THE STRUCTURE, CONSTRAINTS, AND SUGGESTIONS OF THE INDIAN MEDICAL TEXTILE PRODUCT INDUSTRY WITH A FOCUS ON FABRIC MANUFACTURERS

Poonam Parab
University of Rhode Island, poonambangar82@gmail.com

Follow this and additional works at: https://digitalcommons.uri.edu/theses

Recommended Citation
https://digitalcommons.uri.edu/theses/2296

This Thesis is brought to you for free and open access by DigitalCommons@URI. It has been accepted for inclusion in Open Access Master's Theses by an authorized administrator of DigitalCommons@URI. For more information, please contact digitalcommons-group@uri.edu.
THE STRUCTURE, CONSTRAINTS, AND SUGGESTIONS OF
THE INDIAN MEDICAL TEXTILE PRODUCT INDUSTRY WITH
A FOCUS ON FABRIC MANUFACTURERS

BY

POONAM PARAB

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN
TEXTILES, FASHION MERCHANDISING AND DESIGN

UNIVERSITY OF RHODE ISLAND
2022
MASTER OF SCIENCE IN
TEXTILES, FASHION MERCHANDISING, AND DESIGN THESIS
OF
POONAM PARAB

APPROVED:

Thesis committee:

Major Professor: Ji Hye Kang

Saheli Goswami

Koray Özpolat

Brenton DeBoef
(DEAN OF THE GRADUATE SCHOOL)

DEPARTMENT OF TEXTILES, FASHION MERCHANDISING AND DESIGN
UNIVERSITY OF RHODE ISLAND
2022
ABSTRACT

Medical textiles are specialty fabrics and products doctors, nurses, and other healthcare workers use. These include bandages, surgical gowns, hospital sheets, artificial hearts, and hernia meshes. India has been a global textile manufacturing hub and has recently shifted its focus to medical textile/textile products. However, there is no clear understanding of the basic structure of the Indian medical textile product industry related types of companies involved and their interactions with each other. The information about the industry needs to include categorization and depth, and there is no value chain-related information. A well-integrated value chain improves efficiency and effectiveness, which could lead to a sustained competitive advantage for the Indian medical textile product industry.

The study aims to identify- 1) the structure and activities of the companies which are part of the Indian medical textile product value chain, 2) the challenges they face that prevent them from attaining their full potential, and 3) what changes can help these companies overcome them. This study interviewed medical textile/textile product manufacturers and medical textile/textile products industry experts. The interview data brought first-hand information on the challenges faced by the companies in the medical textile/textile products industry. Furthermore, it also provided information on what they feel will help them overcome the hurdles they face in running their businesses.

From the interview data, this study identified six sequential stages for the Indian medical textile products industry: (1) research and development, (2) manufacturing, (3) distribution, (4) agency, (5) market, and (6) retailer. The study identified three constraints
faced by the Indian medical textile/ textile products manufacturers: (1) a highly competitive market with price-sensitive products, (2) a lack of standards, and (3) a lack of government support. Based on the interview analysis and intense literature review, this study suggests two approaches to overcome the constraints: internal at the company level and external at the national level.
ACKNOWLEDGMENTS

I want to thank my advisor, Dr. Ji Hye Kang, who has patiently guided me from the first semester till my thesis defense. I am so thankful to have worked with such an excellent and meticulous teacher who has nothing but her student’s success as her goal. I also wish to thank all the faculty and staff members at the TMD department. The department is heavily involved in every student’s work. I am fortunate to have a very responsive thesis committee whose feedback helped me understand what serious research is.

Lastly, I thank God for blessing me with the most loving husband and daughters. They inspire me to be a kinder and more loving person every day.
# TABLE OF CONTENTS

ABSTRACT.......................................................................................................................... ii
ACKNOWLEDGMENTS .......................................................................................................... iv
TABLE OF CONTENTS ....................................................................................................... v
LIST OF TABLES ............................................................................................................. vi
LIST OF FIGURES ........................................................................................................ vii
CHAPTER 1. ....................................................................................................................... 1
INTRODUCTION ............................................................................................................... 1
CHAPTER 2. ....................................................................................................................... 7
REVIEW OF LITERATURE ............................................................................................... 7
CHAPTER 3. ..................................................................................................................... 21
METHODOLOGY ........................................................................................................... 21
CHAPTER 4. ..................................................................................................................... 31
FINDINGS ....................................................................................................................... 31
APPENDICES ................................................................................................................ 60
BIBLIOGRAPHY .......................................................................................................... 62
<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1. Medical textile product categories</td>
<td>6</td>
</tr>
<tr>
<td>Table 2. Interview Questions</td>
<td>27</td>
</tr>
<tr>
<td>Table 3. Characteristics of Interviewees</td>
<td>29</td>
</tr>
<tr>
<td>Table 4. Consolidated constraints and suggestions for solutions</td>
<td>55</td>
</tr>
<tr>
<td>FIGURE</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Figure 1. Global Value Chain of medical devices</td>
<td>10</td>
</tr>
<tr>
<td>Figure 2. Theory of Constraints process</td>
<td>17</td>
</tr>
<tr>
<td>Figure 3. The Structure of the Medical Textile Product Value Chain in India</td>
<td>34</td>
</tr>
<tr>
<td>Figure 4. Schematic representation of the N95 mask with various layers</td>
<td>36</td>
</tr>
<tr>
<td>Figure 5. Cotton crepe bandage with bandage clip</td>
<td>37</td>
</tr>
<tr>
<td>Figure 6. Non-Absorbable sutures</td>
<td>40</td>
</tr>
<tr>
<td>Figure 7. The flow of goods from manufacturer to customer</td>
<td>43</td>
</tr>
</tbody>
</table>
CHAPTER 1.

INTRODUCTION

Issues in the Indian medical textile product value chain

Medical textile products are textile products specifically developed for medical and healthcare applications. Medical textiles are textile structures designed and produced for various medical applications, including implantable applications (Haque, 2012). The medical textile product industry has potential growth due to India’s strong textile industry, which is a medical textile product industry supplier. Medical textiles are specialty textiles developed for their technical properties rather than appearances (Haque, 2012). Medical textile/ textile product companies use innovations in chemistry, engineering, and other fields to process textiles or composites into high-end medical textiles. Medical textiles/ textile products undergo several tests and require technical certifications to be considered fit for medical use (Qin, 2016). Medical textiles are used to make products like gauze bandages, biocompatible implants and tissues, antibacterial wound treatment material, prosthetics, and intelligent textiles (Qin, 2016). The global medical textile market, valued at US$ 24.7 billion in 2020 (Grand View Research, 2020), is expected to reach US$26.21 billion by 2026 at a CAGR of 4.5% (Grand View Research, 2021). The Indian medical textile market was US $780 million in 2016 (ICRA Management Consulting Services Limited, 2016).

The Indian medical textile product market has enormous growth potential but is still not doing well. Previous research shows that factors such as low health awareness among Indian people, the high cost of products, and the non-availability of many products in the retail market have contributed to the sluggish growth in the medical
textile product industry (Vadodaria, et al., 2019). Value chain issues are potentially the leading cause of the slower growth of the Indian medical textile product industry (Sharma, Gupta, & Jha, 2020). The medical textile product industry is an interdisciplinary field requiring textile and technology. India’s well-established woven textile industry mainly uses cotton and polyester fabric as raw materials. It is a supplier of intermediate materials to Indian medical textile products (Vadodaria, et al., 2019). However, the Indian medical textile product industry is still heavily reliant on other countries for raw materials to make non-woven fabric and advanced technology to manufacture medical textiles/textile products. Previous studies show that India’s textile industry struggles with outdated machinery and technology. For example, the machine manufacturing the melt-blown nonwoven fabric used for PPE manufacturing was unavailable during the COVID-19 pandemic (Park Non Woven, 2022). Most of the research and development in the medical field happens in developed countries like the United States, United Kingdom, Germany, France, and others (IBEF, 2021). There is a lack of technology and raw material to manufacture medical textile products in India. Due to this, the manufacturers of traditional textiles are hesitant to invest in medical textile manufacturing. Medical textile products in India are a relatively new industry. They do not have a well-integrated value chain setup compared to traditional textiles.

Poor value chain management intensified during the COVID-19 pandemic, which drew social attention and became an issue threatening Indian people’s health and well-being (Vadodaria, et al., 2019). When the Covid-19 pandemic started, personal protective equipment (PPE) was the primary medical textile product required by healthcare providers and individuals. The PPE equipment includes N95 masks, respirators, fluid-
resistant garments, etc. India had previously relied entirely on imports for PPE kits. The machines (e.g., the seam sealing machine) and materials (e.g., PU-coated nylon/polyester fibers) required to manufacture the PPE were not available in the early pandemic stage in India (Sharma, Gupta, & Jha, 2020). The government saw the gravity of the situation and lifted import restrictions for PPE machines and materials (Sharma, Gupta, & Jha, 2020). Due to the temporal restriction removal, local fabric and garment manufacturers stepped in to supply PPE but found transport and logistics challenges (Sudan & Taggar, 2021; Lakshmanan & Nayyar, 2020).

