



Daffodil
International
University

Faculty of Engineering

Department of Textile Engineering

Project On

**A Study on The Development of Pre-Production Sample of T-Shirt
for Bulk Production**

Course Title: Thesis

Course code: TE-400

Submitted By:

Md. Rahat Babu ID: 213-23-1069

Md. Mehedi Hasan Mithu ID: 213-23-1065

Supervised

Mr. Md. Masud Raihan

Assistant Professor

Department of Textile Engineering

Daffodil International University

This Information Represented in Partial accomplishment of the Necessity for the degree of
Bachelor of Science in Textile Engineering.

Advance in Apparel Manufacturing Technology

Duration Time: February 10, 2025 to May 12, 2025

LETTER OF APPROVAL

To,

The Head

Department of Textile Engineering Daffodil

International University

Daffodil Smart City (DSC), Birulia, Savar, Dhaka-1216, Bangladesh

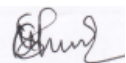
Subject: Approval of Thesis Report of B.Sc. in TE Program

Dear Sir,

We are just writing to let you know this project report titled as study on Industrial Engineering has been prepared by the student is bearing **Md: Rahat Babu** ID: 213-23-1069, **Md. Mehedi Hasan Mithu** ID: 213-23-1065 is completed for final evaluation. The whole report is prepared based on the proper investigation and interruption through critical analysis of empirical data with required belongings, the student was directly involved in their project activities and their port become vital to spark of many valuable information for the readers.

Therefore, it will highly be appreciated if you kindly accept this Thesis report and consider it for final evaluation.

Yours Sincerely



.....
Mr. Md. Masud Raihan

Assistant Professor

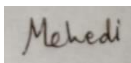
Department of Textile Engineering

Submitted by:



.....
Md: Rahat Babu

ID: 213-23-1069



.....
Md. Mehedi Hasan Mithu

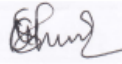
ID: 213-23-1065

DECLARATION

We hereby declare that this thesis has been carried out by us under the supervision of **Mr. Md. Masud Raihan, Assistant Professor, Department of Textile Engineering, Faculty of Engineering, Daffodil International University.**

We further declare that neither this thesis nor any part of it has been submitted elsewhere for the award of any degree or diploma.

Supervised by:



.....
Mr. Md. Masud Raihan

Assistant Professor

Department of Textile Engineering

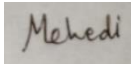
Submitted by:



.....
Md: Rahat Babu

ID: 213-23-1069

Department of Textile Engineering



.....
Md. Mehedi Hasan Mithu

ID: 213-23-1065

Department of Textile Engineering

DEDICATION

First and foremost, we express our heartfelt gratitude to **Almighty Allah**. By His grace, we have successfully completed our thesis.

We are especially grateful to our **parents**, whose hard work, dedication, and sacrifices have enabled us to reach this stage in our academic journey also our career journey.

ACKNOWLEDGEMENT

First, we express our heartiest thanks and gratefulness to **Almighty Allah** for his divine blessing makes us possible to complete this industrial training successfully. We feel grateful to and wish our profound my indebtedness to **Mr. Md. Masud Raihan (Assistant Professor)**. Department of Textile Engineering, Daffodil International University, Dhaka. Deep knowledge and keen interest of our supervisor in the field of garments manufacturing influenced us to carry out this project. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts and correcting them at all stage have made it possible to complete this project.

We would really like to particular our heartiest to the authority of the Department of Textile Engineering Daffodil International University. For their kind help to finish my project. Special thanks to **Mr. Arnob Chowdhury Mithun (Lecturer)** Department of Textile Engineering Daffodil International University, who guided us in the manufacturing facility and gave their valuable time for us.

We would like to thank to them for their sincere co-operation, support and advice which they have provided us during these two months of training. Our sincere appreciation goes to the entire ABA Fashion ltd for extending their hands of cooperation throughout the training period.

Finally, we must acknowledge with due respect the constant support and patients of my parents.

ABSTRACT

This thesis investigates the development of a pre-production sample of T-shirts for bulk production, focusing on optimizing various stages of the garment manufacturing process to enhance efficiency, quality, and cost-effectiveness. The research delves into the complexities involved in T-shirt production, from material selection and pattern making to cutting, sewing, and finishing, with an emphasis on the importance of pre-production samples in securing bulk orders. The study applies optimization techniques such as Lean Manufacturing, Time Study, and Line Balancing to streamline operations, reduce waste, and improve worker productivity. By analyzing production efficiency and implementing quality control measures, the research identifies key areas where improvements can be made, particularly in fabric handling, cutting accuracy, and labor allocation. The results demonstrate that adopting automation and optimizing work processes lead to higher productivity, reduced costs, and improved product quality. Recommendations for future research include exploring sustainable practices and integrating new technologies like AI to further enhance production efficiency. This study provides valuable insights for manufacturers seeking to improve the accuracy and efficiency of pre-production sample development, ensuring successful transitions to bulk production.

TABLE OF CONTENTS

CONTENTS	PAGE
Letter of approval	ii
Declaration	iii
Dedication	iv
Acknowledgement	v
Abstract	vi
CHAPTER	PAGE
CHAPTER 1: INTRODUCTION	2-4
1.1 Background of the Study	2
1.2 Objectives of the Study	3
1.3 Structure of the Thesis	3-4
CHAPTER 2: LITERATURE REVIEW	5-10
2.1 Garment Production Processes	6
2.2 Key Tools and Techniques for Optimizing Production	7-8
2.3 Work Study and Time Analysis in Garment Manufacturing	8
2.4 Efficiency and Process Flow in T-Shirt Production	9
2.5 Challenges in Garment Manufacturing Processes	9-10
CHAPTER 3: METHODOLOGY	11-36
3.1 Introduction	11
3.2 Purchase Order sheet	13-16
3.3 Measurement sheet	13-17
3.4 Fabric collection	18

3.4.0 Fabric Quality Test	18
3.4.1 WPI (Warp/ Walles Per Inch)	18-19
3.4.2 CPI (Weft/ Course Per Inch)	19
3.4.3 GSM (Grams per Square Meter)	19-20
3.4.4 Count Test	20
3.4.5 Strength Test (Ball Busting)	21
3.5 Cross match with measurement sheet	23
3.6 Pattern making	23-25
3.7 Pattern Cutting	25-26
3.8 Pattern grading	26-27
3.9 Fabric Cutting	27-28
3.10 Fabric Sewing	28-32
3.11 Quality test	32-34
3.12 End product	35-36
CHAPTER 4: RESULTS & DISCUSSION	37-41
4.1 Quality Test Comparison	38
4.2 Overview of Bulk Production Process	38
4.3 Purpose in Bulk Production	38-39
4.4 Production Efficiency Analysis	39-40
4.5 Recommendations for Future Bulk Production Improvements	40-41
CHAPTER 5: CONCLUSION	42-45
5.1 Conclusion	43
5.2 Summary of Findings	43-44
5.3 Limitations and Future Work	44-45
REFERENCES	46

LIST OF FIGURES

Figure No.	Page No.
Figure 1: Challenges in Garment Manufacturing Processes	12
Figure 2: Flowchart for Pre-Production Sample Review	13
Figure 3: Sample T-shirt from PO sheet	15
Figure 4: CPI of this fabric	19
Figure 5: Grams per Square Meter	20
Figure 6: Count Test	20
Figure 7: Strength Test	21
Figure 8: Pattern Make	25
Figure 9: Pattern Cutting	26
Figure 10: Fabric cutting	28
Figure 11: Single needle lock stitch	30
Figure 12: Overlock	30
Figure 13: Flat lock with cover stitch	31
Figure 14: Lock stitch	31
Figure 15: Overlock and plain stitch	32
Figure 16: Sample T-shirt	36

LIST OF TABLES

Table No.	Page No.
Table 1: Pre-Production Sample Purchase Order (PO) Sheet	14
Table 2: Fabric & Trim Materials Specification	16
Table 3: Measurement Sheet for Classic T-Shirt (Short Sleeve)	17
Table 4: Quality Check	33
Table 5: Quality Test Comparison with Standards and Buyer Requirements	37

CHAPTER –1 INTRODUCTION

1.1 Background of the Study

Making T-shirts is a part of the garment industry which is indispensable to millions of people around the world. T-shirts can be made in a wide variety of styles and materials, and may come in many colors. This is especially true in the competitive garment manufacturing industry, where survival depends on the ability to maintain efficiency, quality, and cost. The T-shirt manufacturing process has many steps, from T-shirt design to selection of fabric and then actual T-shirt factory production. Each of these steps must be closely managed and employ best production practices in order for the end product to meet both the sell order and consumer expectations.

Across technical and political borders, the competition of business is global, which places higher demand on manufacturers to be cost efficient and at the same time maintain a competitive product quality level. In case of single T-shirt, this is more serious problem due to size of production and diversity of design, size and personalization. All dimensions of the process, from the fabric, the way it's stitched and even the final touches raise or lower the costs of manufacturing and the quality of the final product.

