ÇUKUROVA UNIVERSITY

INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc. THESIS

Application of Value Stream Mapping to Increase Productivity Within the Textile Industry

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Department of Industrial Engineering

January, 2024

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MSc THESIS APPROVAL

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We certify that the thesis titled above was reviewed and approved for the award of the degree of the Master of Science by the board of jury on 02/01/2024.

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M.Sc. Thesis is written at the Department of Industrial Engineering Institute of Naturaland Applied Sciences of Çukurova University
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MASTER OF SCIENCE THESIS

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ABSTRACT

Value-stream mapping (VSM) is a useful tool for identifying waste and areas for improvement. It has emerged as a preferred method of assisting and implementing the lean approach. While lean principles are well-established and have a wide range of applications in manufacturing, their application to the textile industry is limited.

Based on a case study approach, this paper describes the implementation of VSM as a lean improvement initiative in a t-shirt manufacturing company. It entails mapping the firm's current activities and identifying areas for improvement. Following several interviews with current process participants, a current state map is created to describe the existing problem areas. A future state map has been created to depict the proposed improvement action plans. Value stream" to be "all the actions (both value added, and non-value added) currently required to bring a product through the main flows essential to every product: the production flow from raw material into the arms of the customer, and the design flow from concept to launch".

Taking a value stream approach means focusing on the big picture rather than individual processes. VSM establishes a common foundation for the production process, allowing for more deliberate decisions to improve the value stream. VSM is a pencil-and-paper tool that uses a predefined set of standardized icons. VSM implementation results in reduced lead time, cycle time, and resource requirements. Our findings show that the new process change can reduce total lead time from 40 days to 19 days - a 52.5% reduction in overall lead time.

Keywords: VSM, lean principle, textile industry

ÇUKUROVA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ

YÜKSEK LİSANS TEZİ

Bir Tasnif Makinesi Kullanarak Farklı Besleme Hızına Yer Fıstığının Sınıflandırılması

Raissa Rebecca KAMSEU MONGO

Danışman: Prof. Dr. Ali KOKANGUL

Endüstri Mühendisliği Anabilim Dali

ÖZ

Değer akışı haritalaması (VSM), israfı ve iyileştirme alanlarını belirlemek için yararlı bir araçtır. Yalın yaklaşıma yardımcı olmak ve uygulamak için tercih edilen bir yöntem olarak ortaya çıkmıştır. Yalın ilkelerin yerleşik olmasına ve imalatta geniş bir uygulama yelpazesine sahip olmasına rağmen, bunların TEKSTİL ENDÜSTRİSİNE uygulanması sınırlıdır.

Bir vaka çalışması yaklaşımına dayanan bu makale, bir tişört imalat şirketinde yalın bir iyileştirme girişimi olarak VSM'nin uygulanmasını açıklamaktadır. Firmanın mevcut faaliyetlerinin haritasını çıkarmayı ve iyileştirme alanlarını belirlemeyi gerektirir. Mevcut süreç katılımcıları ile birkaç görüşmenin ardından, mevcut sorun alanlarını tanımlamak için mevcut durum haritası oluşturulur. Önerilen iyileştirme eylem planlarını tasvir etmek için bir gelecek durum haritası oluşturulmuştur. Değer akışı", bir ürünü her ürün için gerekli olan ana akışlardan geçirmek için halihazırda gerekli olan tüm eylemlerdir (hem katma değerli hem de katma değeri olmayan): hammaddeden müşterinin kollarına üretim akışı ve tasarım akışı konseptten lansmana".

Bir değer akışı yaklaşımı benimsemek, bireysel süreçler yerine büyük resme odaklanmak anlamına gelir. VSM, üretim süreci için ortak bir temel oluşturarak, değer akışını iyileştirmek için daha bilinçli kararlar alınmasına olanak tanır. VSM, önceden tanımlanmış bir dizi standartlaştırılmış simge kullanan bir kalem ve kağıt aracıdır. VSM uygulaması, tedarik süresinin, döngü süresinin ve kaynak gereksinimlerinin azalmasına neden olur. Bulgularımız, yeni süreç değişikliğinin toplam teslim süresini 40 günden 19 güne indirebileceğini gösteriyor - toplam teslim süresinde %52,5 azalma

Anahtar Kelimeler: VSM, yalın ilke, Tekstil endüstrisi

DETAILED ABSTRACT

The clothing industry is central to the world's production system and vital to economic prosperity and job creation. Over the years textiles have been growing exponentially. However, the textile industry is facing multiple issues including the problem of increasing productivity in this industry to meet up dynamic consumer demands remains a challenge. There exist several methods and machines that has successfully being used and implemented to increase productivity within the textile industry. However, increasing productivity in this industry remains challenging to professionals all over the world involved in clothing production.

The paper provides Value Stream Mapping as a Lean Production Tool to Increase Productivity in the Textile Industry, and in light of this, certain VSM literature was assessed qualitatively taking into account its benefits in other industries, particularly the automobile industry. The lean technique of Value Stream Mapping was used to increase production at the textile company called Tailors of Cameroon.

This company face several issues which make them less productive like overproduction, overprocessing and long lead times. VSM was used to map the entire production process from raw material input to finished product output. The VSM analysis identified a few areas where waste could be eliminated, such as excess inventory, idle times of operators and defects.

On the basis of the VSM analysis carried out at the company, a few changes were implemented such as using a fixed production pace and implementing a Just-in-time production strategy, cross training all operators and moving them when needed to the required process and smoothening of the production. The company managed to reduce lead time from 39.93 days to 19 days, cutting lead times by 52.4%, raising productivity by about 20%, and increasing the quality level by 10% because of these alterations.

The case study also shows that a VSM is a useful approach to increasing a company's textile manufacturing productivity. Textile companies will benefit from VSM because they will be able to identify waste and cut costs as well as enhance their own production processes. This review's expertise would serve as a roadmap for engineers and professionals in this field.

GENİŞLETİLMİŞ ÖZET

Bu makale, tekstil endüstrisinde verimliliği artırmak için Lean Üretim Aracı olarak Değer Akış Haritalama'yı sunmaktadır. Bu bağlamda, özellikle otomobil endüstrisindeki faydaları da dikkate alarak VSM literatürü nitel olarak değerlendirildi. Değer Akış Haritalama, Kamerun'da Tailors of Cameroon adlı tekstil şirketinde üretimi artırmak için kullanıldı.

Bu şirket, aşırı üretim, fazla işlem ve uzun kurşun süreleri gibi nedenlerle verimsizdi. VSM, ham madde girişinden bitmiş ürün çıkışına kadar tüm üretim sürecini haritalamak için kullanıldı. VSM analizi, fazla envanter, operatörlerin boş zamanları ve hatalar gibi atıkların eleme alanlarını tanımladı.

Şirkette yapılan VSM analizi temelinde, sabit bir üretim hızı kullanma ve ihtiyaç duyulan işleme taşındığında operatörlerin çapraz eğitim alması ve üretimin düzgünleştirilmesi gibi değişiklikler uygulandı. Bu değişikliklerin sonucunda, kurşun süresi 39.93 günden 19 güne düşürüldü, kurşun süresi %52.4 azaltıldı, üretkenlik yaklaşık %20 artırıldı ve kalite seviyesi %10 artırıldı.

Bu vaka çalışması, VSM'nin bir şirketin tekstil üretim verimliliğini artırmak için kullanışlı bir yaklaşım olduğunu göstermektedir. Tekstil şirketleri, VSM sayesinde atıkları tanımlayabilir, maliyetleri azaltabilir ve kendi üretim süreçlerini geliştirebilirler. Bu incelemenin uzmanlığı, bu alandaki mühendisler ve profesyoneller için bir yol haritası olarak hizmet edecektir.

ACKNOWLEDGEMENTS

First and foremost, I want to express my heartfelt gratitude to the Almighty God for his divine strength and protection in completing this program successfully. Furthermore, my heartfelt gratitude goes to Prof. Dr. ALI KOKANGUL for his guidance and unending support of this masterpiece as a supervisor.

I'd like to take this opportunity to thank the Professors, lecturers, and colleagues in the Industrial Engineering Department at Cukurova University in Turkey. This thesis could have been a disaster without them.

My heartfelt gratitude also goes to my brother Douglas and my mother for providing me with this once-in-a-lifetime opportunity to study abroad. It was a once-in-a-lifetime opportunity for which I will be eternally grateful.

Finally, I'd like to express my gratitude to my family and loved ones for their prayers and unwavering support throughout my studies in Turkey.

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LIST OF ABBREVIATIONS AND SYMBOLS

CO : Change Over-time.
CT : Cycle Time CO
FIFO : First In First Out
LM : Lean Manufacturing
MIFM : Material and Information Flow Mapping (MIFM)
PCS : Production Control and Scheduling
PLT : Production Lead Time PLT
Sec : Seconds
SEM : Structural Equation Modeling
T : Takt Time
Ta : Net Available Time to Work
Td : Total Customer Demand.
VSM : Value Stream Mapping

1. INTRODUCTION

1.1. Background

Nowadays it is impossible to talk about the basic necessities of life without mentioning clothing. The older generation would argue that only food and health count as important necessities of life, but people will live tormented and prone to disease due to lack of clothing. The exponential growth of the world's population has shined light on the indispensable need for clothing and thus the need for textiles. Rapid population growth has caused the need for textiles to skyrocket. This has led to the rapid growth of the textile industry forcing the production rates within the textile industry to be faster than ever before.

We are aware that the textile industry is a multi-billion-dollar industry that contributes greatly to the Turkish economy. It goes without saying that as this industry grows, competition increases and there is a need to remain competitive among thousands of companies in this field (Jones, 2016). An effective way for any company involved in textiles to stay relevant and compete in this industry is to increase productivity. Productivity plays a critical role for businesses as it controls the real income needed to meet obligations to customers, employees, shareholders, and the government through taxes and remain competitive in the marketplace. The textile industry, one of the most labor-intensive sectors, has managed to expand its competitiveness over time by acquiring new production and marketing strategies (Kumar, 2017). Based on real-world observations, the industry faces numerous challenges to meet demand and avoid delays in product delivery, often caused by non-value-added activities at various workstations in the production of textile product components. One approach that can address all of these, reduce waste, remain efficient and increase productivity is lean manufacturing.

Textile mills and other manufacturing sectors around the world have used lean manufacturing principles to achieve their goals. Lean is now the talking point for every organization. Nearly every manufacturing or service industry has attempted to become "lean" in recent years even though it has been used as a production strategy since the 1950s (Jones, 1994). Lean manufacturing is a production method that uses fewer resources than traditional manufacturing. It requires the elimination of all activities that do not add value to the customer or Muda which is a Japanese word for waste. The idea of lean manufacturing is the identification and elimination of wastes which are overproduction and inventory, material movement, waiting and delays, over processing, motion, rework, and defects. Lean manufacturing, also known as lean production, is the most efficient way to produce goods by eliminating waste and implementing flow, as opposed to batch and queue (Kumar, 2017). Lean manufacturing is a general process management philosophy based primarily on the Toyota Production System (TPS). Companies not only eliminate waste, but also strive to maintain their competitiveness in line with their competitors. To improve the effectiveness of the production system, lean manufacturing employs tools such as VSM, Kanban, kaizen, 5S, CONWIP, and others

(Singh, 2020). The tools that enable the elimination of waste in technical processes are equally important, and little has been done to transfer the application of lean tools from manufacturing to the textile producing industries. One graphical tool we will concentrate our efforts on for this paper is value stream mapping.