India is the world's second-largest populous country, with a population of 1.4 billion in 2022 (Worldometer, 2022). The population is already high, and the anticipated birth rate growth is 0.68% in 2022 (Macrotrends, 2022). The increased lifespan and healthcare awareness will surge the demand for medical textile products (e.g., diapers, implants, personal protective equipment). The Indian government has set up the National Technical Textiles Mission (IANS, 2022) to promote the growth of the medical textile/textile product industry. In addition, an anticipated increase in domestic manufacturing will eventually produce cost-effective medical textile products and open up doors for exports (Vadodaria, et al., 2019). However, despite the expected increase in demand for the medical textile product market and its investments, the medical textiles/textile products industry’s potential has not been fully tapped.

Existing literature

The studies on the Indian medical textile product industry focus on a general overview. Studies in the Indian medical textile product industry focused on the overall reasons for the poor growth of the sector (Vadodaria, et al., 2019). The medical textile
field also gathered attention recently in 2019, when the COVID-19 pandemic hit. Value chain issues in distributing masks intensified during the pandemic from 2019 to 2022. To address the value chain issues, the Indian government implemented some changes, such as relaxing import restrictions on machinery (Sharma, Gupta, & Jha, 2020; Vadodaria, et al., 2019).

There is still a void in the literature regarding a clear understanding of the basic structure of the Indian medical textile product industry, the types of companies involved, and how they interact. There is no information about the value chain issues or the categorization and depth of the industry, further strengthening the need for research.

**Purpose of the study**

To address the existing literature gap in the medical textile industry, the researcher conducted a study to find the missing information about the Indian medical textile industry. The study aimed to 1) identify the structure and activities of the Indian medical textile product industry’s value chain, 2) find the challenges faced by medical textile/ textile product manufacturers that prevented them from attaining their full potential, and 3) find the changes which could help medical textile/ textile product manufacturers overcome them. To meet the research purpose, the researcher specified the following research questions.

1. Who is involved in the acquisition, production, and value addition of medical textile products, and how do they interact?

2. What constraints are responsible for the issues and problems in medical textile product manufacturers?
3. What means would support and improve the product manufacturers Indian medical textile product industry?

This study had three objectives to find answers to the mentioned research questions:

1. First, the researcher developed a value chain structure map for the Indian medical textile product industry.

2. In the second step, the researcher identified constraints that prevent material, information, and finance flows to the manufacturers of the Indian medical textile product’s value chain.

3. Finally, in the third step, the researcher suggested feasible solutions to improve the performance of the textile and product manufacturers of the Indian medical textile value chain.

India has a strong textile industry, a significant intermediate supplier to the Indian medical textile/textile product industry. To unearth the problems and issues in the Indian medical textile product industry, the researcher interviewed professionals in the medical textile/textile product industry. In addition, the researcher examined government restrictions, patents, raw material supply, and manufacturing issues. Depending upon the constraint, companies and the government can work on solutions to ensure that medical textile/textile products reach healthcare providers at the right time and at the right time price. By employing the Theory of Constraint (TOC) (Goldratt E., 1984) as a theoretical framework, the researcher found the constraints limiting the Indian supply chain system from achieving its full potential or causing obstruction in the flow of material, information, and finances. First, the researcher analyzed various interlinked processes
from start to finish of a product or service. Then, the researcher broke down each cycle by the monetary impact and prioritized the constraints that impact profitability most.

**Significance of the Study**

There are several reasons to study the Indian medical textile product market. First, this study is crucial to medicine, textiles, and business. Second, India is a large producer of textiles worldwide and has a robust manufacturing industry (Tiwari & Jana, 2021). This study attempted to understand why India needs to rely on imports for most medical textile/textile products from foreign countries. Third, it provides an in-depth understanding of the value chain structure in India's medical textile product industry. Fourth, this research aimed to fill gaps in the medical textile/textile product industry literature by bringing first-hand information on the challenges faced by companies in the medical textile/textile product industry in India. Fifth, this study shows how businesses in developing countries and leading emerging economies can benefit from and overcome the hurdles they face in running their business.

**Scope**

This research focused on India’s medical textile/textile product companies and their value chain. The researcher conducted in-depth interviews with eight medical textile/textile product manufacturing companies. The companies are all based in India and manufacture products used in the healthcare industry. The researcher also interviewed professionals and experts in the medical textile product industry to get a deeper understanding of the Indian medical textile industry.
CHAPTER 2.

REVIEW OF LITERATURE

Medical Textile Product Classification and Categories

Medical textile products are a part of the medical devices industry. Surgical dressings (30.74%) constituted the largest share of the Indian medical textile product market in 2019-20, followed by surgical sutures at 27.52% (Indian Institute of Technology Delhi, 2020). Medical textile product examples include the cuff of the blood pressure monitor, non-woven nanofiber filters used in respiratory equipment and transfusion/dialysis machines, lead-free X-ray shielding aprons, clothing incorporating electronic functions to monitor biological parameters or fibers that can facilitate the bonding of an implant to the living bone (Texman, 2012).

Medical textile products are divided into four categories depending on usage: healthcare and hygiene products, extracorporeal devices, implantable materials, and non-implantable materials (Kramer, Tan, Sato, & Kesselheim, 2014). Medical devices belong to one of three device classes (see Table 1) as per the risk involved: Class I, Class II, or Class III (King, Gupta, & Guidoin, 2013). In India, Central Drugs Standard Control Organization regulates overall medical devices as Drugs under the Drugs and Cosmetics Act of 1940 and Rules made thereunder in 1945 (Central Drugs Standard Control Organization, 2022). Medical devices are a significant cost driver in healthcare expenses. The Indian medical textile product industry focuses on healthcare and hygiene products, mainly low-risk products. Therefore, it is essential to understand the medical device industry since it also applies to the medical textile industry. More information about the classification follows.
**Class I devices:** These devices impose the lowest risk on the patient and are not intended to support or sustain life or be critical to improving human health. Class I devices have the least number of controls and are subject to general rules, such as good manufacturing practices. In addition, they must be registered with the medical textile regulating body. Still, most Class I devices do not have to undergo a review process. Class I devices include bandages, diapers, and surgical mask meshes (Kramer, Tan, Sato, & Kesselheim, 2014; King, Gupta, & Guidoin, 2013).

**Class II devices:** These devices are considered a medium risk and require more controls than Class I devices. These products are expected to enhance human health without causing injury or harm to the user. They might have unique labels or be required to meet specific performance requirements. The regulating body will undergo an intense quality process before market approval to ensure that the device is safe and effective for users. Class II devices include surgical gowns and artificial kidney meshes (Kramer, Tan, Sato, & Kesselheim, 2014; King, Gupta, & Guidoin, 2013).

**Class III devices:** These devices typically support human life and are essential to preventing harm to humans. Since most Class III products include implants, they must undergo animal and clinical trials to ensure their safety and benefits for humans. In addition, these devices require premarket approval and scientific review and are subject to Class I and II controls. Class III devices include implantable pacemakers, artificial heart valves, and hernia meshes (Kramer, Tan, Sato, & Kesselheim, 2014; King, Gupta, & Guidoin, 2013).

Table 1

*Medical textile/ textile products product categories.*
<table>
<thead>
<tr>
<th>Products</th>
<th>Class of medical devices</th>
<th>Fiber type</th>
<th>Fabric type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Healthcare And Hygiene Products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniforms, protective clothing</td>
<td>I</td>
<td>Cotton, polyester, polypropylene</td>
<td>Woven, non-woven</td>
</tr>
<tr>
<td>Wipes</td>
<td>I</td>
<td>Viscose rayon</td>
<td>Non-woven</td>
</tr>
<tr>
<td>Surgical hosiery</td>
<td>I</td>
<td>Polyamide, polyester, cotton, elastomeric yarns</td>
<td>Non-woven, knitted</td>
</tr>
<tr>
<td><strong>Extracorporeal Devices</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial kidneys</td>
<td>II</td>
<td>Hollow cellulose fibers or polyester fibers</td>
<td>Woven, non-woven</td>
</tr>
<tr>
<td>Artificial liver</td>
<td>III</td>
<td>Hollow cellulose fibers</td>
<td>Woven</td>
</tr>
<tr>
<td>Artificial heart</td>
<td>III</td>
<td>Plastic, decomposed velour</td>
<td>Non-woven</td>
</tr>
<tr>
<td>Mechanical lungs</td>
<td>III</td>
<td>Hollow polypropylene fibers or hollow silicone membrane</td>
<td>Non-woven</td>
</tr>
<tr>
<td><strong>Implantable Materials</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sutures</td>
<td>III</td>
<td>Collagen, polylactide, polylactidepolyester, polyglycolide, polyamide, polytetrafluoroethylene, polypropylene, polyethylene</td>
<td>Mono-filament, braided</td>
</tr>
<tr>
<td>Orthopedic implants, artificial joints, artificial bones</td>
<td>III</td>
<td>Silicone, polyacetal, polyethylene, polysulphone, carbon, polyester, glass, ceramic</td>
<td>Composite</td>
</tr>
<tr>
<td>Cardiovascular implants, vascular grafts, heart valves</td>
<td>III</td>
<td>Polyester, polytetrafluoroethylene</td>
<td>Knitted, woven</td>
</tr>
<tr>
<td><strong>Non-Implantable Medical Textile Materials</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absorbent pads, wound contact layer</td>
<td>I</td>
<td>Cotton, viscose, silk, polyamide, polyethylene</td>
<td>Non-woven, knitted, woven</td>
</tr>
<tr>
<td>Simple bandages, elastic bandages</td>
<td>I</td>
<td>Cotton, viscose, polyamide, elastomeric fiber, and yarn</td>
<td>Woven, knitted, non-woven</td>
</tr>
<tr>
<td>Plasters</td>
<td>I</td>
<td>Viscose, polyester, polypropylene, perforated film</td>
<td>Knitted, woven, non-woven</td>
</tr>
</tbody>
</table>

*Note.* Reprinted from “Analysis and Improvement of the Medical Textile Supply Chain in North Carolina” by Hayes (2019).