In such scenario, optimization tools like Lean Manufacturing, Time Study and Line Balancing are imperative in increasing efficiency and productivity. Applying these methods can help streamline operations reducing waste and improving worker performance that will lead to shorter turnaround times and improved profit margins. The necessity of sampling before mass production enhances the complexity of the process. A sample is a prototype of design that will be sent and approve for fit and design. Poor samples can lead to costly win/loss scenarios on hard-earned business, incentivizing always aiming to create samples as an accurate representation of mass-produced T-shirts. Therefore, we need to properly study the whole production process to find out inefficiency and bottleneck if any.

In this work, we study the complexity of a T-shirt making process and in particular aim to complete the process in a better way for productivity, minimizing waste, and quality piece delivery. The purpose of this thesis is to investigate and analyze the impact of different optimization methods and provide an applicable solution to the problem based on real-world problems found in T-shirt manufacturing industry. The results will be valuable as a straightforward guide in developing an efficient and cost-effective single T-shirt production and encourage success of the T-Shirt industry as a whole.

1.2 Objectives of the Study

- 1 **Optimize Pre-Production Sample Development:** Investigate the key stages of T-shirt sample development (material selection, pattern making, fabric cutting, sewing, and finishing) and apply optimization techniques to enhance efficiency, reduce waste, and improve quality.
- 2 **Evaluate the Impact of Samples on Securing Bulk Orders:** Assess how accurate and high-quality pre-production samples increase the chances of buyer approval and secure bulk orders, ensuring a smooth transition to mass production.
- 3 **Identify Challenges and Risks in Sample Development:** Analyze risks and challenges, such as fabric quality, pattern accuracy, and stitching precision, to prevent production delays and wastage while ensuring design accuracy.
- 4 **Provide Recommendations for Improving Production Efficiency:** Offer actionable recommendations to improve T-shirt production efficiency, focusing on automation, quality control, and better workforce management to reduce costs and enhance product quality.

1.3 Structure of the Thesis

The thesis is organized into the following chapters to provide a comprehensive analysis of the T-shirt production process and its optimization:

1. **Introduction:** This chapter introduces the study, providing the background, objectives, importance, and scope of the research. It also outlines the limitations and the structure of the thesis.
2. **Literature Review:** A detailed review of relevant literature on garment production, industrial engineering techniques, and sample development.
3. **Methodology:** This chapter describes the research design and methodology used for data collection and analysis. It covers the steps involved in studying the T-shirt production process, applying optimization

techniques, and conducting case studies.

4. Results and Discussion: The findings from the research are presented here. This chapter discusses the impact of optimization techniques on production efficiency, labor productivity, quality control, and cost savings. It also compares the results before and after the application of industrial engineering practices.

5. Conclusion: The final chapter summarizes the key findings, provides recommendations for improving T-shirt production, and discusses the limitations of the study. It also suggests areas for further research.

CHAPTER- 2: LITERATURE REVIEW

2.1 Garment Production Processes

Making clothes is not easy and is rather a time consuming, complex process with many sequential processes by which the production process of finished apparel involves. Garment production is a process that consists of five major stages; fabric preparation, pattern making, cutting, sewing and finishing with quality control. Specialist skills and instruments are used to ensure that production is implemented in an effective and precise manner at each point along this journey.

One of the garment production processes is fabric checking, which includes fabric dyeing, printing, and treatment. The quality, comfort and durability of the end product greatly depends on the type of fabric used. Pattern Making Pattern making is the process of drafting, manipulating and modifying a design pattern the shape of which is assembled into garment making. The pattern is used as the template for cutting fabric in the shape of the components of the garment.

After they are designs are made, the cutting is done wherein cuts the fabric pieces as per the shapes of the pattern. This process may be achieved manually or by use of automatic cutting machines. Accuracy is critical at this point, to avoid wasting fabric, and to ensure the dress is the perfect fit. Sewing: Once cut, the sewn section of the garment comes together where all the pieces are joined together to create a base outline of what the garment will look like. This involves a variety of operations depending on the type of garment, for example straight stitching, overlocking, or attaching buttons.

After the garment has been sewn, it will undergo one or more finishing treatments, such as pressing, washing and checking for quality. These procedures serve to improve the look, feel and wear of the garment. The last step, quality control, is used to look for possible errors in the garment, such as stitching, color, or fabric errors and, after checking, the garment is packed and shipped to the buyer. According to Sharma et al. (2021) quality control is essential in the entire production process to maintain customer satisfaction levels and reduce returns (Sharma, V., et al., 2021).

2.2 Key Tools and Techniques for Optimizing Production

It is important to streamline the production of garments to save costs, save time, increase productivity, and to produce quality garments. Over the years a number of tools and methods have been developed to address these goals. Key approaches are Lean Manufacturing, Just-In-Time (JIT), 5S, Kaizen and Total Quality Management (TQM) making easier more efficient production and waste reduction.

Lean Manufacturing is the tool of choice to strike the right balance between the wastage, The lean manufacturing concept is an extensive world-wide popular methodology, concentrating on waste and efficiency optimization through identifying and eliminating non-value-added activities. This means continually refining production processes, cutting cycle time, and getting more for the resource dollar. Based on Womack and Jones (2016), the implementation of Lean within the garment industry may generate substantial cost savings in addition to short lead times, and increase production volume (Womack, J. P., & Jones, D. T., 2016).

The ‘Just-in-Time (JIT)’ is another method of optimizing the production by ensuring the arrival of materials at the production line only when they are required. This lowers the inventory and costs of carrying it. JIT production is a challenging operation involving close collaboration of suppliers and manufacturers to deliver materials when needed and yet avoid delays in the assembly line. A study by Singh et al. (2019) found that the JIT practices in the garment industries had brought down the inventory costs and had improved the production flow (Singh, A., et al., 2019).

5S, based on Japanese manufacturing techniques, focuses on organizing the workplace to enhance productivity and safety. The five steps that help implementing 5S—Sort, Set in order, Shine, Standardize, and Sustain lead to a clean, organized, and efficient working environment combined with the ergonomic benefits of shadow boards. Manufacturers can also save time, which means faster production, by keeping workstations organized, eliminating clutter, and requiring compliance with standardized work practices, he adds. Research by Kumar et al. (2020) applied 5S in garment production and obtained the enhanced workplace efficiency with reduced production timeline for manufacturing (Kumar, A., et al., 2020).

Kaizen is a theory of practice with a relentless focus on the making of small and continuous improvements every day, in every aspect of a company. Kaizen encourages involvement of all employees in the identification and solving of problems and, thus, a continuous improvement culture. Clothing manufacturing has embraced this practice to improve quality output, decrease defects and optimize the functioning of the enterprise. Kaizen at clothing production One study of the Kaizen at a garment manufacturer in Pakistan showed that it resulted in a remarkable decrease in waste and was able to enhance productivity (Tanaka, S., & Takahashi, H., 2018).

Total Quality Management (TQM) concentrates on enriching quality at all levels and stages of production processes by engaging all employees. TQM focuses on customer satisfaction and incremental improvements, with employee involvement, training, and standardization of process. As per Juran and Godfrey (2010), TQM is very important for the garment industry as It ensures a constant level of product quality; among our customers as well as in their products and processes that in case of errors or defects are minimized and all spare parts and defective goods as possible will be on reattached (Juran, J. M., & Godfrey, A. B., 2010).

2.3 Work Study and Time Analysis in Garment Manufacturing

Work study aims at analyzing techniques and procedures followed in a garment in such a way that the method of production can be standardized, and the time study measures the time taken for performing each job element, with a view to removing wastages and increase in efficiency.

Another significant element of work study in garment manufacturing is method study. This may involve streamlining our workflow, removing extra steps, using the right (better) tools or methods so it takes less time and effort. When paired with time study, method study can largely improve the efficiency of garment making.

Line balancing is one of the most important methods in the workflow organization of the clothing industry sector. It is to evenly distribute work among production lines so that the workload of each worker is acceptable. This cuts down the waiting time and facilitates the continuity of the production. Research by

Khan et al. (2018) demonstrated that efficient line balancing can minimize bottlenecks and increase overall production rate of garment factories.

2.4 Efficiency and Process Flow in T-Shirt Production

Efficiency is crucial in T-shirt manufacturing in order to be competitively priced and fulfil customers' demand. In the flow process of T- shirt manufacturing various processes are involved may be describe as below. Each relying on the step followed and the type of garment made, the production flow steps will be adjusted accordingly. And these are; fabric preparation, pattern making, cutting, sewing, finishing, and quality control.

T-shirt production system should be optimized to reduce cost and increase efficiency. For example, during cutting operation, an automatic cutting machine can be applied to save materials and enhance the precision of operation. Industrial engineering tools such as line balancing and time study may improve worker productivity and decrease cycle times during the sewing stage. A study by Mehta et al. (2021) revealed that the sewing manufacturers are able to increase output and minimize the cost per unit through making better the sewing process, less idle time was also confirmed (Mehta, R., et al., 2021).

