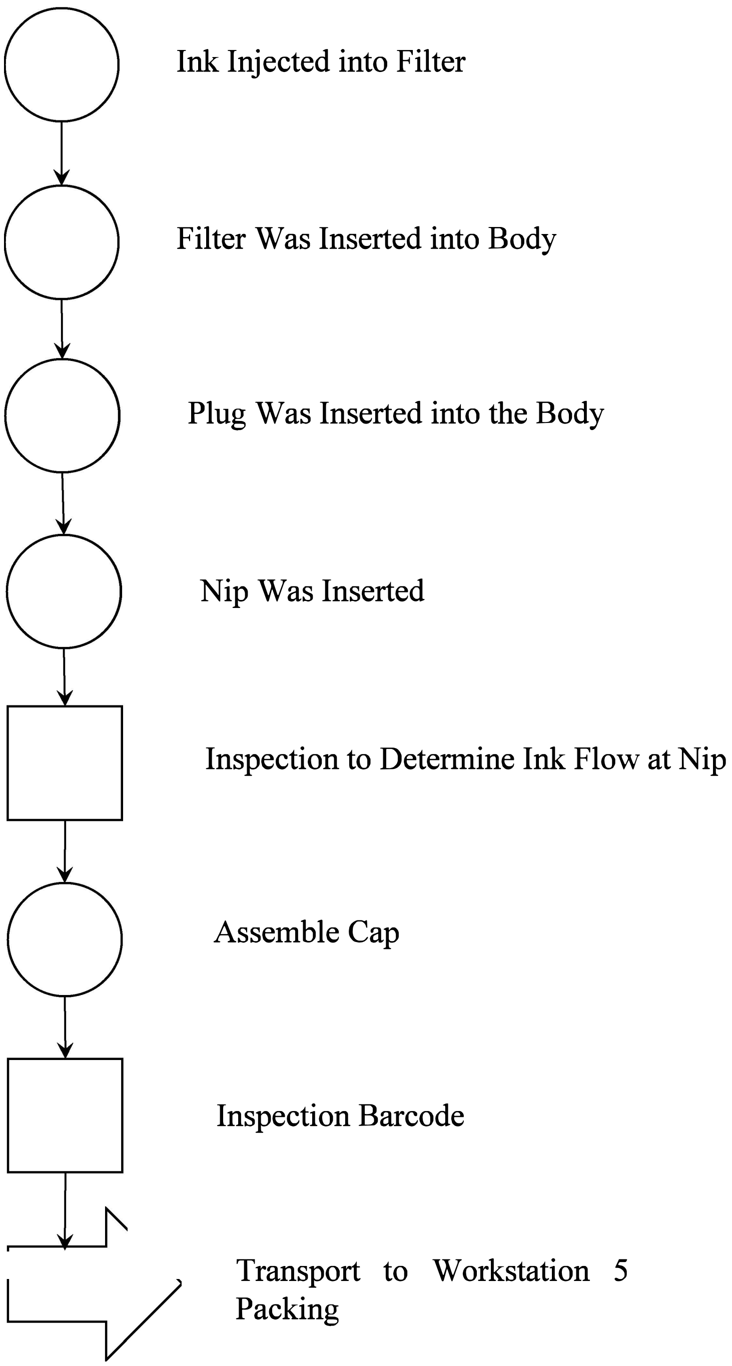

Figure 7. Process Flow of Workstation 4

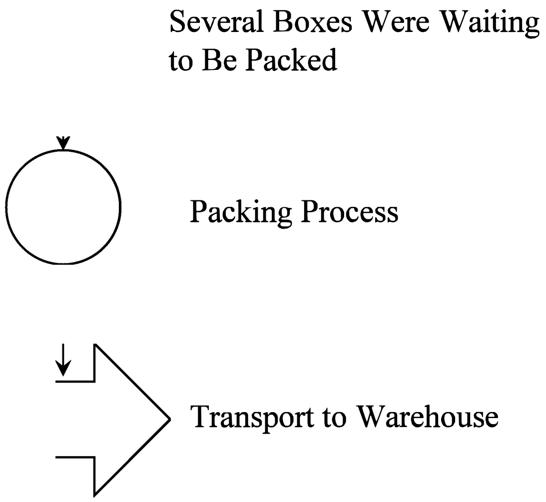

