THE IMPLEMENTATION OF LEAN PRODUCTION MANAGEMENT THROUGH THE USE OF LEAN TOOLS IN THE AIR FILTRATION INDUSTRY

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Chemical Engineering

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MAY 2016

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

During the course of the implementation of lean management, the concept was studied and the associated different forms of lean parameters such as MUDA, MURI and MURA was analysed. By determining the lean parameters different forms of waste can be identified in the air filtration production facility which is in line with lean methodology implementation. To determine lean parameters and facilitate in the elimination of wastes, lean tools such as Value Stream Mapping (VSM), cycle time and takt time analysis were used. The purpose of this research to implement lean production management in the air filtration production industry by eliminating MUDA, MURI and MURA from the production line, improving the cycle time to match it with the takt time and analysing this improvement effect through value stream mapping. A mix of quantitative and qualitative research method was used throughout this lean implementation. In quantitative data collection, the cycle time and takt time were obtained through the production demand as well as the available production time. In qualitative research analysis, informal meeting with the worker as well as production walk through observation was used to identify the associated non value added activities. Four filter products were selected for lean management including GI Frame Pocket Filter, Aluminium Frame Pocket Filter, M-HI Filter and M-HII Filter. MURI was identified in the production process of GI Frame Pocket Filter in which improvements to the ergonomics of the workstation was carried out. MUDA waste of defect was identified in the production of Aluminium Frame Pocket Filter in which a brand new stapling device was suggested to replace the existing stapling device. Whereas for the M-HI filter the MUDA waste of defect was identified and overcome using a ratchet strap, whilst waste of waiting was reduced using an industrial fan to speed up the curing process. Lastly, for the M-HII filter which was produced in a clean room the MUDA waste of waiting was eliminated using a hot air blower to speed up the glue curing process.

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LIST OF SYMBOLS / ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
JIT	Just In Time
TPS	Toyota Production Systems
TQM	Total Quality Management
US	United States
VSM	Value Stream Mapping
WIP	Work In Progress
IAQ	Indoor Air Quality
AL	Aluminium

CHAPTER 1

INTRODUCTION

1.1 Background

Production management has become one of the most important aspects in the world today. With new companies entering the market almost every day it is important that companies find new ways to stay afloat in this competitive business market. As such many companies have turned their attention to improvements in their production management. This is usually achieved through the use of lean production management. So what is actually lean production management? Lean production management originated from Toyota Corporation in Japan and was pioneered by a production engineer by the name Taichi Ohno in the year 1980. Lean production means manufacturing without waste (Rahman, Sharif and Esa, 2013), so the lean production management system aims to eliminate waste in each step of the production process and thereby improving quality of product and minimizing time and cost spent in production (Rahman, Sharif and Esa, 2013). Basically this can be done by reducing all non-value added activities and waste from the business (Arunagiri and Gnanavelbabu, 2014). Waste in a production can be defined to anything that is unnecessary to production except for important things such as materials; equipment's and working time which crucial is in a production line (Rahman, Sharif and Esa, 2013). After its introduction into the Toyota Production Systems (TPS), lean production management found its way into the west such as US and Europe, where when it was first launched in the west, it was known as Just in Time (JIT). Companies from the west soon realised that the reason why Japanese manufacturers were so efficient is because they carry no stock and only produce what is needed and when it is needed (Training-management.info, 2015).

Ohno identified 7 main wastes or also known as 7 MUDA wastes which need to be eliminated to improve production processes which are Defects, Over Production, waiting, transporting, movement, inappropriate processing and inventory (Training-management.info, 2015). By identifying this seven wastes or also known as 7W's the production process can then be improved using lean production tools which would be used as aids during the duration of the improvement process. Some of the many improvement tools which will be used are value stream mapping (VSM) together with the calculation of takt time and cycle time. There are also other lean improvement tools available to be used such as Kanban, Total Preventive Maintenance, Setup time reduction, Yamazumi chart, Total quality management (TQM), 5s and VSM (Arunagiri and Gnanavelbabu, 2014). However, these tools will not be discussed in this report.

1.2 Aim and Objectives

Aim

- To implement lean production management in an air filtration industry.

Objective s

- To identify and eliminate MUDA, MURI and Mura on the production floor
- To improve the production by matching the cycle time to the takt time of every process
- To analyse the improvement effect through Value Stream Mapping in the air filtration production industry

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Air Filtration Production Industry

The purpose of this research is to highlight how the implementation lean production management with the use of lean tools carried out in the air filtration production industry, thus it is only appropriate to give some background information on the particular industry. Air filters are used in many different industries such as the medical industry where HEPA and HVAC filters are used to filter out viral microbes and infections which are present in the air. These filters provide the highest form of filtration one can expect from air filters. Filters are also used in clean room applications where air filters ensure the particulate such as dust are below a certain level (ppm) or range to suit the manufacturing of materials such a semiconductor wafers in the electronic industry. In addition, in the automobile industry air filters are widely used in automobiles to enhance the engine hygiene. These filters can range from exhaust air filters and inline filter which are usually fitted as part of the engine component itself (Manufacturers and Directory, 2015).

To suit the many different range of impurities removal, not all air filters are designed the same way, as different impurities need different level of filtration efficiency. There are a few factors that determine air filtration efficiency. These factors are the relative size of the filter media, the density of the filter media and the velocity of air which passes through the filter media. By studying and determining the selected factors one is able to select the most appropriate filter for the desired use. This is because if the wrong type of air filter is selected for the desired application it may affect their filtration efficiency as that particular air filter is not designed to handle that particular type of particulate. From this we can say air filters are specific in their application. Moreover, air filters can also be categorised based on the location in which the air filtration unit is situated in a system. Usually primary filters are the first barrier of defence against air particulates, whereby large particles are first filtered in this stage. Secondary filters on the other hand are the secondary defence barrier in a system. They are able to filter more minute particles compared to the primary filter. The third barrier of defence in a system is the use of filters such as carbon filter, HEPA and ULPA filter which are used to filter out viral or pathogens in the air molecules thereby increasing the Indoor Air Quality (IAQ) (Mayair.com.my, n.d.).

The company which lean production management was carried out produces many different ranges of air filtration products with the desired filtration efficiency for particular applications. However, lean production management was carried out for their four different air filtration products which are M-Pack (GI frame and Al frame), M-HI, and M-HII. The type of air filter model, frame material construction together with its Average dust spot efficiency is summarised in Table 2.1.

Table 2.1: Air Filter Model Classification(Mayair.com.my, n.d.)

MayAir Product Model	Average Dust Spot Efficiency(%)					Frame Material		
	40-55	60-65	80-85	90-95	>90	GI	Aluminium	Stainless Steel
	F5	F6	F7	F8	F9			
M-Pack	X	X	X	X	X	X	X	
M-MII		X	X	X	X	X	X	X
M-HII							X	
M-HI							X	X

2.2 Parameters in Lean Production Management

MUDA is derived from Japanese which means waste; it can also be termed non value adding activities which do not contribute to the final value of the product. The goal is to reduce the amount of non-value adding activities and improve the value adding activities to deliver better products and services. However, during the implementation of lean production, many industries fail to see that the concept of MUDA does not cover the entire lean production perspective; as such there are two other lean parameters which needs to be looked at which are MURI (Overburden) and MURA (Unevenness) (Maciej, 2014). These three parameters are strongly related to one another and determine the success of implementing lean production management.

2.3 MUDA

As it was written earlier MUDA can be termed as something which does not add value to the final value of the product. MUDA (wastes) are identified for the sole reason of knowing which steps are needed and which are not needed in a manufacturing process. (Maciej, 2014) This can be done by using lean tools such as value stream mapping which will be discussed later in this report. Taiichi Ohno the father of lean production, in his book *Toyota Production System* identified that there are 7 main wastes which exist in manufacturing (Chen and Cox, 2012). These wastes are highlighted in Figure 2.1:

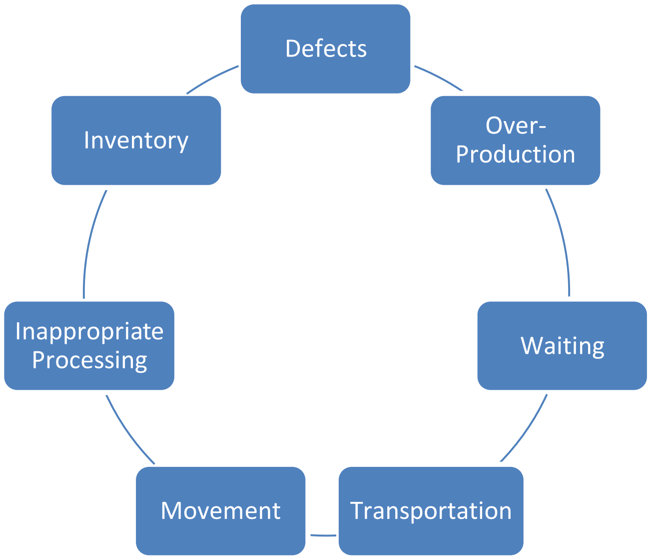

Figure 2.1:7 MUDA(wastes) (Training-management.info, 2015)

2.3.1 Over-Production

Over-Production can be defined as the action of manufacturing more material or product which does not follow the current demand (Arunagiri and Gnanavelbabu, 2014). This can be very costly to the business as it can cause the uneven movement of raw material inventory, which then can affect the production efficiency of a particular product. Moreover, since there are excessive products which are produced the manufacturer has to also spend money on storage as there is no demand for the excess product yet (Charles, 2014).

According to Page, (2004), “eliminating over-production reduces work in progress, and in doing so makes the system more responsive, complacency about rejects is reduced and valuable resources are not wasted on product that has no immediate sales value.” So why is Over-Production one of the seven main wastes? This can be related back to the concept of lean production management which is Just in Time or also known as JIT. This concept emphasizes on producing the required amount of quantity of a product (Training-management.info, 2015).

2.3.2 Waiting

Waiting is considered to be one of the main wastes because time which is available during production is not being used efficiently is considered to be a waste (Training-management.info, 2015). There is a few common waiting waste that occur in the manufacturing process, example includes processing delays, system downtime and response time (Arunagiri and Gnanavelbabu, 2014). When such waiting wastes occur this causes an increase in the production cost and reduced profit generation for the manufacturer. The waste of waiting can be identified by obtaining the lead time or cycle time of a product manufactured and comparing it against the takt time (Training-management.info, 2015). This is because a product which is waiting for the next process in a production line would have a higher cycle time than a normal product which does not undergo waiting (Charles, 2014).

2.3.3 Transportation

In manufacturing terms transportation can be said to the movement of goods to and from a manufacturing facility. Normally a manufacturer incurs transportation costs based on the movement of finished goods from the factory and the movement of raw materials to the factory (Arunagiri and Gnanavelbabu, 2014). Transportation turns into a type of waste when there is unwanted motion which translates into the deterioration or loss of product. If the process flow consists of many break times in between, this will increase the wait time which in turn causes WIP's to accumulate. When this occurs, WIP's need to be stored away which needs it to be shuttled back and forth from the factory to the warehouse. This causes unwanted transportation costs to occur (Charles, 2014). In addition, if there is a bigger warehouse, the transportation costs will also be increased due to the large area that needs to be covered (Arunagiri and Gnanavelbabu, 2014). By reducing break time between manufacturing processes, the cost of transportation can also be reduced.

2.3.4 Movement

Movement is categorized as one of the wastes when there is unnecessary motion of workers and operators on the production floor which does not translate into added value of a product. These unnecessary movements may also cause a waste of time thereby increasing the lead time it takes to manufacture a product. Normally this is caused by an improperly designed plant layout which causes workers to move from one workstation to another. Lifting or moving heavy objects or unfinished products from one place to another may cause injury health problems to the workers (Charles, 2014).

2.3.5 Inappropriate Processing

Over-processing is a waste because it is very redundant to add additional values to a finished product at which the customers are not willing to pay for. This commonly occurs in manufacturing when the product is manufactured way beyond the expected high quality standards. This occurs due to non-uniform procedures, ineffective processes, ambiguous quality acceptance standards, equipment problem, poor communication and unnecessary manufacturing processes (Charles, 2014).

2.3.6 Inventory

Inventory becomes a form of waste when there is an excess products stored in the warehouse with an excess of WIP’s (Arunagiri and Gnanavelbabu, 2014). One of the most common reasons there is an excess in inventory is due to incentives which encourage producing too much product which later needs to be stored. Usually the cost of inventory is of importance and usually generates no profit to the manufacturer (Arunagiri and Gnanavelbabu, 2014). In addition, excessive inventory has a tendency to mask problems in the production floor which must be identified and resolved to improve the production process of a product. Performance improvements translate into shorter lead times and increase the effective use of floor space by preventing littering around the production floor (Charles, 2014).

2.3.7 Defects

Defects are usually caused by errors and mistakes during the manufacturing of a product. When defects occur in a particular product, the product may require replacement or reprocessing. This causes wastage of time and resources and loss of valuable customers (Charles, 2014). Defects occur in manufacturing when a process is poorly controlled. A process which is properly engineered should produce results within the tolerable range every time. Changes in raw materials, equipment wear and tear, poor maintenance and training may lead to differences in quality of one product to another. (Arunagiri and Gnanavelbabu, 2014).

2.4 MURI

MURI is defined to be overburdened or unreasonableness. Overburden leads to less efficient work which translates into poor quality of product produced. Overburdening puts employees and machines into unwanted stress. An overburdened employee may injure themselves while working. In addition, MURI can also be defined as the less then potential use of man and equipment’s, in other words they are not pushed to their full potential. This in turn will cause long idle times which will increase the lead time of a product (Maciej, 2014). Thus, to prevent MURI occurring, there must be an optimum operating environment where man and equipment are not under or over utilized.

Table2.2: Main Causes which Lead to the Occurrence of MURI

Causes	Explanation
Unorganized workstation	Inefficient design of plant layout which leads to poor ergonomics and causes workers to invest more effort in carrying out their tasks
Poor standardization of work	Unclear instructions and poor communication which leads workers to feel burdened.

2.5 MURA

MURA is defined to be variation or unevenness. MURA comes in two different types which are the non-constant production scheduling and unbalanced production workload and rate of work. The occurrence of MURA can be boiled down to a single cause which is the batch logic of certain manufacturers. Usually manufacturers aim to fully use key resources and reduce the cost per unit. This is usually done by producing more units than necessary when there is a variation in demand.

Unknowingly, in an attempt to compensate for the variation, manufacturers accidentally increase an actual fluctuation in a production volume. This then causes higher unevenness on processes which are located further away from the root of the unevenness. This can be termed the “bull whip effect” in which a small change in demand at the end of a value stream translates to a large change in production volume on processes at earlier stages of the value stream. MURA occurs in many businesses and is usually the reason why MURI and MUDA occur (Maciej, 2014).

Table 2.3: Relationship Between MUDA, MURI and MURA (Maciej, 2014).

Type of waste	Explanation
MURI	When variation or unevenness caused by fluctuation in production occurs, the constant change in schedules in turn puts a lot of pressure on workers and machines, thereby reducing their work efficiency. When work efficiency is reduced the lead time will be increased.
MUDA	MURA can be said to be closely related with the MUDA (wastes) of overproduction. Businesses tend to overproduce products more than it is required which then cause's high levels of inventories. Due to this other MUDA then emerge leading to more wastes.

2.6 Summary of MUDA, MURI and MURA

There are three types of lean parameters which are MUDA, MURI and MURA. They are related to one another and understanding all of them is important in implementing lean production management. Once MUDA, MURI and MURA are identified they can be eliminated from the production process. Variation (MURA) or uneven production rate causes companies to alternately overload and underutilize their resources creating MURI and also overproduction (MUDA). Therefore, it can be said that the main causes of MUDA are MURI and MURA (Maciej, 2014).

2.7 Lean Production Tools

This report focus on two main types of lean production tools which is used in the implementation of lean production management. These tools are value stream mapping (VSM) and the calculation of cycle time and takt time.

2.7.1 Value Stream Mapping (VSM)

Value stream mapping (VSM) method originated from Japan when it was first introduced by the Toyota Motor Company at the end of the twentieth century. A value stream map can be defined as a collection of activities from start to finish which adds value to the produce that the customer has requested (Vikas, Sandeep and R.M., 2012). It is used as lean production improvement tool by identifying the current condition of process and uncovering potential opportunities for process improvement.

VSM divides the the processes in a production into two which are value added activities and non-value added activities. By dividing them into two groups one is able to identify at where the accumulation of inventory occurs and to obtain the total manufacturing lead time. The value adding time and the non-value adding time can be calculated by simply obtaining sum of each of the respective from start till the end in a production line.

Examples of value added activities are machining, processing, painting and assembling which are directly involved into adding value to the product. Non-value added activities on the other hand are activities such as scrapping, sorting, storing, counting, moving and documentation (Vikas, Sandeep and R.M., 2012). Non-value added activities can also be termed as activities which do not change the form or character of a product (Lean Manufacturing Tools, 2015).

In a conclusion, the aim of VSM is to identify potential wastes in a production line to improve work processes thereby reducing lead times, reducing costs and thereby improving quality of product and productivity (Rahani and al-Ashraf, 2012).

2.7.2 Process of Creating VSM

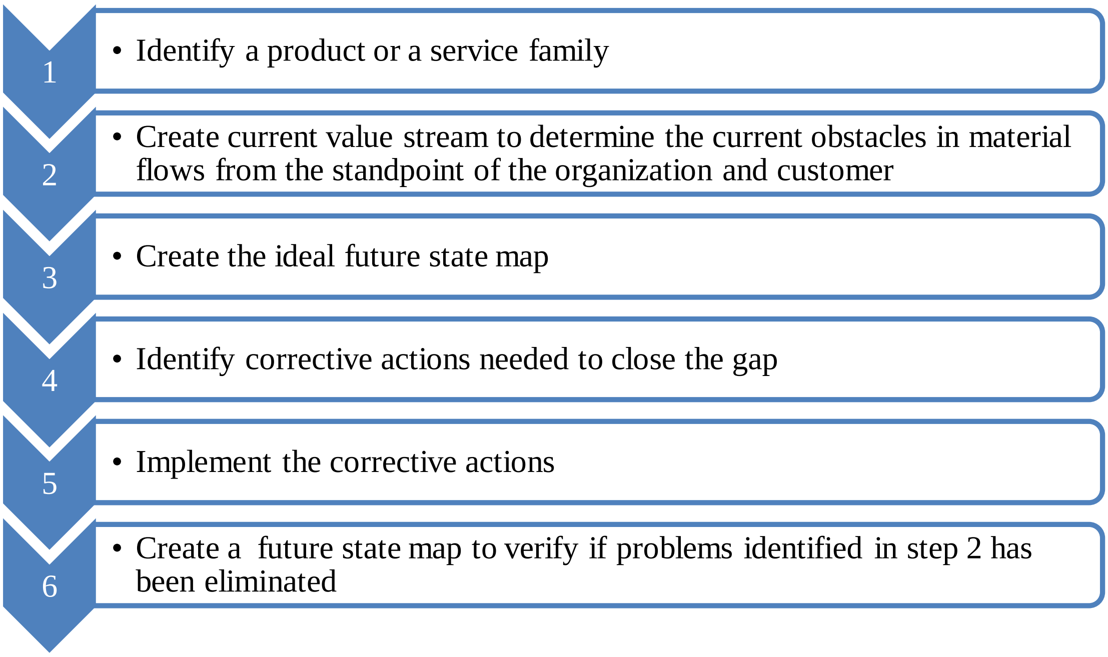

Figure 2.2: Process of Creating a Value Stream Map (Preetinder, 2012)

A more detail description of steps 1-6 is given in this report, as we can from Figure 2.2; step 1 highlights the identification of a product or a service family. During the creation of a value stream map, it is important to identify a product to be focused on at the end of the value stream. During the value stream mapping process care must be taken to map things which are related to this particular product or service. Moreover, products which have the same customers and supplier inputs should be grouped together and incorporated into one value stream map (Chen and Cox, 2012).

Step 2 is the creation of a current state map, what is then actually a current state map? A current state map aims to gives some insight and understanding into the current movement of material and information that goes into the production of a product. The procedure of creating a current state map should begin by using manual method which is the use of pencil rather than computer software followed by hands on method which is to walk through the actual material and information pathway (Chen and Cox, 2012). In addition, during the creation current state map, the walk through process should start from the customer end and work their way from there because products should be driven by customer demand. During the walk through process, it would be better to carry a stopwatch, paper and pencil which aids in the building of the value stream map (Chen and Cox, 2012).

After the current state of the process has been determined in step 2, in step 3 the ideal future state map is thought off, usually this step can be integrated with step 4 by which we can identify corrective actions by asking the following seven questions, the questions are as follows (Chen and Cox, 2012):

- When does the customer need the product?
- How often is the performance monitored to suit the customers' needs?
- What are the steps which add value and do not add value?
- How can the work flow be improved?
- How can work be prioritized?
- Is there any chance to balance workload with other activities?
- What types of enhancements are necessary to the process?

In steps 5 and 6, after implementing all the necessary improvements, a future state map is created; this is to ensure there are improvements done to the process stream as compared to the current state map which was constructed in step 2 (Chen and Cox, 2012).

A value stream map may also be created by using software packages such as Microsoft Visio, iGrafx and Edraw Max could be used to construct a value stream map (Preetinder, 2012). During the creation of a value stream map there are certain symbols that have to be used to show a particular part or section of the process, Figure 2.3 summarizes those symbols used.

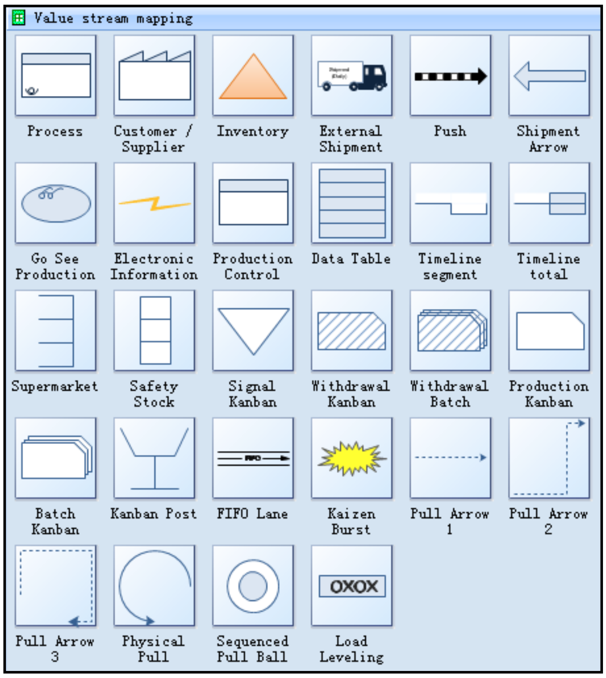

Figure 2.3: Symbols Used to Create a Value Stream Map (Preetinder, 2012)

Upon selecting the correct symbols with respect to their role in the production line, the value stream map can then be drawn. Figure 2.4 shows an example of a value stream map.