Note also that T-shirt (inventory) management is a (key) factor in T-shirt (producing) efficiency. Pooling approaches such as Just-in-Time (JIT) aim at reducing the costs of inventory, so that the demand should be met with insufficient inventory and without creating a surplus. Efficient stock management Eliminates the production shortages resulting from insufficient raw materials stock.

2.5 Challenges in Garment Manufacturing Processes

Developing garment industry has a number of difficulties, directly affecting labor productivity, product quality, and profitability. Typical problems that can be experienced are scheduling of events, meeting the buyers demands, keeping a tight hand on the costs, and staying committed to high product quality.

Meeting relevant buyer requirements is one of the laborious tasks in garment production. Many a times buyers have strict requirements in terms of fabric quality, design and finish and deviating from these can lead to rejected orders. According to Gupta and Sharma (2019), it is essential that the sample garments

conform to the specifications of buyers in order to get orders and to keep good relation of customer (Gupta, N., & Sharma, S., 2019).

Another problem is the quality control requirement in the production process. It is also necessary for garment factories to have a system to control the quality of garments meticulously in the process of being produced to find defects and errors in time. Low-quality goods harm manufacturers by creating potential Rework and Return costs and damage reputation with poor-quality products.

Manpower management is another problem in garment production. This work identified that productivity may be influenced by skill, motivation and conditions of work. Not only will productivity increase, but product quality will also improve if the workers are trained, motivated and work in environments designed for ergonomics.

Finally, cost pressure is a big issue for apparel manufacturing. Higher prices for raw materials, labor and energy have the potential to cut into profit margins. It is necessary to apply effective methods of production and organize the use of resources in such a way that costs are reduced without the quality of products being prejudiced.

CHAPTER- 3: METHODOLOGY

3.1 Introduction

In the first flowchart, the process begins with the Pre-Production Sample Development phase. This includes several key steps such as preparing the Purchase Order Sheet (PO Sheet), Fabric Selection, and Fabric Quality Testing. The fabric undergoes tests like the WPI (Warp Per Inch), CPI (Weft Per Inch), GSM (Grams per Square Meter), and Strength Test. Other processes include Pattern Making, Pattern Cutting, Pattern Grading, Fabric Cutting, Fabric Sewing, and Quality Control, which ensures all the sample elements are aligned with the design requirements. The Quality Control step includes a Stitching Accuracy Test to verify the overall quality.

Once the sample is ready, the Pre-Production Sample Review phase follows. This step includes Sample Approval and possibly some Adjustments (if required) to finalize the design before mass production begins.

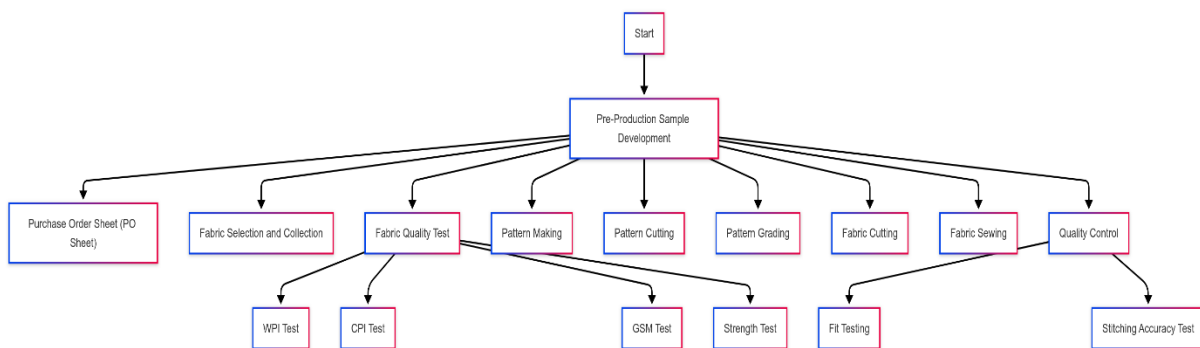


Figure 1: Flowchart for Pre-Production Sample Development

The second flowchart outlines the Bulk Production Process, which starts once the pre-production sample is approved. The process begins with Fabric Sourcing and continues with Pattern Cutting and Grading, along with Sewing. In the sewing stage, attention is given to Line Balancing and Machine Efficiency to ensure that production is optimized. The Finishing Process involves tasks like Pressing and Washing, followed by another round of Final Quality Control. After that, the garments undergo a Final Inspection, followed by Packaging. Finally, the process ends once the product is ready for shipping.

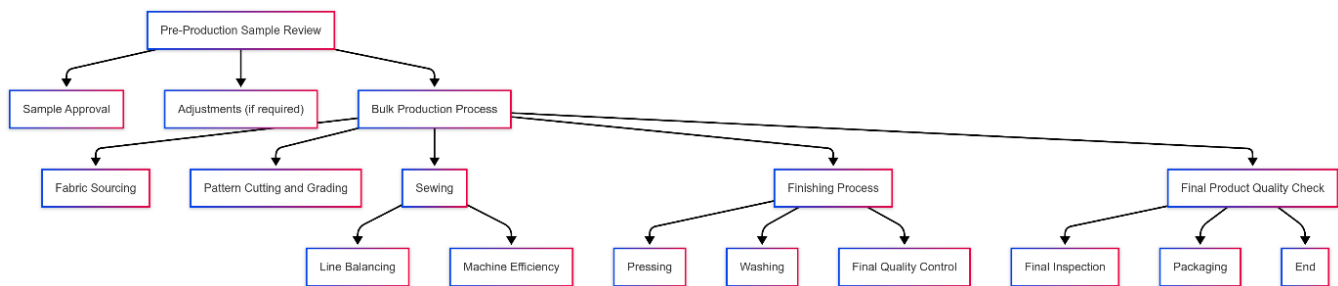


Figure 2: Flowchart for Pre-Production Sample Review

3.2 Purchase Order sheet

PO sheet (Purchase Order sheet) it explains the important information needed to produce a pre-production sample that is compliant with the buyer's standards or specifications. Brand Information the PO sheet normally have the brand information, like the brand name and logo, it's in order the sample could show the same brand, since inquiries could have the PO on the table and try to couple all details between the PO and the sample. It also indicates the design reference number, which is important to follow up that particular design to be produced, and the season in order that the t-shirt is scheduled for.

Table 1: Pre-Production Sample Purchase Order (PO) Sheet

BLOCK REFERENCE	FJB001
AMENDED	03.07.17
BRAND MACHINE GROUP	FLYERS GROUP
DESIGNER	CATARINA SILVA
BUYER	GEMMA RICHARDSON
QA	KASHINATH G.
BRAND	LYLE AND SCOTT
DESIGN REF	LSC0003
DESCRIPTION	PLAIN T-SHIRT
SEASON	SPRING / SUMMER 18
DATE CREATED	-
SIZE	-

The designer's name is to be included to denote the individual behind the creation of the design, and the buyer section aims to make sure that the purchased products are in accordance as per the purchasing individual's specifications. Credited for checking the sample and bulk production for quality samples Production Quality Assurance (Q/A) and Quality control (Q/C). It mentions the responsible person's or team's name who are responsible for checking and conducting the sample, along with the bulk production according to the set quality standards. In addition, the product description is contained on the PO sheet, and will describe the product as a t-shirt, and in some cases other information such as the type of t-shirt, plain, etc. and what type of fabric the product is made from, the color, and possibly specific design features.

Additionally, fields like the date created and size specification are crucial on a PO sheet to tell you when the order was placed and when the products need to arrive. The original date has been modified to represent when changes have been made to the document ensuring all parties are referring to the up-to-date version of the document. It is an essential document that makes sure that everyone participating in the production is aware of what the buyer is expecting and what the products should look like, helping the bulk production to be run smoothly after all the samples are approved.