**Medical Textile Product Value Chain**
The term ‘value chain’ is the set of linked activities an organization performs that impact its competitiveness (Porter, 1985). Industry structure influences how margins are divided among buyers, suppliers, and coalition partners, how technology improves economies of scale, and what differentiates the products from competitors (Porter, 1985). The value chain consists of two or more organizations linked by material, information, and financial flows, firms producing parts, components, and end products, logistic service providers, and even the (ultimate) customer himself (Porter, 1985). Bamber and Gereffi (2013) illustrate the intricately connected medical devices' global value chain through a detailed diagram. Medical textile products are part of the medical device industry, and the same value chain applies to them. The textile industry is the supplier of the medical textile product industry. The textile industry supplies grey fabric for medical applications.

Figure 1
The research and product development phase is the first and highest value segment in the medical device global value chain. In this phase, new products are conceptualized, produced, and tested in addition to prototypes and assessing potential manufacturing capabilities. The company then registers the product for regulatory approval in the desired market (Bamber & Gereffi, 2013).

The second phase is the components manufacturing and assembly, typically the lowest value-added segments of the chain. Components manufacturing usually requires external services such as software development, knitting or weaving, or extrusion and molding. Assembly steps include packaging and sterilization. In addition, input suppliers provide added-value services such as chemical coatings, metals, and textile products (Bamber & Gereffi, 2013).
The setting up distribution channels phase is just as important as manufacturing the product. For example, medical device producers may distribute products through wholesale distributors or to hospitals or clinic administrators via internal distribution centers. Usually, wholesale distributors distribute lower-value products like bandages, gauze, and medical tapes. In contrast, high-value products are likely sold directly to hospital administrators (Bamber & Gereffi, 2013). In addition, high-end or class III products need post-sales service, including training on using the products and their regular maintenance (Bamber & Gereffi, 2013).

**Indian Medical Textile Market**

The textile industry is one of the major suppliers of the Indian medical textile products industry. It is worth reviewing the characteristics of the strengths and weaknesses of the Indian textile market associated with medical textile products. There are different types of specialty fabrics used in manufacturing medical textile products. A textile material used to manufacture a medical/ healthcare product is referred to as a medical textile by the industry. The medical textile industry is still in its infancy in India. The penetration of medical textile/ textile products is significantly less in India due to the cost of products and the non-availability of advanced products (Aurora & Sehgal, 2019). Due to the surge in demand and relaxing trade restrictions during the COVID-19 pandemic, the Indian medical textile market spiked to US $1.3 billion in 2020 (Lakshmanan & Nayyar, 2020). However, the spike does not necessarily show an accurate industry picture. There is still no information if the trade restriction will continue to be relaxed or if the situation will change after the pandemic. Apart from the increase in medical textile consumption during the pandemic, there are several reasons
why medical textile product market use will increase in India and worldwide. First, the Indian population will soon be the largest in the world and reach 1.515 billion in 2030 (Myers, 2022). The new generation in India has a higher disposable income, more education, and easy access to media/the internet (Vadodaria, et al., 2019). Second, there is a shift in Indian culture to western influence. Globalization has created more awareness about the usage of medical textile products in day-to-day life (Vadodaria, et al., 2019). Third, there has also been an attitude change in doctors and nurses due to health risks from bloodborne diseases and airborne pathogens. Most hospitals now prefer to use disposable products to reduce infections and contaminations (Vadodaria, et al., 2019). Fourth, medical costs are considerably lower in India, which has increased medical tourism, thereby increasing medical textile products use (Vadodaria, et al., 2019). The Indian government realized the potential for the medical textile industry and invested in the National Technical Textiles Mission in India in 2020 to increase domestic resilience by 2024 (Cabinet Committee on Economic Affairs, 2020).

India has a strong textile industry but a weak medical textile industry. India’s strength is mainly in cotton textiles, and most textile companies are export-oriented (Baskaran, Nachiappan, & Rahman, 2012; Ministry of Textiles, 2017; Verma, 2002). India is a large-volume producer of textiles but ranks extremely low in monetary value due to the unavailability of manufactured fibers at competitive rates (Indian Textile Journal, 2016). India imports several raw materials required to manufacture medical textile/textile products, such as chemical fibers, including polyester, polyamide, polytetrafluoroethylene (PTFE), polypropylene, carbon fiber, and glass fiber (Henan Lantian Medical Supplies Co., 2019). There is a disconnect in the industry, and
transparent information about various components, members, and factors responsible for their success and failure is missing. Value chain information is crucial to increase the medical textile industry’s efficiency so that the companies involved can deliver the most value for the least possible cost. Past studies discuss the incomplete value chain issues of sourcing raw materials, technology, and logistics (Ministry of Textiles, 2017) as the main challenges or barriers to the Indian medical textile product industry.

However, to my knowledge, no scientific approach has been used to research and investigate the value chain components, members, and factors responsible for the medical textile product manufacturers’ success and failure. As a result, there is no clear literature about the challenges faced by Indian medical textile/ textile product manufacturers. Hence, this research aims to address the literature gap.

**Theory of Constraints**

The Theory of Constraints is a methodology for improving processes by identifying the most important limiting factor (i.e., constraint) that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor (Lean Production, 2022). The theory focuses on the use of existing resources in the company. In manufacturing, the constraint is often referred to as a bottleneck (Lean Production, 2022). A constraint is defined as what “limits a system from achieving higher performance versus its goal” (Goldratt E., 1984) and thus can adversely impact the overall process. When constraints hold back the entire process, the organization needs to use available resources efficiently to address these constraints. Resolving constraints enables the organization to achieve its financial goals while
delivering on-time-in-full to customers, avoiding stock-outs in the value chain, and reducing lead time (Goldratt E., 1984).

An organization's flow of material and services is described as a system (Goldratt E., 1984). Every system is made up of interlinked processes. Processes like manufacturing, delivering parts, shipping goods, and quality control take time. Every step in the flow uses different resources and requires skilled labor or machines. Complicated products containing several materials require multiple suppliers who ship products to a manufacturing site at various time intervals, which can cause a lot of uncertainty.

When the entire process from start to finish of a product or service is broken down, each process has a monetary impact on an organization in varying amounts. For example, the company's goal is to make profits, and TOC uses approaches that will enable an organization to achieve maximum profits. The company can ensure that critical issues that hold back the company’s success are addressed. It can divert resources to focus on the entire company’s profitability instead of improving individual departmental efficiency.

TOC compares the processes in a system to links in a chain. If there is a weak link, the company must concentrate only on the weak link to strengthen the chain. Focusing on other links and supporting them will not improve the existing chain (Noriaki, Sachiko, Nobuta, & Mariko, 2008). For example, if sales orders are a constraint, efforts should be concentrated on improving these sales orders. On the other hand, if a company focuses on improving production output instead of sales orders, this will lead to overproduction, and sales orders will remain the weakest link (Goldratt E., 1984). TOC follows the five-step process as illustrated in Figure 2 and explained below.
1. Identify the Constraint

In the first step, a company must identify the constraints. An excellent way to identify constraints is by looking at undesirable effects such as late orders, rush orders, complaints, or loss of business. When an organization focuses on its constraints, it can increase financial results. Furthermore, since constraints determine the performance of a system, a gradual elevation of the system’s constraints will improve its performance (Rahman, 1998). Constraints can be physical, like materials, machines, labor, or demand for the product, or managerial, like policies, procedures, rules, and methods (Goldratt E., 1984). TOC proposes a detailed investigation of the constraint using “Un-Desirable Effects” (UDEs) down to the root cause. First, it analyzes the current situation and identifies the system constraint. It then links the causes and effects within the current operation to reveal the root causes of problems (Goldratt E., 1984).

2. Exploiting the Constraint

The second step is exploiting the constraint. The strength of the entire chain is considered as throughput. Using the existing tools, the organization needs to understand what they will do about exploiting the constraint. For example, suppose demand is a constraint. In that case, marketing needs to bring more business, or the organization needs to train more people if a staff shortage is a constraint. The organization needs to
maximize the utilization and productivity of the constraint and not the utilization and productivity of non-constraints (Goldratt E., 1984).