VSM developed by Toyota in 1960's emerged because of the success of the Toyota Production System (TPS) in Japan and it is a graphical tool and an effective lean tool used to identify hidden waste and sources of waste. Before we get into the definition of VSM, keep in mind that a value stream exists whenever a product (or service) is provided to a customer, the difficulty lies in seeing it. To identify value streams, the company must first understand what the customer needs in terms of features and performance and how much they are willing to pay for the product. This activity yields a clear understanding of what products the customer requires. All the actions currently required to move a product through the key flows essential to each product are called the value stream. We are essentially looking at the flow of production from raw materials into the hands of customers to the flow of design from concept to market. VSM visualizes and streamlines work processes through the use of lean manufacturing tools and techniques. VSM assists in identifying, highlighting and reducing waste in processes and serves as a blueprint for Lean Manufacturing.

1.2. Problem statement

From a production standpoint, this thesis proposes VSM as a Lean manufacturing tool. VSM complies with a set of parameters that can be used to compare a future state of production to the current situation. Despite the fact that there are numerous other Lean production tools available, VSM meets many of the criteria that researchers believe are required to perform a dynamic evaluation of production processes. The purpose of this thesis is to improve production processes along with productivity in the textile industry by using VSM as a learning tool.

1.3. Advantages of VSM

Many advantages exist to using VSM as a lean tool and some of them are as follows.

- The big picture and cogent communication are used in VSM to help you better understand how to implement the new data and actions properly.
- VSM joins the distribution pathways and supply chains. The information and material flows are also included by connecting all the bodies of the production process.
- All the production control and scheduling functions (PCS), including production planning and demand forecasting, production scheduling, and shop floor control, are linked within the value stream map using the manufacturing system's operating strictures.

- You can include a lot of industrial engineering techniques to analyze flow with value stream mapping.
- VSM provides the foundation for successfully implementing lean manufacturing because you now have a production system that highlights a product's total dock flow.
- VSM provides you with a prototype of your production process, making it easier to strategize and apply the lean principles.

1.4. Disadvantages of VSM

While there are undoubtedly several advantages to consider, it's imperative to also acknowledge the potential disadvantages associated with the use of VSM.

- VSM, unfortunately, does not work for many products with different maps.
- VSM fails to account for delays and changes caused by poor structural layout and material mismanagement as a result of operation structures.
- Just like the industrial engineering flow process charting technique, VSM lacks economic measures for value such as profits, inventory expenses, operating costs, and so on.
- The plant's lack of a three-dimensional structure causes a sense of impracticality when changes to the future map are implemented.
- It is likely that only products with high volume and low variety manufacturing systems will be considered in respect to continuous flow.
- VSM's floor space is an undercooked and often ignored aspect. This causes resource unuse, which affects many production processes, including work in progress storage, support, and production.
- VSM does not explain its role in order throughout, operating expenses, and work in progress adequately.
- VSM does not include all factors related to the production process. Queuing delays, capacity constraints, and order throughout are just a few of the overlooked factors.
- Due to the manual creation of value stream maps, the maps cannot develop rapidly, nor can there be several contingency plans for time or budget limitations.

1.5. Justification

It is expected that at the end of the study, the efficiency and productivity required to meet customer requirements will be achieved and recommended to textile companies to increase productivity and lower production costs. Implementing Lean is about providing the right things, at the right time, in the right place, and in the right quantity to achieve a perfect workflow while minimizing waste and remaining flexible and adaptable. Lean strives to make work easier to understand, do, and manage.

1.6. Objectives

This study's objectives is solely to use of VSM in textile producing companies to

- Identify waste and Increasing productivity.
- Improve the efficiency of the textile manufacturing industry.
- Reduce non-value-added activity.
- Reduce Lead time.
- Maximize machine, men, and space utilization.

1.7. Research Questions

In addition to meeting the stated objectives and fulfilling the purpose of the project, this thesis will provide answers to the following questions to support the research objective:

1. How should VSM be applied in a company that has never been exposed to a structured way of working with lean manufacturing?
2. What are the most important variables to consider when aligning the operations of a recently acquired company with lean manufacturing?
3. What elements are required to make VSM function as a tool for analyzing various lean proposals?
4. How does a dynamic VSM outperform other lean tools?
5. What kind of data can VSM provide for the analysis of different lean proposals?

1.8. Hypotheses

In the course of writing this thesis the following hypotheses were considered.

- VSM as a lean manufacturing tool assists top managers in identifying and eliminating major wastes in the production flow leading to significant in productivity.
- VSM can be used to enhance the flow of materials and information through the textile manufacturing process, resulting in shorter lead times and more efficiency.
- VSM can be utilized to increase communication and collaboration among textile producing departments, resulting in less waste and higher output.
- VSM in combination with another LM tool reduces inventory and thus improves the company's overall turnover.

- Implementing lean activities makes the company more liquid, which increases profits.
- The application of lean activities creates more space and expands business opportunities.

2. LITERATURE REVIEW

This part of the thesis focuses on the literature review, key studies and research were examined and reviewed. This chapter, for ease of understanding, previous studies are divided into three groups for better understanding. Each group begins with the origins of the method and progresses to the current model. In order to receive as much information as possible, articles have been retrieved from a variety of journals, web of science including Google Scholar, Research Gate, Discovery, Journal of Business Logistics, and International Physical Distribution& Logistics. In addition, Cukurova University Library databases and search engines were used to look for relevant material. All of the above-mentioned were selected because of their eminently large body of literature on this subject.

Although a few relevant articles were obtained from these journals, the intention was not to focus solely on them. As a result, the search was not restricted to specific journals; rather, key words related to the specific case in this study were used. These key words were strongly related to the previously mentioned concepts of lean production, value stream mapping, textile plant design, manufacturing transformation and textile production process. The documents searched range from 1989 to most recent publication dates, highlighting the most recent publications.

Aside from the articles from the databases, a few books have also made significant contributions to this study. The book “Case Study Research: Design and Methods” by Robert K. Yin was essential in determining the scope and structure of this study. Other important books include Professor Jan Olhager's “Operations Management Research” and Dr. Klaus Erlach's “Value Stream Design - The Way Towards a Lean Factory”.

In addition, Jeffrey K. Liker's book “The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer” has been used extensively. In 2012, the author of this book was inducted into the Association for Manufacturing Excellence Hall of Fame.

2.1. Lean Manufacturing or Lean Production

Multiple researchers have conducted research on lean manufacturing. According to Womack, Moore and Jones (1998), organizations of all sizes are implementing lean manufacturing or lean production practices to respond to competitive challenges. They found that lean initiatives can be implemented worldwide in the automotive, aerospace, and consumer goods industries. Pavnaskar, Sandeep J., Gershenson, John K., and Jambekar, Anil (2003) offer a classification approach to link manufacturing waste concerns to lean manufacturing tools (Pavnaskar, et.all, 2003). This classification scheme systematically organizes lean manufacturing tools and metrics based on their level of abstraction, the tool's appropriate location of application in the organization, whether it addresses management waste or activity waste, the type of resource waste it addresses, and whether it identifies waste, measures waste, eliminates waste, or does all three. It gathers 101 lean manufacturing tools and metrics using this framework and shows how to apply them to common manufacturing challenges. The program will assist businesses in becoming lean and will act as a platform for future lean science research. Melton and Trish (2005), suggest that lean manufacturing can enhance productivity, quality, and profitability for organizations in process industries. Companies can generate considerable gains by implementing lean manufacturing and focusing on the success criteria of leadership commitment, employee involvement, training, and continuous improvement. Moore discussed various lean manufacturing implementation tools that can be used in the industry. According to Goriwondo et al. (2011), lean manufacturing can reduce waste defects by 20%, unnecessary inventory by 18%, and motion by 37%. Lean manufacturing is a systematic approach to eliminate waste and redesign processes (Alaca & Ceylan, 2011; Hazmi et al., 2012). The survey method was used by Marodin et al. (2014) to categorize the risks that affect lean manufacturing and to determine the relationship between these risks (Marodin, et all. 2015). Castillo et al. (2014) used Lean Manufacturing to study the impact of lean manufacturing in the Chilean mining industry. Netland (2015) examined the impact of contingencies on lean manufacturing. Dora et al. (2015) used LM tools to identify and categorize waste in agriculture in Belgium (Netland and Torbj, 2016). Karakadilar and Hicks (2015) used structural equation modeling (SEM) to examine the impact of lean manufacturing on supplier performance (Karakad, et all. 2016). Zahraee (2016) used a survey method to define affective activities and tools in lean manufacturing and demonstrated the importance of conditions in the application of lean manufacturing (Zahraee and Seyed, 2016). Suhardi et al. (2016) conducted a survey in an Indonesian furniture company and found that a lean manufacturing company was able to reduce cycle times by 42 percent (Suhardi, et all. 2019). According to Mitsuo et al. (2016), kaizen has been used in the metal-mechanical industry to reduce lead time and inventory. Hasan et al. (2017) use lean manufacturing to reduce waste movement, shorten lead times by 8%, and increase production capacity by 8.8%. Aflah et al. (2018) use lean manufacturing to reduce production lead times by 34% in the sock industry (Zahraee and Seyed, 2016). According to Ravizar and Rosihin (2018), implementing lean manufacturing in the production of absorbent materials can reduce production time from 61 minutes 34 seconds to 58 minutes 47 seconds (Ravizar and Rosihin, 2018). Saranya and Nithyananth (2012) [16] sought to identify areas of waste that could be reduced or eliminated using lean techniques in the crankshaft assembly supply chain of two-wheeler manufacturers in southern India. They conclude their work in terms of lead time, Work in progress reduction and cost transfer from current process to proposed process(Suhardi, et all. 2019). Renu et al used a lean approach in the manufacturing industry. The main tool used to identify opportunities for different lean techniques was VSM. As a result of this work, lead time and WIP inventory were reduced.

2.2. Value Stream Mapping (VSM)

Numerous researchers have used VSM to improve production, inventory control, and WIP reduction. This serves as a motivation for the research project. VSM is a standardized method of documenting the process steps and flow of work items, followed by a systematic analysis of these processes to develop an improvement plan (Ali et al., 2016; Chen et al., 2012; Damelio, 1996; Tapping and Shuker, 2003). The visualization and quantification of process flow makes it easier to identify waste and other value chain constraints. VSM has emerged as the preferred method of supporting and implementing the lean approach (Grewal, 2008; Serrano et al., 2008; Seth and Gupta, 2005; Tortorella et al., 2016; Tyagi et al., 2015) VSM is a standardized method of documenting the process steps and flow of work items, followed by a systematic analysis of these processes to develop an improvement plan (Ali et al., 2016; Chen et al., 2012; Damelio, 1996; Tapping and Shuker, 2003). The visualization and quantification of process flow makes it easier to identify waste and other value chain constraints. VSM has emerged as the preferred method of supporting and implementing the lean approach (Grewal, 2008; Serrano et al., 2008; Seth and Gupta, 2005; Tortorella et al., 2016; Tyagi et al., 2015).

Pioneers such as Taiichi Ohno (1988), Womack et al (1990), Womack and Jones (1998, 2005), Daniel. T. Jones (2006), Rother and Shook (1999), Kevin J Duggan (2002), and Peter Hines and Nick Rich (2002), investigated the role and implementation of VSM in depth. Taiichi Ohno (1988) was unable to identify waste with a quick look (especially across a geographical area) (Ohno, 2019). He created Material and Information Flow Mapping (MIFM) as a conventional technique for visually mapping the flows, and it became Toyota's benchmark for designing improvements - as a shared language. It evolved into one of their business planning techniques. John Shook and Mike Rother, who were pioneers in introducing material and information flow diagramming and how to develop lean thinking using that practice together wrote the book that was published by the Lean Enterprise Institute in Cambridge. This book explained that VSM is a flexible tool that allows us to put all the information in one place in a way that process mapping is done while other tools do not allow it. Bhim Singh and collaborators: In their research paper, they discovered that the authentic ideas and meanings of VSM demonstrated the relevance of mapping both inter-company and intra-company value-adding streams.