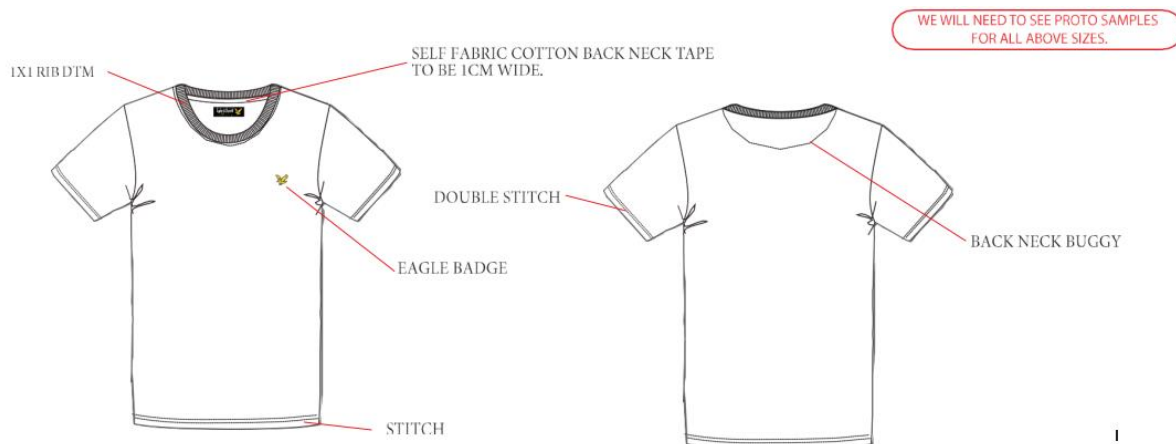


Figure 3: Sample T-shirt from PO sheet

Table contains a detailed breakdown of the materials incorporated in the creation of the T-shirt, which details the specific fabrics, trims, and their respective purposes. These specifications need to be clearly documented so that the product can be produced to meet design requirements and the expectations of the buyer. The chart starts off by documenting the principal textile and this is a 11 rib 95% cotton and 5% elastane. This fabric blend is used because it is soft and elastic, according to Carey, allowing the T-shirt to be comfortable and stretchy. The fabric construction is known as 11 rib which is the knit patterning that gives the fabric the texture and makes it more durable. All colors are described as 160gsm with the exception of dusty pink and white which are described as 180gsm to ensure even printing and longevity across the color range.

Furthermore, the rib to be employed for the neck is also specified in the table. Like the main fabric, this is a 95% cotton and 5% elastane blend, giving the same stretch factor and ease of wear. The build is once again 1*1 rib and the ground of the rib is stated to be 240gsm for a thicker, more hard-wearing finish to the collar. Lastly, the table says 26s for the count which is the type of yarn in thickness that was used to make the fabric. This is an important specification to obtain the desired texture and strength of the cloth.

Table 2: Fabric & Trim Materials Specification

<i>ITEM</i>	<i>DESCRIPTION</i>	<i>COMPOSITION</i>	<i>CONSTRUCTION</i>	<i>WEIGHT</i>
MAIN FABRIC	1*1 Rib	95% Cotton 5% Elastane	1*1	160gsm compact yarn
ADDITIONAL	Eagle batch	Metal	N/A	N/A
RIB	Collar Rib	95% Cotton 5% Elastane	1*1	240gsm
Yarn Count	26s	N/A	N/A	N/A

3.3 Measurement sheet

T-shirt (short sleeve) measure sheet is the chart with the sizes and measurements for this kind of T-Shirt (S, M, L, XL, XXL). The description lists the T-shirt as a standard, generic style and provides size dimensions in cm. That goes all the way out to the various measurements that are taken on each garment at this point, including the front length, chest width, sleeve length, neck drop, cuff width and with defined tolerances to maintain quality and integrity across the size range. The model number is LSC0003S as reference for this frame. These readings are essential to keep in control the tendency to have a variable final product and deliver according to the buyer. The table always tells the clothes of how this T-shirt fits and is how this T-shirt design is made out of a picture before mass production.

Table 3: Measurement Sheet for Classic T-Shirt (Short Sleeve)

Item	Sizing	S	M	L	XL	XXL	Tolerance (cm)
Front Length from SNP to Hem (CA1)	1	53.5	56	58.5	61	66	+/- 1
Across Front - At Mid Armhole (CB2)	0.5	30	31	32	33	35	+/- 0.5
Across Back - At Mid Armhole (CB4)	0.5	31	32	33	34	36	+/- 0.5
Across Shoulder (CB5)	0.5	32.5	33.5	34.5	35.5	37.5	+/- 0.5
Chest at Underarm (CB1)	1	39.5	41	42.5	44	47	+/- 1
Hem Width Straight (CD6a)	1	39.5	41	42.5	44	47	+/- 1
Hem Depth (CD7)	0.3	2	2	2	2	2	+/- 0.3
Armhole Straight (CG1)	0.3	16	16.5	17	17.5	18.5	+/- 0.3
Short Sleeve Length (CF1)	0.3	16.5	17	17.5	18	19	+/- 0.3
Cuff Width Opening (CF14)	0.3	12.5	13	13.5	14	15	+/- 0.3
Back Neck Width - Seam to Seam (CH1a)	0.3	14.9	15.2	15.5	16	16.6	+/- 0.3
Front Neck Drop - FIL to Seam (CH2a)	0.3	7	7	7.5	7.5	8	+/- 0.3
Back Neck Drop - FIL to Seam (CH6a)	0.3	2	2	2	2	2	+/- 0.3
Back Neck Buggy Width Along Shoulder Seam (0)	0.3	2.5	2.5	2.5	3	3	+/- 0.3
Back Neck Buggy Depth at CB (0)	0.3	8	8	8	9	9	+/- 0.3
Care Label Position on LHS AW Up from Hem Edge (0)	0.3	10	10	10	10	10	+/- 0.3
Neck Trim Depth (CH15)	0.3	1.5	1.5	1.5	1.5	1.5	+/- 0.3

3.4 Fabric collection

Fabric collection is very important part of T-shirt manufacturing process, where we have to search perfect fabric whether it's color, quality etc as per buyer's requirement and design. The fabrics used in the research are 180 GSM and 240 GSM providing different characteristics that are perfect for various components of a T-shirt. 180GSM ultra-lightweight fabric for that super-soft, soothing, cool feel that you can migrate to these over-weighted animals while in warmer climates. It offers breathability and can be manipulated by hand during fabrication. The 240 GSM fabric, on the other hand, is a bit heavier and sturdier, which is perfect for areas that need extra strength (like ribbing and seams). Both textiles help the end T-shirt to meet quality requirements (comfort, durability and aesthetics). The process of collecting fabric also includes searching for materials to match the buyer's color and texture preferences, breaking down what the T-shirt should look like and feel like in the market.

3.4.0 Fabric Quality Test

Fabric quality test is an important part of the process of determining if a given fabric complies with the requirements for strength, comfort, and functionality. The fabric is tested a number of key points to determine quality and fitness for t-shirt production. It's a good way to specify the density of the weave of the fabric and hence the fabric's strength or texture. Characteristics Both the cloth's density (measured in WPI or warp per inch and CPI or weft per inch) and the thread weight composition can change its texture. The higher the WPI and CPI the denser the fabric, the sturdier. GSM (Grams Per Square Meter) is a very important test to know about as it relates directly to the weight of the fabric and thus its feel, breathability and ultimately the overall quality. An ideal GSM for a t-shirt fabric is a mixture of comfort and durability. Count test measures the yarn count of the fabric, and thus the fabric's strength and appearance. Finally, the strength test, which tests the fabric's tolerance to tugging and pulling (i.e., the wear ability of the fabric and how to laundry), so it maintains its original form after happening with washing.

3.4.1 WPI (Warp/ Walles Per Inch)

WPI measures how many threads there are per inch of the fabric's warp direction (the vertical threads that run lengthwise). This is an important test, as the warp threads give the fabric strength and stability. A higher WPI translates into a tighter, stronger fabric that will be more hard-wearing and resistant to wear

over time. It also had an impact on the overall feel and texture of the fabric. WPI of this fabric 62.

3.4.2 CPI (Weft/ Course Per Inch)

CPI measures the number of threads per inch of the fabric, and in the fabric's weft, or horizontal threads that run across the fabric. This test is useful in evaluating the flexibility and drape of the fabric. The greater the CPI number, the tighter the weave (which adds to the fabric's strength); the lower the CPI, the potentially softer and more breathable the fabric. Hygiene needed in the T-Shirt production to juggle between comfort and durability.

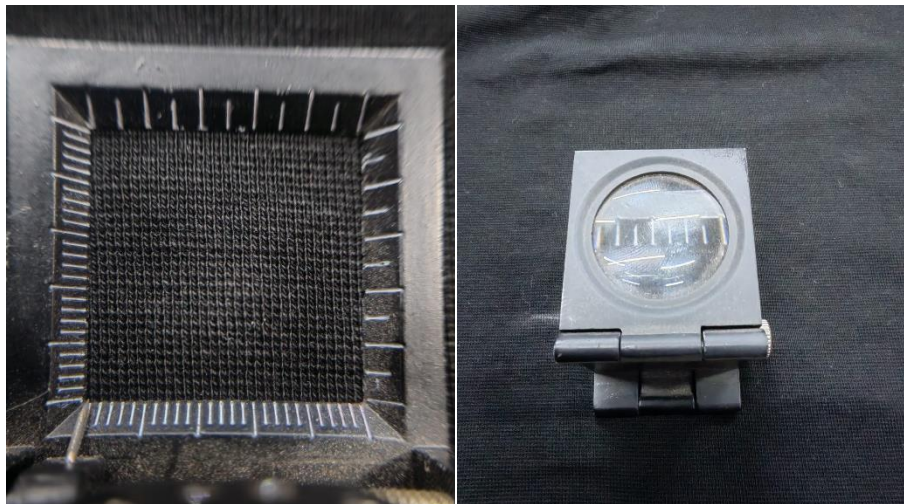


Figure 4: CPI of this fabric

3.4.3 GSM (Grams per Square Meter)

GSM is an acronym which stands for 'Grams per Square Meter' it is a measure of the weight and density of fabric- not necessarily the thickness. This test is critical in assessing the comfort of the fabric, its durability and suitability for the intended end use. For T-shirts, the right GSM ensures that the fabric isn't too thin (which could lead to the material being see-through or not durable enough) or too heavy (which might make the garment uncomfortable). Generally, clothing T Shirts are made of fabric that is between 160 and 180 GSM, which provides for a better fit and more structure than fabric that is 240 GSM.