3. **Subordinate everything to the System constraints**

The third step emphasizes the constraint and subordinate other operations. This is a difficult step because it often requires a change in traditional managerial thinking. Giving the constraint more importance can lead to resistance from other departments in a company. To subordinate everything to the system constraints, other systems may become inefficient. Local optimization is abolished to improve overall efficiencies. Using the Just-In-Time manufacturing philosophy, a company may have a higher cost of materials but less inventory and lower operational expenses. Companies may need negotiations with vendors, and the purchasing department will have to work extra for smaller batches and higher material costs (Hemmondharop, 2002). TOC also uses Optimized Production Technology or Synchronous Manufacturing which uses a computer-based production and planning system (Goldratt & Fox, 1986). The OPT considers the statistical fluctuations and estimates the required time and material (Goldratt, 1984). The Drum-buffer-rope (DBR) system is a shop floor technique that is used to signal problems in production and helps the system to make sure that the constraint is taken care of well ahead of time and that there is enough buffer to align or make changes to the activities so that there is a smooth flow of materials and products (Hemmondharop, 2002).

4. **Elevate the system’s constraint**
The constraint performance is improved depending on the situation. Process improvement in the bottleneck will improve the entire system’s efficiency (Goldratt E., 1984)

5. Identify the next constraint

Managers must not get into inertia. TOC is a continuous improvement process. When one constraint is resolved, management must reevaluate the whole system and decide on the next constraint that needs to be tackled.

TOC use in research

The TOC will be used as a theoretical framework to find the constraints limiting the Indian medical textile value chain system. The interviews will provide the information required to identify the constraints. To exploit the constraint, the strength of the medical textile industry will have to be maximized. The company and government need some intervention to subordinate everything to the constraints by changing the traditional practices to improve overall efficiencies. Process improvements in the bottlenecks will improve the entire medical textile value chain. The next constraint will be found by re-evaluating the whole process by the monetary impact and prioritizing the constraints that impact profitability most.

Using TOC, issues at various stages can be seen, what has the maximum impact can be analyzed, and constraints can be identified. Once constraints are known, appropriate measures to elevate the constraints can be devised. Like Six Sigma, Lean Management, Kanban, and TOC originated in the manufacturing industry. Since its inception in 1984, it has been applied to other fields like software, education, supply chain management, and others. Applications of TOC can be seen in the medical area too.
In a case study carried out by 366th Medical Group, a unit of the US Air Force in rural Idaho, the application of the TOC’s five-step process led to a reduction in patient-waiting times and an increase in customer and employee satisfaction (Womach & Flowers, 1999). The team saw that no-shows for regular appointments and an overworked medical technician prevented the hospital from increasing patient appointments, enrolling more people, and lowering their profits. The team intervened and designated an appointment manager who adjusted the types of appointments. They also offloaded some work from the medical technician and added more medical technicians who helped support the healthcare provider.

The TOC thinking process was used to find the primary constraint, limiting system performance and resolving the problems faced by the maintenance system of the Albuquerque (New Mexico) Water Utility Division (Reid & Shoemaker, 2006). The Water Utility Division Maintenance System (WUDMS) within the Albuquerque Public Works Department had two goals of effective management: (1) completing work in a waste-free manner and (2) responding promptly to customer requests for service. As expected in a large public organization, researchers in the improvement teams found seven undesirable effects (UDEs) such as, 1) increasing customer complaints; 2) managers do not meet their objective of managing effectively; 3) wasteful practices in the organization; 4) repair work not completed promptly; managers are not able to schedule work promptly; 5) the backlog of work is increasing. The UDEs were identified by the improvement teams using the CRT. The groups agreed that the primary constraint of low labor could be resolved by allocating more human resources to repair work or improvement efforts, which would improve the overall performance of WUDMS.
After analyzing 42 TOC implementations in the healthcare industry, researchers found that all cases reported positive tangible and intangible outcomes in terms of increased productivity and increased number of patients treated (Bacelar-Silva, Cox, & Rodrigues, 2020). The article states that TOC can be a promising solution for providing chronic healthcare and improving quality and timeliness.

The theory of constraints (TOCs) was used to diagnose the UDEs of material management systems and identify root problems or conflicting material management actions (Lu, Chou, Huang, & Chu, 2018). The airline industry requires very high-quality materials and components to ensure the reliability of aircraft and passenger safety. However, paint, glue, rubber, and composites deteriorate in quality and value over time, resulting in stock shortages. In addition, frequent design changes are common, and airline manufacturers cannot stock high materials inventory levels. After the TOC analysis, the study uses mathematical planning tools and sensitivity analysis to choose the best action plan.
CHAPTER 3.

METHODOLOGY

To explore and understand the Indian medical textile product value chain through in-depth interviews, the researcher used open-ended questions as the best method to answer the research questions. The following sections go through how the researcher did the interviews to gather data.

Data Collection

After getting the Institutional Review Board (IRB) approval in December 2021, the researcher had to recruit interviewees. The researcher used the convenience sampling technique to make a list of companies to contact the potential interviewees. The researcher used keyword searches like PPE, bandages, masks, sutures, etc., and selected the medical textile companies. The researcher generated a list of companies and their contact person, mentioned on research, trade, and business websites like SITRA, Indiamart, IBEF, InvestIndia, TextileValueChain, and LinkedIn. The researcher contacted 96 companies with the Tax Identification Number mentioned on their website since all legitimate companies display it in their company descriptions. The researcher also called up 80 companies with phone numbers listed to recruit interviewees. The researcher interviewed professionals with at least five years of knowledge and expertise in the medical textiles/textile product industry. The researcher got nine interviews with the list, out of which only six interviewees completed the interviews and three backed out.

The researcher selected a purposive sample of industry experts to get information about the medical textile/textile product industry. This purposive sample consisted of the
head of the department at SITRA, one independent author and senior researcher with extensive work experience in medical textiles, and one marketing executive with extensive knowledge about medical textile distribution knowledge. In addition, the researcher used my network to recruit three more interviewees to increase the overall sample size.

In total, the researcher had 11 people out of the 101 that the researcher contacted. My contact rate for the interviews was 11%. The researcher completed all interviews by the last week of February 2022. My goal was to compare the participants’ responses and fully understand each unique experience. Additionally, the semi-structured interviews let me have a somewhat free-flowing conversation with the interviewees. The researcher took oral consent and sent the consent form to the respondents. No signature was required since the names of the respondents or their contact details were kept confidential due to the minimal risk involved. Interviews were conducted primarily in English; however, the researcher minimally used Hindi or Marathi language in case the respondent needed clarity on the question. The researcher did the interviews by phone or online meeting platforms like Zoom and recorded them. All interviews were transcribed in English for data analysis. The Zoom meeting transcribing feature was used to get the text file of the interview and the text file corrected for any incorrect transcription. There was no compensation provided to the respondents. The study results will be sent to the respondents if they have requested them after the thesis has been published.

**Interview Instrument**

After going through the literature on the medical textile/textile product industry, the researcher adapted an in-depth interview questionnaire from a study done in North
Carolina (Hayes, 2019). The 19-question interview began by getting basic information about the type of company, size, products manufactured, and position of the interviewee in the organization, followed by the questions related to the study's primary purpose. The interview questions were divided into five sections- demographic information of the interviewee, company information, information about the value chain, constraints, and possible solutions. The questions were purposely open-ended to allow the respondent to freely express their views and concerns about being a part of the medical textile product value chain. The following are the interview questions:

**Table 2**

*Interview Questions*

<table>
<thead>
<tr>
<th>Demographic information of interviewee:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is your name?</td>
</tr>
<tr>
<td>2. Position?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Company information:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. If owner-When was the company founded? / If other positions- Since how long have you been with the company?</td>
</tr>
<tr>
<td>4. Where is the company located? Does the company have a single location or multiple locations?</td>
</tr>
<tr>
<td>5. What is the size of the company? Does it come in micro/ small/ medium/ large?</td>
</tr>
<tr>
<td>6. What are the core products manufactured by the company/ services provided by the company?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value chain information:</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. What is the raw material or service required to make the products?</td>
</tr>
<tr>
<td>8. From where do you source the raw material?</td>
</tr>
<tr>
<td>9. Do you need to import any material? If yes, from which country?</td>
</tr>
<tr>
<td>10. Where is the finished product sold?</td>
</tr>
<tr>
<td>11. Do you export any products? If yes, which country?</td>
</tr>
<tr>
<td>12. Can you tell me the structure of the supply chain for your products?</td>
</tr>
<tr>
<td>13. How did you set up your supply chain network?</td>
</tr>
<tr>
<td>14. What changes have you seen in your industry since you started?</td>
</tr>
<tr>
<td>15. Which quality standards do you follow or need to follow? Do your customers require it?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. What are some of the issues your company faced when entering this industry?</td>
</tr>
</tbody>
</table>
17. How did you overcome these challenges, and how long did it take?