Duggan (2006) discusses how to utilize VSM and lean concepts to hybrid model production. Producing a variety or mix of products or product variations through the same value stream at the customer's pull is known as mixed model production. According to Ramesh et al (2008), VSM is a technique that involves flowcharting steps, activities, material flows, communications, and other process elements that are engaged with transformation. Lopez et al. (2013) proposed value stream costing as an alternative costing technique for lowering costs in the lean enterprise. VSM was used by Jasti and Sharma (2014) to analyze materials and manufacturing processes in the Indian auto components industry. VSM was used by Rohani and (2015) in the color industry to improve production lines and eliminate waste; as a result of this case study, Production Lead Time (PLT) and Cycle Time (CT) were reduced. According to Tyagi et al. (2015), VSM was used to achieve lean thinking and to develop products while eliminating wastes, inefficiencies, and non-value-added steps.

Hines, Peter & Rich, Nick (1997), presents a new typology for value stream mapping (VSM) that is based on the many types of trash that exist in value streams. The typology includes seven distinct maps, each of which is intended to identify and reduce a unique sort of waste. The authors contend that this typology is completer and more flexible than other existing VSM frameworks, and that it may be used to efficiently map and optimize value streams across a wide range of businesses. Azizi used VSM and Kaizen activity to improve productivity in small and medium-sized businesses by removing waste and non-value-added transactions. Atieh and colleagues (2016), VSM was used to improve the manufacturing process in a medium sized glass production company. Klç and Ayvaz (2016) used VSM, 5S, and SMED to analyze the influence of a gasket which is used in a Lean Manufacturing assembly line. According to Jeong and Yoon (2016), with the application of VSM, the total lead time for the provision of process databases can be lowered from 20 days to 3 days, a 92 percent reduction in the overall lead time. Using the VSM method, Kumar et al. (2017), were able to increase productivity and reduce production process cycle time by 48.7 percent. VSM was implemented in a bread manufacturing firm by William et al. The following are the current and future states of a manufacturing firm: non-value-added activity was reduced by 40%, and throughput time was increased (Goriwondo,et all. 2011).

Renu et al [22]. used a lean approach in the manufacturing industry. The primary tool for identifying opportunities for various lean techniques was VSM. As a result of this paper, lead time and Work in progress inventory were reduced. Yang-Hua Lian et al. presented a concept for value stream maps of a system using simulation to reduce lead time and Work in progress inventory in their paper. Nitin and Sanjiv used VSM in the gearbox manufacturing industry to determine the takt time, and the implementation effect of VSM was diminished cycle time and waiting time.

In the pharmaceutical sector, W.M.Goriwando explain value stream mapping. For the case study, the LCO production line is used. The non-value-added activity was then identified and eliminated using the line balancing concept, resulting in a reduction in cycle time and lead time. Abbett and Payne describe a VSM application in the aircraft manufacturing industry. They created current and future state maps with the goal of reducing lead time and increasing productivity in accordance with customer requirements. In their work, Rumbidzayi Muvunzi (2013), sought have tried to reduce waste between processes. So, draw a map of the current state that includes waste as a kaizen blitz, a ranking of the seven wastes, and then reduce processing time. Finally, draw a map of the future state that includes a supermarket pull system, reducing lead time, and improving productivity.

2.3. Original Contribution Value Stream Mapping (VSM) Applied in Textile Sector

Smith (2019), stated that the original contribution of Value Stream Mapping (VSM) application in the textile industry lies in its ability to identify hidden waste and sources of waste in the textile production processes. By visualizing and streamlining work processes through the use of lean manufacturing tools and techniques, VSM can assist in identifying, highlighting, and reducing waste in processes and serve as a blueprint for Lean Manufacturing in the textile industry. Jones (2016), also noted that the application of VSM as a Lean manufacturing tool can help to improve production processes along with productivity in the textile industry by providing a set of parameters that can be used to compare a future state of production to the current situation. This researcher also added that despite the availability of numerous other Lean production tools, VSM meets many of the criteria required to perform a dynamic evaluation of production processes in the textile industry. Therefore, the use of VSM as a leaning tool in the textile industry can significantly improve the effectiveness of the production system (Kumar, 2017), and enable companies to remain competitive in line with their competitors while eliminating waste and increasing productivity.

Senthil Kumar and Sampath (2017), conducted a case study on VSM implementation in the T-shirt production industry and found that reducing the work in progress level by changing the layout of the production process increased profit by 20-22 percent from the previous level. In another study, Aflah et al. (2018) utilized lean manufacturing to reduce production lead times by 34 percent in the sock industry. GÜZEL, Dilşad, Ahmet Kamil KABAKUŞ, and Muhammed Sabri Şirin (2018) apply lean manufacturing techniques, notably value stream mapping (VSM), to optimize a textile company's production line. The writers used 5S concepts to shorten lead times and boost production. The results revealed that using lean methodologies reduced production lead time (PLT) from 14.5 days to 5.2 days.

Sakthi Nagaraj, Thandapani, Jeyapaul, Rajamani, Vimal, KEK, and Mathiyazhagan, Kaliyan (2019) studied how to integrate human factors and ergonomics (HFE) with lean manufacturing strategies to increase workers' quality of life and operational performance. The authors created a modified value stream map (VSM) named Ergonomic VSM (Ergo-VSM) to identify ergonomically significant operations and evaluate human aspects alongside lean criteria. Action study conducted in the Sri Lankan textile sector revealed the efficacy of Ergo-VSM in obtaining the desired results. The findings indicate that an integrated approach to HFE and lean manufacturing benefits both workers and companies. Carvalho, CP, Carvalho, DS, and Silva, MB (2019), focus their article on the use of lean manufacturing tools value stream mapping (VSM) and Kanban in a textile industry to improve cost-cutting techniques. The authors argue that VSM and Kanban are useful for lowering inventory and increasing overall efficiency. They also argue that traditional accounting methods should be updated to better reflect the advantages of lean production. It is worth noting that there is little literature on this topic because few people have attempted to apply VSM to the textile industry, so the focus of this paper is exclusively on the textile industry.

VSM has been shown to be an effective tool in identifying waste and inefficiencies in production processes, which can lead to improved productivity in the textile industry. By visualizing the entire production process and analyzing each step, VSM can help to identify areas where time and resources are being wasted and suggest changes to streamline the process and increase efficiency.

Overall, the use of VSM in the textile industry can lead to a reduction in lead times, increased productivity, and ultimately, increased profitability. However, it is important to note that the effectiveness of VSM implementation can vary depending on the specific company and production processes, and successful implementation may require the support and cooperation of all employees involved in the production process.

3. MATERIAL AND METHOD

3.1. Method

This section of the thesis will also go over the step-by-step VSM implementation, method and outline some VSM vocabulary terms used for this thesis. VSM is a lean manufacturing technique that is commonly used to optimize processes and improve efficiency in various industries, including the production of textiles and T-shirts. Here's an overview of how VSM can be applied to the production of T-shirts. The first step is the identification of the scope of the Value Stream by identifying all problems you can find on the value stream. Once the value stream is identified, a current state map is created. Then we have the identification of waste. Next, the creation of the future state map and finally the implementation of changes.

3.2. Value Stream Mapping Terminology

- **Bottleneck:** The operation with the longest cycle time per unit or the lowest capacity is referred to as the bottleneck. A bottleneck operation not only determines the production rate, but also determines the capacity of the manufacturing process (AIGPE, 2023).
- **Buffer:** The Buffer, which is the inventory taken between operations, creates a counterbalance in the cycle time of the operations (AIGPE, 2023).
- **Changeover:** The changeover time, also known as the setup time, is used to prepare an operation for the introduction of a new product (AIGPE, 2023).
- **Customer Demand:** This term refers to the number of products that are likely to be ordered by customers within a given time frame (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Cycle Time:** This is the total amount of time required by an operator to complete one cycle of a task from start to finish before repeating this operation (AIGPE, 2023).
- **Downstream;** Downstream processes are the operations that follow the current operations in focus and receive finished or unfinished work-in-progress goods (Vinodh, 2022).
- **Downtime:** Downtime is the time when a piece of equipment or machinery that is required is not available for a variety of reasons. These reasons can range from machinery breakdown to scheduled maintenance (Vinodh, 2022).
- **Essential Non-Value-Added Time:** This term refers to all of the unnecessary but inefficient periods of time spent in an operational process, such as unpacking deliveries, delivering parts, and even transferring tools from one hand to the next.

- **FIFO**: The acronym FIFO stands for First-In-First-Out. The first in, first out (FIFO) system manages products as they arrive in the queue (Lian and Van Landeghem, 2002).
- **Flow**; is defined as a continuous production process with no buffers in the middle of operations (Heidelberg, 2012).
- **Heijunka Box;** It is a scheduling system that equalizes operations in the heijunka box. The Heijunka box is covered in detail in a separate part of this thesis (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Inventory:** It is all stored goods are referred to as inventory. Inventory is performed prior to, during, or after a process with finished products (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Inventory Lead Time:** This is the time it takes for goods or products in inventory to arrive (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Kanban:** Kanban cards are signs that guide customers' needs downstream (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Lead Time:** The lead time can range from minutes to hours to days. It is the amount of time required for an operation process to be completed. The lead time can also refer to the time it takes for the next action to begin (Alaca and Ceylan,2011; Karmarkar and Uday,1993).
- **Non-Value Adding Time;** This is time that the customer is unwilling to pay for. Non-value-adding time includes time spent on activities such as double handling, stacking intermediate products, or even waiting time because they do not directly add value to the product. It is a waste that should be eliminated or reduced as much as possible (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Operation Time:** The amount of time spent on the production of a product is calculated as the changeover time plus the processing time (Abdulmalek, 2007).
- **Process Efficiency:** Also known as flow time efficiency, process efficiency is calculated by dividing total process time by total lead time. It is the proportion of process or value-adding time to lead time (Damelio and Robert, 2011).
- **process time:** The processing time, also known as the process lead time, is the approximate amount of time required to handle a process in a production step. The processing time includes the time it takes to prepare the order, move it, run it, put it away, and inspect it. The processing time and cycle time are interchanged in simple processes (Damelio and Robert, 2011).
- **Pull**: According to the pull principle, customer demands drive production. When there are no customer demand, there is no production process (Damelio and Robert, 2011).

- **Push**: The push principle comes into play when the production process operates at full capacity, notwithstanding the customer demands (Damelio and Robert, 2011).
- **Quality Rate**: While the quality rate can be indicated by defective products sometimes, it is well known as the ratio of all acceptable products (Seth, Dinesh, Gupta, and Vaibhav, 2005).
- **Setup Time;** Check changeover time (Heidelberg, 2012).
- **Takt Time;** Takt time is the amount of time required to produce one unit of a product to meet customer specifications. Takt Time can be calculated using the following formula: T = Ta divided by Td. Takt Time is denoted by the letter T. Ta is an abbreviation for Net Available Time to Work, and Td is an abbreviation for Total Customer Demand (Das, et all. 2014).
- **Upstream;** Upstream refers to all operations that are part of the first stages of the manufacturing process or the value stream (https://www.oee.com/takt-time/origins/. [Accessed 3 February 2023]).
- **Uptime:** Uptime is a term used to indicate that the required equipment is operational. It is the inverse of the term downtime (https://www.oee.com/takt-time/origins/. [Accessed 3 February 2023]).
- **Value-Adding Time;** This is the time that the customer is willing to pay for. The value-adding time, which is usually indicated by the processing time, is the total amount of time spent on activities that add value to the product (https://www.oee.com/takt-time/origins/. [Accessed 3 February 2023]).
- **Value-Adding Operations**; Value adding operations are the operations that involve the transformation of raw materials into finished products (Hines and Nick, 1997).
- **Waiting Time;** it is a type of waste that occurs when both the equipment and/or personnel do nothing and remain idle. It can happen during inventory or while waiting for raw materials to arrive. It can also happen during a machine's unplanned downtime (Rahani, Al-Ashraf ,and Muhammad, 2012).
- **Waste:** Waste is a catch-all term for any process, action, or inaction that does not add value to the manufacturing process. Overproduction, over processing, unnecessary transportation, inventory, motion, waiting periods, and defects are all examples of waste (Lian, Van Landeghem, 2002).
- **Work-In-Progress;** Work in progress, abbreviated WIP, follows the product throughout the manufacturing process. It displays the product's current position in the manufacturing chain. It is frequently used before the finished goods inventory and is used interchangeably (Abbett and Payne, 2023).