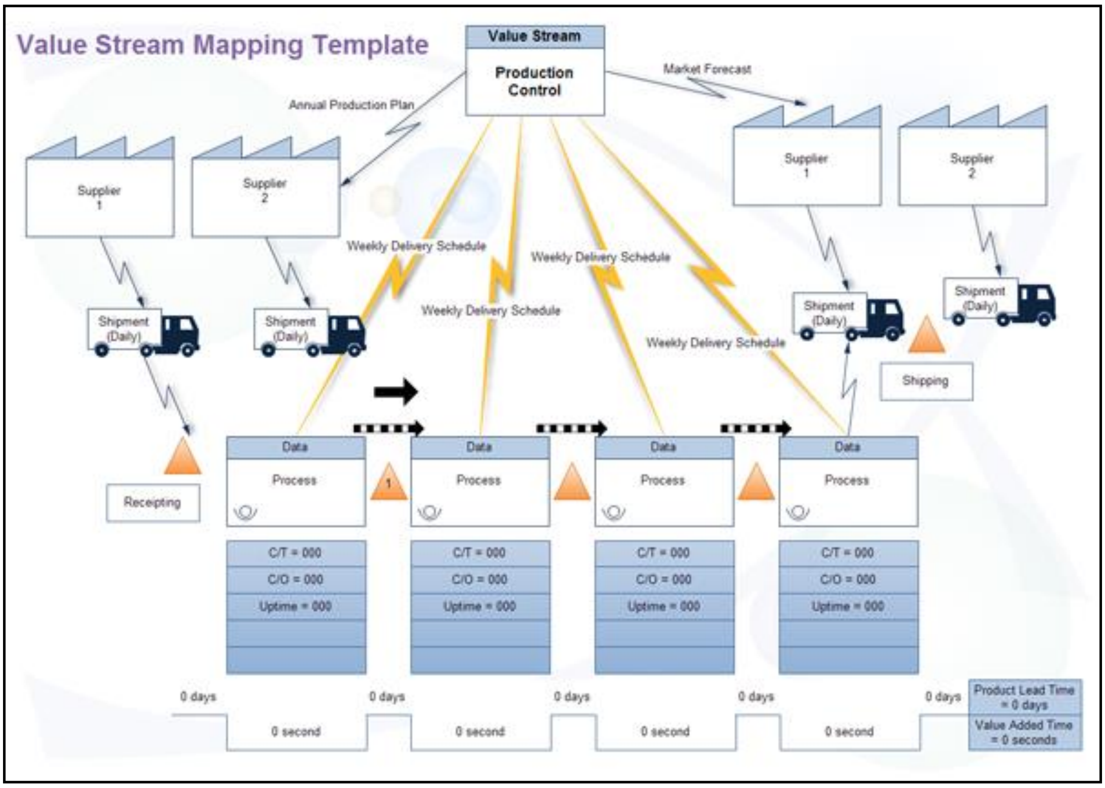

Figure 2.4: Example of Value Stream Map (Edraw,2010)

2.7.3 Takt Time

Takt originated from the German language which is known as the baton which the conductor uses to during an orchestra to control the orchestra at a certain speed (Fiona, 2013). In the manufacturing industry takt is referred to as the frequency of a part or component that needs to be produced to meet customers demand (Rahani and al-Ashraf, 2012). In manufacturing takt time can be calculated using Equation (2.1).

$$Takt\ time = \frac{Available\ Production\ time}{Customer\ Demand}$$

Equation (2.1)

Takt time matches the actual production to the customers' demand. Lean manufacturing companies usually aim to achieve this calculated takt time. Takt time will not be achieved if the production is faster than the takt time which results in overproduction which is one of the MUDA wastes. On the other hand, producing slower than the takt time causes bottlenecks in the production line and the demand of the customers will not be met (Vorne, 2015).

Thus some of the many benefits of incorporating takt time into manufacturing are as follows:

- Production flow will be steady without interruptions
- Waste of overproduction can be curbed by producing according to the current demand
- Promotes equality, efficiency and the culture of standardized work
- Real time targets can be set for production

2.7.4 Cycle Time

Cycle time is defined as the production frequency of a product or the total time a product spends in a workstation before moving to the next. Cycle time is a tool which is used to show the actual work time as compared to the takt time. During lean implementations cycle time can usually be reduced by eliminating all non-value added activities which increases the lead time of a product. The difference between lead time and cycle time is that lead is a measure of elapsed time (hours, minutes and seconds) until the product has been delivered whereas for cycle time it is the measure of the amount of time per unit customer/piece. The frequency of a product manufactured in terms of cycle time can be calculated based on Equation (2.2) (Sandip, Niranjan and Sanjay, 2014).

$$Cycle\ time\ = \frac{Total\ Production\ time}{Quantity\ of\ production\ produced}$$

Equation (2.2)

Whereas for the cycle time taken at each workstation is calculated using Equation (2.3):

$$Cycle\ time = Total\ time\ spent\ by\ the\ product\ in\ each\ workstation$$

Equation (2.3)

In manufacturing, reducing cycle time provides many benefits to a business, the benefits are as follows:

- Cost reduction
- Increase in throughput
- Process streamlining
- Communications improvements
- Reduction in process variation
- On-time deliver improvements

2.7.5 Relationship between Cycle Time and Takt Time

In the implementation of lean production management, success comes when the takt time is balanced against the cycle time, in other words they both equal to each other. Figure 2.5 further illustrates this concept.

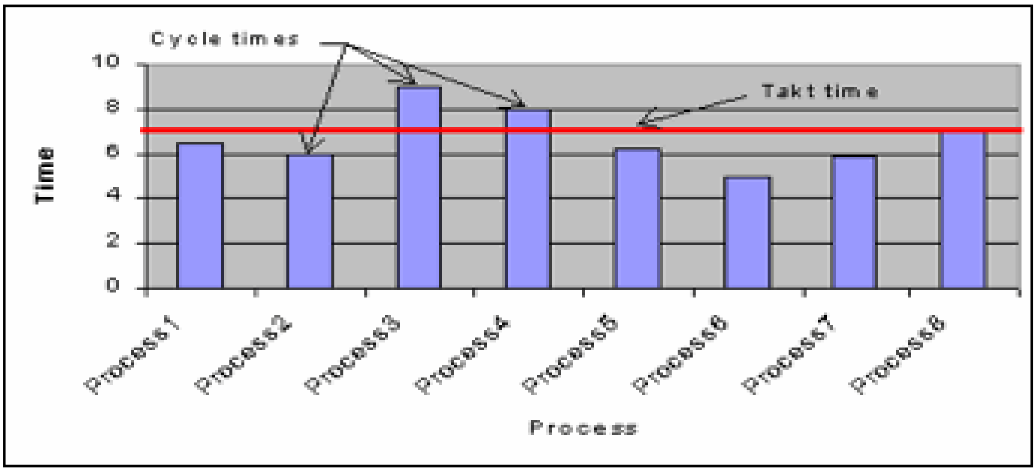

Figure 2.5: Relationship between Cycle Time and Takt Time (Marshall, 2015)

Referring to Figure 2.5, in processes four and five the cycle time is more than the takt time which results in bottlenecks. What lean management helps to do is to achieve a balance between these two as what is being done in process eight. After we have matched the cycle time against the takt time, the production output can then be further increased and the process lean management is repeated again. However, in real life applications a production line may only be operated at a cycle time close to the takt time and not exactly on takt time as issues such as machine downtimes have to be taken into account for.

2.8 Case Studies

2.8.1 Case Study 1 – Caparo Limited

Caparo Limited is a company involved in the automobile industry which is located in Bawal, Rewari India. The company manufactures about 150 different types of products. Out of the 150 products manufactured a product known as inner wheel housing was selected for the purpose of lean improvement. This particular product was selected since it was the most important product from the safety standpoint of the customers. In addition, this product provides a wider spectrum for study and is suitable for further improvements on the production process to achieve higher production rates (Vikas, Sandeep and R.M., 2012). VSM together with the calculation of takt time and cycle time was used to improve the production rate of the inner wheel housing. The VSM implementation flowchart is shown in Figure 2.6.

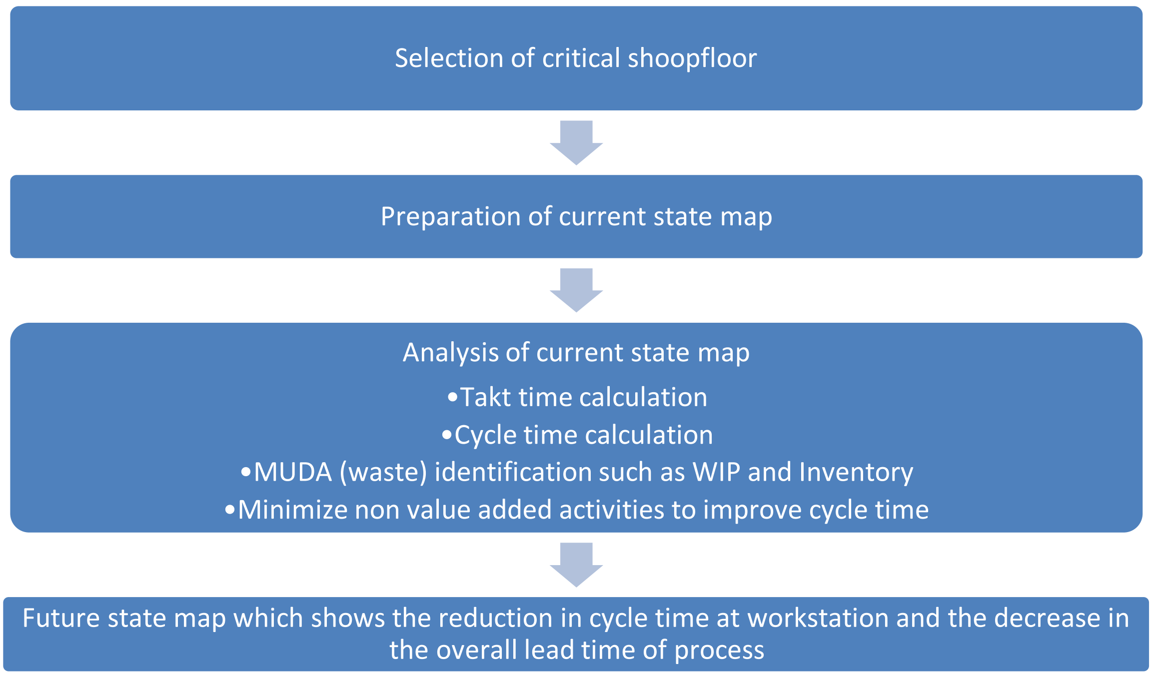

Figure 2.6: VSM Implementation Flowchart used in Caparo Limited for Process Improvement (Vikas, Sandeep and R.M., 2012)

According to Figure 2.6, the current state map needs to be drawn for that particular product under study. Figure 2.7 shows the current state map of inner wheel housing which was drawn.

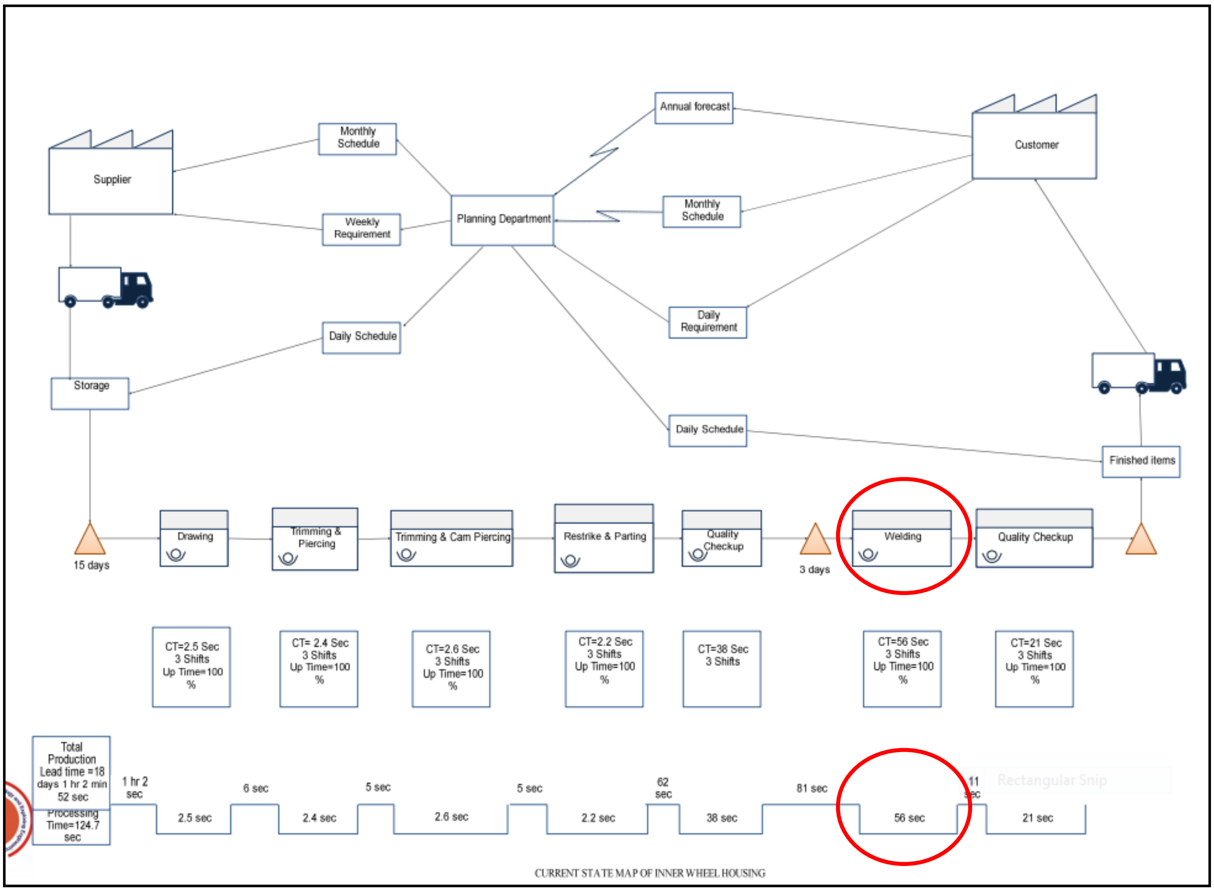

Figure 2.7: Current State Map of Inner Wheel Housing (Vikas, Sandeep and R.M., 2012)

The takt time for the inner wheel housing was calculated and shown in Table 2.4.

Table 2.4: Takt Time Calculation of Inner Wheel Housing (Vikas, Sandeep and R.M., 2012)

Number of shifts per day = 3
Number of working days = 27
Net working time per day = 1320 min
Maximum forecast Demand for month = 50000

$$Production\ capacity\ per\ month = 27*1320*60/\ 56$$ $$= 38000\ parts$$
$$Takt\ Time = \frac{Available\ time}{Customer\ Demand}$$ $$= 27 * 1320 * 60/50000$$ $$= 42.7\ seconds$$

When the cycle time tabulated in future state map in Figure 2.7, the cycle time of the welding process exceeds the takt time, thus improvements need to be done to improve the cycle time so as to meet or be lower than the takt time. In addition, it can also be seen that the actual production capacity for a month does not meet the maximum forecast demand for a month, thus this has to be dealt with. It was then decided to improve the welding process by introducing a new fixture, a robot welding machine and improving the layout of the weld shop. Upon doing so the cycle time was able to be reduced, this in turn also reduces the overall lead time. The prior and after improvements in processing time and lead time is given in Table 2.5.

Table 2.5: Comparison between Prior and After Improvements in Process (Vikas, Sandeep and R.M., 2012)

Variables	Units	Prior to Improvement	After Improvement
Inventory	No. of days	3	1
Production lead time	Days-hrs-minutes-sec	18-1-2-52	11-1-1-39
Processing time	sec	124.7	107.2
Production capacity per month	Parts	38000	55000

The future state map on the production process of inner wheel housing was then drawn with the newly calculated cycle time of the welding process and the changes in the material flows are illustrated in Figure 2.8:

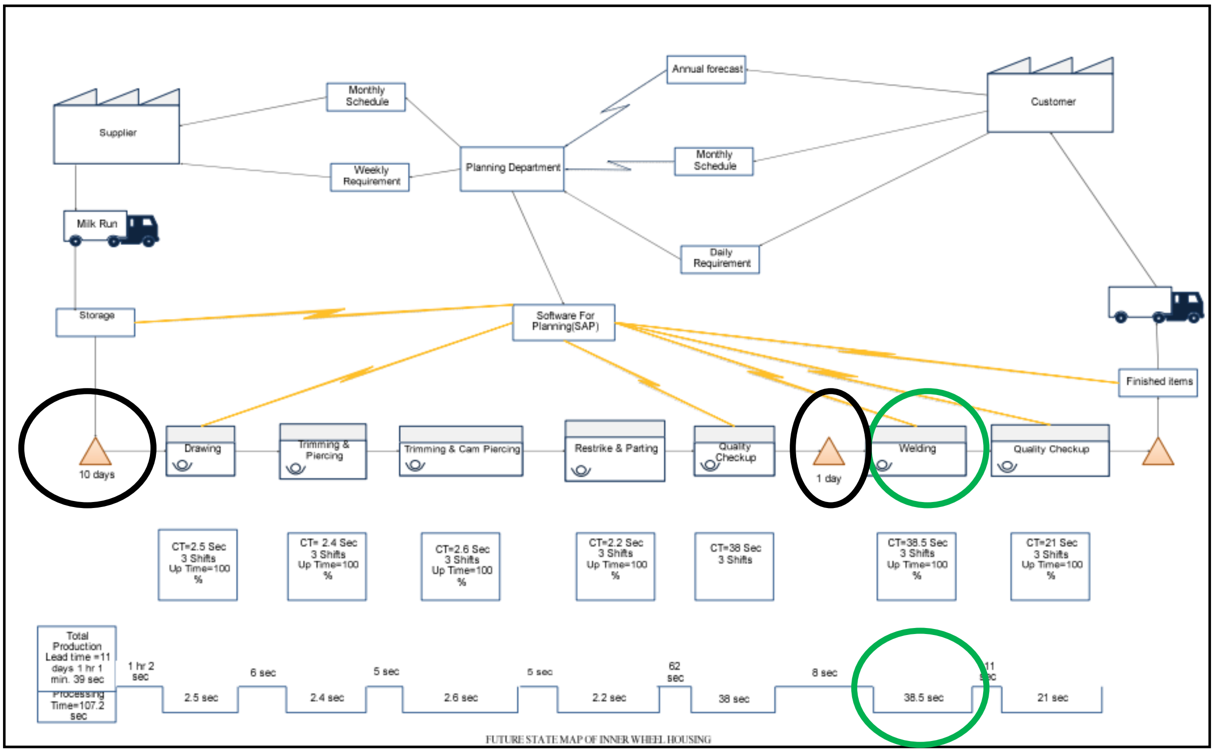

Figure 2.8: Future State Map of Inner Wheel Housing (Vikas, Sandeep and R.M., 2012)

In a conclusion, the production process of inner wheel housing has experienced some improvements, there is about 44% improvements by improving value added activities which is by decreasing the cycle time at the welding process and the reduction in WIP and inventory.

2.8.2 Case Study 2 – Pharmaceutical Industry

This case study focuses on a multinational pharmaceutical company which manufactures various types of pharmaceutical products. These products can be in the form of pills, tablets or even capsules. This multinational company has an employee number of 400 and their annual production hits a value of 100 million packages which targets the European market in addition to the 100 other markets which their product is sold globally.

Since this is a multinational company, there are many plants which were available for this case study to take place. However, a plant which produces ‘growing’ products has been selected for this case study. ‘Growing’ here means that in a couple of years the production capacity of that particular selected plant has grown in a substantial way. Thus, the improvement on its production flow and reorganization is priority. The management has decided to implement lean management by focusing on factors such as reduction in set up time, non-value added activities elimination, reducing inventories and decreasing balance delays. By focusing on the factors above the management hopes to increase its production efficiency in line with lean management.

The main ways that will be used for the improvement programme is through the re-engineering of the production flow. By re-engineering the production flow through layout re-design specific goals such as the creation of a continuous production flow, reduction in the total length of the production flow and more efficient use of manufacturing space (Nenni, Giustiniano and Pirolo, 2014).

Re-engineering of the production flow

The drug manufacturing process is outlined in Figures 2.9 and 2.10 gives a pictorial idea of the production process.

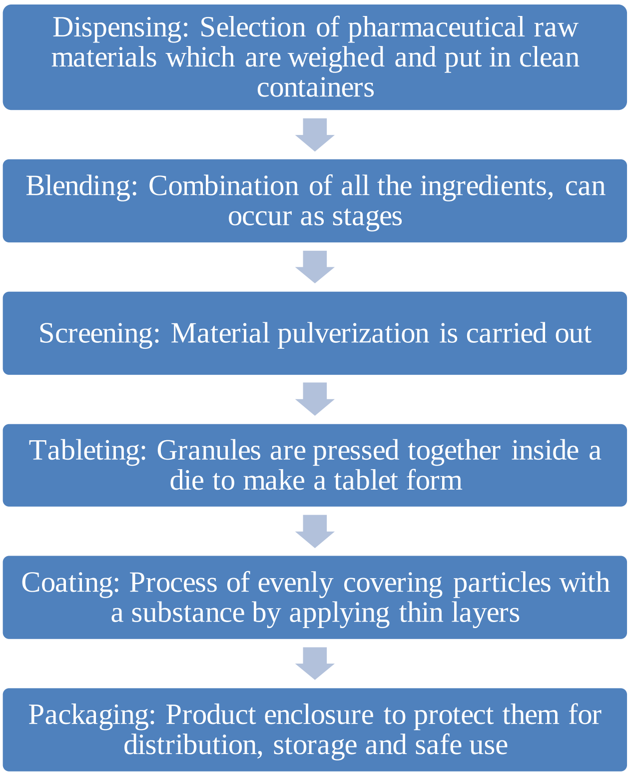

Figure 2.9: Drug Manufacturing Process (Nenni, Giustiniano and Pirolo, 2014)

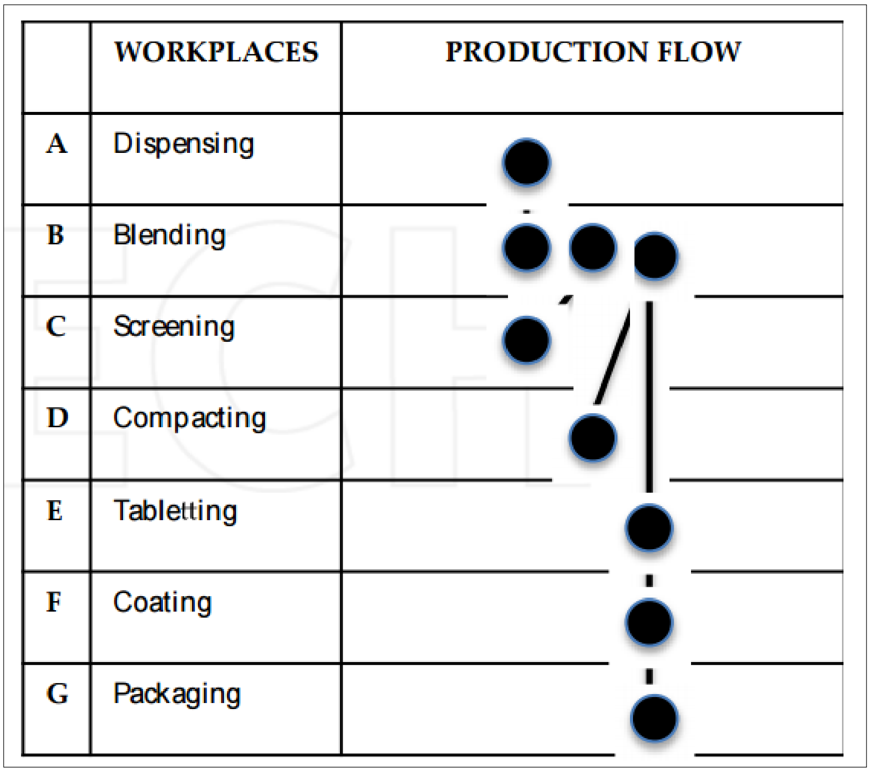

Figure 2.10: Pictorial Diagram of Manufacturing Process (Nenni, Giustiniano and Pirolo, 2014)

Based on the outline of the manufacturing process, it can be seen that just after the second blending process, the production flow seems to have a buffer. In addition, the cycle time data up to the second blending process is very identical but when compared to the second part of the flow turns out to be different. This may seem to carry an image of a two-step production flow. Since lean management is being carried out lean tool such as VSM has been used in this case study to eliminate the different types of wastes present. These wastes included inappropriate processing, overproduction, rework, inventory, WIP and also transportation.