**Possible solutions**

18. What tools do you rely upon for your market research? Government, magazines, reports, trade bodies?

19. What do you feel prevents you from getting the necessary information or services?

20. What can be done, in your opinion, to support businesses like yours?

---

**Data Preparation**

In the first data preparation phase, the researcher downloaded the transcript of the interview data files and the audio files from Zoom. Then, the researcher corrected some minor mistakes that Zoom misinterpreted, like the interviewee's accent in the transcript.

In the second phase, the researcher ran the audio files through Atlas.ti software which also generated audio transcripts. The researcher carefully listened to the audio files, compared the Atlas.ti and Zoom transcripts, and corrected any remaining mistakes.

Finally, a fully updated transcript file was prepared on Atlas.ti and ready for thematic analysis.

**Data Analysis**

In the first phase of data analysis, using the software, Atlas.ti. The researcher generated codes like price, communication, utilities, government, etc., using responses to each question. Due to the free-flowing conversation during the interviews, answers to the questions were not just restricted to the questions the researcher had asked. Sometimes participants provided information about an unrelated topic when answering another question. The researcher found that the data had too many codes in Atlas.ti. The researcher narrowed them down to company, government, price, market, etc. In the second phase of the data analysis, the researcher used these themes and made a table in
Microsoft Excel for a better organization of the interview data to address the research questions.

Qualitative reliability indicates that the researcher’s approach is consistent across different researchers and projects (Gibbs, 2007). In this research, reliability was checked with the stability of responses to multiple coders (me and my major advisor) for the data. In addition, recording the interviews and transcribing the digital files helped enhance the quality of the data. Validation in qualitative research is trying to assess the accuracy of the results, as best described by the researcher, the participants, and the readers they consider (Creswell & Poth, 2013). Triangulating different data sources of information by examining evidence from the sources and using it to build a coherent justification for themes is one of the ways to establish validity (Creswell & Poth, 2013). The researcher interviewed different types of data sources from company decision-makers and industry experts, such as researchers, which would enhance the validity of the results.

Since the government of India has specific schemes and programs to help companies depending on their size, it was essential to understand how they are classified. Therefore, the researcher used this data to analyze the results and suggestions. As per the Government of India’s Ministry of Small-Scale Industries, the industries can be classified as under:

1. A micro-enterprise is one where the investment in Plant and Machinery or Equipment does not exceed one crore rupees, and turnover does not exceed five crore rupees (Sharma A., 2020).
2. A small enterprise is one where the investment in Plant and Machinery or Equipment does not exceed ten crore rupees, and turnover does not exceed fifty crore rupees (Sharma A., 2020).

3. A medium enterprise is one where the investment in Plant and Machinery or Equipment does not exceed fifty crore rupees, and turnover does not exceed two hundred and fifty crore rupees (Sharma A., 2020).

Table 3

Characteristics of Interviewees

<table>
<thead>
<tr>
<th>Case</th>
<th>Position in company</th>
<th>Location</th>
<th>Type of manufacturer</th>
<th>Class of medical devices</th>
<th>Size of the company by investment in plant and machinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>Owner</td>
<td>Kanpur, Uttar Pradesh</td>
<td>Fabric manufacturer (Cotton or cotton-polyester blend woven fabric, cotton knit fabric)</td>
<td>I</td>
<td>Micro</td>
</tr>
<tr>
<td>Company B</td>
<td>Owner</td>
<td>New Delhi</td>
<td>Fabric manufacturer (Smelt blown non-woven fabric, bags, and medical disposables like gowns, shoe covers, masks, caps)</td>
<td>I</td>
<td>Small</td>
</tr>
<tr>
<td>Company C</td>
<td>Owner</td>
<td>Bangalore, Karnataka</td>
<td>Product manufacturer surgical sutures</td>
<td>III</td>
<td>Small</td>
</tr>
<tr>
<td>Company D</td>
<td>CEO</td>
<td>Nahan, Himachal Pradesh</td>
<td>Fabric and product manufacturer spun bond non-woven fabric, shopping bags, masks, bedding, hygiene products</td>
<td>I</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Summary of Cases

1. Company A is a privately owned fabric manufacturing company that has existed for 14 years. It manufactures cotton and cotton-polyester blend woven and knit fabric for apparel and home. The company primarily uses cotton yarn sourced from the domestic Indian market but also uses polyester if required by customers. The company sells its fabric to local wholesale distributors. The participant interviewed (Participant A) is the owner of the company.

2. Company B is a privately owned fabric manufacturing company that has existed for 11 years. It manufactures non-woven fabrics used in the medical, hygiene, agriculture, and packaging industries. The company uses polypropylene sourced from the Indian market. It sells its products to Indian companies converting the
non-woven fabric into medical disposables like gowns, shoe covers, masks, and caps. The participant interviewed (Participant B) is the owner of the company.

3. Company C is a privately owned product manufacturing company that has existed for 27 years. It manufactures surgical sutures used in hospitals for closing wounds. The company uses silk yarn imported from South Korea by other Indian importers as the raw material. This company is export-oriented and sells its products in the United States and Europe. The participant interviewed (Participant C) is the owner of the company.

4. Company D is a privately owned fabric manufacturing company that has existed for 15 years. It manufactures non-woven fabrics and products like shopping bags, masks, and bedding liners. The company uses polypropylene mainly sourced from the Indian market or Gulf countries. It sells its products all over India and exports them to the United Arab Emirates, Vietnam, Spain, and Yemen. The participant interviewed (Participant D) is its CEO and has been with them for three years.

5. Company E is a privately owned fabric manufacturing company that has existed for 20 years. It manufactures non-woven fabrics to make filtration media used in face masks, air filters, and filters for hospitals and operation theaters. The company uses polypropylene imported from South Korea and exports the products to the USA, Europe, and Vietnam. The participant interviewed (Participant E) is the company’s Managing Director and has been with them for 20 years.

6. Company F is a privately owned product manufacturing company that has existed for 15 years. It manufactures surgical sutures and transdermal patches for
hospitals and operation theaters. The company imports silk and crepe material for non-absorbable silk along with several other synthetics like polypropylene, polyamide, and polyester from China, South Korea, and Brazil and sells its products all over India through wholesale distributors as well as exports them to various countries in the South Asian Association for Regional Cooperation (SAARC), Eastern Pacific as well as Africa. The participant interviewed (Participant E) is the company’s Managing Director and has been with them for 20 years.

7. Company G is a privately owned product manufacturing company that has existed for 30 years. It manufactures wound dressings for hospitals and operation theaters. In addition, it manufactures adhesive bandages for a leading brand and assembles first aid kits. The company uses cotton for manufacturing cotton bandages and polypropylene for adhesive bandages. The products are sold all over India through wholesale distributors. In addition, the company exports first aid kits to some African countries. The participant interviewed (Participant G) is the company’s CEO and has been with them for two years.

8. Company H is a privately owned product manufacturing company that has existed for 38 years. It manufactures grey fabric, bedsheets, and apparel fabric. The products are sold all over India through traders and wholesale distributors. Occasionally the company lobbies through mediators for large orders of hospital gowns, bedsheets, and masks. The participant interviewed (Participant H) is the partner and director of the company and has been with them for 15 years.
The researcher also interviewed three people who shared their thoughts and insights into the medical textile industry.

1. Participant X is the Head of the Department at SITRA.

2. Participant Y is an author of medical textile industry articles

3. Participant Z is a marketing executive at a pharmaceutical company.
CHAPTER 4.

FINDINGS

This chapter addresses the findings of the interviews. The three research questions

1) Who is involved in the acquisition, production, and value addition of Indian medical textiles/ textile products, and how do they interact? 2) What are the constraints in the Indian medical textile product industry? Furthermore, 3) What solutions will eliminate the constraint and improve the value chain of the Indian medical textile product industry?

This study used the base of the medical device value chain structure (Bamber & Gereffi, 2013). The researcher developed a modified structure from the field data to show the various steps of India’s medical textile value chain. This study answers the first research question by providing an overall value chain structure of the Indian medical textile product industry. For the second research question, this study finds the issues faced by the interviewees. It identifies the constraints that prevent the growth of the Indian medical textile product industry manufacturers. Finally, for the third question, this study explores what companies have done to overcome the challenges in the value chain. Based on the literature review and interview findings, this study provides suggestions.

Structure of the Indian Medical Textile Products Value Chain

Based on 11 interviews, this study identified six sequential stages for the Indian medical textile products industry: (1) research and development, (2) manufacturing, (3) distribution, (4) agency, (5) market, and (6) retailer. Figure 3 below shows the medical textile value chain’s overall structure. Depending upon the product type and maturity of the company, some manufacturers may or may not follow all the stages explained below. The six value chain stages are discussed in detail and give a broad overview of the Indian
medical textile product industry’s structure. Though the medical textile industry in India comprises many products, the value chain structure does not limit to a particular product line. Instead, it provides a comprehensive map of the industry.

Figure 3

*The Structure of the Medical Textile Product Value Chain in India*

**Research and Development**

The first stage in the value chain is research and development. The research and development process is long and involves product conceptualization, prototype production and testing, and assessing potential manufacturing capabilities. Depending on the risk category, the clinical trials required vary. The total time needed for a new medical textile product to come to market can be as long as eight years (Bamber & Gereffi, 2013). Large international companies do their research and development abroad and manufacture products in India for tariff and trade concessions, cheap labor, capital subsidies, and reduced logistics costs (Ferdows, 1997). For example, KOB Medical textiles is a German company that manufactures and sells bandages in India but does its R&D in Germany (KOB, 2022). Most domestic textile companies in India manufacture
low-value-added goods of low quality since they cannot afford the investments required for research and development.