3.3. Case Study/Study Area

This section begins with a detailed description of our case study, which is the clothing company we used for this thesis. This section of the thesis will also go over the step-by-step VSM implementation in this company. Our case study involves a textile company with offices in both Cameroon and France and production site in both countries. Tailors of Cameroon specializes in producing high-quality fabrics, including cotton, linen, and silk blends. The company offers a range of products, including bed sheets, curtains, and apparel fabrics. They make white garments such as white shirts for school and government institutions and any company that requires white Garments. They also make white blouses for hospital doctors and nurses, as well as hospital bed sheets. Tailors of Cameroon is a supplier to several successful African fashion boutiques. They have both a sewing line and tailors who make shirts by hand for special clients or at the request of certain clients. Tailors of Cameroon is a small-sized textile company with approximately 50 employees working across two locations in Cameroon. The company has an annual production capacity of 1,000,000 units and a production rate of 3,000 units per day.

3.4. Manufacturing process at Tailors of Cameroon

This chapter will also go over the textile bulk white t-shirt production line and process. Normally, this factory produces hundreds of shirts with the same fabric and design. They produce white garments for the export market as well as for domestic brands. The production process of the company’s bestseller, which is only white t-shirts, was considered for ease of calculation. The entire process of making a t-shirt begins with sourcing the material, the design, pattern making, grading, cutting, sewing, finishing, packing, and the process ends once the order is shipped. The order's material requirements are calculated, and the order is sourced directly from mills and fabric suppliers. The factory purchases all materials, including woven fabrics, trims, and accessories. Fabric procurement takes about a month at the factory.

The design process for a T-shirt begins with a single hand sketch that considers what the client or customer has in mind. This sketch then develops into a pattern. To ensure that patterns are made correctly, sample shirts are made first. Because the factory must produce t-shirts in a variety of sizes, pattern grading is performed and patterns for all sizes are created. The first thing that the software AutoCAD designer does is determine the correct base size and fit, which is then used for grading. The CAD system can be used for pattern grading. Patterns are then created using CAD base programs, which are then printed out using a plotter. The plotter takes whatever was on CAD and turns it into a pattern that you can cut out. The printed sample is then taken to a cutter, who will use it to cut from a new roll of white textile material. This process necessitates highly skilled hand cuts. When we receive the cut pieces from a skilled cutter, they are delivered to the first sewer to be sewn together from the inside out. An experienced sewer knows exactly how to do this quickly with a sewing machine. When everything is in place. This sewer takes the cut panels and sews them together, starting from the shoulder tip through the shoulder and then sewing the neckband. Once sewed together, the sewer irons the t-shirt to keep the dimensions and ensure the t-shirt does not curl up while she returns to close the t-shirt, making sure it is closed in the correct place.

Once the sample is completed, it is sized and checked to ensure that it matches the client's description, and any changes are made. Once the pattern has been finalized, it is sent to production. At production, the pattern is checked, and the information is uploaded to the computer on the cutters. Markers are extracted from these computers. The computer stores the exact number of pieces to be cut, as well as all other specifications. The cutter then cuts according to the data that has been uploaded to it. Before cutting the textile material into pieces, this machine vacuum seals it on its table. This precisely cuts everything.

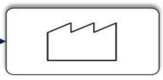
After all patterns are cut out, they are sewn together by a team of 10 other sewers, each with their own sewing machine. Each sewer is required to sew approximately 50 T-shirts per day. After this, the shirts are taken to the quality control department, where another team of five workers ensures that the shirts are sewed upright and that there are no loose threads or other issues that could result in a return or a bad product and do the packaging.

It is ready to be shipped or delivered to customers across the country once it has been sewn up and expected. The company primarily handles small-size orders, but these are increasing on a daily basis. When orders arrive, they are first assigned to a staff member. This staff picks up the order and brings it to the parking area, where another worker double checks that the order is correct, and once approved by this worker, it is ready for the logistic company to pick up and deliver, 5 days after the order is placed online.

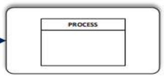
3.5. Value Stream Mapping Symbols

Value stream maps are constructed from up of several distinct symbols. A value stream map makes use of symbols to represent and simplify the flow of information and inventory within a system. It is a tool for eliminating waste and increasing efficiency to provide the best value to customers in the form of products or services. There are over 200 VSM symbols and they are divided into four categories: VSM general symbols, VSM process flow, VSM material flow, and VSM information flow .The icons used in this project are all listed below and could be found on the most engineering website like oee.com(OEE, 2023) and ToolingU.com (Toolingu|SME, 2023).

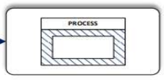
- **VSM PROCESS FLOW SYMBOLS**



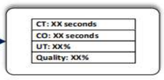
Customer/Supplier Icon: Indicative of the end point of the material, this icon represents the seller on the upper left and the customer on the upper right of the value stream map.



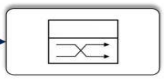
Dedicated Process Flow Icon: This icon represents a process, machine, operation or department through which material flows. It symbolizes departments with continuous and set internal flow.



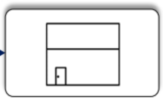
Shared Process Icon: This icon represents a work center, process, machine, or operation that is used by other value stream families.



Data Box Icon: This icon is listed with other icons that have the pertinent information needed for the analysis and inspection of the system.



Cross-dock Icon: this icon represents the receiving dock of the facility that transfers the incoming materials to outbound shipping without inspection.

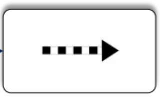


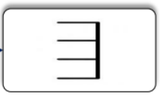
Warehouse Icon: this icon represents the warehouse that stores the materials.

- **VSM MATERIAL FLOW SYMBOL**


Inventory Icon: indicates the inventory in the middle of two processes.

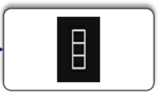

Shipment Icon: this icon can either represent the movement of raw materials from the sellers to till it gets to the factory or the movement of the finished products from the moment it leaves the factory until it gets to the customer.


Push Arrow Icon: signifies the movement of materials from one process to the next.


Supermarket Icon: this icon represents a Kanban stock point or an inventory 'supermarket'.

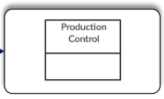

Material Pull Icon: this icon, which indicates physical removal, link the supermarkets with the downstream processes.

FIFO Lane Icon: depicting the First-In-First-Out, this icon links processes that are attached by a FIFO system which restricts input.

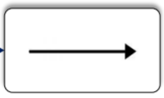

Safety Stock Icon: the icon is indicative of the safety stock or the inventory edge available to protect against sudden problems such as sudden changes in customer orders, downtime or system failures.


External Shipment Icon: this portrays the movement of materials or products to sellers or customers using external transport.

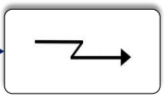
- ## VSM INFORMATION FLOW SYMBOLS



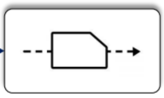
Production Control Icon: this icon can mean a person, department or operation. It signifies a key production arrangement.



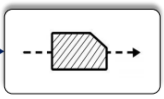
Manual Info Icon: the thin and straight arrow signifies the information flow from memos, conversations or reports.



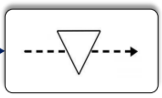
Electronic Info Icon: this icon shows how information flows by the means of electronic devices through the internet, the intranets, the LANs (local area networks), the WANs (wide area network) or the EDIs (electronic data exchange). It also indicates the frequency of information exchange, type of media used and type of information exchanged.



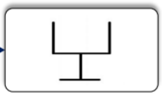
Production Kanban Icon: this icon kick starts the supplying procedure to deliver parts to a downstream process. This icon signifies that the manufacturing of a set amount of parts.



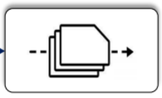
Withdrawal Kanban Icon: the presence of this card or icon informs the worker handling the materials to deliver parts from the supermarket to the receiving area.



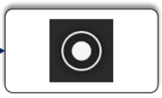
Signal Kanban Icon: also known as the 'one-per-batch' Kanban, this icon is used when the inventory levels in the supermarket on-hand drops to a minimum point between two procedures.



Kanban Post Icon: used with the two-card system for the removal and construction Kanban, this icon reveals the site where the Kanban sign stay for pickup.

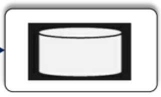


Kanban in Batches Icon: the presence of this icon reveals that several Kanban cards are going through the assembly process together.



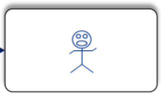
Sequenced Pull Icon: the pull system that delivers instructions to the several subassembly processes to make a specified number and type of products without the supermarket is indicated with this icon.

Load Leveling Icon: this icon is used to batch Kanbans. Kanbans are batched for the smoothening of the manufacture volume and mix over a particular period of time.



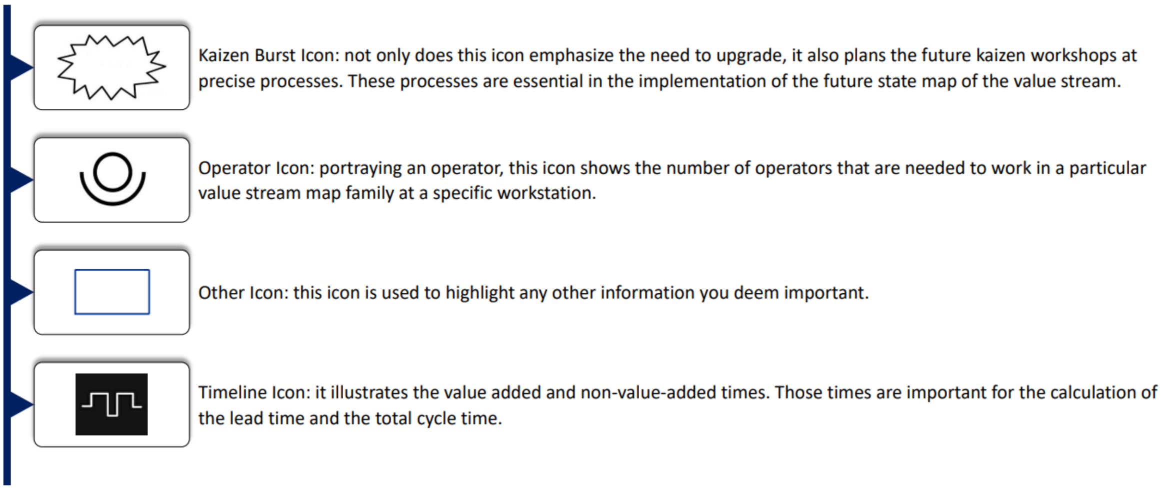
MRP/ERP Icon: it is used to plan the usage of MRP/ERP or any other centralized system.

Go See Icon: this icon stands for the visual collection of information or information that is personally and visually obtained.



Verbal Information Icon: this icon stands for the flow of information orally and personally.

- **VSM GENERAL SYMBOLS**



3.6. Steps Used in Creating the Current VSM Of Case Study

According to extensive research and VSM specialists, the best way to create a VSM is by hand. This is due to the fact that using a laptop frequently gives the impression of a finished product with no room for improvement. VSM created by hand allows for corrections and additional information. Selecting a product family, creating a VSM team, determining customer demand, mapping and designing process flow, mapping material flow, and mapping information flow are the steps to take in creating a current state VSM both manually and with the aid of a computer.