With regards to making the production flow to a continuous process with regards to its current batch wise process, the elimination of bottlenecks in the production flow is suggested to be carried out. An operation with slowest cycle time usually is the bottleneck and this was identified in the case study to be the tableting process in the process flow. Upon identifying the bottleneck improvements were carried out to eliminate the bottleneck by speeding up the tableting process. This is achieved by replacing the production machines with more modern machines which are more advanced in technology. Moreover, the new machines not only reduce the cycle time but also save valuable manufacturing space since they are smaller in size (Nenni, Giustiniano and Pirolo, 2014).

Upon carrying out the re-engineering of the production flow through lean management the following results were then obtained after 90 days. The results are summarized in Table 2.6.

Table 2.6: Results After 90 days (Nenni, Giustiniano and Pirolo, 2014)

Goal	Target	Results
Total Pipeline Lead Time Reduction	6 days	5 days
Throughput Time reduction	3 days	2 days
WIP reduction	30%	37%
Layout redesign (walkthrough reduction)	300mt	284mt

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter of the report, the research methodology will be introduced;The research methodology outlines the direction or path that was used to obtain the desired results and achieve the objectives of the research. The outline includes the research approach design, data collection technique and the data analysis tools which was used to obtain the desired results.

3.2 Research Setting

The implementation of lean production management was carried out in MayAir Manufacturing (M) Sdn. Bhd. Despite MayAir manufactures many different air filtration products, this research mainly focused on four different types of air filtration product which includes the GI frame pocket filter, aluminium frame pocket filter, M-HI and M-HII.

3.3 Data Collection Methods

Quantitative and Qualitative data collection method were applied in this particular research; data collection was carried over a 24-week period whereby out of the 6 set of products, 4 weeks was spent for each product to properly study and collect data.

In addition to the collection of data such as production volume involved the production engineer, for the purpose of this research the focus was more on the employees/workers working in the production line itself. In other words the main focus was more towards the employees who have directly contributed to the efficiency and effectiveness of production.

3.3.1 Quantitative Research

Burns and Grove defined quantitative data to be *"formal, objective, systematic process to describe and test relationships and examine cause and effect interactions among variables".* By obtaining quantitative data, certain theories or hypotheses can be verified as it has been backed up by the raw hard data which has been collected. Unlike qualitative research method, when using quantitative research method one can plot graphs and determine patterns through the data that has been collected.

In this quantitative research technique data such as production output and cycle time was collected. By collecting the cycle time one can obtain the outcome on the implementation of lean production management which is matching the cycle time against the takt time. A decrease in cycle time would increase the production output since more products can be manufactured in a shorter time

3.3.2 Qualitative Research

Qualitative research however can be said to be exploratory and not limited to theories or hypotheses like quantitative research. By conducting the research in a qualitative method of direct observation, the researcher will be able to determine the key places in which the MUDA occurs. This direct observation was aided by taking data in the form of pictures and asking informal questions to the workers in the production floor.

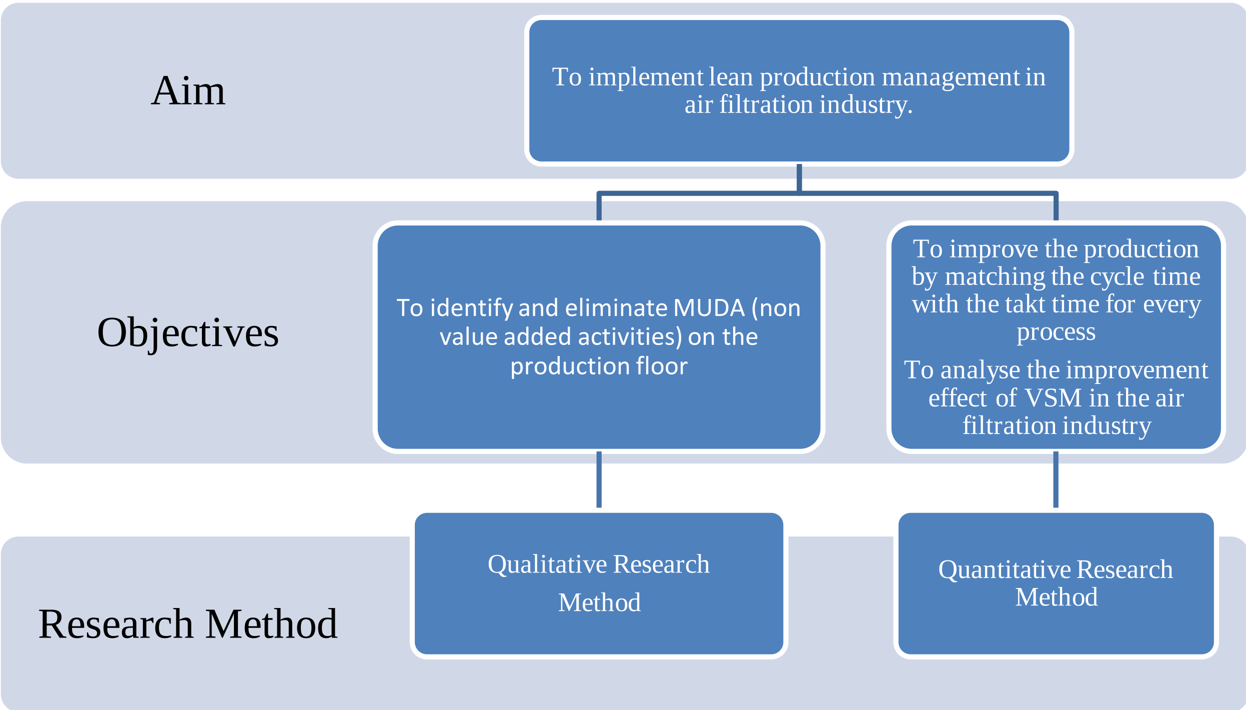

Figure 3.1: Link between Research Methods, Aim and Objectives

3.3.3 Summary of Data Collection Methods

Thus, for this particular research a mix of quantitative and qualitative research methods was employed for the collection of the required data. The following sections in this report will highlight these quantitative and qualitative data collection techniques and provide the reader with the suitable elaboration for each technique specified.

3.4 Takt Time Calculation

This consists of going through past sales and demand records to determine information such as the projected customer demand for the selected product, allocation of materials and manpower used in the production process itself. Through this method the researcher was able to determine the maximum demand received by any one product which is selected for lean implementation. Moreover, by obtaining the maximum demand the researcher was able to obtain the takt time according to Equation (3.1).

$$Takt\ time = \frac{Planned\ Production\ time}{Customer\ Demand}$$

Equation (3.1)

3.5 Cycle time Measurement

Cycle time analysis enables the researcher to determine the efficiency of the process and detect problems such as overproduction and bottlenecks. There are three steps to carry out cycle time analysis:

Cycle time calculation: the cycle time at each workstation/stage of the process will be determined using a stopwatch. Cycle time at each workstation is determined according to the Equation (3.2). To show that the process is operating in a lean fashion the cycle time must be balanced with the takt time or come close to it, thus a bar chart will be plotted to show the relationship between the cycle time and takt time and also to determine whether the process is lean enough. If the process is not lean, we move on to the next step.

$$Cycle\ time = (Machine\ time + Workers\ time)$$

Equation (3.2)

Usually the analysis of cycle time and takt time is integrated together with the value stream map which is constructed for the identification of MUDA (wastes) such as accumulation of inventory and WIP.

3.6 MUDA (wastes) Identification

3.6.1 Informal Meetings

The aim of such meetings is too enhance the employee-researcher relationship with one another (someone) in the organization itself. More often this informal meeting gives an idea to the workers on the production floor that a research is being carried out and the researcher would need some information from them. This is because workers on the production line might feel that such research which is being carried out in their production line might be a disturbance to their daily work schedule and will be less cooperative to the researcher. Thus, informal meetings are important to create a favourable relationship between the researcher and the workers on the production floor. It can be said to be initiating step in conducting this research. (Mohd, 2013)

3.6.2 Observation (Production walk through)

After informal meetings have been conducted with the workers, direct observations were carried out. These observations were done by the researcher together with the production engineer to locate and identify the 7 MUDA (wastes) in the production line. Method of the observation is described below (Mohd, 2013):

- Process recording: a work process video recording was carried out while the worker was working on the same single product. A digital camera was used to record the process at each workstation. A few pictures was also taken to help with the process recording.
- Non value added category: by using the video as an aid the production engineer, researcher and the skilled worker, was able to through it to determine non-value added activities which would cause the cycle time to be higher than usual. Activities such as machine set up, inspection of products and even scheduled delays parts increases the cycle time.
- Re-computation of cycle time: after determining and minimizing the non-value added activities, the cycle time calculation was carried out again same as in step 2. This was to ensure that the cycle time matches or comes close to the takt time which ensures that the process is lean.

3.6.3 Value Stream Mapping (VSM) Technique

For the VSM technique which is also a lean tool, the plant manager has suggested to give attention to a single value stream as a start, but was then expanded into the other 4 value streams which was highlighted earlier for lean implementation. Value stream here can be defined as the flow of raw materials in a production process until it is manufactured into a product. The selection of which value stream will go first was carried out by the production engineer there based on whether there is a demand for the particular product and the simplicity of the production process itself. A walk through was carried out on the selected value stream together with the production engineer to determine the existing flow of materials in the process (current state map), it is during this stage also that the accumulation of inventory or WIP was to be determined from the process. If there are such MUDA wastes which are present in the production line it will increase the lead time of the product thereby showing up in the value stream map. Thus after eliminating the wastes which increases the lead time the future state map was drawn to show the improvements done to the movement of materials in the value stream (Mohd, 2013).

3.7 Data Analysis Tools

Microsoft Excel: This program was used to record and calculate data such as the takt time and cycle time. It will be also used to plot graphs which are attached in this report for the comparison of takt time with cycle time.

Microsoft Visio: This program was used to construct the manually drawn value stream map into a digital copy on the computer. A digital copy provides a better picture and is more organized compared to a VSM drawn manually by hand.

3.8 Summary of Research Methodology

This section gives a summary on the chronological steps that was followed to give the reader an idea on how this research was carried out and the total time duration that was taken from the beginning till the end of the research. This has been condensed into a flowchart in Figure 3.2 and a Gantt chart in Figure 3.3. The flowchart aims to provide a summary on the steps that was taken to collect data whereas the gantt chart highlights the timeline during which the research was carried out.

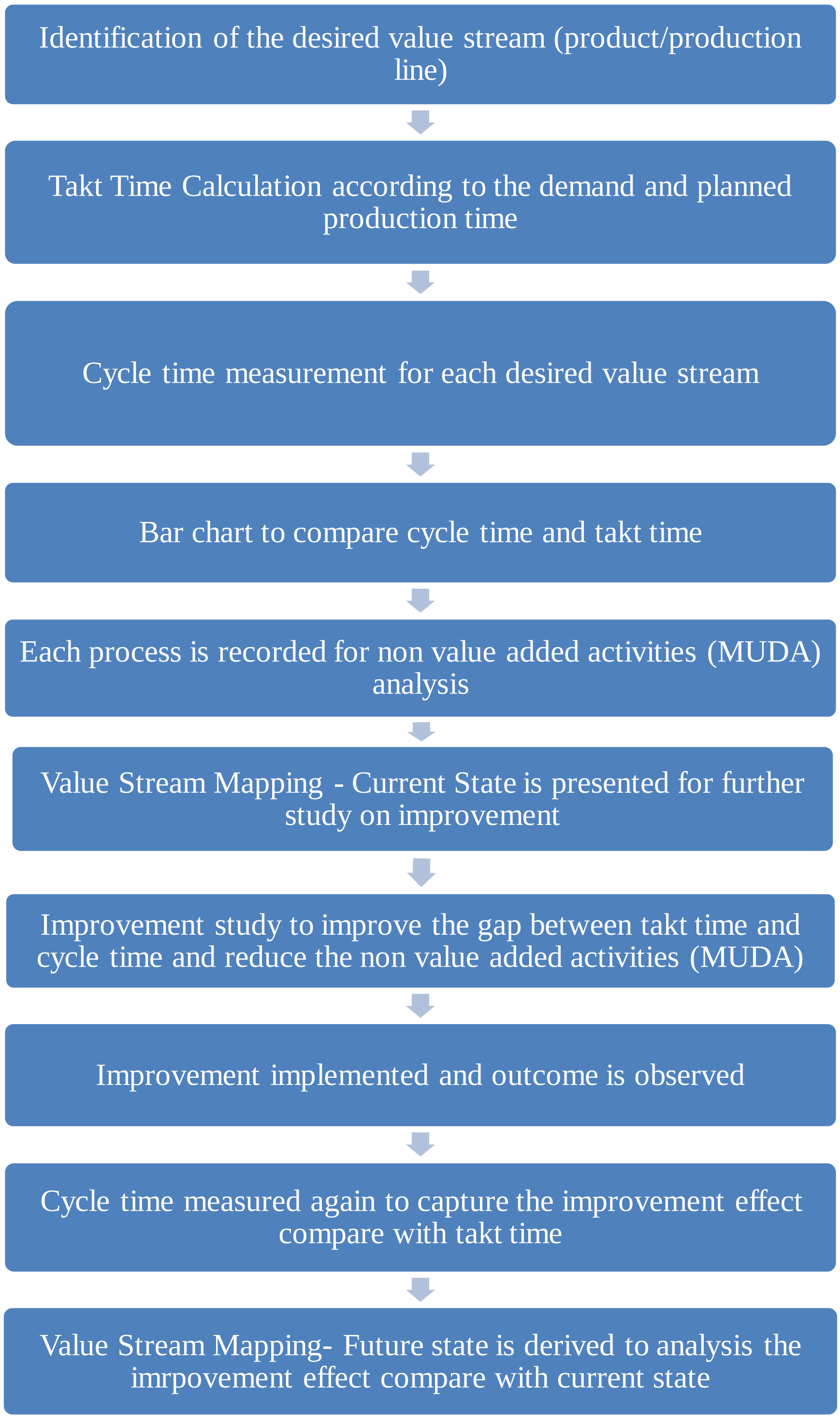

Figure 3.2: Summary of the Chronological Steps which was Taken to Conduct this Research

Table 3.1: Projected Timeline for Carrying Out Research

Task Name	Abbreviation	Start	End	Duration (days)
Data collection for GI Frame Pocket Filter	A	3/8/2015	21/8/2015	18
Data tabulation for GI Frame Pocket Filter	B	22/8/2015	28/8/2015	6
Data collection for Al Frame Pocket Filter	C	1/10/2015	23/10/2015	22
Data tabulation for Al Frame Pocket Filter	D	26/10/2015	30/10/2015	4
Data collection for M-HI	E	1/12/2015	18/12/2015	17
Data tabulation for M-HI	F	28/12/2015	31/12/2015	3
Data collection for M-HII	G	1/1/2016	22/1/2016	21
Data tabulation for M-HII	H	25/1/2016	29/1/2016	4

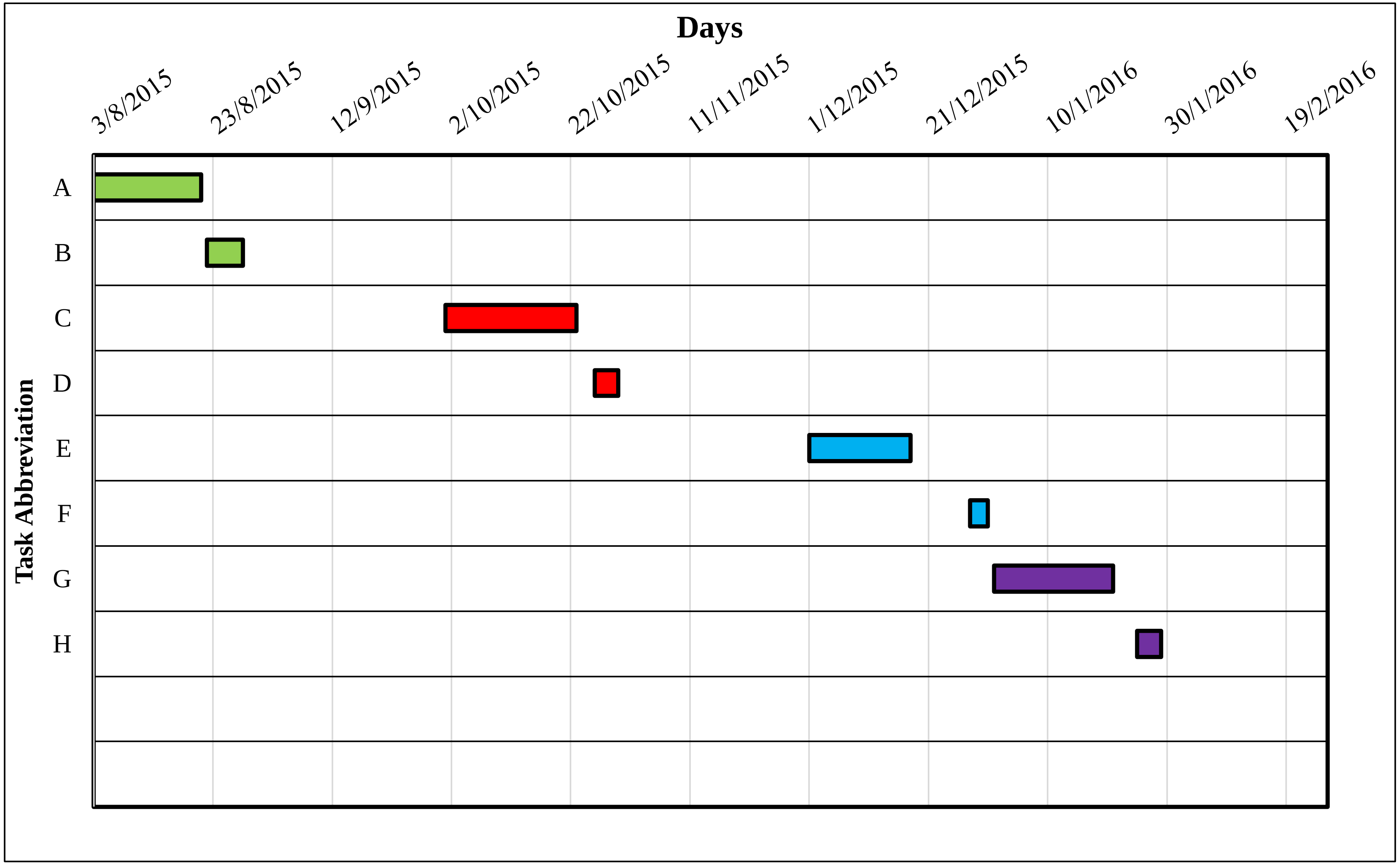

Figure 3.3: Projected Timeline for Carrying Out Research

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter the report aims to discuss on the results that were collected and the improvements carried out to the process flow of the products thereby making manufacturing at MayAir more efficient and leaner.

As it was outlined earlier in this report, this research was focused namely on the four different air filtration products which are being manufactured at MayAir. These products were GI Frame Pocket Filter, Aluminium Frame Pocket Filter, M-HI and M-HII.

Thus, in the subsequent sections we will be looking at the results that were obtained based on the study done and also the improvements that were done to make the production of these products in a leaner manner.

4.2 GI Frame Pocket Filter

This particular filter is a M-Pack filter made up of a galvanized frame, together with pockets in its filtration media thereby giving it the name pocket filter. This particular filter can be produced in its standard size which is 24’’x24’’x21’’ which is made up of six pockets.

However, at MayAir non-standard size filters are also produced. This is mainly due to the fact that clients tend to request for filters of various different sizes depending on the application purpose. This particular filter is a primary filter and is usually the first line of barrier that the air encounters before making its way to the secondary filter. Figure 4.1 shows an example of a GI frame pocket filter.