The government research agency, SITRA, helps businesses with the research and development of medical textile companies. For example, SITRA provides pilot-scale manufacturing for face masks, sanitary napkins, surgical gowns, and wipes (SITRA, 2022). SITRA also evaluates the quality of medical textile products. However, the companies interviewed do not use any of the services provided by SITRA. The participating companies have in-house quality testing laboratories and do not develop innovative products in their company. For example, Company G is a manufacturing contractor for Johnson & Johnson (J&J), uses J&J’s manufacturing and quality control processes, and does not require to be associated with SITRA. On the other hand, participant C, a suture manufacturer, follows international quality standards and mentioned, “[…] we are export-oriented and use the United States Food and Drug Administration and European medical device standards. We have our testing lab”.

Manufacturing:

Product manufacturing is the second stage in the value chain. Manufacturers use raw materials like natural or artificial fibers or polypropylene to make gowns, bed sheets, uniforms, public personal protective equipment, bed liners, sanitary pads, air filters, and surgical sutures. In addition, inputs like metal or plastic components like hooks and loops, grommets, zippers, and Velcro, are often required for making the finished product. Depending on where suppliers fall in the supply chain, their customers may be other suppliers or manufacturers of the end product. For example, Participant E is a manufacturer that supplies non-woven melt-blown fabric to face-mask-making
companies and automobile air-filter-making companies. Participant D makes spun-bond non-woven fabric and delivers it to converters that make masks, disposable bed linings, and hygiene products.

Figures 4 and 5 are examples of the various materials used to manufacture a single product. Figure 4 gives a schematic diagram showing the different layers of an N95 mask. The N95 mask comprises four layers - the outer and inner layers are made of non-woven polypropylene, the filter layer is made of non-woven melt-blown polypropylene, and the support layer is modacrylic. In addition, there are elastic bands that keep the mask in place, and some have an aluminum nose clip for an adjustable close fit. For example, Figure 5 shows a cotton crepe bandage with a metal and elastic bandage clip.

**Figure 4**

_Schematic representation of the N95 mask with various layers_

![Schematic representation of the N95 mask with various layers](image)

**Figure 5**

_Cotton crepe bandage with bandage clip_
Manufacturers have dedicated assembly lines for mass production. Resetting assembly lines to manufacture specialized orders adds extra effort, downtime, and expenses. Products are customizable and undergo value-addition as per customer requirements. The manufacturing systems in the Indian medical textile product industry are mostly flexible due to the lower volume of items produced. Labor is vital for any manufacturing company. Medical textile/textile products generally require specialized operators for manufacturing lines. Products that require assembling can be done manually or by automation. Textile manufacturer Participant H mentioned, “We receive orders with the required specifications from our customers and manufacture the grey fabric accordingly. Depending upon the order, the grey fabric goes to a chemical company for dyeing and bleaching. For example, hospitals usually require a green-dyed fabric for curtains, gowns, caps, and bedsheets. The company outsources processing (like flame retardant, hydrophilic or hydrophobic coating).” Participant D added, “Vendors do coloring. If someone needs hydrophilic or hydrophobic coating, we outsource it.” Participant H mentioned, “[…] along with the textile manufacturing, we occasionally also manufacture bedsheets and gowns if there is a large order from the customer”. Participant G mentioned, “We assemble wound dressings, adhesive bandages, and first aid kits.”
Textile manufacturers may add value by using inputs like dyes, coatings, and finishes depending on the manufactured products’ complexity. Companies modify product manufacturing as per customer order specifications. For example, participant H mentioned, “[…] processing is outsourced for processes like flame retardant coating, hydrophilic or hydrophobic coating […]”. Finished products are labeled, packed, and sterilized before distribution.

Based on the interviews and literature, this study identified three main medical textile product categories in the Indian market: (1) woven and knit products, (2) non-woven products, and (3) yarn products.

Woven and knitted products are made from mainly cotton or polyester. Companies may source spun fibers from spinning mills. Spun fibers are then woven into textiles used in apparel, upholstery, home furnishing, and healthcare industries. In general, manufacturers do not manufacture fabrics solely for the medical industry. The companies commonly manufacture wound dressings and reusable products like hospital gowns, bedsheets, lab coats, and uniforms. Participant H mentioned, “[…] to achieve economies of scale and reduce reliance on just one industry, the company manufactures fabrics used in other apparel and home furnishing applications. As a result, only some of the total fabric manufactured goes to medical textile manufacturing companies”. Woven and knit textile manufacturers require fibers for woven and knit fabric production. Companies source the fibers from the domestic market. Participant A mentioned, “[…] no imports are required because everything is available in the country. 30 number and 40 number cotton yarn are sourced from domestic suppliers to make the fabric. […] cotton yarn comes mainly from Coimbatore in Tamil Nadu, India.”.
Polypropylene is the raw material used for non-woven fabric production. Polypropylene is sourced from Indian companies like Reliance Industries or imported from South Korea and Gulf countries. Some companies still need to import machines for manufacturing. There is hesitation when choosing the country for importing non-woven raw materials. Participant B said, “We import machinery from China but do not import raw material because of the trade war between India and China and the border (international border between the two countries) attack by the Chinese.” Participant D mentioned, “We prefer not to import raw material from China due to negative emotions developed due to the Covid-19 pandemic”.

Disposable non-woven products like gowns, shoe covers, masks, caps, bed liners, sanitary pads, and other hygiene products usage have increased in healthcare. Companies also make air filters used in automobiles, masks, and clean rooms. Participant B mentioned, “We make spun-bond fabric and sell to converters. Converters provide cutting, fusing, laminating, and other unique treatments”. Like woven and knitted product manufacturers, companies are not exclusive medical textile manufacturers. Companies manufacture non-woven fabrics used in several applications other than healthcare, like construction, packaging, and agriculture. Participant B mentioned, “[...] we are in several areas, and we do not overlook any sector for the products, like packaging, medical disposables, and geotextiles. We manufacture spun-bond non-woven fabric for shopping bags, masks, bedding (liners), and hygiene products. Diversifying into several sectors has helped us maintain a consistent demand.” Participant D mentioned, “We supply non-woven disposable bed liners to hospitals, spas, and railways (for use on railway sleeper
berths). Our company also supplies non-woven fabrics for agriculture and building construction”.

Sutures are the main yarn products manufactured in the Indian medical textile market. Figure 6 shows different types of non-absorbable sutures. Sutures are made from synthetic fibers like polypropylene and polyamide or natural fibers like silk. They undergo twisting and coating and are assembled with surgical needles, as shown in Figure 6.

**Figure 6**

*Non-absorbable sutures*

Companies in India prefer to use silk imported from South Korea, China, and Brazil. Participant C mentioned, “I get my silk from the domestic market. Silk thread is imported from South Korea by large bulk importers and sold in the domestic market in India. I need a small amount to manufacture sutures and. I had to work with an importer who would source the material from China and sell a small quantity.” Participant F mentioned, “We import raw materials from China, South Korea, and Brazil.” Small companies compete against medical device manufacturing giants like Johnson & Johnson
by offering flexible sizes. Participant C mentioned, “Products are assembled as per
requirement and are packaged to the required size as instructed by the customer.”

**Distribution**

Distribution is the third stage in the value chain. Distributors purchase a wide
variety of products from several different manufacturers. Participant Z explained that
distributors buy goods from manufacturers, store them in central warehouses, and resell
them to hospitals and other healthcare providers. Distributors manage product availability
in the value chain by working with multiple manufacturers. Participant Z also mentioned
that pharmaceutical distributors often move medical textile products in the value chain.
Distribution channels generally depend upon the type and value of medical textile
products. Wholesale distributors usually distribute lower-value products. In contrast,
high-value products are likely sold directly to hospital administrators (Bamber & Gereffi,
2013).

Wholesalers distribute Class I products such as gowns, caps, bed sheets, curtains,
uniforms, lab coats, and bandages. Participant A mentioned, “[…] product is sold locally
in Kanpur and India via distributors”. Most Class I products are low-tech, cost-driven,
and require less medical expertise in manufacturing. Woven and knit products are
generally multi-use, but non-woven products are almost always single-use. Increased
competition to become the preferred suppliers means that medical textile product
manufacturers spend significantly on direct marketing and building customer
relationships. Participant A mentioned, “We have good connections with customers and
others we interact with. […] All our orders are repeat orders”.

39
Yarn products like sutures are almost always distributed through pharmaceutical stockists and sold to hospitals. Suture manufacturers mainly manufacture products for the international market. The government of India provides the exporters and importers list for international trade. Participant C said, “dealers and distributors help sell the products (sutures).”