Figure 8. Process Flow of Workstation 5

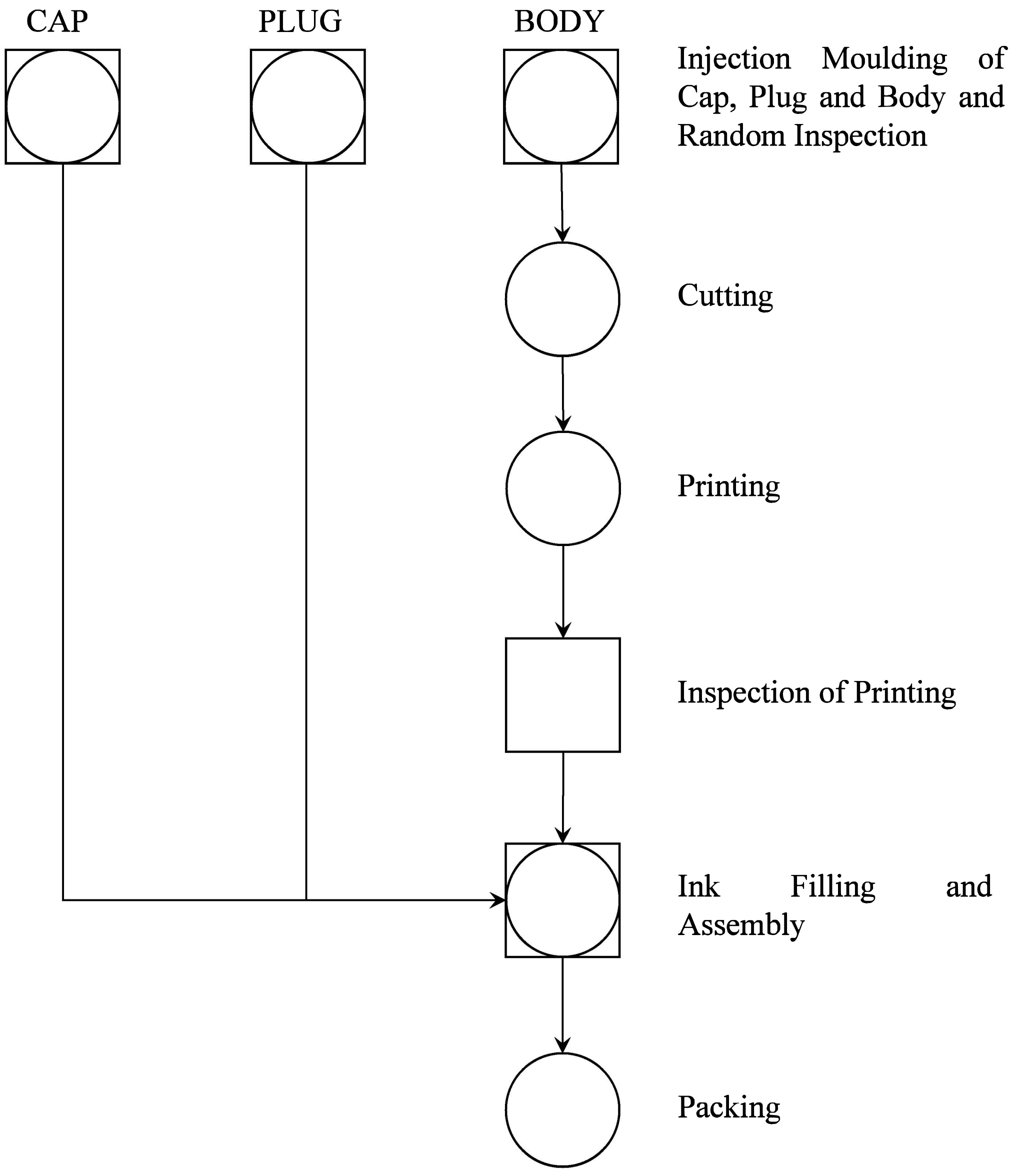

Figure 9. Sequences of Process