Figure 5: Grams per Square Meter

3.4.4 Count Test

The count test gauges the thickness and quality of the yarn in the fabric. This test can be used to measure the strength and texture, as well as wear and stress analysis of a yarn. The count is generally expressed as a number, number that is higher it would be the thinner and stronger the yarn. The higher the yarn count, the softer/smoothier/more durable the fabric, and the lower yarn count, the rougher fabric, but it can be more breathable and comfortable.



Figure 6: Count Test

3.4.5 Strength Test (Ball Busting)

The strength test known as the Ball Busting test, this identifies the cloth's tensile strength or how much 'pull' (force) it can take before tearing or breaking. In this test, a ball is repeatedly forced through the cloth mushrooms on the maintain insect protective fabric until it is damaged or penetrates. The more pull force of fabric, the more resistant to pressure, which is suited to the pressure displayed on daily wear, washing, etc. This is a test to ensure that material will not stretch out of shape or develop holes in the normal course of use.



Figure 7: Strength Test

3.5 Cross match with measurement sheet

This is a crucial step in verifying that the fabric selected for the production matches the measurement sheet sizing. This means checking that the fabric, once cut and tested, complies with the original dimensions of all sizes (S, M, L, XL, XXL). The measurement sheet which includes critical measurements like the front length, chest width, sleeve length and neck sizes, that all have to be proportionate and consistent across all sizes.

As part of cross-matching, the stretch of the fabric, the width of the fabric, and the texture of the fabric are meticulously checked against the measurement sheet, to make sure that it fits the way it is supposed to and looks the way it is supposed to for every size. That includes verifying that the given fabric has the right amount of give or structure required for a design to maintain its shape, all while ensuring the item will be comfortable and adjustable to the wearer. They also compare the fabric for color, weight, pattern and if it is right or left-handed, as these variations can cause inconsistencies in a garment's fit and quality.

Through this cross—match, a manufacturer is able to guarantee that the fabric performs as envisioned in every stage of production — cutting and sewing — while still maintaining the integrity of the design. This step reduces chances of fitting issues and production delays, making sure that the final product follows buyer's size specs and fits uniformly in all sizes. In the final analysis, this attention to the alignment of the fabric and measurement sheet is of crucial importance in providing a high-quality T-shirt in its finished form that is both aesthetically acceptable and fulfills its functional criterion.

3.6 Pattern making

Pattern Making is a pivotal stage of the T shirt manufacturing. Garment makers make the patterns for the T shirt, that is cutting computer patterns or manual patterns define the dimension and design of each T shirt components before sewing it. This process will help ensure that all the different elements of the T-shirt need, like the front, back, sleeves and collar are all properly designed in such a way that they will fit together and be what you want in the finished T-shirt. It starts from measurements found in the measurement sheet and arrive to pattern parts, which will allow cutting out of fabric.

Today's pattern maker has the use of Computer-Aided Design (CAD) available to aid in the design

process for quick iteration and adjustments for precision in production. For smaller-scale productions, patterns could still be drafted by hand on paper or fabric, providing a hands-on design experience. The patterns are generally done as one size and graded for all size (S, M, L, XL, XXL) and just upsize the pattern one or more sizes if need be.

Precision in the pattern is key, because if it's not accurate, then certain issues can arise- fit, there might be wastage of fabric or difficulty in constructing the piece. When the patterns are made up, they form the template for cutting the fabric into exact shapes and sizes that are then assembled so that they fit perfectly when sewn together. What's more, pattern making isn't just about size and fit; it also takes into account things like fabric properties, design details, ease of construction. The by-the-books creation of the patterns lets manufacturers know that the T-shirt they end up with, be it functional or stylish, will serve a purpose in the overall design of a proper fitting, well-constructed T-shirt.





Figure 8: Pattern Make

3.7 Pattern Cutting

The pattern cutting stage represents an important part of the T-shirt manufacturing process, in which the fabric is cut in to the shapes and sizes specified in the patterns produced previously in the pattern-making stage. The object of the pattern cut system is to cut out each piece of fabric directly on the appropriate piece of the pattern piece so that the garment components can be put together without complications. This step is crucial if you want the intended fit, you want to waste as little fabric as possible, and you want the simulated effect of your design.

Automatic cutting machines are used in mass production to cut many layers of fabric at the same time and, therefore, to increase efficiency of speed and accuracy. The machines are set to run according to the pattern and pattern specs so that T Shirt pieces all come out the same every time. Manual cutting techniques can still be utilized for small scale factories with more labor intensity and more waste of fabric if not properly cut.

The cutting process requires considerable attention to detail, and even a small cutting error can alter the fit and appearance of the resultant garment. Correct fabric alignment is crucial for waste prevention, by optimizing the number of pieces you get out of your yardage, even if only a small amount is wasted. Tracing: Other than the most basic use of cutting, cutting markers (which are pattern pieces showing how to lay it out on fabric) are used together with the Cutting function to make the best use of the fabric. And after the fabric is cut, the pieces are primed for the sewing phase, which means at this stage, the garment's architecture is built properly from the very beginning.

In conclusion, pattern cutting is essential in maintaining the precision of the T-shirt design and fit, which results in more efficient production and ultimately reducing the amount of fabric waste produced and creating a better end product.



Figure 9: Pattern Cutting

3.8 Pattern grading

Grading the pattern is increasing or decreasing the size of the pattern to make smaller or larger while keeping the proportionate ratio of the garment. When you draw your T-shirt pattern, pattern grading is the technique allows you to scale the original pattern up or down to any size pattern, small to extra-large, large to extra small, without losing the proportions of the design. This however, requires that you adjust the pattern pieces measurements (chest, waist, length, sleeve size) to be able to fit a variety of body types while keeping the proportions looking balanced.

Grading of a pattern can be done by hand, though in modern ready-to-wear and mass-produced patterns pieces are graded mechanically, using a computerized pattern grading machine that can be operated by a pattern grader (the person who adjusts the size of the applied grade rule), a drafter (the person who traces the model or prototype and adds important information such as identification, size of the pattern, and any further marking), or a CAD pattern editor. The objective is to make sure that the changes made to the pattern, for example, to increase the size from, say, small to medium do not change the look and fit of the T-Shirt. This makes it imperative that grading lines (which will expand or reduce the pattern pieces) are placed very carefully.

For instance, with larger sizes the bust will often need to be adjusted more, and with smaller sizes, less. The grading process is critical to making sure that the T-shirt fits comfortably and looks good in a full size range from small to extra-large. Grading is important to prevent bad fit (e.g., some tight in places whereas loose in others, etc.) and to make sure that the t-shirt meets the quality level and fitting standards that the buyer wants it to meet. Finally pattern grading guarantees a design that is both expandable and a uniform look for a successful garment line.

3.9 Fabric Cutting

Fabric Cutting is one of crucial steps in garment manufacturing processes, where laying or spreader fabric is cut into pieces which will be later stitched and formed as a T-shirt. This comes after pattern making and grading because the fabric pieces need to correspond to the pattern specifications for each size. The cutting must be performed with precision to guarantee that all T-shirt elements (front; back; sleeves; neck strip) are cut to the correct sizes.

Cutting multiple layers on automatic cutters is usually normal of mass production. These machines are computerized in nature and hence every piece is cut to accuracy, thus reducing human errors and fabric wastage. The fabric is meticulously layered on a cutting table, with markers, or templates showing where cuts should be made, placed on top. The markers are designed to maximize fabric utilizations by plotting the pattern's pieces in most efficient layout, with the less waste.

However, for a smaller or more complex operation manual cutting can still be used, but is slower and can be inconsistent. But no matter what process you use, taking the time to match of fabric and making each precise cut is key to ending up with properly fitting pieces when everything is assembled. The process of cutting the fabric not only influences the quality and fit of the garment, but also is crucial to maintain low production prices and to prevent wastage of the fabric. By providing each piece is cut with precision and consistency, quality of the design is preserved, while helping manufacturers to value and save materials, resulting in a better product quality as well as more waste reduction.