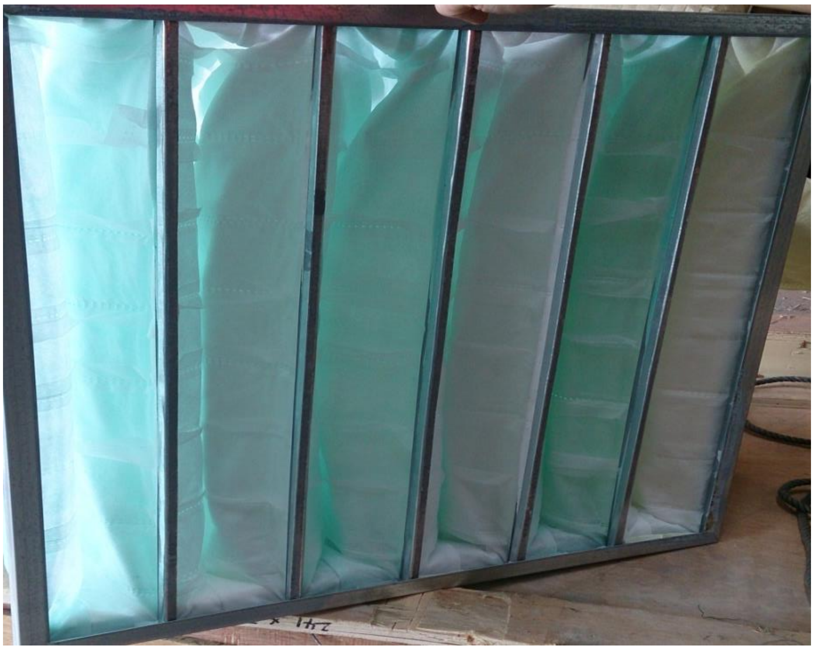

Figure 4.1: GI Frame Pocket Filter

4.2.1 Cycle Time and Takt Time Analysis (BEFORE IMPROVEMENT)

Table 4.1: Takt Time Analysis (GI)

Takt time analysis	Values
No of shifts in one day (shifts/day)	3
Total available production time (hours/day)	10.5
Planned Production time (hours/shifts)	3.5
Customer Demand (units/day)	150
Customer Demand (units/shift)	50
Calculated Takt time (seconds/unit)	252

Table 4.2: Cycle Time Analysis (BEFORE IMPROVEMENT-GI)

Cycle time at each workstation			
Workstation		Cycle Time (seconds/unit)	No of Workers
Parallel Process	**Cutting of each Media into shape (Using cutting machine)**	45.0	1
	Sealing of media (Ultrasonic Stitching)	65.6	1
	Use knife to cut open pockets	36.8	1
	Frame Assembly (Riveting)	5.0	1
Assembly of media to frame		320.0	2
Clamping of media to frame (Clamping machine)		32.0	1
Packaging		7.0	1
Total processing time (seconds/unit)		511.4	N/A
Total processing time (minutes/unit)		8.5	

According to Table 4.1, the takt time for the production of 150 units of GI frame pocket filter in a day is around 252 seconds for one unit of this particular filter. According to the definition of takt time, takt refers to the frequency of a product which comes out of the production line, thus it can be deduced that for every 252 seconds one unit of this particular type of filter has to be produced.

However, when the cycle time collected at each workstation is tabulated as shown in Table 4.2, at which the takt time was compared against the cycle time at each workstation, it was found that the cycle time at the workstation of *assembly of media to frame* exceeded the takt time.

When this occurred, the production demand was not met as bottlenecks would be formed in the process, thereby increasing the processing time required to produce the product. To give a better illustration, the bar chart in Figure 4.2 shows the process or workstation in which its cycle time exceeded the takt time.

Thus, in the subsequent sections the identification lean parameters of MUDA, MURI and MURA was carried out to determine the non-value added activities which caused the cycle time of *assembly of media to frame* workstation to be higher than the takt time.

Furthermore, a current state map was also constructed to facilitate lean parameter identification and also highlight the process flow together with the overall processing time taken to produce a single GI frame pocket filter. Upon bridging the gap between cycle time and takt time, a future state map was constructed.

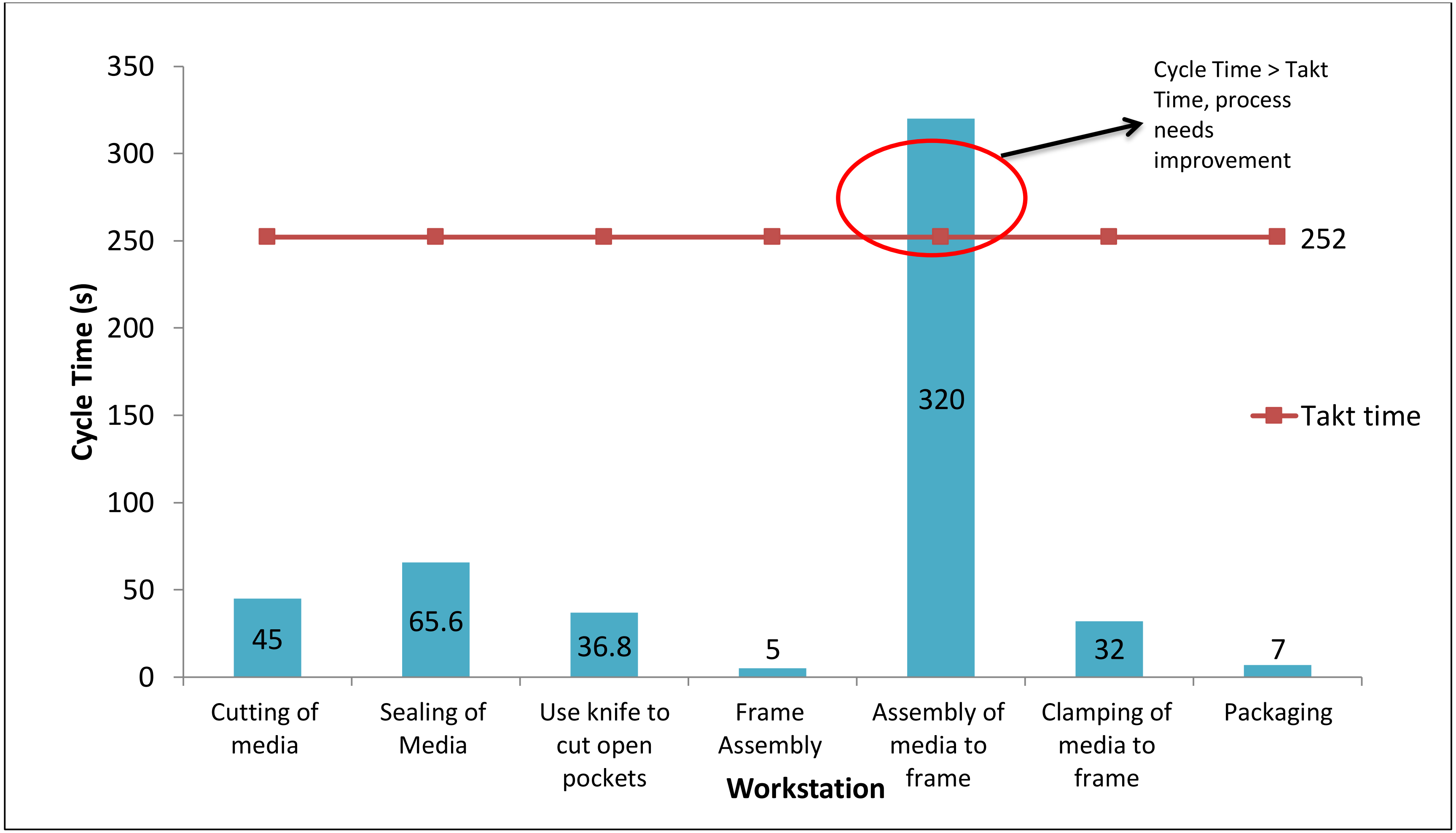

Figure 4.2: Comparison of Cycle Time against Takt Time (BEFORE IMPROVEMENT-GI)

4.2.2 Current State Map

A current state value stream map was drawn to show the existing process flow, which also highlights the inventory or products and raw materials, the cycle time at each workstation, the number of workers and also the overall processing time. A current state map aims to show the process as it is, prior to elimination of non-value added activities in the process. Figure 4.3 shows the current state map.

This production process is made up of seven different workstations from start to finish, the workstation of *assembly of media to frame* which was flagged red was set for improvement as the cycle time exceeds the takt time. The overall processing time took about 511.4 seconds to produce one unit of GI frame pocket filter.

Moreover, the default finished item deliver time was about two days before it was sent to the customer. However, this time was not fixed as it could vary from one customer to another depending on how soon the customer wants the product to be delivered.

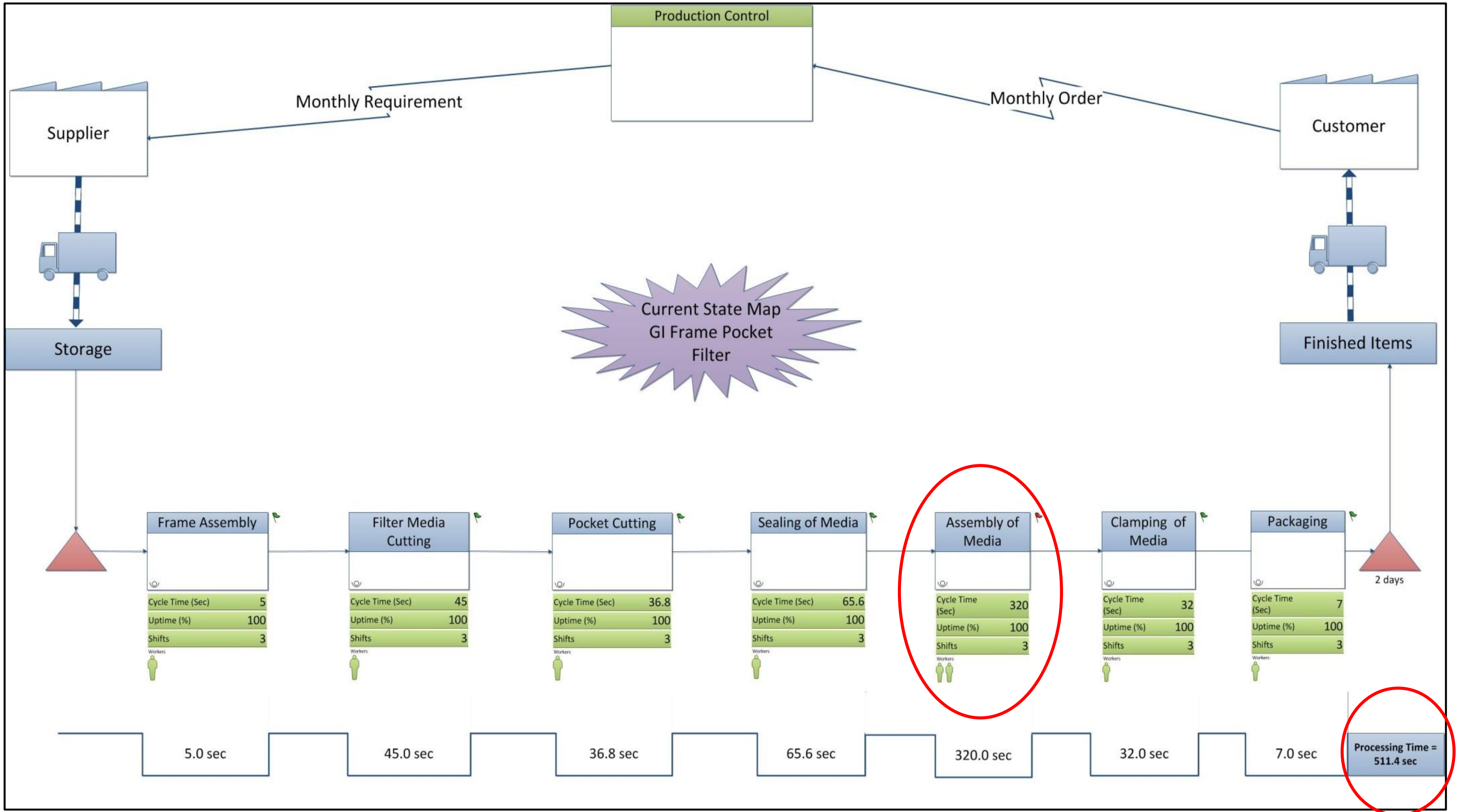

Figure 4.3: Current State Map

4.2.3 Identification of Lean Parameters (GI)

As can be seen from the current state map in Figure 4.3 among the seven processes/workstations the workstation of *assembly of media* has its cycle time above the takt time. Thus, process recording and pictures were taken for references, between the production engineer and the researcher.

Upon close observation of the workstation and process recording it was deduced that there was an occurrence of MURI. This was because the workstation was found to be lacking the ergonomics needed for the workers to carry out their tasks. This causes workers to invest more time in carrying out their tasks thereby increasing the cycle time of that particular workstation.

As can be seen from Figure 4.4, during the assembly of the pockets to the GI frame the workers would have to place the frames on the floor before the assembly of pockets on the particular frame could be carried out. Thus, each worker would have to bend over to pick up each piece of frame which would be time consuming and also would not be very ergonomically feasible.

Figure 4.4: GI Frame Prior to Assembly Placed on the Floor

4.2.4 Improvements and Elimination of MURI

Based on the previous section we have known that there was occurrence of MURI in the workstation of *assembly of media to frame*. Based on the observation and process recording it was identified that the ergonomics of the workers in that workstation needed improvement to reduce the cycle time. The improvements done are shown in Figure 4.5 and 4.6

Figure 4.5: Workstation Overview

Figure 4.6: Metal Mounting

It can be seen that there were a few improvements carried out to the workstation. Firstly, there was a metal mounting installed to facilitate the hanging of the GI Frame before the media could be installed to it. By hanging the GI Frame to the mounting the ergonomics of the worker has been improved as the worker does not have to bend down to reach the frame during the assembly process. This in turn increased the efficiency of the worker as the worker were at ease in carrying out their task.

By improving the ergonomics, the workers risk of having a back injury could also can be reduced, as now the worker do not have to constantly bend down to reach for the GI Frame. Instead they just have to reach for it from the metal mounting which was installed. This is in line with the definition of ergonomics which is fitting the work to the worker.

Secondly, the number of worker involved in this workstation has not been changed. The original number of workers which was two people has been maintained. This also explains why there are two metal mountings installed opposite of each other.

In addition, to use production place efficiently the storage of the metal pockets used in the *assembly of media to frame* has also been stacked together with a rack which houses the metal mountings (Figure 4.7). Moreover, this also helped in the work efficiency as the metal pockets are easily accessible to the workers during the assembly process.

Figure 4.7: Stacking of Metal Pockets

4.2.5 Cycle Time Analysis (AFTER IMPROVEMENT)

Table 4.3: Cycle Time Analysis (AFTER IMPROVEMENT-GI)

Cycle time at each workstation			
Workstation		**Cycle Time (seconds/unit)**	**No of Workers**
Parallel Process	**Cutting of each Media into shape (Using cutting machine)**	45.0	1
	Sealing of media (Ultrasonic Stitching)	65.6	1
	Use knife to cut open pockets	36.8	1
	Frame Assembly (Rivetting)	5.0	1
Assembly of media to frame		210.0	2
Clamping of media to frame (Clamping machine)		32.0	1
Packaging		7.0	1
Total processing time (seconds/unit)		401.4	N/A
Total processing time (minutes/unit)		6.7	

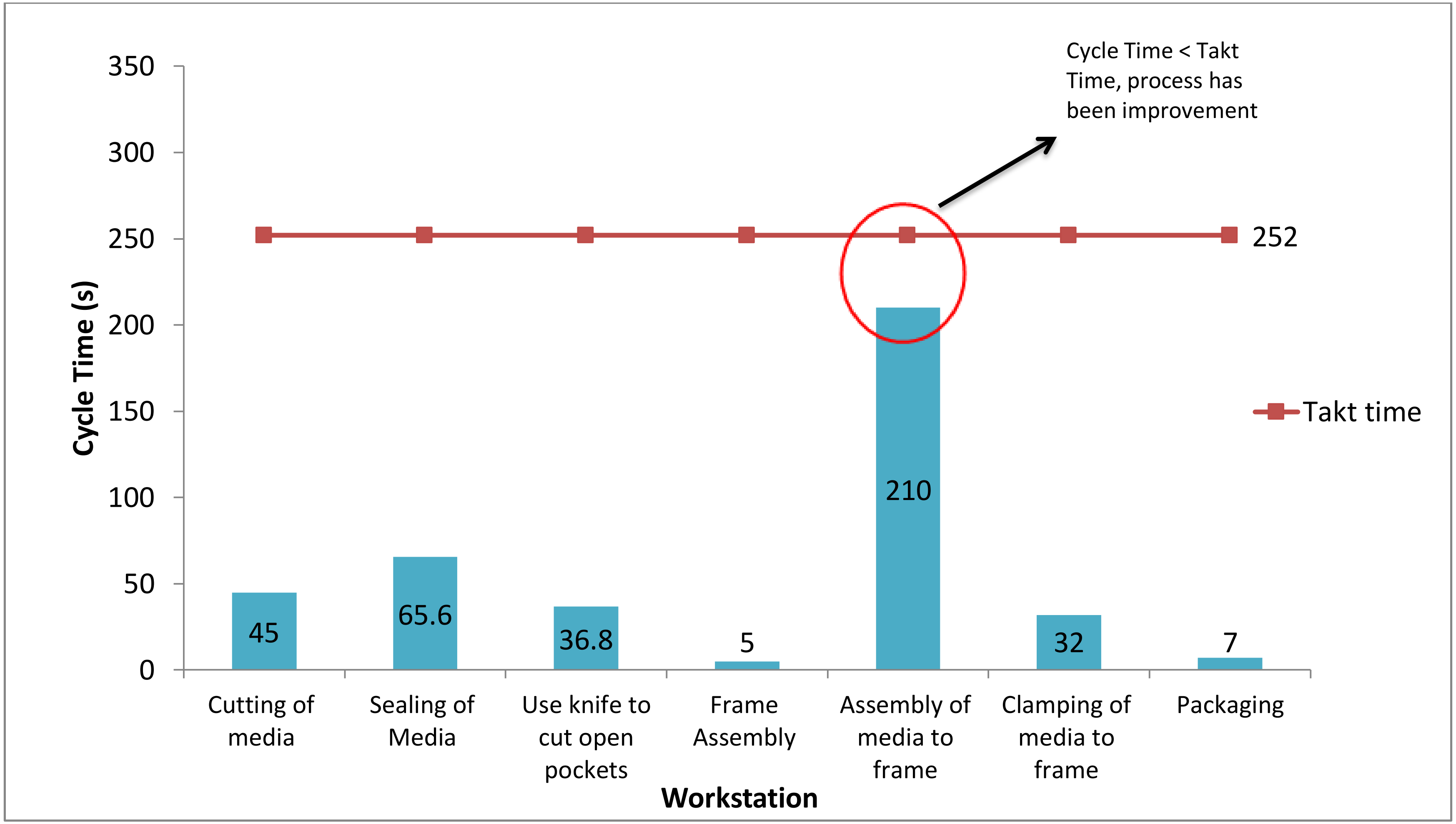

Figure 4.8: Comparison of Cycle Time against Takt Time (AFTER IMPROVEMENT)

As can be seen from the cycle time analysis carried out after improvement for the workstation of *assembly of media to frame*, an improvement of 34% could be observed as compared to the cycle time prior improvement.

As can be seen from Table 4.3 and Figure 4.8 the cycle time has been reduced from 320 seconds/unit to 210 seconds/unit. The objective of achieving a cycle time lower than the takt time has also been achieved as the new cycle time of 210 seconds/unit was lower than the takt time of 252 seconds/unit.

Moreover, by comparing the total processing time or lead time in Table 4.4 we can also see that there was a reduction of overall processing time from 8.4 minutes/unit to 6.7 minutes/unit. This was a 20% reduction in processing time that it took 20% less time for one single unit of GI Frame Pocket Filter to be manufactured from a raw material to a finished product.

Table 4.4: Comparison of Current versus Improved Process for GI Frame Pocket Filter

Variables	Units	Current	Improved	Percent Reduction
Cycle Time at Assembly of Media Workstation	seconds/unit	320	210	34%
Total Processing Time	minutes/unit	8.4	6.7	20%

4.2.6 Future State Map

To further capture the improvement effect which was carried out to the process of producing GI Frame Pocket Filter a future state map (Figure 4.9) was constructed to highlight the changes in cycle time and also the processing time it takes to produce the product.

We can also see from the future state map in this process, the accumulation of WIP does not occur in the production line. This suggests that GI Frame Pocket Filter during production does not have to be put on hold temporarily during the course of its movement from one workstation to another.

However, despite the reduction in cycle time, much could not be done to the finished goods delivery time of 2 days. This was because this time is dependent on the customer's discretion on how soon they want the product from MayAir.

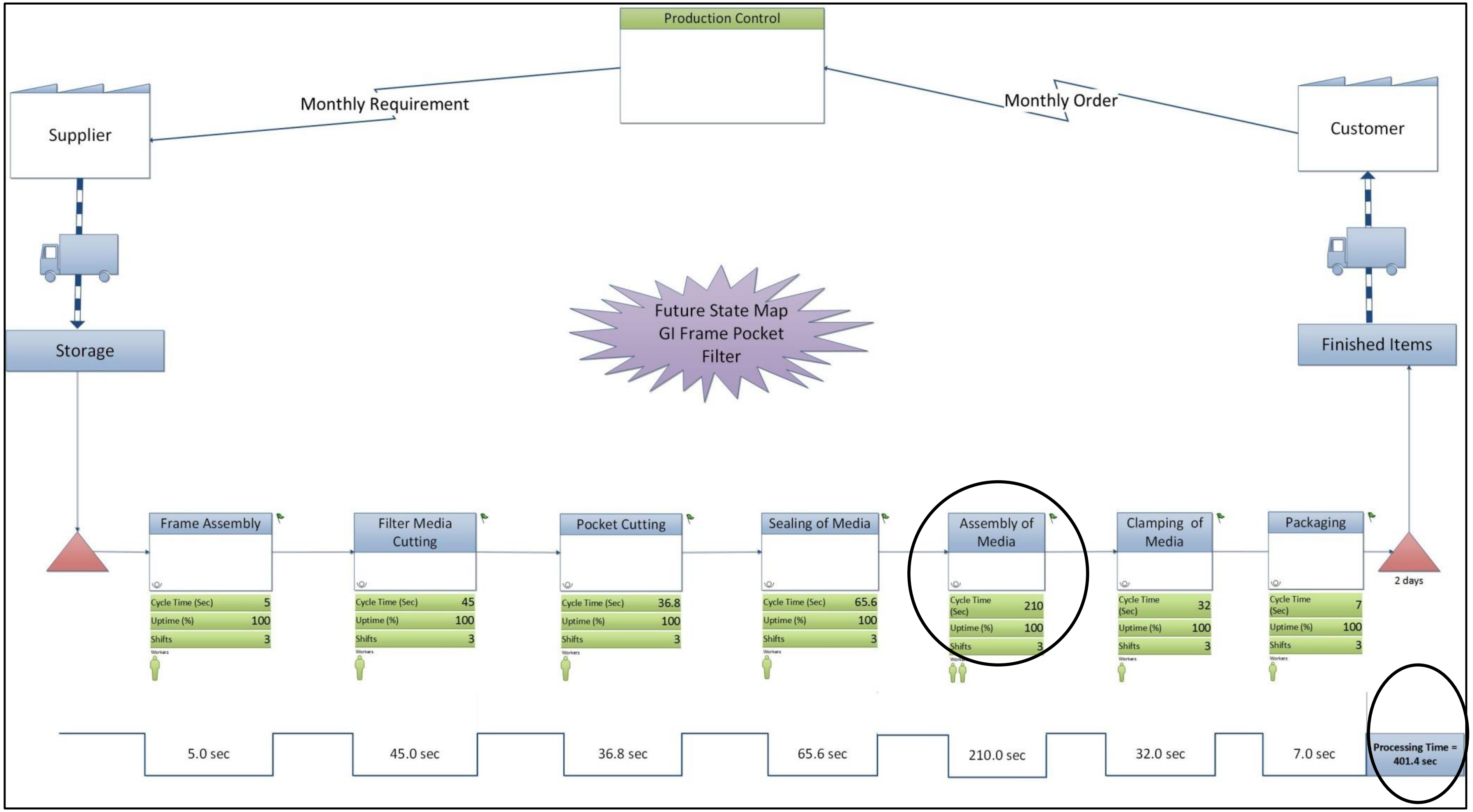

Figure 4.9: Future State Map (GI)

4.3 Aluminium Frame Pocket Filter

As can be seen in Figure 4.10 this filter is a M-Pack type of filter which is used as a primary filter and is similar in terms of function when compared against the GI Frame Pocket Filter, however the materials used to construct the filter are different. This can be seen when this filter frame is constructed out of aluminium as compare to GI which uses galvanized frame.