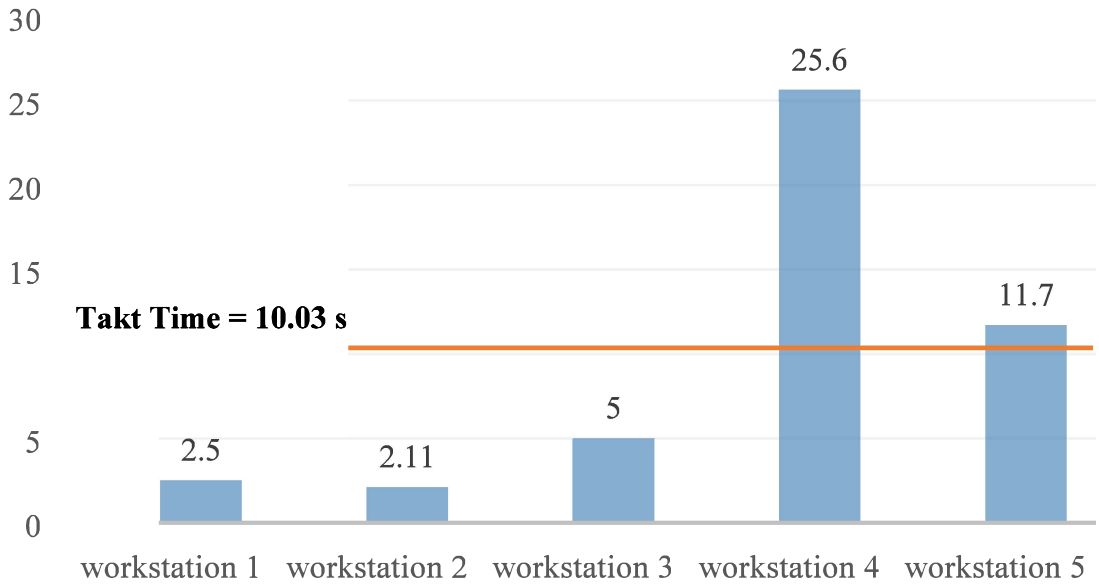

Figure 10. Yamazumi Board of Existing Process Flow

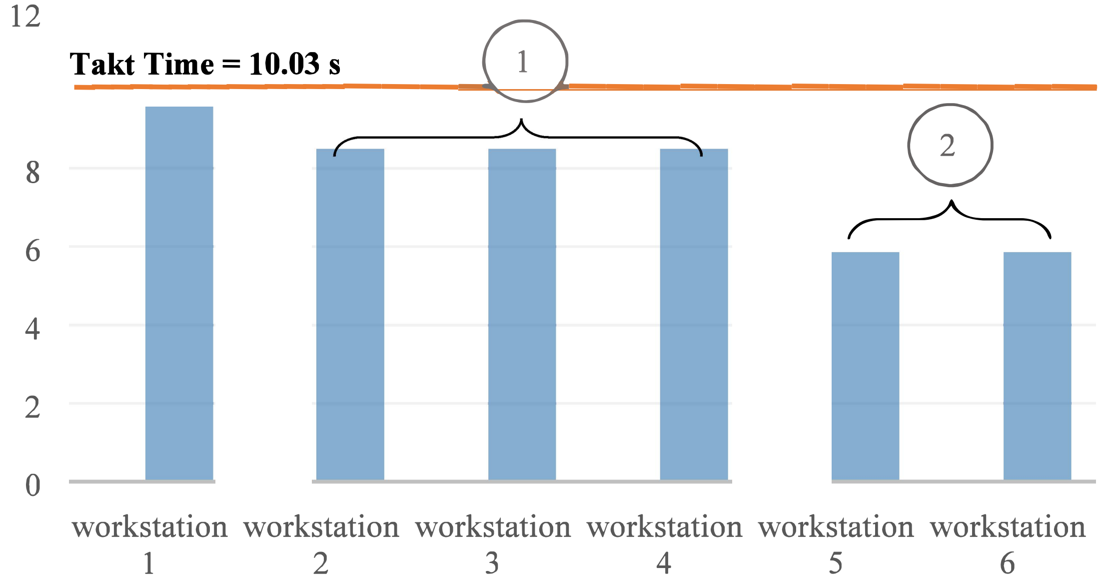