Figure 10: Fabric cutting

List of Machines:

Machine Type	Purpose
Scissor	Cutting
Single Needle Lock stitch	Neck, Side Safety
Overlock Machine	Side Seam join
Flatlock Machine	Arom Hole, Bottom Hem
Stram Iron	Final process

3.10 Fabric Sewing

Fabric sewing is a very important stage in T-shirt manufacturing process, where the cut fabric parts are stitched together to make a complete t-shirt. During this stage, front and back pieces, sleeves, neck and underarm/shoulder areas are sewn together using sewing machines made for this style of garment. While it may seem like a small detail, quality sewing is necessary to ensure your T-shirt will fit the way that it should, feature the proper design elements, and hold its shape throughout countless wearing and

washings.

For today's factories, industrial sewing machine is used for fast and efficient production. There are different machines for different jobs, straight stitch is used for seams and the straight hems, overlock machines are for finishing edges, cover stitch is for hems. These pieces of equipment are capable of handling a range of fabrics and styles of stitch, so that the T-shirt not only feels sturdy, but also looks fantastic. Experienced operators can set the machine as well as the type of sewing, so that all parts of the garment are sewn smoothly and evenly into both thick and thin fabrics.

Line balancer is an important one such as fabric sewing that distributes the work uniformly over sewing station in order to avoid bottlenecks and balances production." An appropriate line balance will prevent bottlenecks from being formed at any one work station, thereby minimizing lag and achieving a uniform work rate.

Just so quality control is part of the sewing process. Everything is scrutinized from the hems/cuffs down to the last stitch and corner. The intention is that in the end, the output should match the whole design, be able to wear and wash.

In the end, fabric sewing is particularly important to consider, when it comes to how the T-shirt will look and how it will perform. It joins the fabric pieces together to convert into finished garment which passes overall aesthetic and quality standards and is ready to proceed to finishing and quality control and then finalize for packing.



Figure 11: Single needle lock stitch

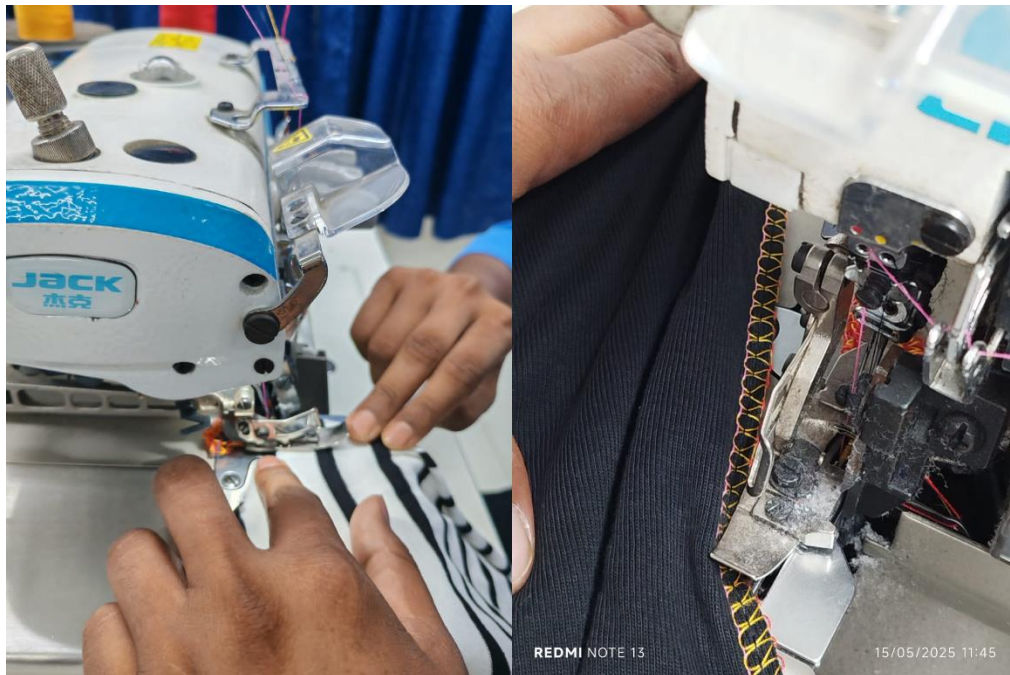


Figure 12: Overlock



Figure 13: Flat lock with cover stitch

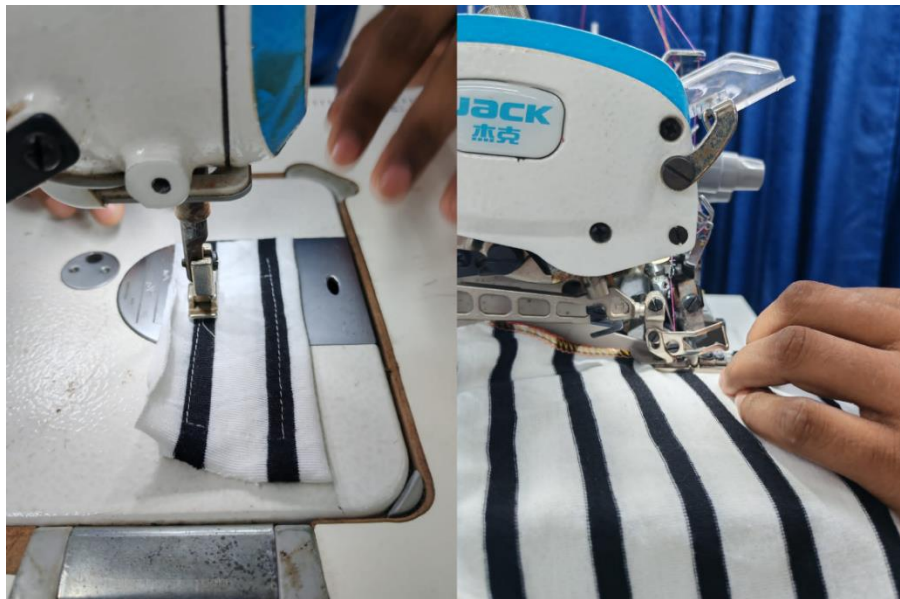


Figure 14: Lock stitch



Figure 15: Overlock and plain stitch

3.11 Quality test

The most important part of the T-shirt production process is being able to test each shirt and make sure they are built to last, fit perfectly and look amazing. After the t-shirt is assembled it then moves on to a quality control where it is examined to see if it meets the design specifications and holds up to everyday wear and usage. These tests will evaluate different characteristics of the T-shirt: among them its seams, fabric, fit, and general appearance.

One of the most important parts of a testing the quality is the examination of the stitching. This is for looking at even seam strength and no loose and or missed stitches that can cause the garment to fail. Also, the fabric undergoes a fresh scrutiny for flaws-holes, stains, irregularities in the weave-that may have been overlooked. Special tests like color fastness may also be conducted to determine whether the fabric will run or fade when laundered.

Fit testing is also performed to verify that the T-shirt fits the measurements on the measurement sheet. That includes looking up measurements like chest width, sleeve length, and length from hem to face to make sure the garment falls within my desired range. Shrinkage tests are also performed to see how much the material would shrink after placed in a method to check whether the garment still keeps its size and shape after laundering.

Finally, test like ball-busting, which test the strength of the fabric when it is under stress, also are undertaken. This test is designed to guarantee that the T-shirt will be able to withstand the wear and tear of everyday washing and wearing without losing it retaining its shape or integrity.

Whether the item is designed for food, magic or music, having the ability to put these demanding quality checks into the production process is key to getting a final product that looks and performs how the user expects. Through identifying and addressing defects before the T-shirt is delivered to a customer, manufacturers can minimize the occurrence of defects from the production line, reduce returns, and foster customer satisfaction.

Table 4: Quality Check

Quality Check Parameter	Description	Accepted Standard	Check Method	Remarks
Stitching Accuracy	Ensure even and strong stitching throughout the garment.	No loose or missed stitches	Visual inspection, tension testing	Important for garment durability and comfort.
Fabric Integrity	Check for holes, stains, or irregularities in the fabric.	No fabric defects	Visual inspection	Fabric should meet buyer's specifications.
Fabric Shrinkage	Ensure fabric maintains size after washing.	<5% shrinkage	Wash & measure	Test under typical consumer conditions.

Color Fastness	Ensure fabric color doesn't bleed or fade.	No color bleeding or fading	Dyeing test	Essential for long-term garment use.
Measurement Compliance	Ensure garment measurements match the size specifications.	±0.5 cm tolerance	Measurement tape, ruler	Verify dimensions for consistency across all sizes.
Fit Testing	Ensure the T-shirt fits as per design specification.	Consistent fit across sizes	Fit on mannequins or volunteers	Ensure comfort and appearance.
Neckline Integrity	Check the neck's shape and stitching.	No stretching or puckering	Visual inspection	Important for garment finish and comfort.
Seam Strength	Test the seam's ability to handle stress without breaking.	Minimum 50 N strength	Pull testing	Essential for durability.
Logo/Design Placement	Ensure logos/designs are correctly placed and aligned.	Accurate placement	Visual inspection	Confirm design matches approved sample.
Packaging Quality	Ensure garments are packed as per requirements.	No wrinkles, properly folded	Visual inspection, check fold methods	Prevents damage during shipping.