- **STEP 1: Selecting a product family and data collection.**

This was done by selecting a high-revenue good that could be produced in large quantities at our factory. The factory's best-selling t-shirts were chosen as the focus of this project. T-shirts were also chosen with the client in mind, taking into account speed, cost, and how satisfied the company's clients will be. My focus was on a single production of white t-shirts for ease of application of my thesis work. During the selection process, analyses were conducted with an intracompany focus, implying that the emphasis was on all departments involved in the creation of our white T-shirts.

Once the product line to be focused on is chosen

- **Data Collection**

Present The most important activity is data collection in order to get a clear picture of the assembly process and to understand the problems associated with it, and thus to define the problem. Data collection is divided into two categories, which are as follows:

- **Primary Information**

Personal observations, discussion, personal assumption were done after in-depth investigation on the floor was done considering the set of objectives. The primary data is gathered by the student. This is firsthand knowledge. The primary data is gathered through observations and personal discussions with the company's operational workers in light of the objectives. These data were inventory level, operator's productivity, Machine downtime, Takt time, Cycle time, production schedule and company's working hour, material waste, number of breaks and number of operators and packagers.

- **Secondary Information**

Table 1.1 depicts the Production activities.

Secondary data includes published data, cost sheets, income statements, and other relevant sources.

Table 1.1. Activity productions process table

Activity	Node	Description
	0	Receive order
A	1-2	Receive raw material and enter the BOM to the purchase end
B	2-3	Designing
C	3-4	Cutting
D	4-5	Sewing
E	5-6	Control and release to warehouse
F	6-7	Packaging and release to warehouse
G	7-8	Dispatch To customer

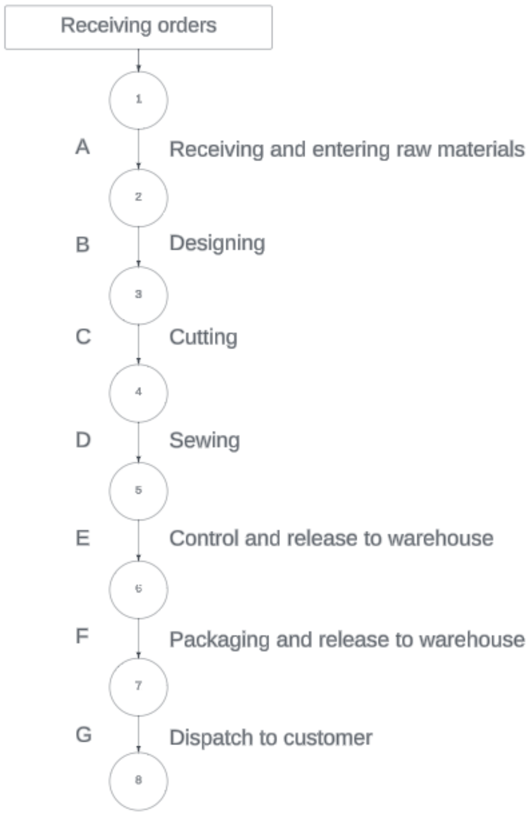


Figure 3.1: Production process flow chart

The next step to be taken is collecting data. Data collected is foundational for the creation of VSM. Heijunka box and Heijunka techniques was used to level up workload by volume. Heijunka box may not be used in this scenario. Figure 2 shows visual of what a Heijunka box.

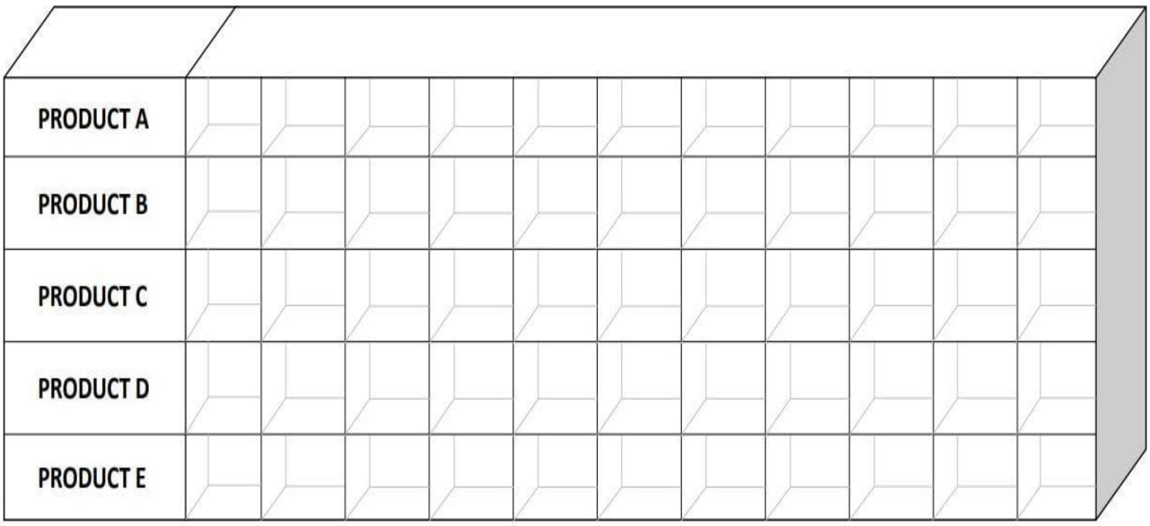


Figure 3.2. Heijunka box example

- **STEP 2: Creating a VSM team.**

The building of a VSM will often require effort from a team. To form a team, I collaborate with one person from each department involved in the production of the chosen product. Each person at the company I worked for had in-depth knowledge of this product and was very familiar with its production, which facilitated the pursuit of my thesis work. Working with members from each department has helped me understand the upstream, downstream, and parallel processes. The team also eased my work in collecting data I needed for my research work.

- **STEP 3: Determining customer demand.**

Identifying customer demand was critical for my thesis. A production history and sales review were completed. A weekly forecast was created as needed. This company's customer demand was a consistent quantity of 500 T-shirts per day. The customer is usually listed in the top right corner of VSM, and the customer demand is to the right of the customer icon.

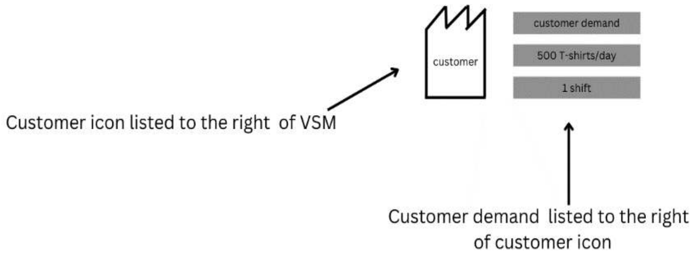


Figure 3.3: First part into creation of current VSM showing customer demand and number of shift.

- **STEP 4: Mapping and designing process flow.**

In this step, we begin mapping and designing process flow by defining the process's start and end points. This is an important step because an unclear boundary can lead to scope creep. To accomplish this, you must visit the company's production site and observe the production line of your chosen product. This allowed me to identify all the steps involved in bringing the product to life.

Before shipping of our product is done, they are kept in the warehouse. Before storing products in a warehouse, certain procedures must be followed. The final step is packaging, and the step before that is a quality control check. Sewing is the last step before quality control. The step before sewing is cutting, and the textile is kept in the warehouse before cutting.

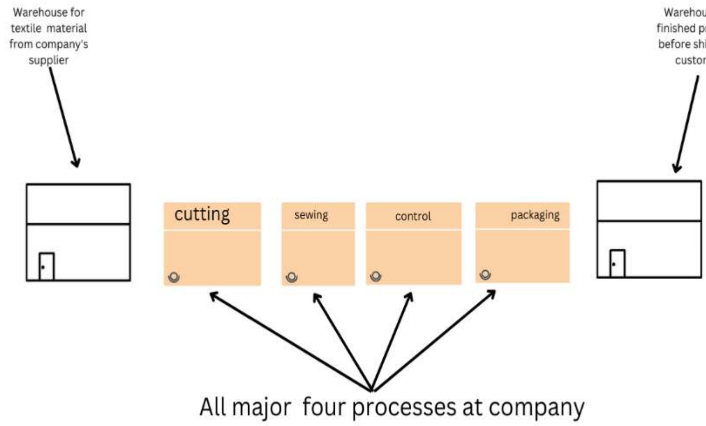


Figure 3.4. Part of current VSM that shows processes.

- **STEP 5: Mapping material flow**

Material flows from left to right on a VSM, while production flows from right to left. A truck symbol is usually placed on the arrow connecting the warehouse and the customer, indicating shipment from warehouse to customer. Arrows are added from one process to the next, each of which overlaps with the triangle icon indicating buffer material between two operations. Then, in the top left corner of the map, a supplier symbol is added, and an arrow is drawn between the supplier icon and the warehouse with a truck icon, indicating shipment from the supplier to the company's textile warehouse.

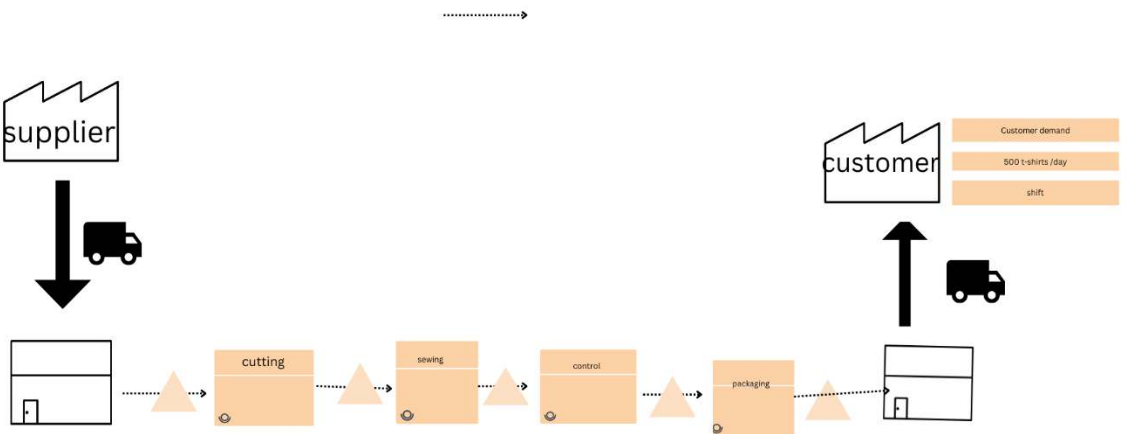


Figure 3.5. A portion the incomplete current VSM that maps material flow.

Each of these steps in the material flow receives the collected data. Before adding this data, data boxes are drawn beneath each process. This data box contains information gathered during a visit to the production site. These are the cycle time, change over time, up time, and quality. Because we were only dealing with white T-shirts, there was no need for a time change. Second, because the machines were new, the uptime in all operations was 100%.

A fluctuating line from left to right is drawn beneath the data. This fluctuating line start with non-value adding activity at the extreme left of the line and value adding activity at the extreme right of the line. This line begins with an inventory icon and progresses to the bottom with process details. The top section of our lines holds a number representing the delay from the accumulated buffer, and the bottom section of our lines holds the cycle time of each process.