Figure 11. Revised Yamazumi Board

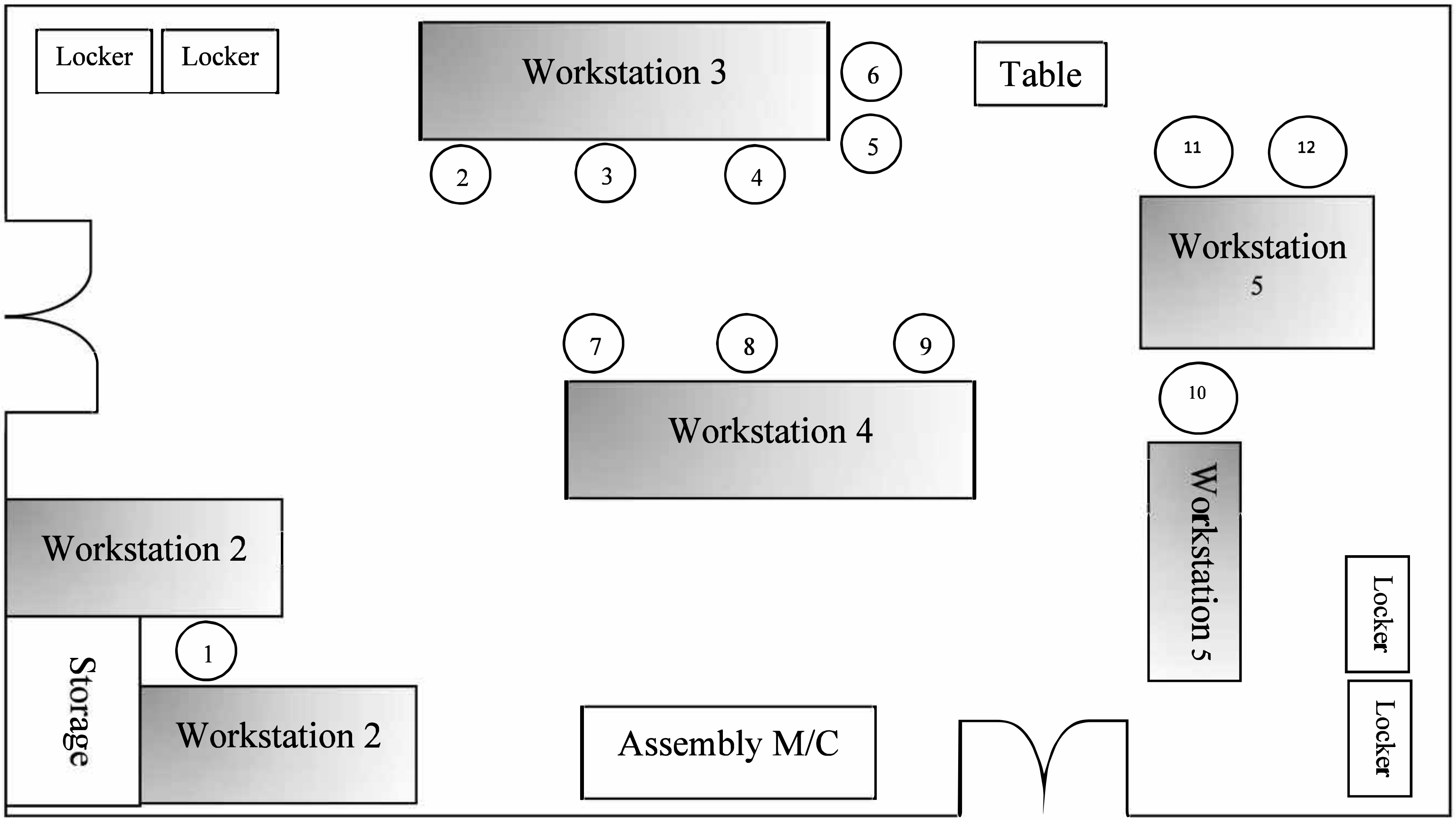

Figure 12. Location of Workers