The aluminium for the frame is cut into specific sizes as requested by the customer when making the order. Each aluminium is made up 4 pieces of aluminium which is held together by rivets. Moreover, for aluminium frame the filter bag assembly is also different from GI Frame, because the filter pockets for aluminium frame are assembled into wire rods.

Despite, the availability of various different size of the aluminium frame pocket filter, our lean implementation will be focused on the standard size of this filter which is the 24”x24”x21” filter.

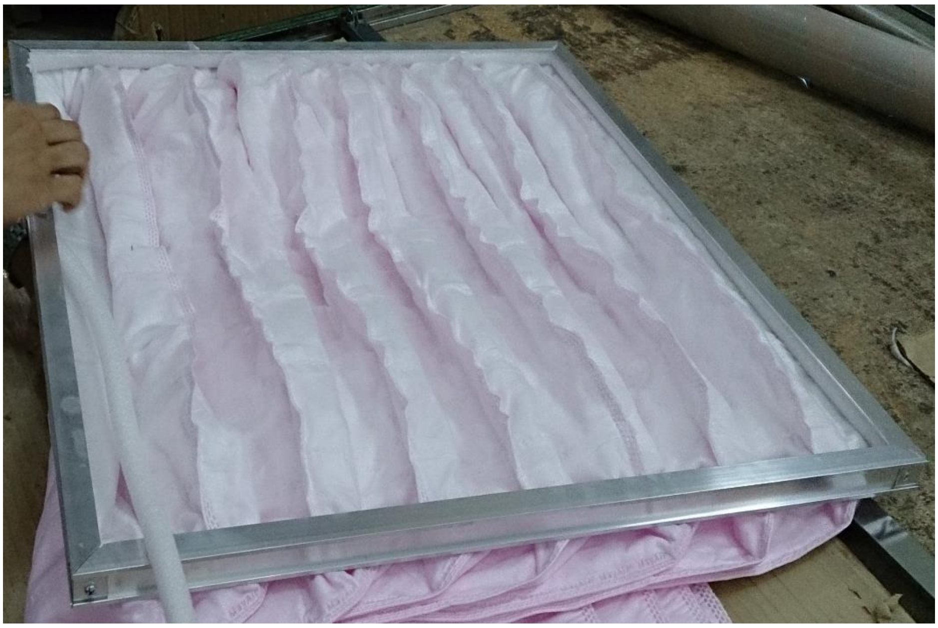

Figure 4.10: Aluminium Frame Pocket Filter

4.3.1 Cycle Time and Takt Time (BEFORE IMPROVEMENT)

Table 4.5: Takt Time Analysis (AL)

Takt time analysis	Values
No of shifts in one day (shifts/day)	3
Total available production time (hours/day)	10.5
Planned Production time (hours/shifts)	3.5
Customer Demand (units/day)	204
Customer Demand (units/shift)	68
Calculated Takt time (seconds/unit)	185

Table 4.6: Cycle Time Analysis (BEFORE IMPROVEMENT-AL)

Cycle time at each workstation			
Workstation		**Cycle Time (seconds/unit)**	**No of Workers**
Cutting of Extruded Piece		11.2	1
Formation of WR		36.5	1
AL Frame Assembly	**Riveting**	49.8	1
	Assembly of Frame into shape	14.4	
Filter Media Cutting (Using cutting machine)		59.0	1
Sealing of Media (Ultrasonic Stitching)		87.4	1
Assembly of media to WR Frame		240.0	1
Assembly of WR to AL Frame	**Gluing**	10.0	1
	Attachment of WR	170.0	
Total processing time (seconds/unit)		678.3	N/A
Total processing time (minutes/unit)		11.3	

According to the data tabulated in Table 4.6, it can be seen from the table that the workstation/process of *assembly of media to wire rod frame* has its cycle time more than the desired takt time, the calculated takt time is about 185 seconds/unit of aluminium frame pocket filter.

However, the workstation/process has its cycle time to be about 240 seconds/unit which is clearly higher than the takt time of 185 seconds/unit.

Thus this higher cycle time values as compared to the takt time suggests that the demand for 204 unit of aluminium pocket filter in a day cannot be satisfied as the production is being slowed down by this high cycle time.

The bar chart in Figure 4.11 shows the gives a better picture for the processes which their cycle time exceeds the takt time.

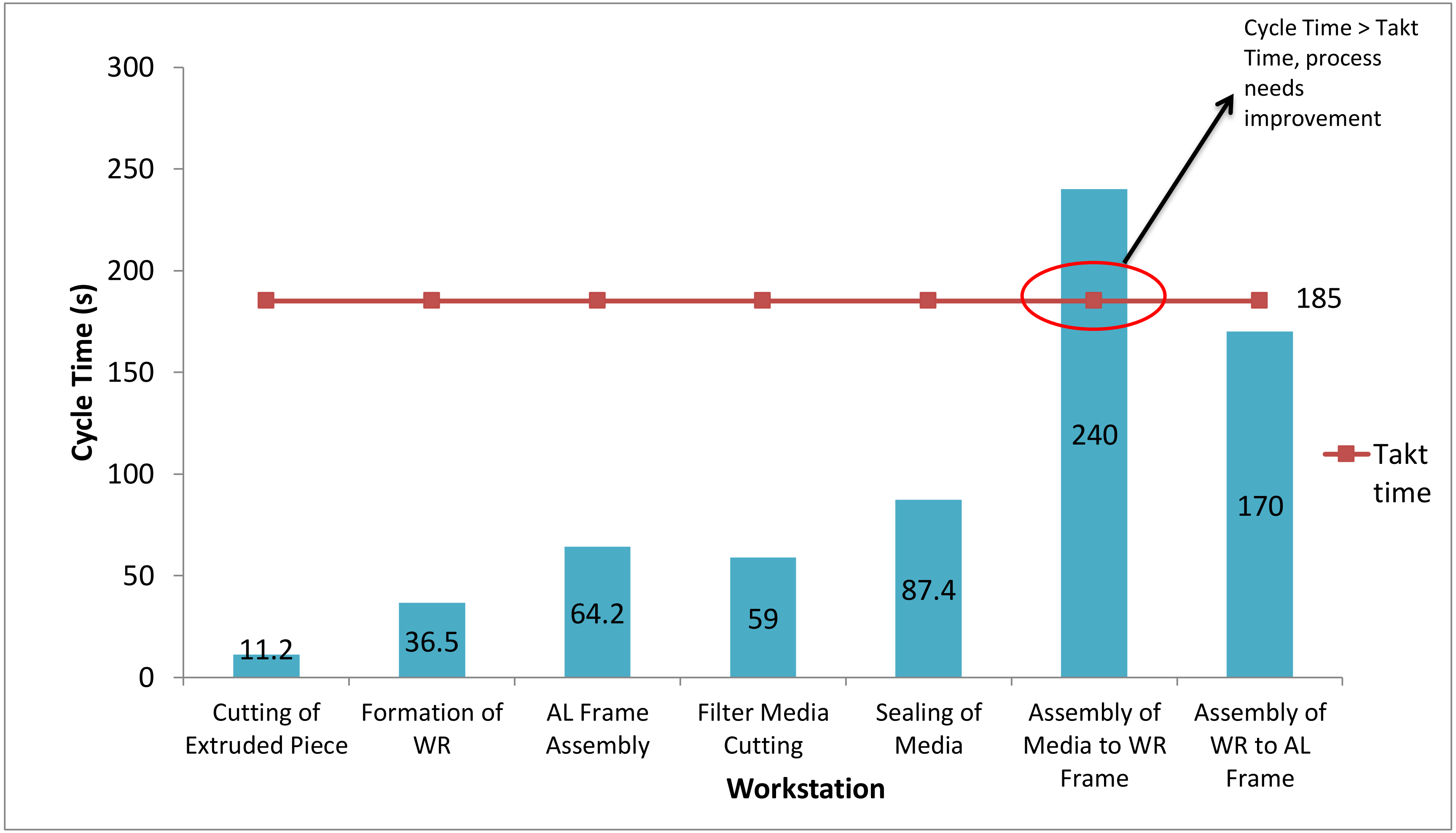

Figure 4.11: Comparison of Cycle Time against Takt Time (BEFORE IMPROVEMENT-AL)

4.3.2 Current State Map

Figure 4.12 shows the current state map for the production of aluminium frame pocket filter. It can be seen from the current state map that the production process is made up seven workstations from start to finish. Each workstation uses one worker, however since MayAir practices a batch production method instead of a continuous production, the workers are used interchangeably from one workstation to another.

In addition, from the current state map the workstation of *assembly of media to wire rod frame* is flagged red. This means that the workstation is set for improvements as its cycle time exceeds the takt time, this production process has no accumulation of WIP along its production process. The total processing time for the production of one unit of aluminium frame pocket filter is about 678.3 seconds.

Moreover, for this production process the finished items delivery time is also set to a default of two days as it cannot be certain the duration the product will be kept with MayAir before delivery. This is because as it has been mentioned earlier in the previous sections the delivery time of finished products is different from one customer to another.

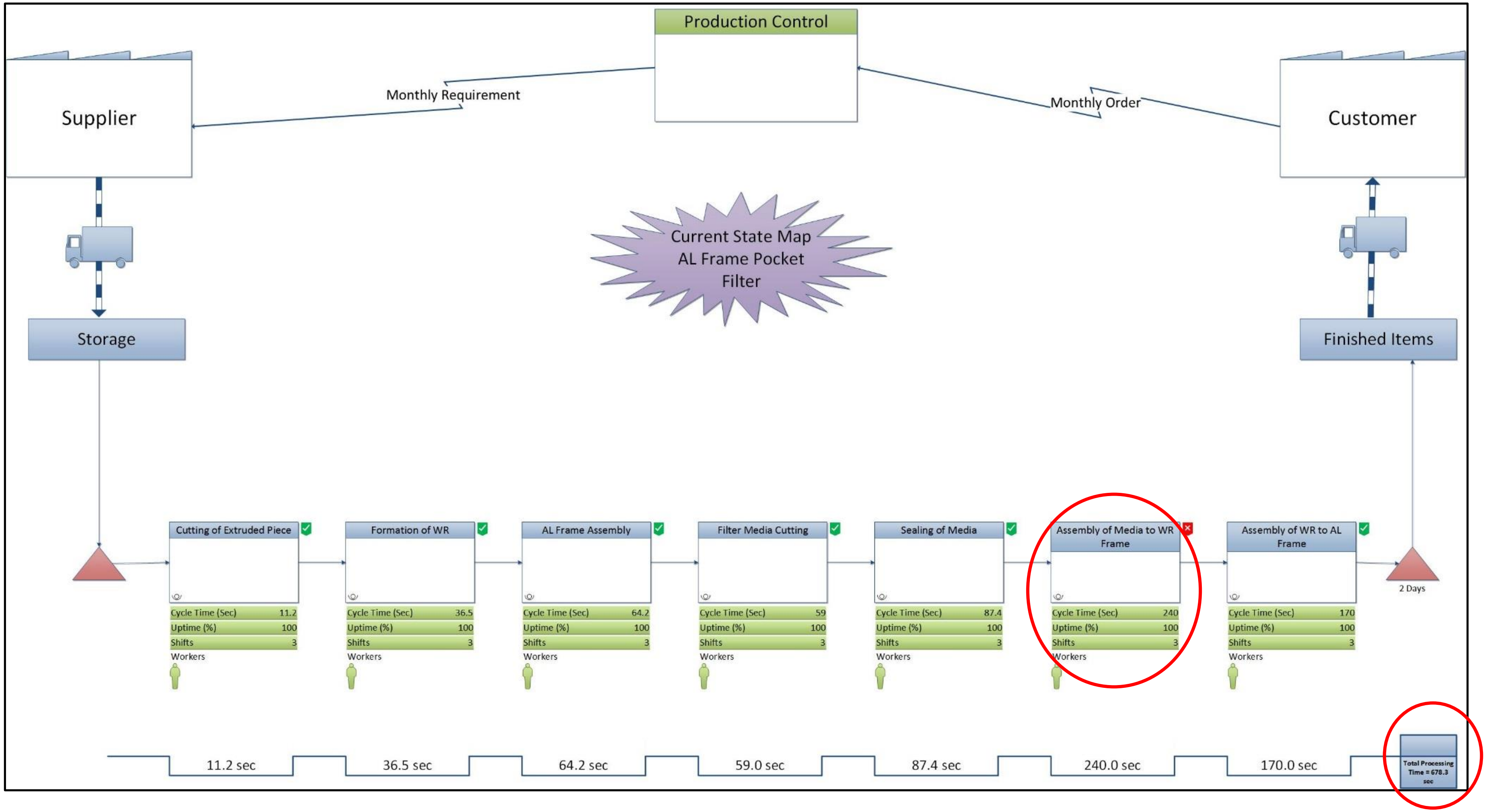

Figure 4.12: Current State Map (AL Frame)

4.3.3 Identification of Lean Parameters (AL)

It has been identified that among the seven workstations in the production process of aluminium pocket filter, the workstation of *assembly of media to wire rod* has the cycle time higher than the takt time. Thus, to reduce the cycle time process recording was carried out as how it was done for the GI frame and M-MII filter.

Upon careful observation during the production process, it can be seen the MUDA waste of defect was occurring in this workstation. This is because during this stage of the production the filter media is attached to the wire rod frame using a stapler.

However, during the attachment process using the stapler, some of the thin stapler bullets refuse to properly attach to the surface of the media thereby not properly securing it to the wire rod frame. When this occurs, the worker has to plie out the improperly attached stapler bullet to attach a new stapler bullet.

This in turn causes the worker to spend more time working on the product which leads to defect on the product if any improperly attached stapler bullets go un-noticed by the worker during the assembly process. Figures 4.13 and 4.14 shows the stapling process and the type of stapler which is used to attach the filter media to the wire rod frame.

Figure 4.13: Stapling Process

Figure 4.14: Stapler

4.3.4 Improvements and Elimination of MUDA

In the previous section, it was identified that the waste of **defect** which is associated with the lean parameter of MUDA is occurring in the workstation of assembly of media to wire rod. One of the reason pointed out was due to the type of stapler device used to carry out the attachment process of the media to the wire rod. To solve this problem, it was suggested to upgrade the stapling device from the current device to an industrial stapling plier. The suggested stapling plier is shown in Figure 4.15.

Figure 4.15: Stapling Plier

This is because a stapling plier uses heavy duty staple bullet which has a much more rigid staple bullet as compared to a standard stapler which is currently used. Table 4.7 shows the specifications and the price of the stapling plier in Figure 4.15.

Table 4.7: Specifications of Stapling Plier

Model	Price	Capacity	Material (Body)
HD 31 Stapling Plier	RM 256	70 sheets	Nickel Plated

However, this improvement was not implemented as the product aluminium frame pocket filter does not have a high production demand. As such it would not be a feasible investment to invest in the stapling device as this would increase the production cost of the filter unit. Moreover, based on the opinion of the workers in the production floor, the design of the stapling plier which is big and bulky may cause some ergonomics problem when the workers are trying to use it to carry out the stapling process.

As such this improvement to the workstation of assembly of *media to wire rod frame* was suggested to be put on hold by the production engineer, until a better cost effective solution can be devised to solve the problem. Nevertheless, at the moment the production worker who is carrying out the stapling process was asked to carefully monitor and carry out the process to ensure that the bullets properly attach to the media to the wire rod frame in an effort to minimize the defect to the product.

4.4 M-HI

As can be seen in Figure 4.16 the M-HI air filter is a secondary filter which is used in environments which contain high moisture content and humidity. Due to its high dust holding capacity the filter is capable of produce high efficiency values based on the MPPS Efficiency values which were determined. M-HI is also made up of aluminium separators in between its pleats, which work together with the high performance glass fibre media to filter air.

However, due to the presence of about 120 aluminium separators in every unit of M-HI the pumping capacity for this type of filter might be higher than M-HII filters. This is because the presence of separator reduces the number of pores which are present in the pleats, this causes the surface area for the entrance of the air to decrease, which causes more pumping power needed to channel air from one side of the filter to another.

Despite the drawback in requiring more pumping power, the cost of M-HI is less than when it is compared with other secondary filter such as M-HII. Moreover, the filter frame can be made from aluminium or stainless steel, which depending on the customers' specification and environment of usage will be used accordingly.

Figure 4.16: M-HI Filter

4.4.1 Cycle Time and Takt Time Analysis (BEFORE IMPROVEMENT)

Table 4.8: Takt Time Analysis (M-HI)

Takt time analysis	Values
No of shifts in one day (shifts/day)	1.5
Total available production time (hours/day)	5.3
Planned Production time (hours/shifts)	3
Customer Demand (units/day)	20
Customer Demand (units/shift)	13
Calculated Takt time (seconds/unit)	945

Table 4.9: Cycle Time Analysis (BEFORE IMPROVEMENT-M-HI)

Cycle time at each workstation		
Workstation	**Cycle Time (seconds/unit)**	**No of Workers**
Production of Separator	360.0	1
Combination of Pleating with Separator	900.0	1
Assembly of header	60.0	1
Assembly of filter and media	1000.0	2
Application of AB Glue (1)	330.0	1
Drying (1)	1200.0	N/A
Application of AB Glue (2)	330.0	1
Drying (2)	1200.0	N/A
Total processing time (seconds/unit)	5380.0	N/A
Total processing time (minutes/unit)	89.7	N/A

As can be seen from Table 4.8 the takt time calculation in M-HI is slightly different from the calculation of takt time for all the other air filtration products selected for lean management. This is because out of the three working shifts per day, it is estimated the workers in the production process of M-HI use about one and a half working shifts to carry out the production of M-HI filter.

Moreover, the demand for the M-HI is also significantly lower compared to the other air filtration product which was suggested for the implementation of lean management. Upon finding out the amount of hours there is in one shift, the value of the takt time can be calculated for the production of M-HI. The value which was obtained was 945 seconds/unit of M-HI filter.

However, based on the cycle time which is tabulated in Table 4.9 the workstation of *assembly of filter and media*, *Drying (1)* and also *Drying (2)* has a cycle time of 1000 seconds/unit, 1200 seconds/unit and 1200 seconds/unit respectively. This shows that the cycle time in these three workstations are higher than the calculated takt time of 945 seconds/unit of M-HI. Figure 4.17 describes the workstation/processes which its cycle time exceeds the takt time.

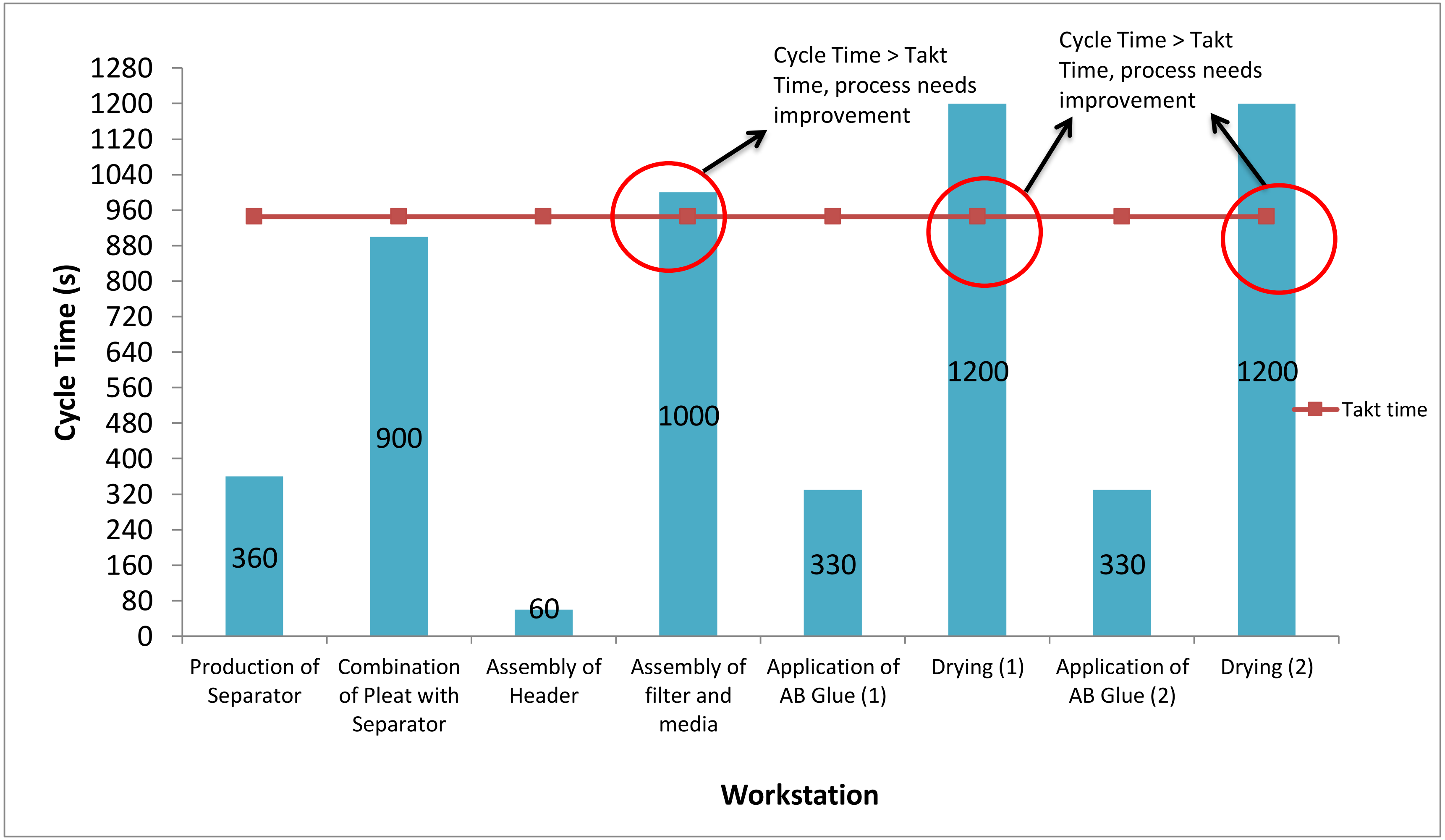

Figure 4.17: Comparison of Cycle Time against Takt Time (BEFORE IMPROVEMENT M-HI)

4.4.2 Current State Map

Based on the current state map constructed for the production process of M-HI in Figure 4.18, there are about eight workstations/processes in the manufacturing process of the filter from start to finish. Based on the current state map it can be seen there are no accumulation WIP's along the production line. The number of workers in each workstation varies from one to two workers.