**Agency**

Some companies rely on agents for large orders. For exports, companies use sourcing or export agents to send orders. Participant H mentioned, “we lobby with middlemen for government orders.” Participants C and F noted that they rely on the importers’ list provided by the Ministry of Trade, Government of India. Participant D said, “We export our products to Dubai, Vietnam, Spain, and Yemen.” Participant E mentioned, “[...] We export to the USA, Europe, and Vietnam.” Participant F said, “We export to the SAARC countries, East Pacific, and African nations.”

**Market**

Wholesale distributors obtain goods directly from manufacturers (typically from multiple manufacturers), store them, and ship them to hospitals, often bundled with other goods. Hospitals are the primary customer category for the medical textile value chain. In addition, medical textile/textile products users can range from small, privately owned physicians to large, multistate integrated healthcare delivery systems and the general public.

First, the medical textile products go to nationwide stockpiles and wholesale distributors, also known as super stockists. Then, a smaller wholesaler dealing with a
lesser variety of products is called a stockist. Finally, international distributors take charge of all global sales. Distributors buy products from medical textile product manufacturers and sell them to retailers or hospitals. If there are large orders, manufacturers directly contact big hospitals' purchase departments and fulfill them. Figure 7 shows a simplified flow of goods from the manufacturer to the customer.

**Figure 7**

*The flow of goods from manufacturer to customer*

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Finished goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distributor</td>
</tr>
<tr>
<td></td>
<td>Hospital</td>
</tr>
<tr>
<td></td>
<td>International distributors</td>
</tr>
<tr>
<td></td>
<td>Hospital</td>
</tr>
<tr>
<td></td>
<td>Pharmacy</td>
</tr>
<tr>
<td></td>
<td>Patients</td>
</tr>
</tbody>
</table>

**Retailer**

Retailers sell products over the counter to the general public. The products sold by retailers are self-explanatory or have simple instructions that do not require specialized training. Pharmacists are the retailers of medical textile products in India. Pharmacies usually sell Class I medical textile products like first aid supplies, female hygiene products, and orthopedic products. However, pharmacies in the hospital building are typically specialized and stock Class I and II medical textile products.

**Constraints**
This section answers the second research question, “What are the constraints in the Indian medical textile product industry?” As explained in the literature review, constraints are the steps or processes that limit the manufacturer’s potential in the value chain structure of the medical textile industry to achieve the desired profit (Goldratt E., 1984). Even though each company produces different products, this study uses the theory of constraints. It expands the theory’s scope to an industry level. The responses to questions “What are some of the issues your company faced when entering this industry?” and “How did you overcome these challenges, and how long did it take?” provided the data for constraints. After going through all the codes, the researcher used responses that were repeated at least three times to generate themes. Themes of a competitive market, standards, and government support emerged. Through the interviews, the study identified three constraints faced by the Indian medical textile manufacturers: (1) a highly competitive market with price-sensitive products, (2) a lack of standards, and (3) a lack of government support.

Highly Competitive Market with Price-Sensitive Products

The Indian medical textile product manufacturers revealed that the market was highly competitive and price sensitive. Even though there is room for growth, the Indian medical textile product manufacturers felt that the market conditions might not support their growth. As part of the apparel and textile industry, the medical textiles industry also holds similar advantages and disadvantages as the apparel and textile industry. However, intense competition for price-sensitive products in the global market was a constraint hindering the growth of the Indian medical textile product industry.
One of the advantages of the Indian medical textile product industry is a skilled workforce and cost of production. Still, despite this, India lost to other countries like China due to a lack of advanced technology. Many medical textile product manufacturers are also textile and apparel manufacturers following the old manufacturing industry practices to keep costs low. Nearly all of India's medical textile product manufacturers low-risk are Class I product manufacturers (Indian Institute of Technology Delhi, 2020). Class I products like absorbent cotton and cotton dressings are some of the dominant medical textile products manufactured. Most medical textile product manufacturers in the Indian market do not see the long-term benefit of developing new medical textile products. Due to the high costs, manufacturers tend to use old machines rather than invest in new imported machines. India imports nearly all its textile machinery (Thevar, 2022), putting it at a disadvantage in earning a higher investment return. Since most medical textile products in India are not sophisticated, manufacturers compete with each other over price rather than differentiate products on innovation.

Low innovation in medical textile products compared to other countries can be attributed to India's lack of investments in research and development. Medical textiles are non-traditional, majorly using non-woven fabrics, and require high investments in research and development. For example, India spent US$ 48.1 billion on research and development in 2018. In contrast, other countries spent a much higher amount (Desjardins, 2018), namely USA (US $ 476.5 billion), China (US $ 370.6 billion), Japan (US $ 170.5 billion), and Germany (US $109.8 billion). As a result, the USA, Germany, the UK, China, and South Korea hold the most share of the global medical textile
industry (Trivedi, 2021). Moreover, India appears to have only a low-price strategy to thrive in the market.

Another reason for India’s struggle in the global medical textile industry is the small size structure of the medical textile manufacturers. The small-sized structure intensifies the issues, and India loses its comparative advantage. Small medical textile product manufacturers in India compete with large multinational corporations. Small manufacturers lose out on achieving economies of scale. They cannot take big orders due to the small production capacity. Participant C pointed out, “[…] big companies like Johnson & Johnson are my competitors.” Participant E mentioned, “[…] if the order size is small, running a batch production is delayed and not profitable”. In general, small-sized companies dominate the Indian business market. In the past, the Indian government policies have incentivized firms to remain micro and small by giving them tax benefits and subsidies (The Economic Times Rise, 2019). As a result, Indian manufacturers purposely set up several small plants even though they can extend to a single large company. Therefore, India’s textile and clothing sector (and thereby the medical textile industry) mainly has small manufacturing companies with little vertical integration in the textile industry (Shetty, 2001). The textile industry is primarily a family business in India. They often lack the technical and business knowledge to build a competitive business (Dhanabhakyam, 2007). Indian medical textile product manufacturers keep their products' prices down, affecting profitability.

In addition to losing out on economies of scale, utility expenses reduce the profits of Indian medical textile manufacturers. For example, the electricity required to run power looms is much costlier than in other textile manufacturing countries like
Bangladesh and Vietnam (The World Bank, 2014). There have been known incidents in an attempt to curtail expenses, small entrepreneurs evading taxes, and electricity tariffs, insufficiently or improperly selecting and maintaining machinery, and even exploiting laborers, adversely affecting textile production (Dhanabhakyam, 2007). Furthermore, the lack of reliable and professional factory working conditions increases risks. It dissuades international buyers from working with small companies. Textile products from India are less innovative. As a result, they do not have a competitive advantage over other countries in the global medical textile market (Lal, 2020). Participant C said, “[…] (Profit) margins are meager in the industry, and it is very competitive.” Participant G said, “We must constantly find new markets to sell our products due to competition.”

**Lack of Knowledge and Technical Standards**

Medical textile/textile products are essential tools for healthcare and directly impact public health and quality of life. Therefore, medical textile/textile products are subject to stringent standards to ensure that the manufacturing and design produce the quality required to serve patients and healthcare providers. For instance, IS:9473 is a standard used to test the N95 mask. Under the IS:9473 standard, only the masks which have a particulate filtration efficiency of 95%; are breathable, which means when a wearer inhales air through the fabric, the air pressure does not drop dramatically, forms a tight seal around a person’s face so that unfiltered air does not leak inside; and resists fire and withstands temperature fluctuations without losing its efficacy are certified as N-95 (Pulla, 2020)

The domestic supply chain is messy, and there is a lack of communication on the required industry-level standards. Manufacturers in India struggle to find information or
align their production systems to meet the required quality standards. Class I medical textile product manufacturers often find the quality standards complicated, so entrepreneurs find it challenging to move out of their comfort zone. Participant C mentioned, “[…] there is no external support, and entrepreneurs have to fend for themselves. There is no government support or workshop where one can get tips (for aligning production systems to specific quality standards). You have to do your market research.” Participant E mentions, “Technical gap quality between us (manufacturers) and end-users (hospitals and healthcare buyers) is a huge issue. Conventions used by customers and us are different. […] Customers and end-user are unaware of the different quality standards. Since there is no standardization, the fabric gets rejected, leading to a huge burden on us.” Participant G mentioned, “Since we manufacture adhesive bandages for Johnson and Johnson, we must follow their standards.”

It is difficult for them to target several customers for exporting a product, selling in the domestic market, and being profitable if the customers follow the standards mentioned before. Participant C mentions, “[…….] I follow international standards for USA and Europe as there are no standards for medical products in India”. Interviewees also mentioned the technical gap related to a lack of standards between customers and manufacturers. Participant C said, “there is a lack of technical standards, and each company uses its standard.” This gap in quality testing between the manufacturers and customers is a massive issue in the medical textile industry.

The current medical textile companies producing advanced Class II or Class III products like sutures, filtration devices, and hernia meshes follow different quality certifications like ISO, BIS, FDA, and European standards. Central Drugs Standard Control
Organization (CDSCO) regulates India's medical textile/ textile products. The Indian government agencies ISO and BIS are still developing standards for medical textile products. However, due to the lack of standards for medical textile products manufactured in India, companies often need to identify and determine the best means by doing their market research. For example, before the Covid-19 pandemic, the N-95 masks were supplied by an American company, 3M, and India’s Magnum Health & Safety. Several companies started producing substandard masks due to the sudden demand surge and lack of medical textile product testing facilities (Pulla, 2020).