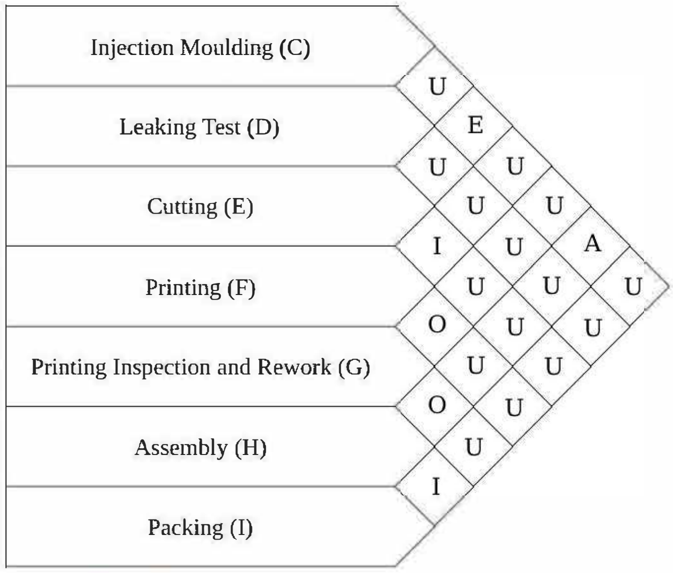

Figure 13. Activity relationship chart

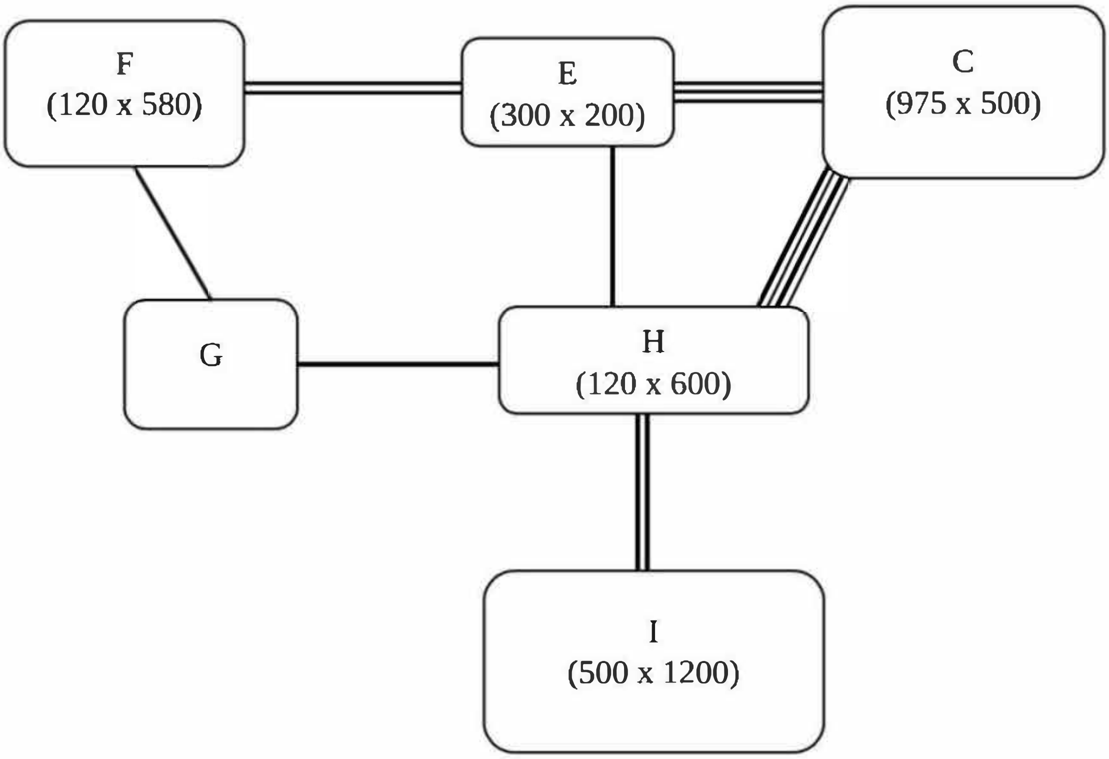