However, the workstations of *Drying (1)* and *Drying (2)* does not require any workers as the AB glue which was applied is allowed to dry without any involvement of physical elements. The workers in the production process are used interchangeably from one workstation to another as the production process follows a batch process then a continuous one.

In addition, from the current state map it can also be seen the workstations which needs improvements are flagged red due to the cycle time being higher than the takt time. The total processing time can be also derived from the current state map which is about 89 minutes/unit of M-HI filter. The time it takes to deliver the products to the customer is still set to be two days as the actual finished product delivery time varies from one customer to another.

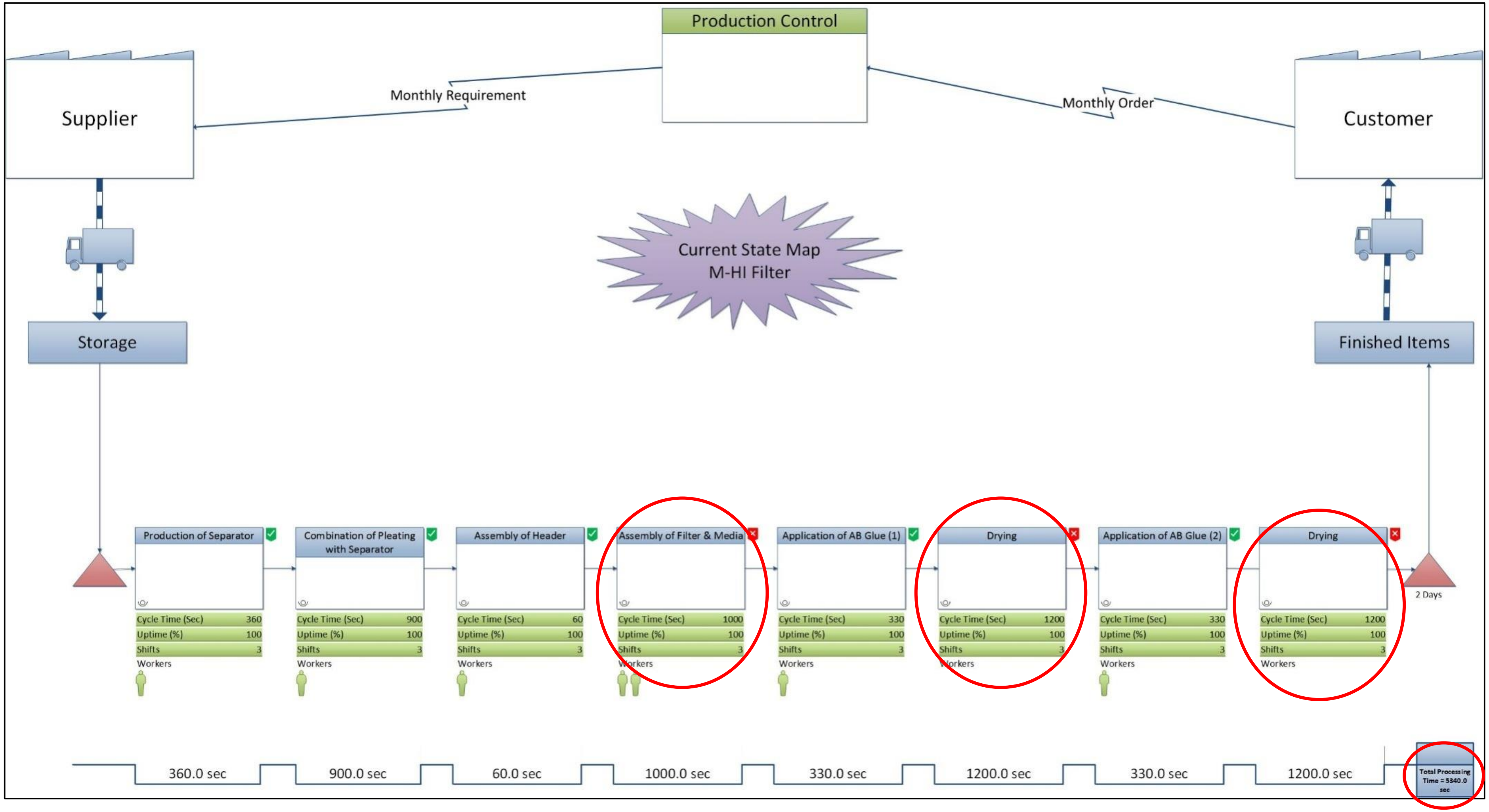

Figure 4.18: Current State Map (M-HI)

4.4.3 Identification of Lean Parameters (M-HI)

As it has been mentioned earlier in this section the workstation of *assembly of filter and media, Drying (1) and Drying (2)* has their cycle time more than the desired takt time. Thus, observation and process recording has been carried out together with the production engineer to determine the lean parameter which is causing non-value added activities to occur in these workstations.

The lean identification is started out at the workstation of *Drying (1)* and *Drying (2),* the drying process is carried out to allow the AB glue which has been applied to cure properly so there are no air leaks which occur during the use of the M-HI filter. However, this drying process which is repeated twice during the entire course of the production line uses up a significant amount of the available production time.

Upon close observation, it was determined that the MUDA waste of waiting occurs in the production line as the workers have to wait for the AB glue to fully dry before moving on to the next workstation in the production line. This drying period which is about 1200 seconds is higher than the takt time and is one of the reason the production demand of 20 units in a day to not be met. The drying workstation is shown in Figure 4.19 in which the M-HI filter is put aside for the drying process to take place without any physical aid.

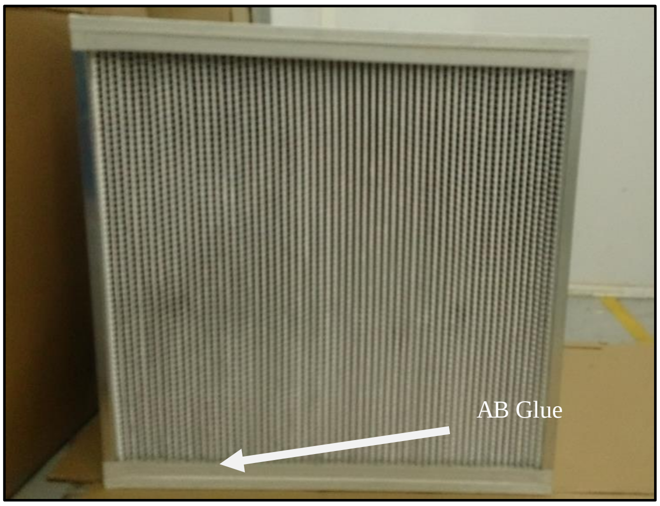

Figure 4.19: Drying Process

The lean identification then moves to the workstation of *assembly of filter and media*. It was found that the MUDA waste of defect was occurring in this particular workstation. The reason why the cycle time was high for the M-HI product is because when it is moved from the workstation of *combination of pleating with separator* to the workstation of *assembly of filter and media* in the production line, the aluminium separators which are inserted earlier during the pleating process has to be readjusted before the side frames can be assembled. This is because there are no restraints to prevent the aluminium separator from moving. The readjusting of the aluminium separators is a kind of defect and a non-value added activity which causes additional time to be incurred. The M-HI filter which needs to be moved is shown in Figure 4.20.

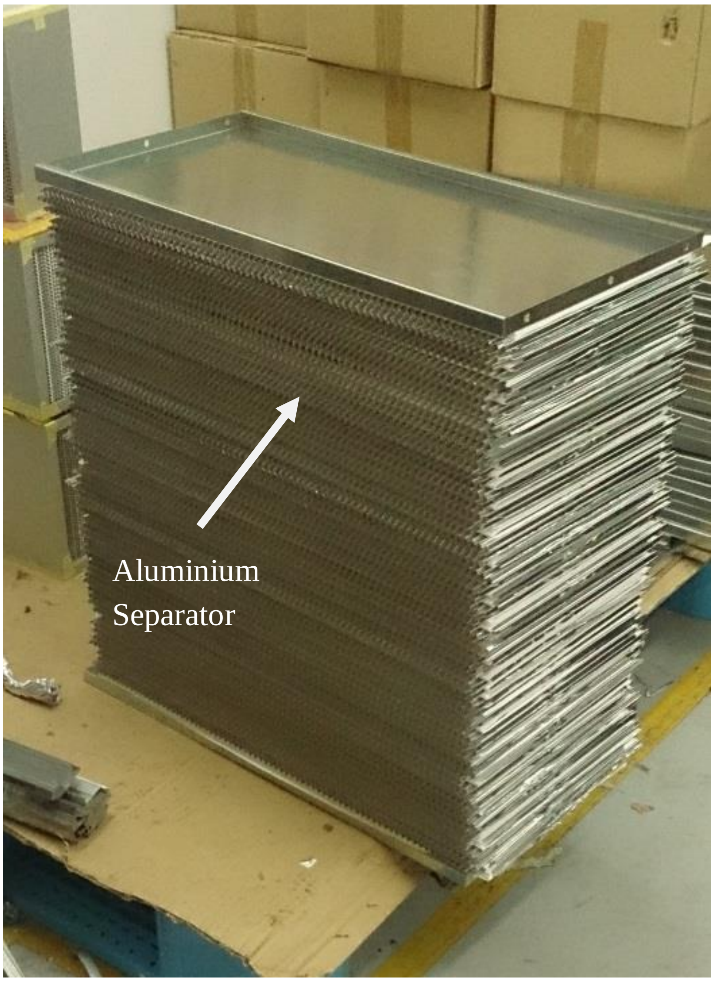

Figure 4.20: M-HI Filter Product

4.4.4 Improvements and Elimination of MUDA

To eliminate the occurrence of MUDA waste of waiting in the drying process of the AB glue, the drying cycle time of 1200 seconds/unit has to be reduced to a value less than the takt time of 945 seconds/unit. This can be done through using an industrial fan unit to assist in the cooling process of the M-HI filters as shown in Figure 4.21.

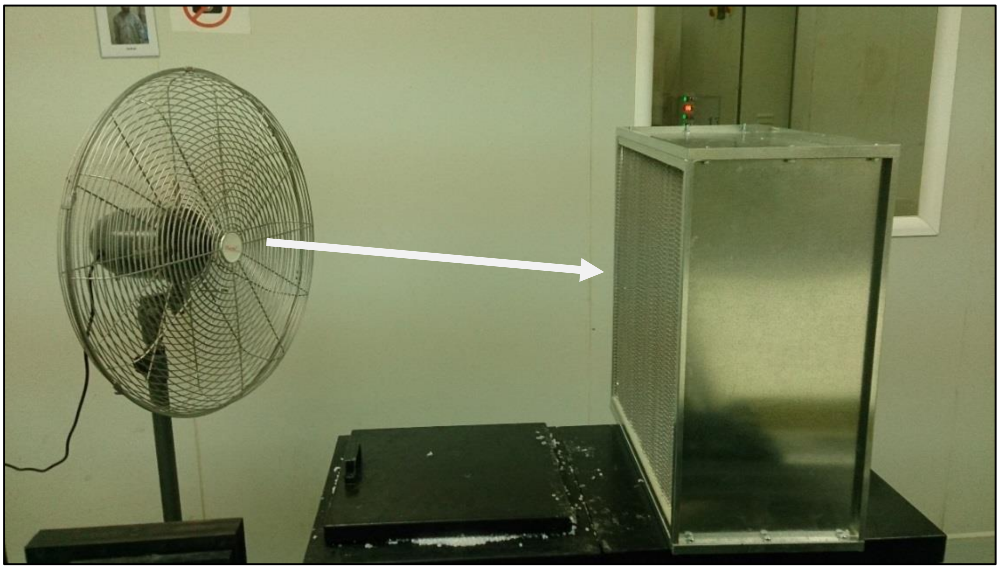

Figure 4.21: Industrial Fan Unit to improve drying time

To prevent the aluminium separators from moving during the transport process of the M-HI product from one workstation to another, an improvement was suggested which is to use a Ratchet Strap (Figure 4.22) to hold everything in place before moving the M-HI product. By using a strap like that the aluminium separators are prevented from moving when the workers move it from the pleating machine to another assembly station.

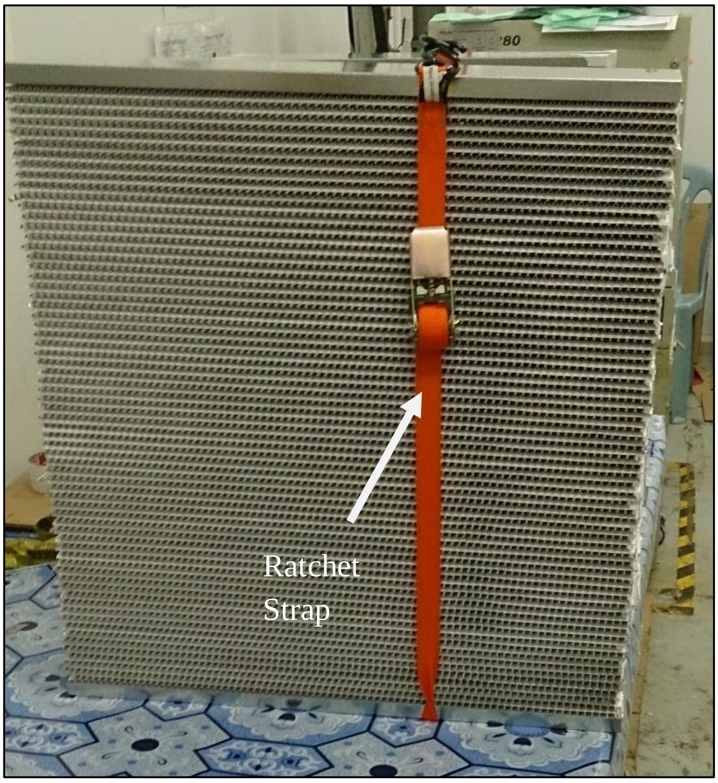

Figure 4.22: Ratchet Strap used on M-HI Filter

4.4.5 Cycle Time Analysis (AFTER IMPROVEMENT)

Table 4.10: Cycle Time Analysis (AFTER IMPROVEMENT-M-HI)

Cycle time at each workstation		
Workstation	**Cycle Time (seconds/unit)**	**No of Workers**
Production of Separator	360.0	1
Combination of Pleating with Separator	900.0	1
Assembly of header	60.0	1
Assembly of filter and media	600.0	2
Application of AB Glue (1)	330.0	1
Drying	900.0	N/A
Application of AB Glue (2)	330.0	1
Drying	900.0	N/A
Total processing time (seconds/unit)	4380.0	N/A
Total processing time (minutes/unit)	73.0	

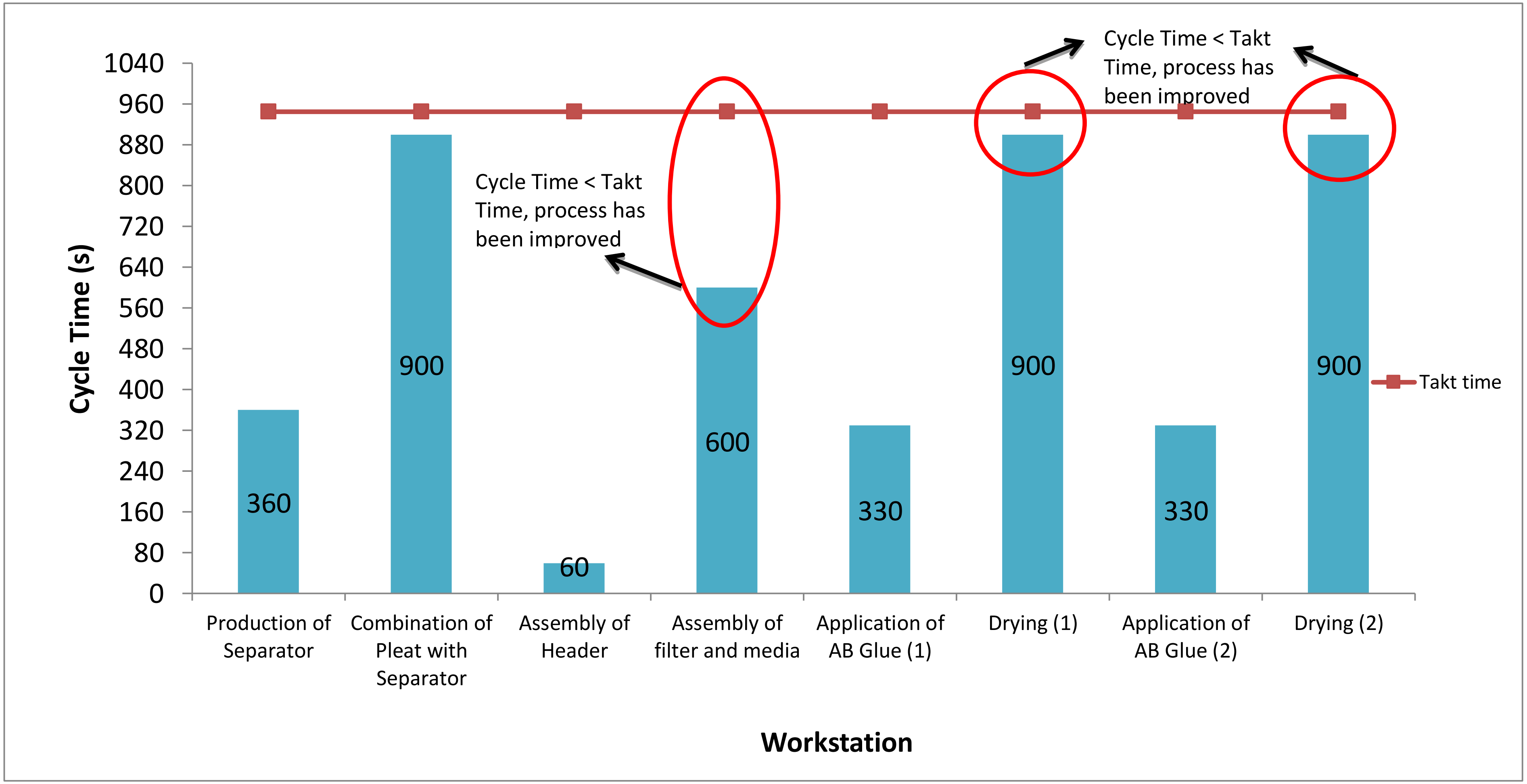

Figure 4.23: Comparison of Cycle Time against Takt Time (AFTER IMPROVEMENT)

From the cycle time analysis which has been carried out on the M-HI filter after improvement it can be seen that in the workstation of *Drying (1)* and *Drying (2)* there has been a 25% improvement in the recorded cycle time. This is because the MUDA waste of waiting has been eliminated from both the drying workstations by speeding up the glue curing process by using an industrial fan.

As it is observed from Table 4.10, the reduction in cycle time is about 300 seconds/unit of M-HI filter as the cycle time has been reduced from 1200 seconds/unit to about 900 seconds/unit. Moreover, from the graph tabulated in Figure 4.23 the objective of achieving a cycle time of lower than the takt time of 945 seconds/unit of M-HI filter has also been fulfilled.

Secondly, in the workstation of *assembly of filter and media* a 40% reduction in cycle time is recorded based upon the cycle time analysis carried out after improvement. By eliminating the waste of defect by using the Ratchet Strap to hold everything in place, a reduction on cycle time of about 400 seconds/unit of M-HI filter can be seen. The reduction of cycle time is from 1000 seconds/unit before improvement to about 600 seconds/unit after improvement. This new cycle time is also below the calculated takt time for the product.

In addition to the reduction in cycle time on each workstation, there is an improvement in the total processing time which is the overall lead time taken to transform the raw material into the M-HI filter product. The total processing time has been reduced from 89.7 minutes/unit of M-HI filter in Table 4.9 before elimination of MUDA to about 73 minutes/unit of M-HI filter in Table 4.10 after elimination of MUDA.

Table 4.11: Comparison of Current versus Improved Process for M-HI

Variables	**Units**	**Current**	**Improved**	**Percent Reduction**
Cycle Time at Drying Workstations	seconds/unit	1200	900	25%
Cycle Time at assembly of filter and media	seconds/unit	1000	600	40%
Total Processing Time	minutes/unit	89.7	73.0	19%

4.4.6 Future State Map

As can be seen from the future state map in Figure 4.24, due to the improvement and the elimination of the lean waste, the workstation of *Drying (1)* and *Drying (2)* now have their cycle time less than the calculated takt time. Moreover, the workstation of assembly of filter to media has also experienced a reduction in cycle time. These workstations which previously had a red mark on the current state map, now has a green mark in the future state map.

The production work flow and the number of workers in each workstation is kept the same as before. However, the number of workers in the workstation of assembly of filter to media may reduce from two to one depending on the production demand for the M-HI filter. There is no accumulation of WIP along the production line, which suggests that the production of M-HI is carried out in a single day rather than over a period of few days. This in turn translates to a shorter processing time to produce one unit of M-HI filter.

However, like all the other product the actual product delivery time for the M-HI filter could not be determined. This is because as it was mentioned before, the products which are manufactured are delivered according to the customer's request, which means they can collect the finished product whenever they want it. Despite this, the delivery time in the value stream map is set to two days as the actual delivery time varies from one customer to the other.