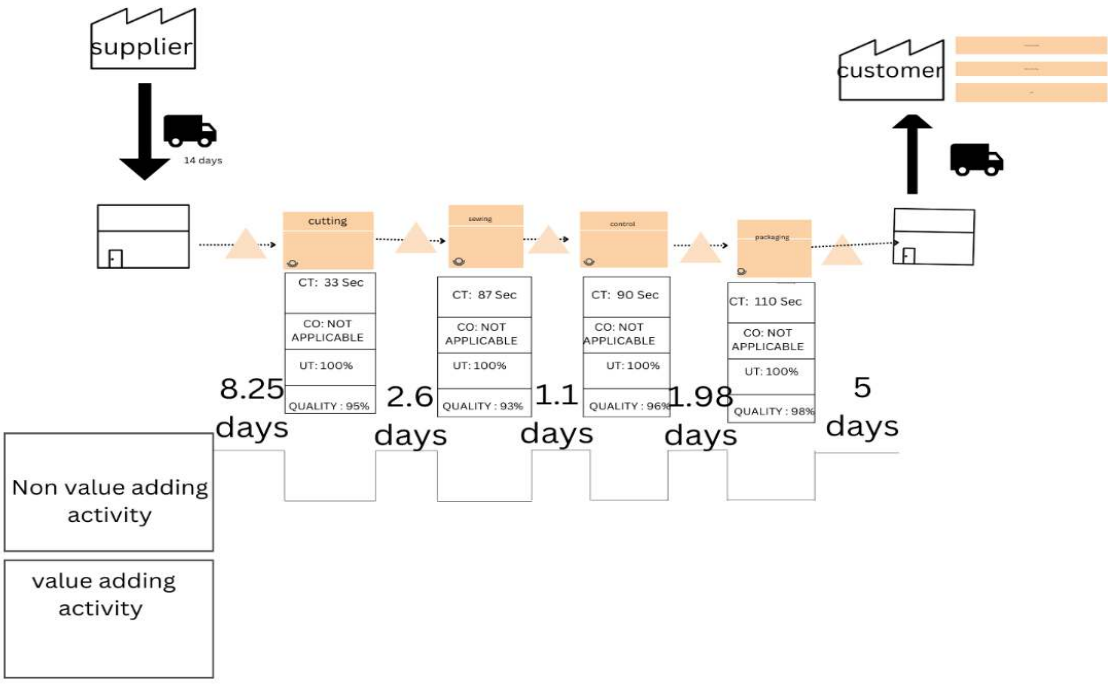


Figure 3.6. A portion the incomplete current VSM that maps material flow and shows data boxes.

- **STEP 6: Mapping information flow**

Information goes from right to left. First, when a customer calls and places an order, it is estimated that the customer will need 500 T-shirts per day. The forecast is only used for calculation purposes because demand is not linear and has a seasonality factor. The customer service team gets the order through call or when customer comes at the office and the customer's order is entered into a system; the data is then stored in a data storage and retrieval server. The customer service team generates a buying list of raw materials based on orders and the availability of existing inventory. This buying list is generated once per week based on the customer orders received that week, and then a preliminary production schedule is generated. The procurement team is then given a preliminary production schedule to work with. The procurement team waits another week before compiling a demand list based on preliminary production, schedule requirements, and available raw materials. The demand list is sent to the supplier for raw material procurement, and as you are aware, the supplier takes 14 days to send the raw materials. The production manager accesses the preliminary production schedule once the raw materials are received. The production manager creates and distributes a weekly production schedule to the floor supervisors. The weekly production schedule is distributed by the floor supervisors to each of the operational teams.

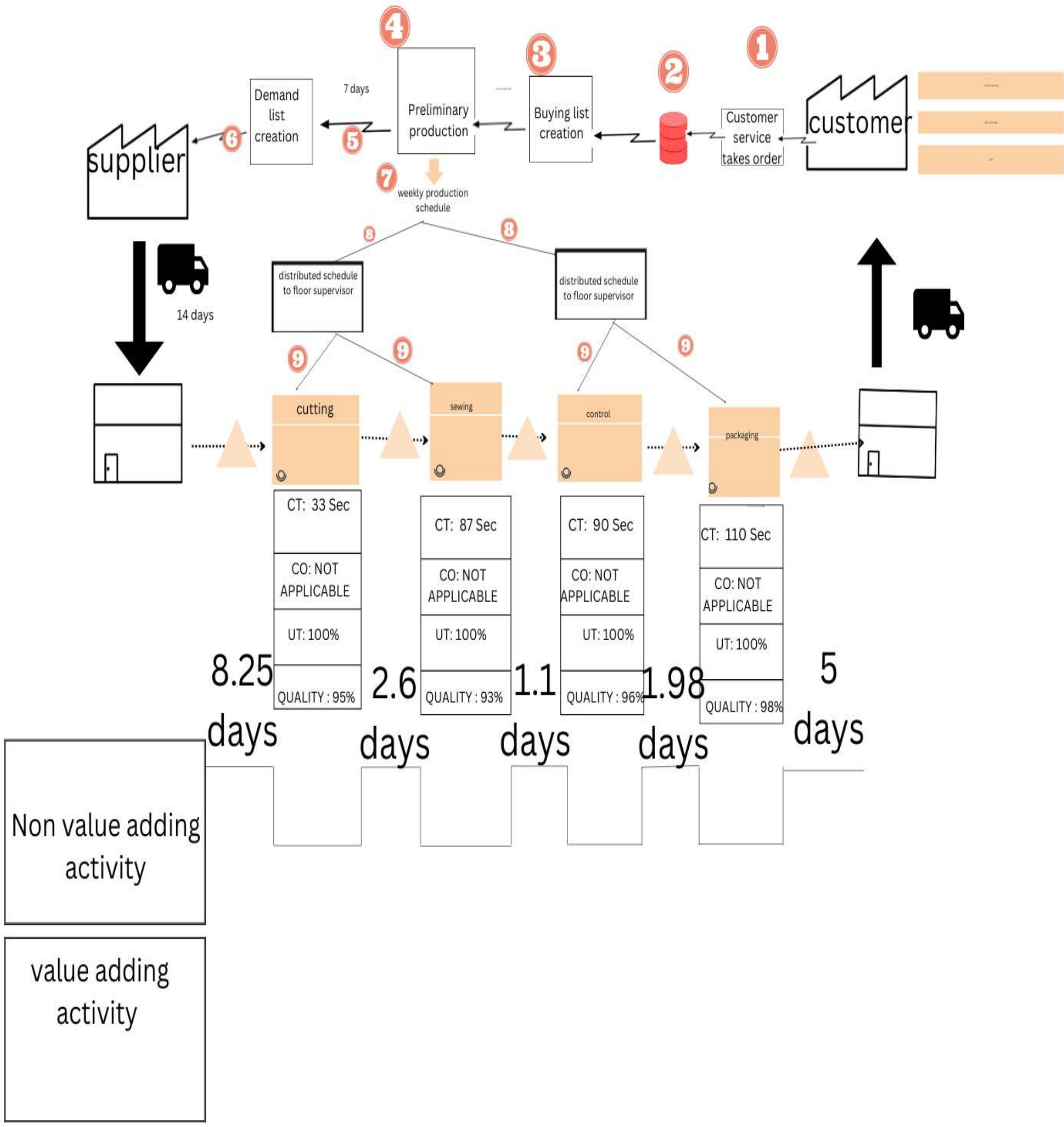


Figure 3.7. Almost complete current VSM that maps the process flow, material flow and information flow.

- **STEP 7: Calculations**

Step 7 performs calculations for the current state value stream map. This step involves calculating the following: process lead time, storage time, takt time, process time, or processing time of the value-added time, cycle time. All these are essentials for the analyses, improvement of the Current VSM in order to create the Future VSM. This will be further seen in the next Chapter.

3.7. Current State VSM

This chapter explained and built the current state value stream map piece by piece. Begin by mapping the process flow, then the material flow, and finally the information flow. The following step will be to compute and analyze the current state value stream map. The process begins when a customer calls and shares their requirements with the customer service team; the organization receives approximately 500 T-shirt orders per day; the customer service team documents the order on a data storage and retrieval system after receiving the orders for that week. Based on this buying list and the customer orders, a preliminary production schedule is created and sent to the procurement team. The procurement team waits one week before creating the demand list for the raw materials, which is then sent to the supplier. As raw materials are received from the supplier, the production manager accesses the preliminary production schedule and prepares the weekly production schedule. This weekly production schedule is passed on to the floor supervisors, who then send it to each operational process. The cutting process has a raw material inventory of 2475 days old. There is no changeover time in the cutting process, which has a cycle time of thirty-three seconds. Moving on to the sewing process, it has 786 work-in-process items with an aging of two days, a cycle time of 87 seconds, no change over time, and a quality of 93%. Coming to the control process, there are 330 work-in-process items with an aging of one point one day, a cycle time of ninety seconds, and no change over time. The up time is one hundred percent, and the quality is at ninety-six percent. Moving on to the packaging process, it has 594 work-in-process items with an ageing of 1.98 days, a cycle time of one hundred and ten seconds, no change over time, a 100% uptime, and a quality of 98%. The completed T-shirts are then delivered to the warehouse. The warehouse has an inventory of 1,500 finished T-shirts with a five-day aging period. After five days, these T-shirts are shipped to the customer. The operations team consists of three resources who work together to complete the four processes in one shift. The number of operators in this area is generally denoted, and this is how the entire current state value stream map was built.

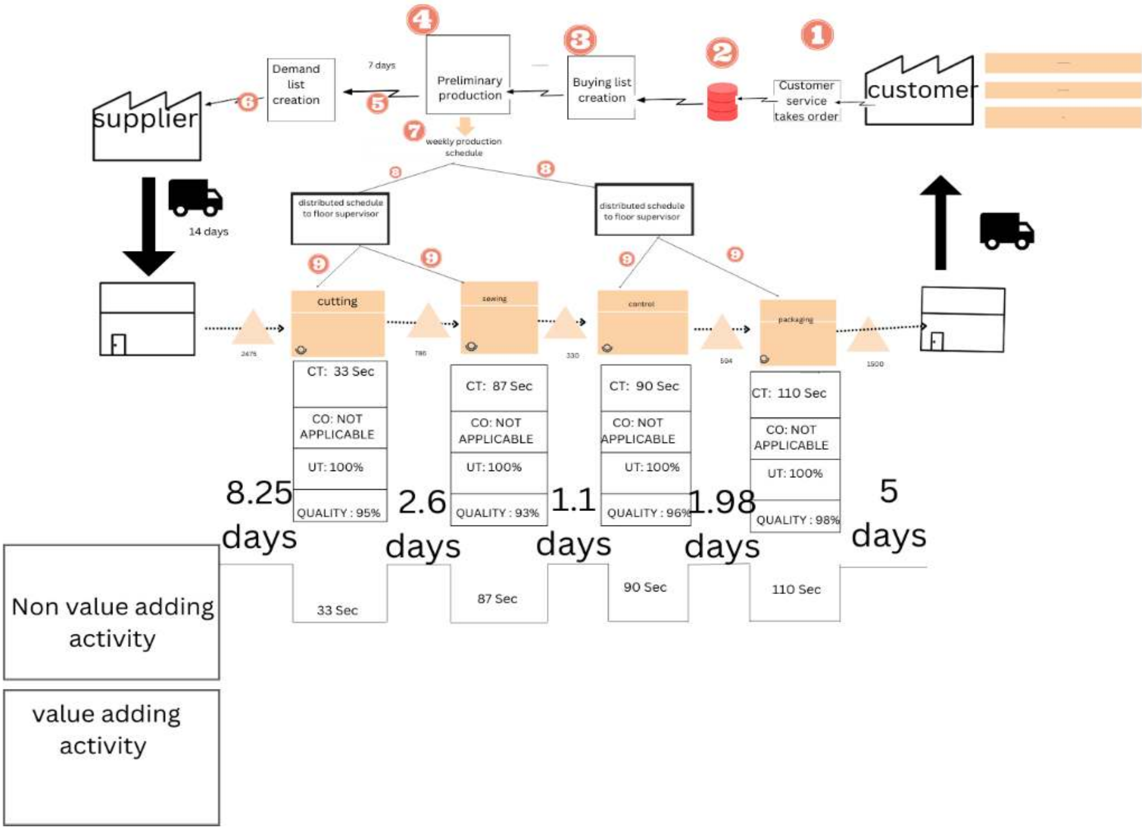


Figure 3.8. Glimpse Of Current State VSM.