3.12 End product

End product means result of T-shirt after doing all the process for producing, starting from fabric selection, sewing, finishing till on quality check and same measurement as per approved sample. The T-shirt is now finished, and it has met all design requirements and quality standards. The final merchandise is

certified according to the buyer's requirement like fit, color, quality of fabric, stitching and workmanship. This step is important to ensure that the garment is packed and prepared to be sent to your customers or stores.

After passing the final inspection (quality control) tests of the T-shirt: appearance, fitness and function, it is ready for finishing. That means making sure they are WRINKE FREE and look fresh and after a nice press or a good ironing they should look professional. Other process treatments, such as garment dyeing or screen printing could also be performed at this time as necessary for the desired design.

Once the printing is done the T-shirt is neatly folded, tagged and packed per the packaging rules which ensure it arrives in pristine condition during delivery. Finished product is then ready to ship either to store or your customers with confidence, knowing it has been checked at every stage against your quality and customer satisfaction requirements.

Basically, the End Product is what everything in the entire manufacturing process leads up to – all the hard work from choosing the fabric to the last quality control resulted in a great garment that is ready to be released to the market. Thanks to careful planning, focus on small details and high-quality standards, this is a shirt that will last, be comfortable, and will look good.



Figure 16: Sample T-shirt

CHAPTER- 4: RESULT & DISCUSSION

4.1 Quality Test Comparison

We compare the quality test results of the T-shirt production with standard industry requirements and specific buyer specifications to evaluate whether the produced T-shirts meet the expected quality benchmarks.

Table 5: Quality Test Comparison with Standards and Buyer Requirements

Quality Check Parameter	Industry Standard	Buyer Requirement	Test Result	Met Requirement?	Remarks
Stitching Accuracy	Even stitching with no missed stitches	No loose or missed stitches	No loose stitches, even stitching	Yes	Matches both industry standards and buyer's expectations.
Fabric Integrity	No fabric defects (holes, stains)	No fabric defects, proper color consistency	No visible defects, consistent color	Yes	Meets both standard and buyer requirements.
Color Fastness	No bleeding or fading	No color bleeding, specific shade matching	Minor fading in some colors	No	Improvement needed in color fastness for certain shades.
Fabric Shrinkage	<5% shrinkage	<4% shrinkage	3% shrinkage	Yes	Satisfied buyer's shrinkage limit.
Measurement Compliance	±0.5 cm tolerance	±0.5 cm tolerance	±0.5 cm for all measurements	Yes	Fits within both standard and buyer's size tolerance.

Fit Testing	Consistent fit across sizes	Same as standard, accurate fit per size	Good fit, no distortion	Yes	Meets both standards and buyer's fit criteria.
Neckline Integrity	No stretching or puckering	No stretching or puckering	Slight puckering at some points	No	Further attention needed to improve neckline finishing.
Seam Strength	Minimum 50 N strength	Minimum 50 N strength	45 N in some samples	No	Slightly below the desired strength, adjustments needed.
Logo/Design Placement	Accurate placement and alignment	Precise placement as per design	Correct placement, well aligned	Yes	Matches buyer's requirements perfectly.
Fit Testing	Correct body shape fit	Accurate fit for all sizes	Consistent fit with size variations	Yes	Satisfied both industry standards and buyer's specifications.
Quality Check Parameter	Industry Standard	Buyer Requirement	Test Result	Met Requirement?	Remarks

While the overall production quality meets most of the industry standards and buyer requirements, there are a few areas that need improvement, particularly with color fastness, neckline integrity, and seam

strength. Implementing corrective measures in these areas will ensure that the T-shirts not only meet the standard but exceed buyer expectations, resulting in higher satisfaction and reduced risk of product returns.

4.2 Overview of Bulk Production Process

This is the terminal stage in garment production in which pre-production samples, that have been approved, are changed into actual production. A T-shirt sample count confirmed Inside the factory of choice the T-shirt sample count was confirmed – at this point in time thousands of T-shirts needed to be produced. This is the next T-shirt development step: to make the T-shirt design in a high quantity of units, in similar way small samples were made but more efficiently and with less hassle. It starts with fabric sourcing; bulk fabric developed as per the sample developed during the sample development stage. After the fabric is ready, the pattern pieces are cut following the graded size and the T-shirt parts are sewn together by automatic machines for accuracy and speed.

During the bulk production process, a number of basic operations must be performed for every single garment, including cutting, sewing, and finishing. These processes must be fine-tuned and made efficient to minimize nationwide wastage, standardize size and fit, and conform to the stipulated timelines of production. The mass-production equipment, which includes high-speed sewing-machines, cutting rooms also makes packaging of the final product also very efficient. The whole operation is closely managed, with workers and machines working in tandem sequences to ensure the maximum amount of work gets done with as little downtime as possible.

A very large part of the success of this type of mass production operation depends on pre-preparation such as accurate pattern grading, precision cutting of fabrics and work measurement and stitch control. Also important is quality control to ensure that each run of the garments achieves the same high quality as when the samples were made. The objective is to provide lots of good, high-quality T-shirts at the lowest possible price possible, on time and to meet demand.

4.3 Purpose in Bulk Production

The aim of bulk production is to evaluate the commercial manufacturing process at production level. The objective of this part of the thesis is to analyze to what extent the mass production is performed according

to the objective defined at sampling, revolving around effectiveness of the production lines, quality of the final product and cost-effectiveness of the full production process. Manufacturers can find out the strengths and weaknesses of the bulk production process, consider the impact of any optimization and see clearly which production targets are met (such as time, cost and quality).

This conversation will bring out the main challenges encountered in bulk 127 production, such as consistent quality, production rate control, worker productivity or machine efficiency problems, etc. It will also indicate the role of optimization approaches like lean manufacturing and line balancing in enhancing the production efficiency and reducing the wastage. What is more, the outcome concentrates on the importance of quality control measures in the bulk production and evaluates how effective these measures are in avoiding issues and obtaining desired final products.

Finally, it is to go through the bulk production, compare the planned results and establish what on standard would be cost-effective, high-quality production. The findings and discussions will not only illuminate the present scenario of production but will also suggest future improvements and innovations in the bulk production process in garment industry.

4.4 Production Efficiency Analysis

PE (Production Efficiency) studies are an important part of the assessment of performance in bulk manufacturing. It is centered on the evaluation of the performance of the manufacturing system in time, resources, and on the quality of the output. The objective of this approach is to evaluate the production process to determine if it produces at the maximum capacity achieved with minimal waste, labor cost and material input the fabric cutting part is one of the most important part of the production. The accuracy of the cutting is of vital importance in mass production because fabric waste should be kept at minimum and each pattern piece should match with another one. Automatic cutting machines contribute to efficient operation by preventing human error and promoting cutting efficiency. That analysis considers cutting times and the use of fabric with a computerized process in contrast with manual processes to see how efficiently robots help eliminate waste and smooth production flow.

Line Balancing – Work distribution to different operators - In another critical aspect in productive efficiency of production process, the sewing process, line balancing and allocation of work for operators

are important for optimizing productivity. In a well-balanced line, every station has work that matches its time available such that there is no idle time and no bottleneck. The study models cycle times, the rate of the numerous elements of sewing, and the overall output rate of the cell. When operational issues in sewing are identified and resolved, manufacturers gain a tremendous productivity boost while preserving quality.

Production efficiency is also affected by the finishing process, e.g., pressing, washing, quality control. Slow completion times can hinder throughput and inefficiencies in the completion process can result in cost overruns and late delivery. The study examines the time that each finishing process took and where savings could be made, e.g., reduction of drying time, increasing the effectiveness of quality checks.

Finally, the Production Efficiency Analysis gives us total visibility on how well manufacturing is working at scale. This analysis, by isolating the sources of delay or overutilization of resources, allows a manufacturer to target the improvements being made. Such improvements may involve adjustment of machine settings instruction of operator's better coordination of stages in the production process, or introduction of new technologies to improve efficiency. Finally, a properly done production efficiency analysis can make certain that the manufacturing process is a cost-effective and timely one, without compromising the desired quality.

4.5 Recommendations for Future Bulk Production Improvements

According to these results, some suggestions for the improvement of bulk production in the future can be suggested. The first is that additional automation in the finishing process has the potential to greatly increase the overall efficiency. "Robotic pressing and drying systems can alleviate the bottlenecks in the final stages of production, which results in faster response times and more uniform products," he explains. Advanced quality control systems like machine vision for defect detection can also detect issues before they can be found through manual inspection further reducing error caused by human and increasing the speed of inspection.