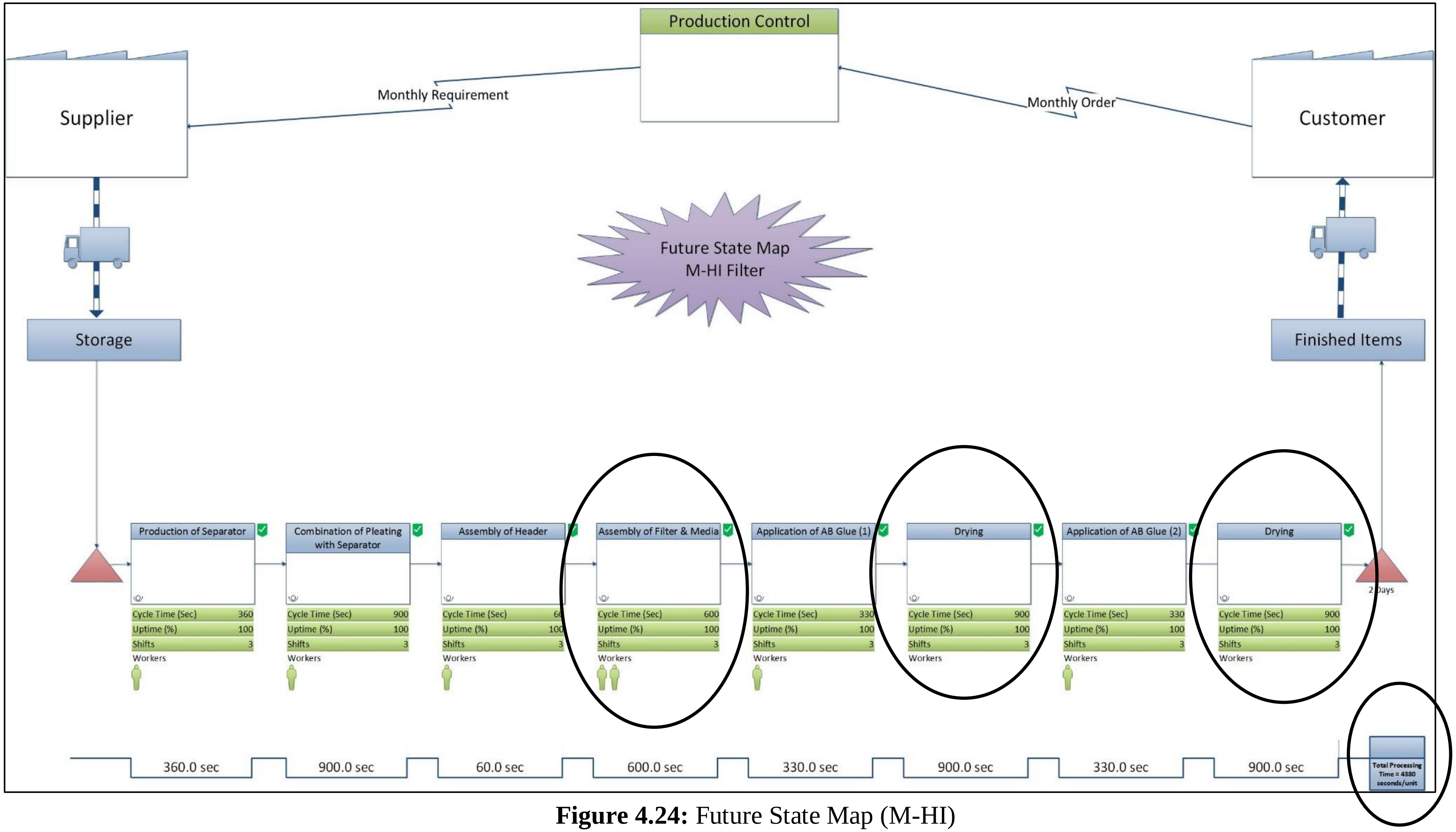

Figure 4.24: Future State Map (M-HI)

4.5 M-HII

As shown in Figure 4.25 M-HII filters are secondary filters which are widely used in many different industries such as pharmaceutical, clean room applications and also the semiconductor industry. The filter is one of the high range filters among HEPA filters. This is because M-HII cost more and also comes with features such as faceguard which are absent in low range HEPA filters.

Due to its wide range of application in various industries, the frame of the M-HII filter is made up of a resilient aluminium which is suitable to be used in most conditions. Moreover, M-HII filters have also a thin design which enables them to be space friendly as they do not occupy large amounts of installation space. According to the customers' specifications, the M-HII filter can be manufactured in various sizes depending on the size of the installation space.

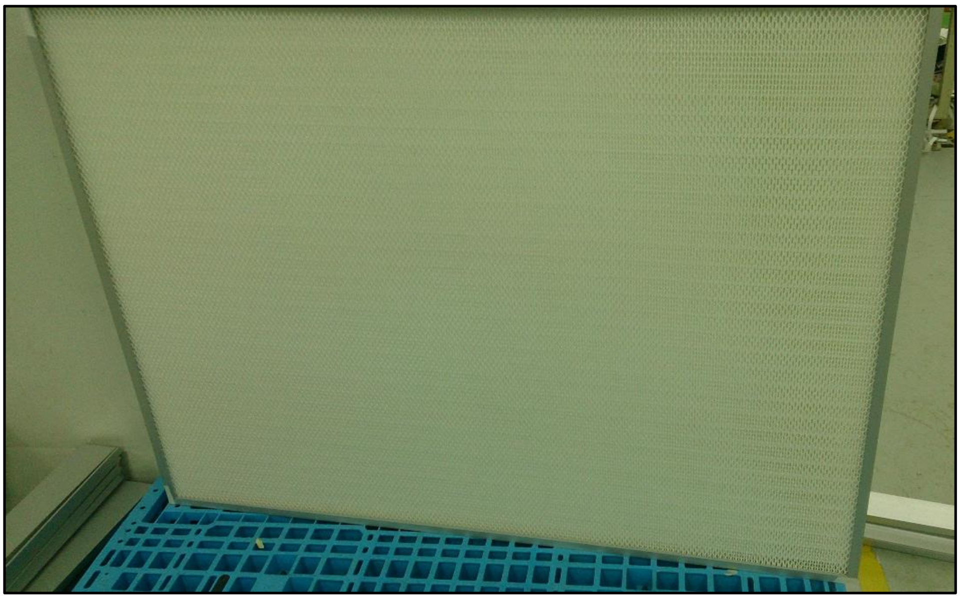

Figure 4.25: M-HII Filter

4.5.1 Cycle Time and Takt Time Analysis (BEFORE IMPROVEMENT)

Table 4.12: Takt Time Analysis (M-HII)

Takt time analysis	Values
No of shifts in one day (shifts/day)	3
Total available production time (hours/day)	10.5
Planned Production time (hours/shifts)	4
Customer Demand (units/day)	60
Customer Demand (units/shift)	20
Calculated Takt time (seconds/unit)	630

Table 4.13: Cycle Time Analysis (BEFORE IMPROVEMENT-M-HII)

Cycle time at each workstation		
Workstation	**Cycle Time (seconds/unit)**	**No of Workers**
Bracket Assembly to Frame	80	2
Pleated Media Formation	300.0	1
Assembly of frame to minipleat with faceguard	300.0	2
Gluing Station 1	240.0	2
Drying (1)	900.0	2
Gluing Station 2	240.0	2
Drying (2)	900.0	2
Total processing time (seconds/unit)	2960.0	N/A
Total processing time (minutes/unit)	49.3	

Based on the takt time analysis in Table 4.12 done for the production of M-HII it can be seen that the takt time is found to be 630 seconds/unit of M-HII filter. This value was calculated based on a M-HII demand of 60 units in a day. However, based on the cycle time analysis in Table 4.13, it was found that two out of the seven workstations has their cycle time above the takt time.

The workstations involved are *Drying (1) and Drying (2).* Since both the gluing workstation use the exact same glue and go through the same drying step, each of the gluing stations has the same cycle time of 900 seconds/unit. These values are significantly higher than the takt time of 630 seconds/unit. Figure 4.26 will give a better illustration.

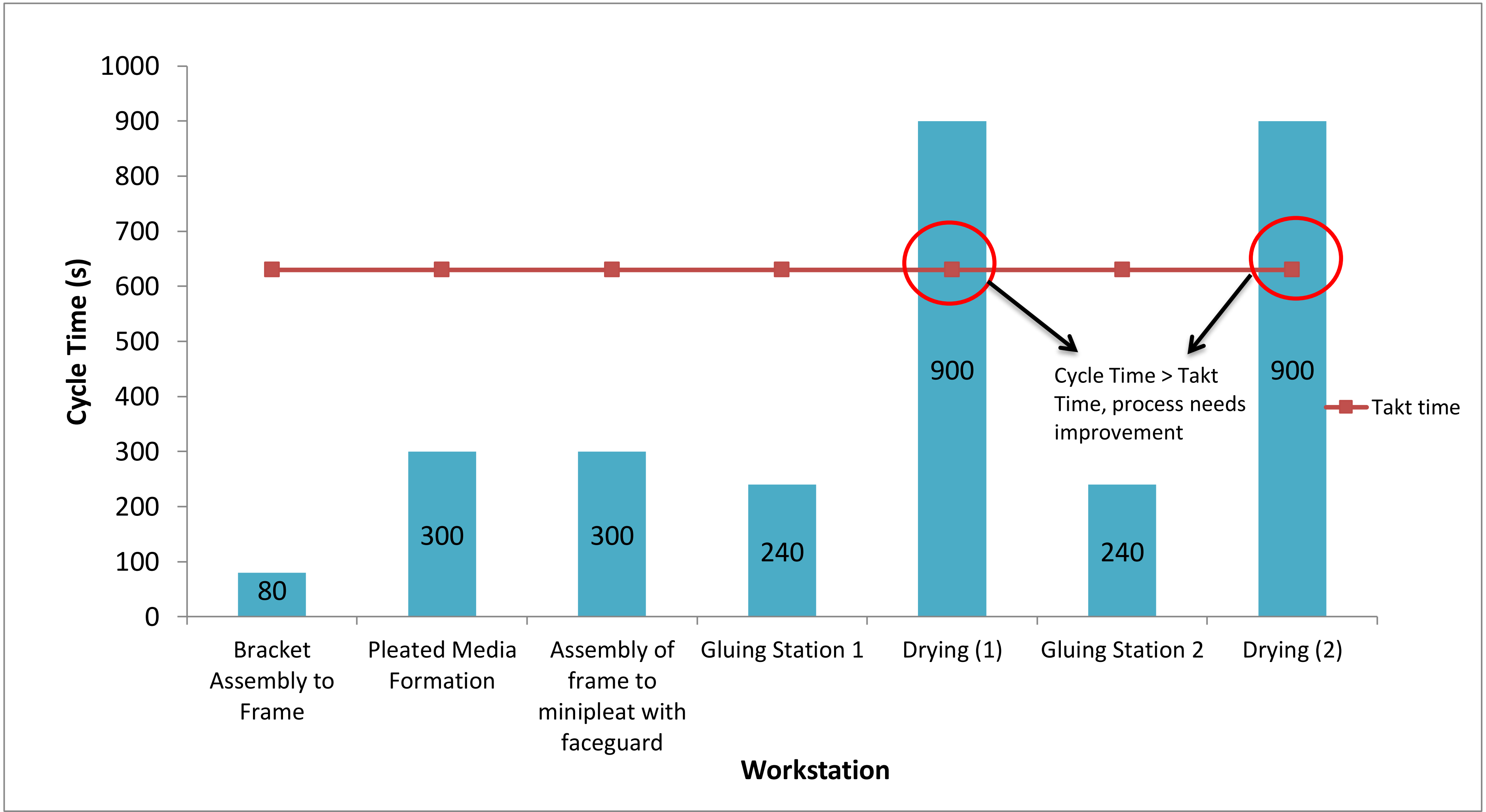

Figure 4.26: Comparison of Cycle Time against Takt Time (BEFORE IMPROVEMENT M-HII)

4.5.2 Current State Map

As can be seen from the current state map which was constructed for the production of M-HII in Figure 4.27, the production line is made up of seven different workstations/processes from start to finish. Moreover, from the current state map it can also be seen that the number of workers in each workstation varies from one to two workers.

However, similar to M-HI the drying workstation does not require any workers. The workers are dispensed interchangeably from one workstation to another. This means one worker in the production line is capable of working in different workstations in the production line. The workstations which are flagged red by the current state map needs improvement as their cycle time which was recorded exceeds the takt time of 630 seconds/unit of M-HII filter.

In addition to that, the drying time of the M-HII filter after the application of the AB glue has been combined together with the cycle time gluing process, this is because the M-HII is allowed to dry in the respective gluing station after the AB glue has been applied. The total processing time can also be obtained from the current state map, which is about 49.3 minutes/unit of M-HII filter.

Figure 4.27: Current State Map (M-HII)

4.5.3 Identification of Lean Parameters (M-HII)

In the previous subsection it was determined that the workstation of *Drying (1)* and *Drying (2)* has their cycle time higher than the calculated takt time. Thus, process recording was carried out at both this workstation, to determine the occurrence of any lean waste. Upon completion of the process recording it was concluded that the MUDA waste of waiting occurs in these workstations.

This is because like the M-HI filter the AB glue which is used to seal the sides of the filter has to be allowed to properly dry before the filter could be sent packaging. Because of this the workers would need to wait for about 900.0 seconds/unit or 15 minutes/unit for the AB glue in the M-HII filter to be completely dry. Due to this waiting waste the production process stops for 15 minutes before moving on to the next stage in the production process.

Since there are two gluing stations in the production process of M-HII the drying process of the AB glue is also repeated twice. This means that about 30 minutes out of the total production time for M-HII is allocated for the drying process for every unit filter produced. Figure 4.28 shows the drying step, in which the M-HII filter is allowed to dry on a pellet after the application of the AB glue.

Figure 4.28: Drying of M-HII Filter

4.5.4 Improvements and Elimination of MUDA

1) INDUSTRIAL FAN

Since the lean waste of waiting which is associated with MUDA is occurring in the workstations of *Drying (1)* and *Drying (2)* which is due to the long duration it takes the AB glue to completely dry. There are two alternatives to overcome this problem. The first alternative is to use a similar industrial fan that has been proven and tested in the drying process of M-HI filter

The report begins the discussion with the first alternative which is to use an industrial fan. Despite being two different air filtration products, both the M-HI and M-HII filters use the same type of AB glue to seal the gaps at the side so that most of the air is directed towards the filtration media.

Moreover, with a stable temperature control of the clean room in which the M-HII drying process takes place coupled with the additional cooling effect provided by the industrial fan the drying time of the AB glue can be somewhat reduced from the current cycle time of 900 seconds/unit of M-HII filter. Figures 4.29 and 4.30 show the improved drying step and the type of industrial fan used.

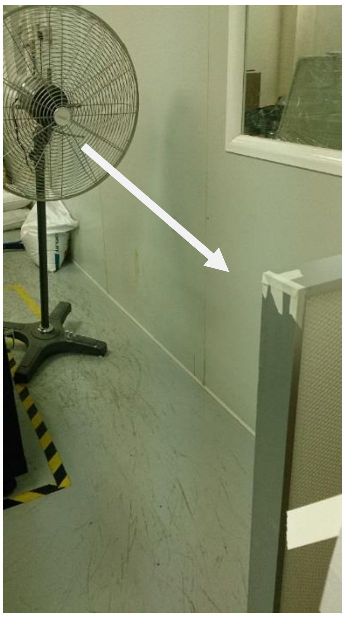

Figure 4.29: Improved Drying Step

Figure 4.30: Industrial Fan

2) HEATER METHOD

The report now moves on to the second alternative or improvement that has been suggested to solve the lean waste of waiting in both the drying workstations. This improvement involves using a hot air blower or a strip heater to heat the AB glue from room temperature to about 60 °C to speed up the glue curing time. However, the choice of whether to use a hot air blower or a strip heater will be studied carefully to outweigh the benefits of both heating methods in the subsequent sections.

i) Strip Heater Method

Table 4.14: MSDS Data Extracted

Curing Time (min，27℃，20g)	20-40
Curing Time (min，60℃，20g)	5-10

Based on Table 4.14 which has been extracted from the MSDS of the mixture of the AB polyurethane glue, it can be seen that the curing time of the AB glue varies when the temperature of the glue varies. Currently, at MayAir after the application of the glue to the M-HII filter, the glue is allowed to cure at room temperature, which is about 25 °C to 27 °C. this causes the time it takes for the glue to cure to be about 20 minutes as what it is shown in the MSDS extracted in Table 4.14.

Thus, it was suggested to speed up the curing time of the AB glue after each application by raising the temperature during the drying process. The proposed temperature is 60 °C, in which the curing time is about half of the original time which is about 10 minutes. This is achieved by introducing strip heaters/clamp-on heaters (Figure 4.31) to supply heat which would cause the temperature of the glue to increase during the curing process.

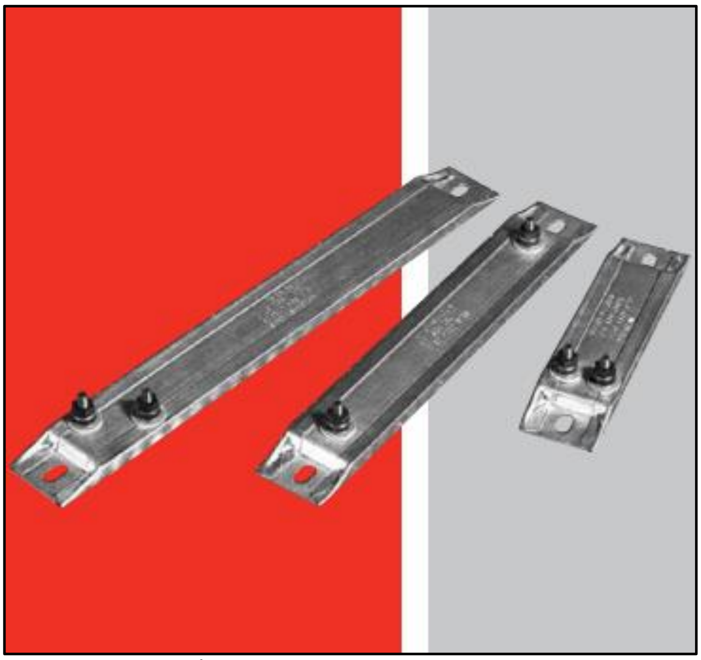

Figure 4.31: Strip Heaters

To select the most suitable type of strip heater for the to be used for the curing process, the amount of heat required to raise the temperature from room temperature to target temperature which is about 25 °C to 60 °C has to be calculated. Since it was proposed to fit the strip heater to the production trolley, the heat conduction across the iron surface of the trolley has to be taken into account when estimating the amount of heat required. The type of production trolley used during the drying process of M-HII and the proposed area where the strip heaters will be installed is shown in Figures 4.32 and 4.33.

Figure 4.32: Production Trolley used During Drying

Figure 4.33: Proposed Area for Strip Heater Installation

Based on the Figure 4.33 the strip heater is proposed to be installed in each of the six iron rods which one of it has been outlined by the white arrow. Upon determining the proposed area of installation, the dimension of the area is measured to obtain information such as the length, and diameter which can then be used in the heat conduction equation to calculate the amount of power required in watts to obtain a temperature of 60 °C. Equation 4.1 is used to calculate the heat conduction.

$$\frac{Q}{t} = \frac{kA(T2 - T1)}{L}$$

Equation (4.1)

Table 4.15: Summary of Heat Conduction Calculation

Variables	**Values**	**Units**
Length of iron rod	1.1	m
Diameter of Iron rod	0.034	m
Radius of Iron rod	0.017	m
Heat conduction constant k	80	W/m.K
Area of Iron Rod	0.00091	m^2
Thot	333	K
Tcold	298	K
Q/t	2.312	J/s or W
	0.00231	KW
Watt Density	0.25455	W/cm^2

From Table 4.15 it can be seen that the amount of heat required to raise the temperature of the glue is about 2.312 W which is about 0.00231 KW. Based on the calculated value, we can also see that the watt density is about **0.25455** $\mathbf{W/cm^2}$ for an iron rod area of **9.1** $\mathbf{cm^2}$. Equation 4.2 is used to calculate the watt density.

$$\text{Watts (W)} = \text{Watt Density}(W/cm^2) \text{ x Area } (cm^2)$$

Equation (4.2)

Table 4.16: Pros and Cons of Using Strip Heaters

Advantage	Disadvantage
Cost saving as one unit only costs about RM 400	10-strip heaters/trolley are needed; this would increase the total cost to purchase the strip heaters for 4 trolleys.
Small and robust, does not occupy a large area	The heater installed my heat the iron rod to a temperature of more than 100 °C and due to the small contact are between the strip heater and the rod may burn the heating element of the strip heater in the long run.
-	Additional wiring cost for installation, a 3 phase current source has to be installed as one piece of strip heater needs 3.6 kW
-	The movement of the trolley together with the strip heaters mounted may cause the wiring to come loose and increase the risk of short circuit
-	The workers may step on the hot iron rod during handling the trolley or moving the filter products which may cause safety risks

ii) Hot Air Blower

The second way to speed up the glue drying time is to use a hot air blower such as the one shown in Figure 4.34. The data sheet is given in Table 4.17

Figure 4.34: Mistral Premium Hot Air Blower

Table 4.17: General Specification Data Sheet of Hot Air Blower

Technical Data	Mistral Premium
Voltage (V)	230
Power (W)	4500
Temperature Open (°C)	20
Max Air Volume (L/min)	350
Weight (kg)	1.4

The working principle of this improvement is based on the fact that by heating the air in the surroundings of the M-HII filter which would conduct the heat through convection to speed up the AB glue curing time. During the initial test one shown in Figures 4.35 and 4.36 the M-HII filter was placed on the trolley with a bottom covering as well as a top covering, in which the hot air blower was allowed to channel air through one of the holes in the top covering. The results of the tests are shown in Table 4.18.

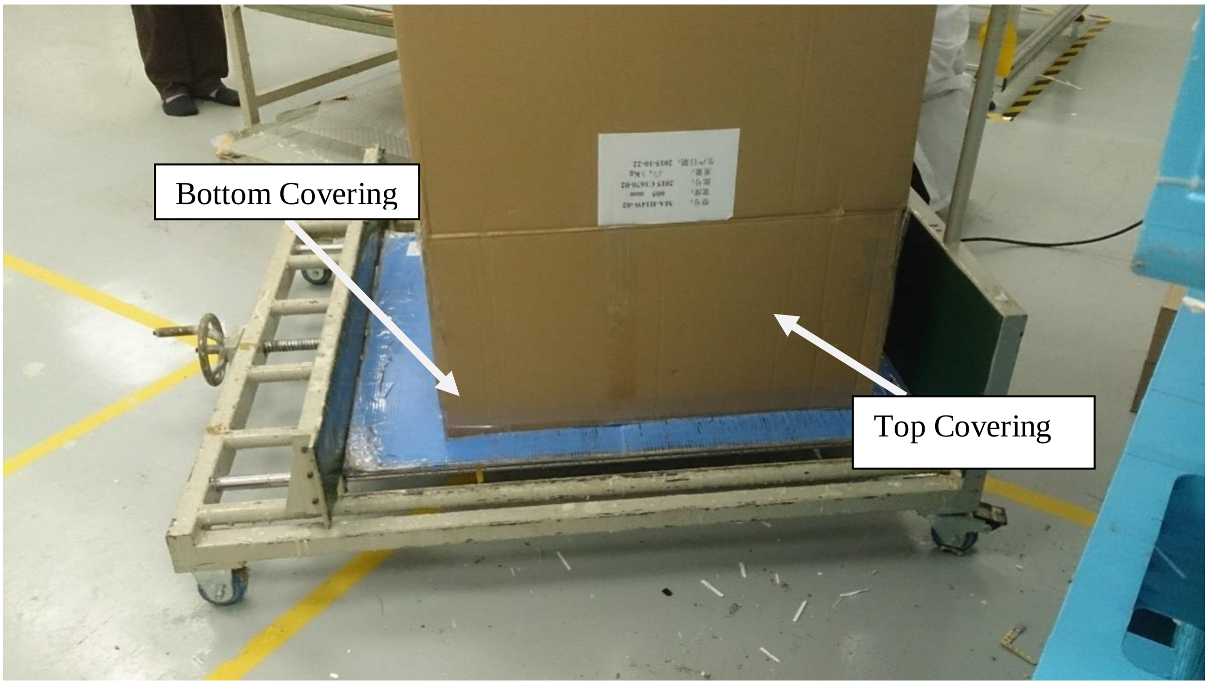

Figure 4.35: Top Covering and Bottom Covering Used to Trap the Hot Air to Speed Up the AB Glue Curing Process

Figure 4.36: Hot Air Blower Used to Speed Up the Curing Process

Table 4.18: Test Results Using Hot Air Blower

Preliminary Test	Temperature of Blower (°C)	Air Volume (L/min)	Volume of top covering (L/min)	Duration of operation (minutes)
1	110	350	91.44	10
2	150	280	91.44	10

Based on the two tests runs which was done using the hot air blower it was found that there is an improvement in the curing time as compared to using only room temperature. However, further improvements can be done to increase the efficiency of hot air which is being channelled into the box or enclosed area. One of the suggestions is to create perforated holes at the bottom area of the box, which allows for the hot air to be channelled into the enclosed area in a constant rate. This is to prevent the hot air from accumulating at any one point in the enclosed area which may cause a high increase of temperature which may result in damage to the filter. Thus, it is important to allow the hot air to be channelled in a constant rate into the enclosed area. The reduction in cycle time of using this hot air blower method is shown in Table 4.22 and Figure 4.38.