4. RESULTS AND DISCUSSION

This part of the study focuses on calculation, Results and analyses that will permit improvement of current VSM to a future VSM that can be used at the company. All these are essentials for the analyses, improvement of the Current VSM in order to create the Future VSM.

4.1. Calculations

The following will be calculated: Process lead time, storage time, takt time, process time, or processing time of the value-added time, cycle time. All these are essentials for the analyses, improvement of the Current VSM in order to create the Future VSM. These calculations lay the groundwork for a Future VSM.

I.Lead Time

The amount of time required for the completion of an operation process is defined as lead time, which is the total amount of time taken from order to shipping [33].

The procurement team waits one week to create the demand list, which equals seven days, the supplier takes fourteen days to deliver goods to the warehouse, and raw materials aging at the warehouse before the cutting process equals eight point two five days. The sewing process takes thirty-three seconds, and the work-in-progress goods age for two point six days between the cutting and sewing processes. The sewing process takes 87 seconds, and the aging of the finished goods between sewing and control is one point one day. The control process takes 90 seconds. Goods take 1.98 days between the control process and packaging. The packaging process takes 110 seconds, and the finished goods are stored in the warehouse for five days before being shipped to the customer. Lead time is calculated following equation

$$\text{Lead time} = \sum \text{waiting time} + \text{preprocessing time} + \text{processing time} + \text{storage time} + \text{transportation time} \tag{1}$$

Lead Time = 7 days + 14 days + 8.25 days + 33 sec + 2.6days + 87 sec + 1.1 days + 90 sec + 1.98 days + 110 sec + 5 days

Lead Time = 39.93 days +320 sec

Lead Time = 39.93 days

II. Storage Time

Storage time can be in minutes, hours or days. It is the amount of time required for raw materials sitting in the warehouse to go through the various stages of operation all the way to storage or finished products before being shipped to the customers [33]. The storage time for this case study was calculated with equation.

Storage Time = 8.25 days + 2.6days + 1.1 days + 1.98 days + 5 days (2)

Storage Time = 18.930 days

III. Takt Time

Takt time is the amount of time required to produce a single unit of product to meet customer specifications. Takt is a German word for drumbeat; it establishes the pace of the processes required to meet customer demand, highlighting areas where flow is uneven, and waste occurs.

Takt Time is denoted by the letter T. and calculated with equation $\text{Takt time} = \frac{\text{Ta}}{\text{Td}}$. , Ta is net available time to work calculated with equation $\text{Ta} = \left(8\frac{\text{hour}}{\text{day}} * 60\frac{\text{minutes}}{\text{hour}} * 60\frac{\text{sec}}{\text{minutes}}\right) - \left(45 \text{ minutes} * 60\frac{\text{sec}}{\text{minutes}}\right)$ (5 , and Td is Total Customer Demand is denoted by equation $\text{Customer demands} = 500\frac{\text{tshirts}}{\text{day}}$ (3)

$\text{Takt time} = \frac{\text{Ta}}{\text{Td}}$ [28] [39]. (4)

This company has just one shift of 8 hours with 3 breaks of 15 minutes each

$$\text{Ta} = \left(8\frac{\text{hour}}{\text{day}} * 60\frac{\text{minutes}}{\text{hour}} * 60\frac{\text{sec}}{\text{minutes}}\right) - \left(45 \text{ minutes} * 60\frac{\text{sec}}{\text{minutes}}\right) \quad (5)$$

$$\text{Ta} = 28800 \text{ secs} - 2700 \text{ secs} = 26100 \text{ secs/Day}$$

$$\text{Customer demands} = 500\frac{\text{tshirts}}{\text{day}} \tag{6}$$

$$Takt\ time(T)\ = \frac{26100}{500}$$

$Takt\ time(T)\ = 52.2\ SEC$/T-shirt

This means it should not take above 52.2 sec to produce one T-shirt in order to meet the customer's requirement of 500 T-shirts per day.

IV. Process Time

Process time is also referred to as the value-added time. It is the approximate amount of time needed to complete a process in production step. Process time includes the time it takes to prepare the order in seconds, the amount of time in seconds needed to move it, run it, put it away and inspect it. This is demonstrated with equation

$$\text{Process Time} = 33\text{ sec} + 87\text{ sec} + 90\text{ sec} + 110\text{ sec} = 320\text{ sec} \tag{7}$$

V. Cycle Time

It is the total amount of time required by an operator to complete one cycle of task from start to finish before repeating this operation. In the context of this company, cycle time refers to the total time required to produce one t-shirt by one operator from start to finish. There are 10 operators and 5 people for packaging at this company and the calculated with equation

$$\text{Cycle time}\ \frac{\text{Proces time}}{\text{Number of operators and packagers}} \tag{8}$$

$$\text{Cycle time} = \frac{320}{10+5}$$

$$Cycle\ time\ = 21.3\ sec$$

It takes 32 sec to produce and package one t-shirt from first to last process.

Table 4.1. Summary table for all calculations done.

Parameters	Time
Lead time	39.93 days
Storage time	18.93 days
Takt time	52.2 seconds
Process time	320 seconds
Cycle time	21.3 seconds

4.2. Analyses of Current VSM

After drawing the current state map with all pertinent information filled in, the next step is to examine the map for problems and obvious solutions. While studying the map, keep a balance in mind in order to create a map that improves your manufacturing process. There is a need to balance in several places, such as between customer demand and total process capacity, as well as between operations, particularly processing time. Striking a balance between product arrangements will also ensure that the production pace is predictable and steady, so this section will focus on various techniques to analyze your current state map. It will work towards balancing it, the following will be observed: Can the process meet customer demand with the current number of operators, analyzing the process balance and finally how to watch for waste in the business process.

4.3. Can the process meet customer demand with the current number of operators?

Previously takt time and it gave a value of 52.2 seconds meaning producing a single t-shirt should exceed this time. In addition, cycle time was calculated, and results was 21.3 seconds. Comparing both numbers, we found out that the 15 workers are more than able to meet the requirement of 500 T-shirts a day. For a company to be optimal few workers will be fired or the company's demand must be slightly increased.

$$Takt\ time(T)\ = 52.2\ SEC$$

$$Cycle\ time\ = 21.3\ sec$$

4.4. Analyzing the process balance

To meet the customer's demand, it is important to balance customer demand and the processing capacity. Effective production will require consumer Takt time to be longer than the cycle time. Using a timer cycle time was recorded.

Table 4.2: Summary table of cycle time of each process.

Process	Process cycle time (Sec)
Cutting	33
Sewing	87
Control	90
Packaging	110

$$Takt\ time(T) = 52.2\ SEC$$

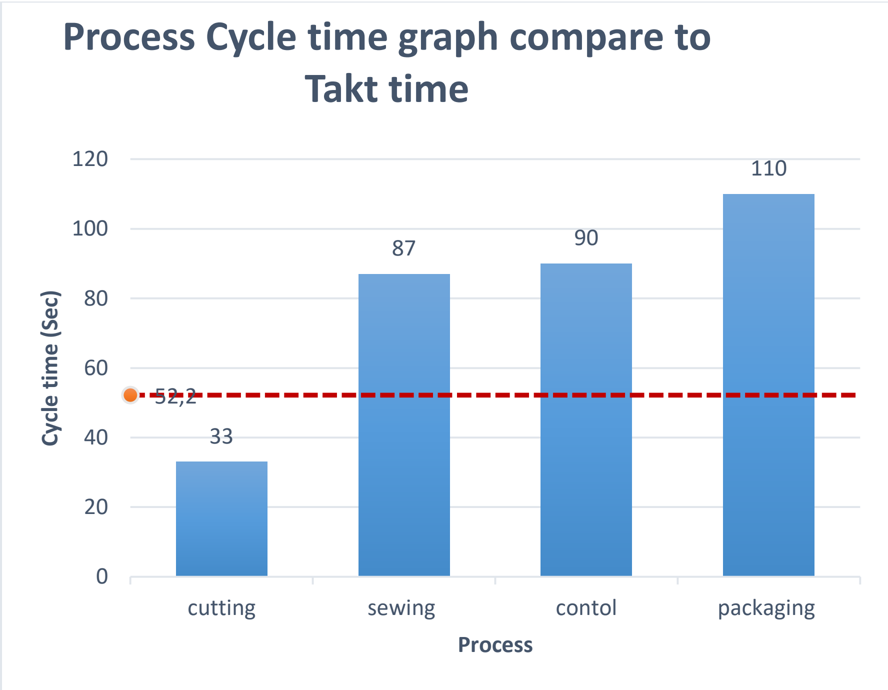


Figure 4.1 Chart showing process cycle time graph compared to takt time.

From Figure 4.1. which is the chart above, it is observed that the cycle time of cutting is lower than Takt time while that of sewing, Control and packaging is greater than that Takt time. Measuring and comparing individual process cycle time against Takt time aids the evaluation of balance and easy identification of bottle neck which is important to identify underutilization of resources during operation with shorter cycle time. Figure 9 also clearly indicates that packaging is creating bottlenecks, and the entire process is not balanced. In order to solve the problems Figure 9 clearly permitted to be spotlighted. The first thing that can be done is attempting to reduce bottlenecks. To achieve a reduction of bottlenecks, the company should consider getting a packaging machine. This will help make the packing process faster and increase the overall amount of t-shirt packaging. Secondly, since the overall process is not balanced the company management can consider cross training the operators, particularly those doing the cutting process which permit more personnel to be assigned to packaging as needed. It will also permit all employees to be used with full potential. Finally, Workload balancing can also be done. Appropriate distribution of workload will prevent a single process becoming overwhelmed.

I) Watching For Waste in The Production Process.

The final thing to keep track of before the build of the Future VSM is any form of waste. Using the Toyota production system which states there are 8 form of waste. These 8 form of waste are Overproduction, Over processing, Waiting, Transport, Motion, Inventory, Defects and Underutilized Employee Skills.

In my case study I identify that this company is over producing. This company's producing capacity is far beyond customer demand, increasing inventory. This increase inventory to a long waiting period eventually resulting in defective products. Overproduction at this company is due to overcapacity and the fact that the company is operating based on push production. This can be fixed using a fixed production pace and implementing a Just-in-time production strategy. Fixed production pace can be achieved by implementing use of Heijunka technique which does a leveling by volume.

The next waste at this company was over processing. The company suffers from over processing because they have both great quality cutting and sewing machines and too many workers. The workers are often idle, and they do nothing. Reducing the number of sewers would be ideal. The company has 15 operators in total. 10 of the workers are all working on the cutting, sewing and control process. The cutting and sewing process are both done with machines which take 33 seconds and 87 seconds, respectively makes both processes the processes with the fastest. Moving cutting and sewing operators working on the packaging process will decrease idle time of worker and underutilization of cutting and sewing operators.

Finally, the company had a lot of rework to do which led to defective T-shirts often. For every 50 T-shirts, there was one T-shirt that had to be reworked. Each time a T-shirt is repaired it leads to a strain in the operation process leading to a change in demand. Often these defective t-shirts are discarded. The total number of defective t-shirts per week was a total of 5.

II) Continuous Flow

The method most used to achieve continuous flow are comparing consumer takt time versus production takt time.

a. Consumer Takt Time Versus Production Takt Time

The consumer takt time, which is the takt time based on customer demand, is frequently used. Consumer takt time is also known as ideal takt time. In the case study, the takt time is 52.2 seconds, which is referred to as the consumer takt buying or the ideal takt time. If the consumer takt time is not met, the production team may be unable to complete the product within the time frame specified. However, in practice, you will not be able to run your business process at 100% efficiency.

Your teams will have unscheduled breaks, urgent meetings, and there may be abrupt shutdowns for any unforeseen reason, so it is best if you consider these probabilities and assume that you will face some problems in day-to-day operations to prepare for this, you may want to set up your processes so that they produce products at a rate that is significantly faster than the consumer takt time and this takt time. In our case study, if the consumer takt time is 52.2 seconds, your production takt time can be much less than 52.2 seconds, say 45 seconds. Production takt is not calculated using a formula. Using the company project manager's experience and process understanding to determine this number optimal production takt time allows for continuous flow, which protects production and avoids waste such as overproduction. For example, the main waste in this case was having many unused precut pattern leading to producing more t shirts than demanded.