Second, efficient supply chain management is suggested to guarantee the availability of the necessary resources in time. Fabric Management Optimizing SUPPLY 30 Reducing the lead time of the production

process while improving interaction with textile suppliers prevents breakdowns due to delays in the availability of fabrics or transport and improves the effectiveness of all processes.

Workforce training and development should remain a focus, third. Even if machines are heavily involved, humans are needed to control them, manage production lines and, when necessary, to make them work again after they break down. Implementing ongoing training for workers to master the use of new equipment and techniques is a great way to have employees remain efficient and knowledgeable, and this benefits productivity as well as job satisfaction.

Finally, integrating sustainable initiatives into the bulk process might not only elevate the brand, but reduce material pl and waste. Zero-waste cutting, for example, or the sourcing of eco-friendly fabrics, are just a couple ways that production can be carried out to be more environmentally friendly, which resonates with the increasing number of consumers interested in sustainable products.

In summary, although there has been substantial progress in the refinement of the bulk production process, ongoing advances, especially regarding automation, quality control, and sustainability, are required to remain competitive and respond to changing market requirements. The advice presented here is meant to further streamline tasks, lower expenses and improve the final product.

CHAPTER- 5: CONCLUSION

5.1 Conclusion

In summary, this study offers an in-depth study on the batch production of T-shirts, with the purpose to maximize production efficiency, ensure quality control, and minimize production costs. The study shows that it is beneficial to optimize different phases of the flow line, such as the fabric cutting and flow down, the sewing, and the finishing. Automation, especially in cutting and machining of garment, was considered as one of the major procedures for minimization of time and fabric loss with uniformity in products over large quantities of production.

The level of sewing line balance was also revealed as a crucial factor in the production flow and in delay reduction and thus labor productivity improvement. In addition, quality control is highlighted that it is important for several production stages to identify defects in the advanced stages, to cut rework, and to satisfy customers but also to deliver good and high-quality garment to the market.

Nevertheless, the results of the study also pointed out some improvement areas especially in the finish operation in which still a considerable implementation in manual operators leads to some lack of efficiency. Moreover, although the mass distribution was much more efficient in the sense of fabric consumption, there was room for waste reduction and better cut planning in terms of sustainability and cost efficiency.

In sum, the study suggests that increased automation, efficient labor practices, and stringent quality controls can indeed make a major difference in bulk production. Eliminating the wastes and following the recommendations enables the manufacturers to not only produce more but also make a product that is aesthetically good, functionally sound and stay ahead in the competitive world of apparels.

5.2 Summary of Findings

The results of this thesis work would give a meaningful judgment of bulk T-shirt's manufacturing process in which certain practical aspects have been revealed which are responsible for efficiency, quality and cost-effective manufacturing. The study showed that there is a clear advantage in the speed and homogeneity of production resulting from automatic fabric cutting and sewing processes. The employment of automatic cutting machines minimized the loss of fabric and guaranteed the accuracy

when cutting the pieces, which was essential to keep the high quality of the final product. Sewing procedure, in addition to effective line balancing, was vital for maximizing worker productivity and minimizing waste time, leading to a smoother production process and quicker output.

The study also discovered that quality control is important to maintain the uniformity and longevity of the T-shirts. In the production environment, preventive defect identification reduced the overall impact of defects and the high cost of rework as well as the risk of customer returns. It was also found that even though significant productivity improvements were achieved through process optimization, some inefficiencies still existed, particularly in the finishing and fabric handling areas which still required manual interventions.

As for material consumption, it was concluded that material usage could still be reduced further by improving fabric alignment and cutting methods, although fabric was used efficiently. With the potential to develop into fresher environmental and economical practices and with no sacrifices in product quality or design, it may just be.

In general, the main results suggest the need for a harmonized strategy that combines automation, quality control and efficient strategies to manage labor. By addressing these challenges, manufacturers are able to greatly improve production efficiency, through its standards of excellence in quality and economy.

5.3 Limitations and Future Work

Although the results in the study help in understanding the T-shirt production process and the effect of optimization methods used in it, the work has limitations. A restriction to the study was the size of the sample. The research was performed at one manufacturing plant, so the results may not be broadly generalized to T-shirt manufacturing facilities. There is likely to be some level of variation in technology, skill and production volume between the different factories and how effective was the optimization approach applied. For future work, a larger/different size of sample, i.e., different factories in terms of scale of production and technology might also be investigated to cross-validate the research findings.

Another drawback is that our study was a short-term study. The time study data was accumulated over a

short period of time and so may not compensate entirely for any fluctuations in production efficiency due to seasonal differences or inherent fluctuations in worker efficiency. A longer-term longitudinal study would reflect a more complete picture of the long-term effects of optimisation and methods on factory efficiency. Not only would it permit the extent of long-term advances in labour productivity and total production costs to be witnessed, but it would also mean that there was continued scope for them to be observed.

In addition, the research primarily addressed improvements to the current way of manufacturing, without taking into consideration new technologies that may further improve efficiencies, such as 3D printing for the development of prototype garment designs, or AI for predictive maintenance of machines. Research on the incorporation of new technologies in the T-shirt making process to make them more productive could also provide some interesting finding. Further studies might also consider the use of AI and automation in the garment sector to hasten production and lower manual labour requirement.

Lastly, this research offered optimized strategies with regards to the labor productivity and machine efficiency in production, but did not take the eco-friendliness of production into consideration. Clothing industry has high environmental impact including water consumption, dyeing and textile waste. Applications to the development of T-shirt production Future studies can also be designed to investigate the implementation of ecological footprint on T-shirt production such as using sustainable materials, waterless dyeing machines, and reducing further waste to IPE of T-shirt to increase the production efficiency and environmental sustainability.

Overall, while this research provides useful insight in optimal production of T-shirt, it could be further investigated and improvement continued. By mitigating constraints and investigating new research areas, the producers may be able to improve the efficiency, quality and sustainability in the making of garments

References

- 1 Womack, J. P., & Jones, D. T., "Lean Thinking: Banish Waste and Create Wealth in Ours Corporation," Free Press, 2016.
- 2 Singh, A., et al., "Just-in-Time Implementation in Garment Manufacturing: A Case Study," Journal of Fashion Technology & Textile Engineering, vol. 7, no. 3, pp. 150-156, 2019.
- 3 Kumar, A., et al., "Impact of 5S on Manufacturing Productivity: A Case Study in the Garment Industry," International Journal of Engineering Research and Applications, vol. 10, no. 6, pp. 44-51, 2020.
- 4 Tanaka, S., & Takahashi, H., "Kaizen: A Case Study of Continuous Improvement in Garment Production," Journal of Industrial Engineering, vol. 27, no. 4, pp. 112-119, 2018.
- 5 Juran, J. M., & Godfrey, A. B., Juran's Quality Handbook, 6th ed., McGraw-Hill Education, 2010.
- 6 Goyal, P., et al., "Time Study and Its Application in Garment Industry for Productivity Improvement," Textile Engineering, vol. 44, no. 2, pp. 67-74, 2017.
- 7 Khan, M., et al., "Line Balancing and Its Impact on Garment Manufacturing," Journal of Textile Science, vol. 31, pp. 123-130, 2018.
- 8 Mehta, R., et al., "Optimizing the Sewing Process in Garment Manufacturing: A Case Study," International Journal of Textile Science, vol. 15, no. 2, pp. 45-53, 2021.
- 9 Gupta, N., & Sharma, S., "Challenges in Meeting Buyer Specifications in Garment Manufacturing," Journal of Textile Research, vol. 22, pp. 89-98, 2019.

213-23-1069

ORIGINALITY REPORT

8%	8%	2%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Daffodil International University Student Paper	3%
2	dspace.daffodilvarsity.edu.bd:8080 Internet Source	3%
3	dspace.lib.ntua.gr Internet Source	<1%
4	researchwap.com Internet Source	<1%
5	fastercapital.com Internet Source	<1%
6	support.jukeboxprint.com Internet Source	<1%
7	123dok.com Internet Source	<1%
8	luanvan.net.vn Internet Source	<1%
9	etd.aau.edu.et Internet Source	<1%
10	pmc.ncbi.nlm.nih.gov Internet Source	<1%
11	www.bio-conferences.org Internet Source	<1%
12	Veysel Tatar, Berk Ayvaz, Dragan Pamucar. "A quantitative ergonomic risk assessment model of maritime port operations: An integrated spherical fuzzy-FUCOM-ARTASI	<1%

approach", Ocean & Coastal Management,
2025

Publication

13	www.mdpi.com Internet Source	<1 %
14	www.researchwap.com Internet Source	<1 %
15	bluewaterdivingschool.co.uk Internet Source	<1 %
16	www.ewubd.edu Internet Source	<1 %
17	www.grossarchive.com Internet Source	<1 %
18	etds.lib.ncku.edu.tw Internet Source	<1 %
19	raiith.iith.ac.in Internet Source	<1 %
20	prin.or.id Internet Source	<1 %

Exclude quotes Off

Exclude matches Off

Exclude bibliography Off