Figure 14. Relationship Diagram

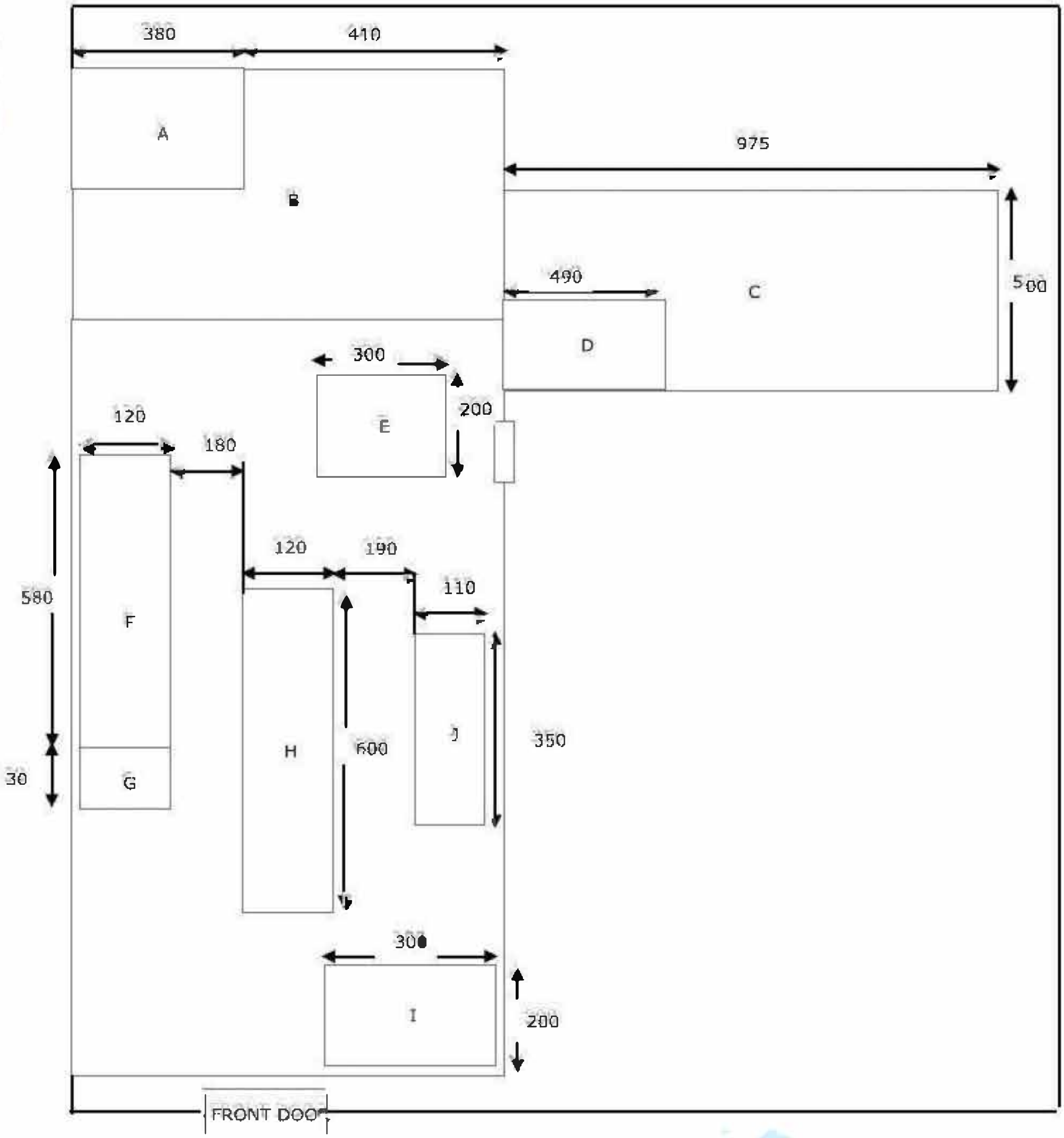

Figure 15. Proposed Layout of the Factory