Like the strip heater, there a few advantages and disadvantages of using the hot air blower to speed up the glue curing process which are summarized in Table 4.19.

Table 4.19: Pros and Cons of Using Hot Air Blower

Advantage	Disadvantage
Only one unit/trolley is required	Expensive as one unit may cost about RM 2000
Small and robust, does not occupy a large area	Blocking of the blower outlet nozzle may cause damage to the heating element
Easy to use and handle as the workers can disconnect it easily	Heating Element is not given warranty by the manufacturer
Good control of temperature due to the built in temperature controller	
Air volume can be varied according to the volume of the space that needs to be heated	
Ease of Maintenance and lower safety risk as all the heating occurs inside the top covering	

By outweighing the pros and cons of using either strip heater or hot air blower in terms of installation, and long term usability the hot air blower is chosen over the strip heater. Thus in the subsequent sections a comparison will be done between the industrial fan and the hot air blower to select the most suitable method between these two to speed up the curing process.

4.5.5 Cycle Time Analysis (AFTER IMPROVEMENT - INDUSTRIAL FAN METHOD)

Table 4.20: Cycle Time Analysis (AFTER IMPROVEMENT- INDUSTRIAL FAN METHOD)

Cycle time at each workstation		
Workstation	**Cycle Time (seconds/unit)**	**No of Workers**
Bracket Assembly to Frame	80	2
Pleated Media Formation	300.0	1
Assembly of frame to minipleat with faceguard	300.0	2
Gluing Station 1	240.0	2
Drying (1)	600.0	2
Gluing Station 2	240.0	2
Drying (2)	600.0	2
Total processing time (seconds/unit)	2360.0	N/A
Total processing time (minutes/unit)	39.3	

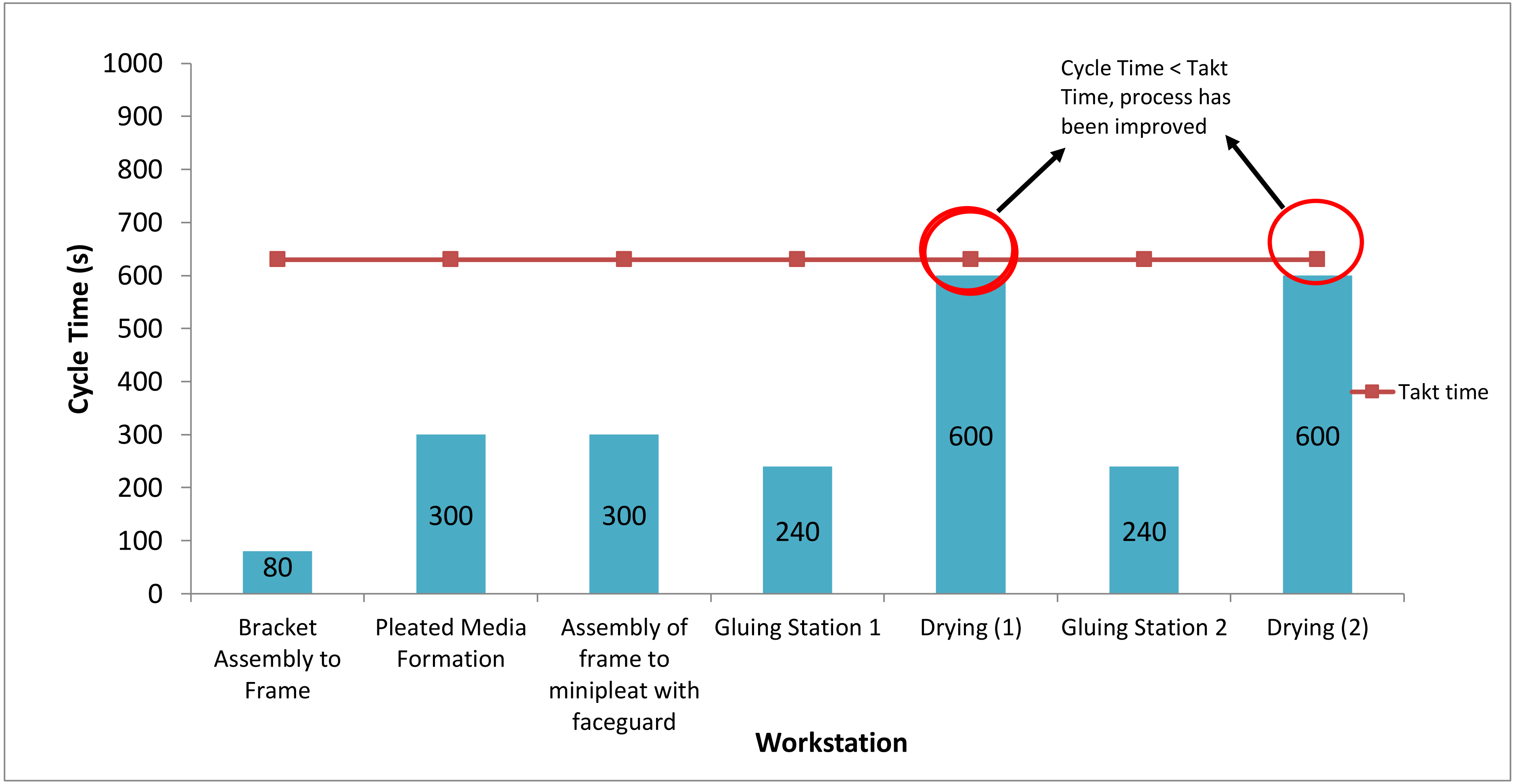

Figure 4.37: Comparison of Cycle Time against Takt Time (AFTER IMPROVEMENT-INDUSTRIAL FAN METHOD)

Based on the cycle time analysis which was carried out after improvement and the elimination of MUDA waste of waiting for both the workstation of *Drying (1)* and *Drying (2)* a 33% improvement can be observed as compared to the cycle time prior to the improvement.

This is because it can be seen from Table 4.20 the cycle time at both the workstations has been reduced from 900 seconds/unit of M-HII to about 600 seconds/unit of M-HII (Figure 4.20). From Figure 4.37 it can also be seen that the cycle time is also lower than the takt time of 630 seconds/unit. This is one of the objectives of carrying out lean management and it has been achieved in the production of M-HII filter.

Moreover, from Table 4.20 a reduction in the total processing time or lead can also be seen. The total processing time for one unit of M-HII has reduced from 49.3 minutes to about 39.3 minutes. This is a 20% reduction in processing time which means that it takes 20% less time for one single unit of M-HII to be manufactured from a raw material to a finished product. Table 4.21 summarizes all the improvements that had been achieved.

Table 4.21: Comparison of Current versus Improved Process for M-HII (Industrial Fan Method)

Variables	Units	Current	Improved	Percent Reduction
Cycle Time at Drying Workstations	seconds/unit	900	600	33%
Total Processing Time	minutes/unit	49.3	39.3	20%

4.5.6 Cycle Time Analysis (AFTER IMPROVEMENT – HOT AIR BLOWER METHOD)

Table 4.22: Cycle Time Analysis (AFTER IMPROVEMENT-HOT AIR BLOWER METHOD)

Cycle time at each workstation		
Workstation	**Cycle Time (seconds/unit)**	**No of Workers**
Bracket Assembly to Frame	80	2
Pleated Media Formation	300.0	1
Assembly of frame to minipleat with faceguard	300.0	2
Gluing Station 1	240.0	2
Drying (1)	420.0	2
Gluing Station 2	240.0	2
Drying (2)	420.0	2
Total processing time (seconds/unit)	2000.0	N/A
Total processing time (minutes/unit)	33.3	

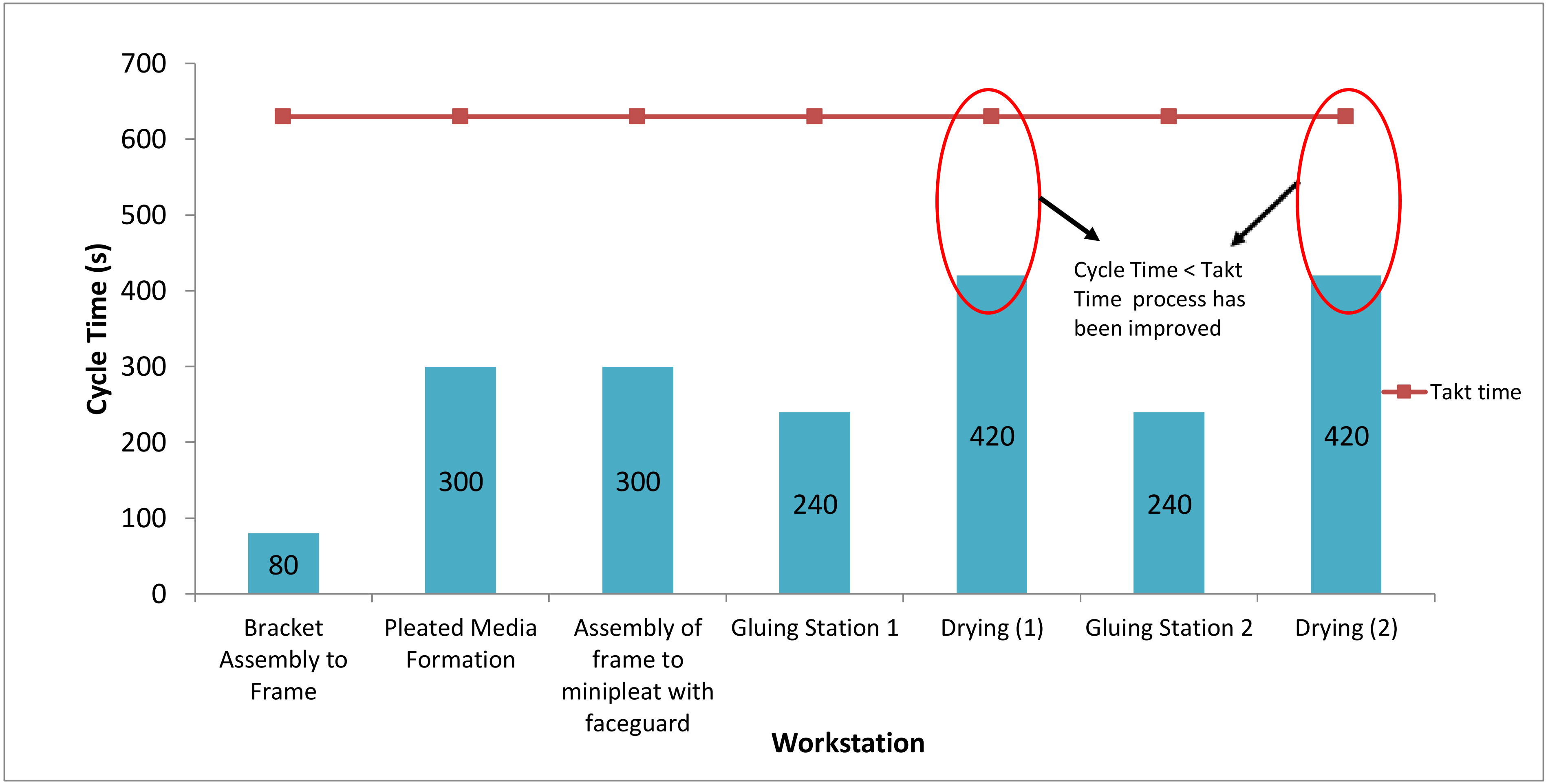

Figure 4.38: Comparison of Cycle Time against Takt Time (AFTER IMPROVEMENT- HOT AIR BLOWER METHOD)

4.5.7 Method Chosen and Justification

Since there are two methods which were tested out to speed up the curing time of the AB glue, the most suitable method between the industrial fan method and the hot air blower method has to be chosen. Thus, in this part of the report the method chosen will be stated as well as the justification why this method was chosen will be elaborated.

Based on the second method which is the use of hot air blower method, it is noticed that the cycle time in the *Drying 1* and *Drying 2* has experienced a 53% improvement as compared to only room temperature for the curing of the AB glue. This improvement show a 20% more improvement as compared to using the industrial fan method which yielded only a 33% improvement in cycle time as compared to using only room temperature.

The objective of achieving a cycle time lower than the takt time has also been achieved by using the hot air blower for the curing process. As shown in Figure 4.38, the cycle time with the usage of hot air blower for the curing was about 420 seconds/unit of M-HII filter, which was lower than the takt time calculated of 630 seconds/unit for the projected demand.

Moreover, by using the hot air blower method there was significant reduction in the total processing time for one unit of M-HII as compared to the industrial fan method. This was because based on Table 4.22 the total processing time by using the hot air blower was about 33 minutes/unit of M-HII.

When this time was compared to the reduction in total processing time using the industrial fan method (Table 4.20) to be only 39.3 minutes/unit M-HII, it is obvious that the hot air blower provided a shorter overall processing time. Table 4.23 summarizes the comparison of between these two methods in terms of cycle time as well as total processing time

Table 4.23: Comparison between the two proposed method to speed up the flue curing process

Method	Variables	Units	Current	Improved	Percent Reduction
Industrial Fan Method	**Cycle Time at Drying Workstations**	seconds/unit	900	600	33%
	Total Processing Time	minutes/unit	49.3	39.3	20%
Hot Air Blower Method	**Cycle Time at Drying Workstations**	seconds/unit	900	420	53%
	Total Processing Time	minutes/unit	49.3	33.0	32%

In a conclusion, the hot air blower method was chosen over the industrial fan method as it offered a 53 % cycle time improvement in the Drying 1 and Drying 2 workstations and also a 32% reduction in overall processing time for one unit of M-HII filter being produced. Since the hot air blower method will be used, the future state map constructed in the subsequent section will follow the cycle time from this method.

4.5.8 Future State Map

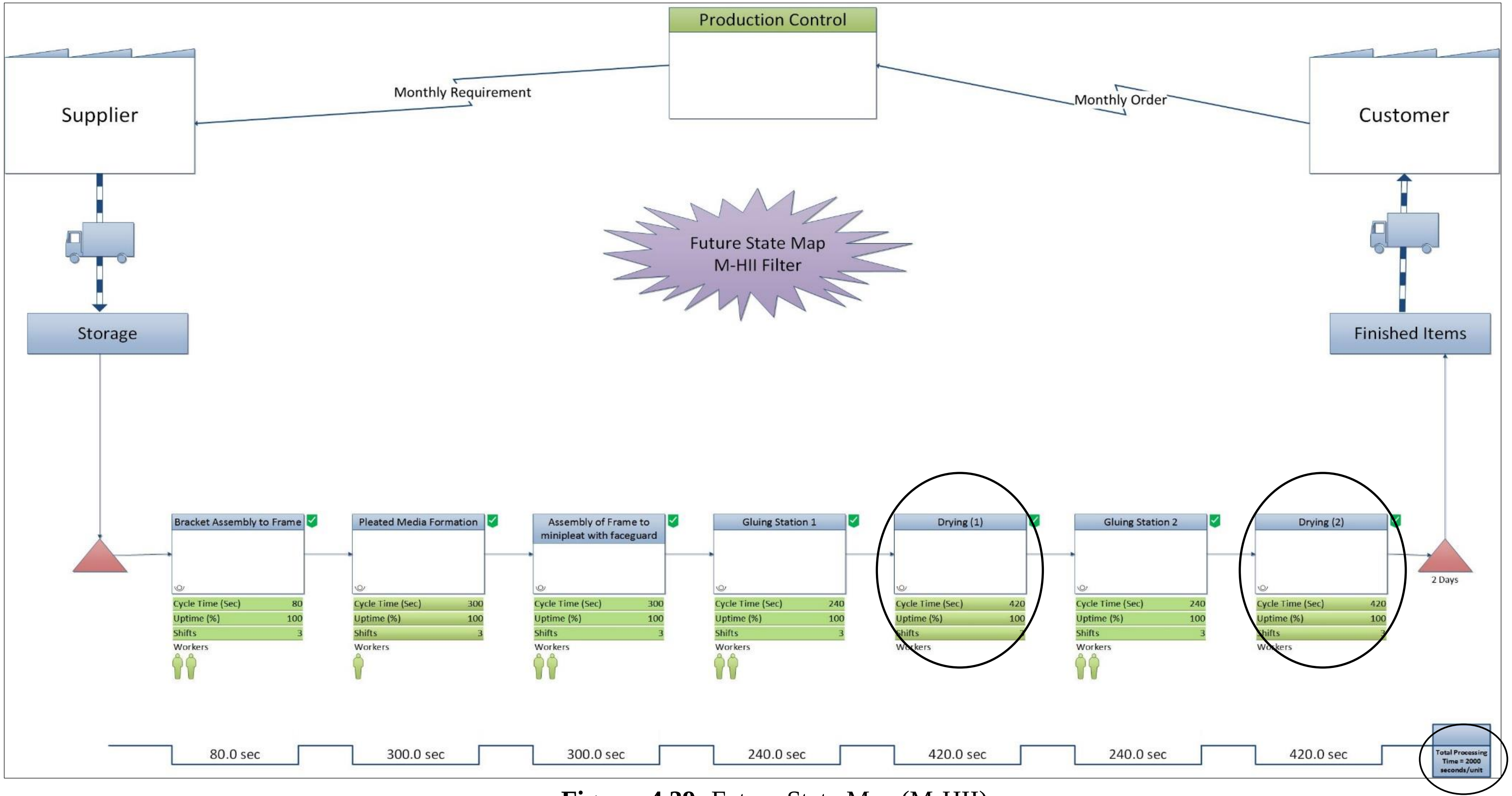

Figure 4.39: Future State Map (M-HII)

4.6 Implication of Using Lean Production Management in the Manufacturing Industry

There are a few implications to implementing lean production management in a production facility. The first implication is that the production capacity of an organization can be increased through the use of lean techniques. This is because after all the processes in the production stream has achieved a cycle time which is lower than the takt time, the production capacity has been achieved.

Thus, what the organization can do now is to increase the production capacity for that particular product. This means that the particular organization will be able to manufacture more units of a product than before by using the same amount of time earlier. This is due to that fact that the takt time is a function of the demand for a particular product. Moreover, another implication of using lean is that the quality of product being manufactured can be further improved. By eliminating the associated wastes from the three main lean parameters MUDA, MURI and MURA, a single piece workflow can be achieved.

This means that only one product is worked on at any one given moment instead of working on large batch sizes or production lots. This is especially useful if whenever there is a defect to the product, the defect can be easily traced back to that single part and one does not need to waste time in testing or isolating other components in the same production line to determine where and why the defect starts.

In addition, by using value stream map analysis in all the four filter products in which lean management was implemented, the accumulation of inventory along the production line of these products was also able to be identified. This is because when there is an accumulation of inventory, the total processing time or the total lead time it takes to manufacture a product increases. Thus, by minimizing inventory which is a type of waste under MUDA, the organization will be able to reduce the processing time for a particular product.

Lastly, besides all the outcomes/implications mentioned earlier, the most important implication lean can deliver to an organization is to provide the production worker with a safer working environment. By making changes to the production layout or certain changes to the workstation, the workers ergonomics can be greatly improved, which in the long run would serve as a safe and efficient working environment. This has been seen in the production process of GI Frame Pocket Filter when a few small but significant modifications made to the workstation of *assembly of media to frame* in an effort to provide better ergonomics to the workers whilst minimizing injury in the long run.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The aim of this project was to implement lean production management in the air filtration industry. To achieve the goal of implementing lean production management the lean parameter of MUDA, MURI, MURA and each of their associated wastes were identified in all the products. By identifying and eliminating the wastes under each of these lean parameters, the cycle time was able to match with the takt time. Moreover, the improvement effect of this cycle time reduction was further analysed by comparing the differences in the current state map and future state maps drawn for each of the products under study for lean implementation.

Four major products which were the GI Frame Pocket Filter, Aluminium Frame Pocket Filter, M-HI Filter and M-HII Filter have experienced an overall reduction in processing time of between 20% - 30%. This was carried out through the identification of MURI in the workstation of *assembly of media to frame* in the production process of GI Frame Pocket Filter. By improving the ergonomics, a reduction of 34% in the cycle time in the particular workstation was observed. Whereas, for the Aluminium Frame Pocket Filter, the MUDA waste of defect was identified in the workstation of *assembly of media to wire rod frame*. In an effort to reduce the cycle time, an industrial stapler was suggested for the improvement to the production process.

In the HEPA Filter manufacturing process, the M-HI production process was improved through the identification of MUDA waste of waiting, as well as defect by reducing the cycle time of about 25% in the *drying* workstations through the use of an industrial fan and reduction in cycle time of about 40% in the workstation of *assembly of filter and media* through the use of ratchet strap to secure the filter during assembly.

Lastly, for the M-HII filter product, the reduction in cycle time came about in the two drying workstations were the MUDA waste of waiting was identified and a 53% reduction in cycle time was observed through the use of a hot air blower to aid in the curing process of the AB glue. The future state maps which was constructed for all four products, showed no accumulation in WIP as well as minimal changes to the production layout and number of workers before and after the suggested improvements were added in to reduce cycle time.

Thus, the implications of lean in manufacturing were that the production capacity can be increased, product quality can be improved, inventory accumulation can be determined and last but not least to ensure a safe working environment for the production workers.

5.2 Recommendations

Implementation of lean production management is not a one off thing, because it may take maybe one to two years to actually get the necessary momentum to be fully absorbed in the production process. No doubt lean tools such as cycle and time and takt time analysis, value stream mapping is able to provide immediate and significant improvement to the production process, but without a proper structure and cooperation from the organization in the long term the lean tools used for the improvement process would actually start to deteriorate. Thus, it is important to have a 2-3 years plan to actually fully implement lean management in an organization.

Since there are only two lean tools used to implement lean production management in this research. Other lean tools such as Yamazumi Chart, Kanban System as well as Kaizen can also be used for further improvement of the production line. Implementation of lean management is a continuous process and a long term program to ensure its sustainability in an organization.

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