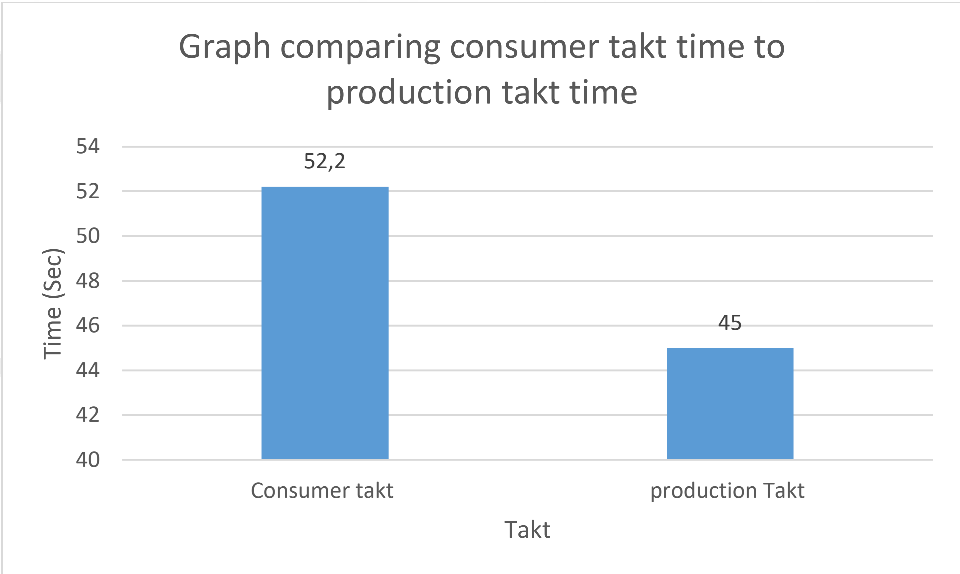


Figure 4.2. Graph comparing consumer takt time to production takt time.

III Leveling Production MIX

The production mix was leveled by implementing the Heijunka technique of workload leveling by volume. Because we only worked on one product line in this case study, the level mix workload was determined by volume. Given that the company has decided to deal with customer demand for 500 white T-shirts weekly, they will maintain a consistent production of 100 T-shirts per day with an inventory of 50 T-shirts to help address any variations. The heijunka box which a method It requires the arrangement and production of a number of products or product variants in a way that production volatility is smoothed out to evenly satisfies consumer demand. In this scenario, the Heijunka box may not be used since we are not dealing with multiple products.

Table 4.3: Table showing workload leveling by volume.

Day	Orders Received	Orders Completed	Borrowed From Inventory	Inventory Left at the end of the day
Monday	**120**	**100**	**20**	**80**
Tuesday	**150**	**100**	**50**	**30**
Wednesday	**180**	**100**	**80**	**-50**
Thursday	**60**	**100**	**-40**	**-10**
Friday	**60**	**100**	**-40**	**30**

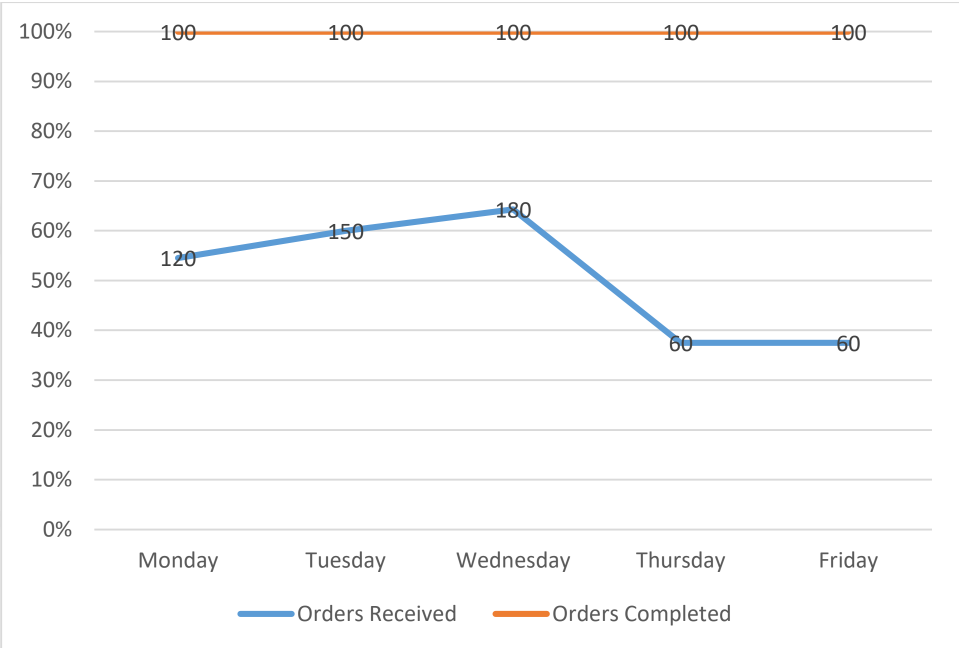


Figure 4.3: Graph showing plot of how production mix was level out following the customer's order in a week.

4.5. Future Value Stream Mapping for Company

This section focused on implementations of all the improvements obtained from doing the analyses of the current VSM that was built. All the analyses was used to clearly define the different process improvement that we want to see on the Future VSM. This will serve as a guideline and prediction for the company should in case, they want to be more productive in the future. Mainly from analyses the following actions are to be executed.

Firstly, the company will have to change to pull systems. Then production takt a reconsideration of takt time that was decided being less than consumer takt time will be used. Secondly, the company will need to consider including safety stock which will help total avoiding waiting time of 14 days to receive raw material from the supplier before production. Finally, the 7 days a week between the receiving order by customer service and the time it arrives at the purchasing department can be removed by using the right automation or software solution like Production Life

Cycle Management (PLM). Also reducing shipping time from 5 to 3 days is possible and reducing material handling period to increase efficiency. All this will reduce the lead time to 19 days.

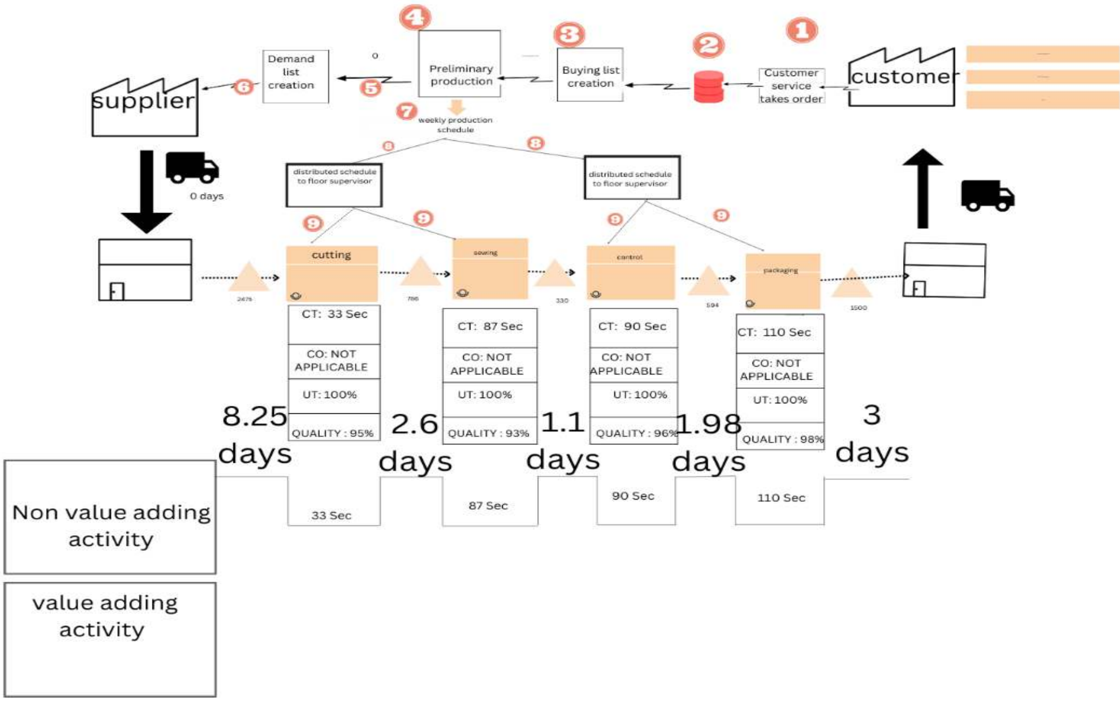


Figure 4.4. Future state map of case study including all improvements.

5. CONCLUSION AND RECOMMENDATIONS

The purpose and goal of this research is coming to an end. It is important to conclude with the recommendation for any future studies. We see how the most out of VSM could be achieved and what are the pitfalls to avoid for future studies. The primary subject of this research paper was increasing productivity at the company using this VSM helping the company to improve its lead time considerably. Also, it permitted identification and elimination of waste and the optimization of production flow.

5.1. Recommendation

To get the most out of your value stream mapping, it is critical to use it for the development of any process you think is necessary. However, without proper use of the available tool, the value stream map may not be as useful in terms of improving quality and effectiveness as you would like. To get the most out of the value stream map, value stream maps were created to improve the point competence of specific elements of your production system.

Here are five things you can do instead of expending a lot of energy. First, create a value stream map based on customer demands. Understanding what the customer wants and building from there may appear simple, but it is critical. If this critical detail is overlooked, all of your hard work will be for naught. Second, document the process as it currently exists, not as it should exist. The creation of an efficient value stream map must focus on how the product currently operates rather than how you believe it should or want it to work. Remember that workers are hired and fired on a daily basis, and new equipment is added or broken down. Take these factors into account when creating a current state value stream map. Walkthroughs are performed to ensure that the correct information about the information and material flow is entered. Follow the process from beginning to end to ensure that the map drawn accurately reflects reality. This will also bring any minor details that you may have overlooked.

5.2. Pitfalls to avoid when creating your value stream map.

In the same way that guidelines tell you what to do to create an effective value stream map, there are some pitfalls to avoid when creating a value stream map. VSM is not the goal in and of itself. Many people believe that simply creating the value stream map is sufficient without going on to implement the suggested changes. Mistakes made when creating value stream maps are merely tools to help you navigate to a more effective and efficient operating system. Begin a detailed end-to-end flow by first conducting a thorough analysis of the manufacturing process. We can become engrossed in the minute details and lose sight of the overall flow perspective. As a result, it is preferable to perform the first couple of walk-throughs at a high altitude before descending.

Overemphasis on tallying inventory lead time is a good metric that should always be reduced as much as possible in finding and tallying as more details are added.

The accumulation of inventory can be enjoyable, but it should not overshadow the reason for the inventory's presence. The accumulated inventory tells you where problems in the manufacturing process have caused interruptions in the flow of values. When such breaks are discovered, you must understand why there is so much inventory at that point. Do not go too far into the future when drawing value stream maps. It is easy to get carried away and draw too far into the future. When you see more than six Kaizen lighting bursts on your map, this is just a guideline that you should take a break rather than thinking too far ahead.

Make a rough sketch of where you want to be in the next few years to give yourself and the organization a sense of direction. Follow the sketch up with a target condition for a few weeks to a year at the most. The more you work on your goal, the more experience you will gain, which will influence your next goal condition. The challenge of target conditions is required for continuous improvement. While mapping can help you see the big picture, you must still create a specific and measurable target condition for the areas you want to improve. To do so, you must answer the following two questions. What is preventing you from achieving the target condition in the process, and what steps are you taking to achieve it?

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