**Lack of Government Support**

Interviewees felt that the Indian government was not doing enough to grow the Indian medical textile product industry. Of the interviewees, 75% expressed dissatisfaction with either the government policies or the internal working of the Indian government.

The first area that required India’s government’s support was research and development. As discussed in the previous section, medical textile production involves research and development funds. However, the interviewees addressed that there is not enough knowledge or machinery available in India to compete with the rest of the world. Technological advancements require huge investments, and small manufacturers struggle to raise funds for innovative medical textile production.

The Government of India promotes domestic employment in the textile industry, leading to a dominance of decentralized power loom and handloom sectors in fabric production and finishing. However, the focus on the traditional textile and apparel
industry rather than the medical textile industry has effectively slowed modernization in the weaving and finishing segments of the organized textile mill sector (Shetty, 2001).

Indian manufacturers stress that the government should improve its information literacy to communicate with the industry. Government policy changes and information are not well communicated. There is a lack of transparency regarding new and proposed laws and regulations that affect businesses. An unclear business environment inhibits the ability of traders and foreign governments to provide input on new proposals or to adjust to new requirements (Privacy Shield Framework, 2022). For example, the GOI introduced the Goods and Services Tax (GST), which led to confusion and protests. In previous research, a small manufacturer mentioned, “The confusion and the cumbersome regulations (of the GST) meant no sales and a halt in production—this was like a double blow for us” (Thevar, 2022). Participant H mentioned, “[…] government taxation is unfair, and the government listens only after protests and strikes. Anticipation of higher taxation prevented us from making future decisions and pricing”.

Indian businesses mentioned that the lack of online presence for Indian government business documentation is not streamlined and prolongs the process. India is a big country size-wise. Most small-scale industries are situated in rural areas, whereas government offices are in urban areas. The poor infrastructure makes travel difficult for documentation, and online forms will reduce this burden on Indian manufacturers. Interviewees also struggled to understand the forms and documents required for conducting business. Most Indian businesses must rely on several agents and officials to complete business document submissions. Participants also complained that government departments work very slowly. A lack of online business document submissions and
tracking systems affects businesses financially. Participant B mentions, “[…] doing business is not easy in India. The government gives a 30% subsidy for new businesses, but the process takes 4-5 years. Late reimbursements make it difficult for small industries to survive in intense competition. It also makes expansion impossible. […]”. Doing the paperwork, yourself is impossible since it is complicated to understand. In India, just being skilled is not enough. Young and new entrepreneurs cannot do their dream business in India because of the bureaucracy obstacles by the government”.

The Indian government has no long-term strategy for the Indian medical textile product industry. The government of India's procurements has price-driven rather than favored domestic manufacturing. Participant E mentions, “[…] the India government healthcare departments continue to buy medical textile products from foreign exporters despite the presence of local manufacturers”. The government of India's massive procurements accounts for nearly 30 percent of India’s $3 trillion GDP (International Trade Administration, 2021). Government procurements of medical textile/textile products can result in stable demand, a win-win situation for medical textile product manufacturers and the government. Participant E mentioned, “[…] government should support Indian companies. Made-in-India products should be given importance. Right now, everything comes from China. Big machines and the raw material are all imported. Government should support and raise awareness of manufacturing products in India. The government should not purchase items made in China or other countries to import if there are domestic manufacturers in India.”

**Suggestion for Solutions**
The researcher derived suggestions for solutions from the interview questions, literature review, and my views on the topic to suggest two approaches to overcome the constraints. The three interview questions were, “What tools do you rely upon for your market research? Government, magazines, reports, trade bodies?”, “What do you feel is preventing you from getting the information or services you need?” and “What can be done, in your opinion, to support businesses like yours?” Two main themes emerged: internal at the company level and external at the national level. Sub-themes of good communication and government support emerged from the data.

In the first approach, companies can change at the company level to control the internal product manufacturing environment. Indian medical textile/textile product companies face the challenge of intense competition for price-sensitive products. One-way companies can achieve a higher profit is through mass customization. Companies could distinguish themselves from others through customization. Mass customization is when companies make a grey product and then provide customization like trims, colors, or some embroidery per customer requirements. For example, a textile manufacturer who supplies medical textile/textile products can mass customize by producing the grey fabric and then dying it or applying coating as per customer request.

Another suggestion that companies can adopt for the intense competition is a very robust communication system with their customers. Interviewees mentioned that inadequate or improper communication hindered the demand and supply of medical textile products. Manufacturers can work closely and frequently with their customers to resolve communication issues. It will also help them anticipate demand and production changes in advance which will help run the operations smoothly. For example, participant
C’s customer required custom-sized packaging. Participant C mentioned, “[…] had to come up with novel packing and size to sell to the customer so that customer could accept them easily”. This example shows that it is vital to understand the customer's exact requirements so that companies can fulfill customer demands accordingly. One of the most critical approaches companies have mentioned is being flexible and making products as per customer requirements. Participant A emphasized good communication as an effective business strategy and said, “We have good connections with customers and suppliers.” Participant D mentioned, “[…] We understand the client’s need and innovate accordingly”. Finally, participant E said, “[…] we try to educate the customer. Knowledge sharing helps”. Good communication is essential for textile manufacturers to gather requirements, understand future needs, anticipate demands, and share knowledge.

Since the market is very competitive and price sensitive, a third suggestion that companies can benefit from is the diversification of product lines. For example, agriculture, construction, and medical industries use non-woven fibers. Suppose companies spread their product lines across volatile and robust demanding industries. In that case, it may reduce reliance on only one sector. As a result, companies will not face excessive demand fluctuations for products. Participants B, D, and E supply non-woven fabrics to medical, construction, retail, and agriculture industries. Participant B mentioned, “we are in several areas, and we do not overlook any sector for the products, […] diversifying into several sectors has helped us maintain a consistent demand.”

In the second approach, the study has suggested some actions for the government of India. Government policy changes can overcome the lack of standards constraints. India's medical textile industry needs the government's centralized management and
communication, which overlooks all aspects related to medical textile/textile products. The study suggests that the Indian government brings medical textile/textile product companies under a single umbrella of SITRA. The Food and Drug Administration (FDA) is a single organization that governs medical textile/textile products standards in the United States. SITRA should be an organization like the FDA for India. SITRA can help implement the required quality standards. Manufacturers and their customers can get guidance and direction from SITRA, and their customers will be on the same page regarding the expected medical textile standards. SITRA can also impart training on quality standards like Six Sigma, ISO, BIS, and others. Training will ensure that Indian medical textile/textile product manufacturers can produce competitive products in international markets. Although the Indian government has projected SITRA as the primary organization for medical textiles/textile products, none of the interviewees mentioned it in the conversation. Companies do not see SITRA as an organization that can bring value to the medical textile industry. SITRA can also impart training programs in vocational institutes with surety of jobs or apprenticeships.

The third constraint, i.e., lack of government support, is a broad area and must be addressed in several ways. Medical textile/textile products are in the advanced technology industry and require high investments. The first suggestion for the Indian government is to provide financial support and incentives for technology up-gradation and innovation. Medical textile/textile product companies in India find it difficult to do well due to a lack of financial aid. Companies hold back on new developments due to financial risks. Relying on banks and other financial institutions is costly, and several companies may not meet the minimum requirements. The interviewed companies rely
heavily on the government of India’s subsidies for their progress, which can sometimes be an issue. One of the ways SITRA can help Indian medical textile/ textile products is by promoting and supporting startups till they find investors and increase their production. In addition, SITRA can include incentives or grants for advancements in medical textile technology. In the U.S., the Small Business Administration (SBA) provides Advantage Loans through its program to qualifying businesses by guaranteeing loans from participating lending institutes. In Kenya, the Uwezo Fund helps youth and women entrepreneurs with grants, interest-free loans, and mentorship opportunities to help build capacity amongst these business demographics (UNESCO, 2022).

A second suggestion for the Indian government to support medical textile/ textile product companies is to provide a digital platform. The digital business platform will provide service to all the documents and forms submission and tracking information related to starting and expanding the business. Simplifying paperwork and online submissions will help medical textile/ textile product companies follow all the procedures for doing business without errors. Participant H mentioned, “Government forms or document submissions for the business are very complicated. We have to use special agents for document submissions.” Agents and intermediaries for document submissions add to additional costs for manufacturers. Simplifying document submissions will speed the application process and reduce costs borne by manufacturers. In addition, the government can design its small business website with a better user experience. Manufacturers will also be able to see the status of their applications.

The Indian government can thirdly support medical textile product manufacturers by buying products from the Indian medical textile manufacturers. The government can
promote its preference for procuring medical textile products, creating a demand for their products and providing them with concessional terms for securing government orders. Having assured large orders will significantly benefit and support small and new entrepreneurs in the medical textile industry. Table 4 sums up all the constraints and the suggestions for solutions.

**Table 4**

*Consolidated constraints and suggestions for solutions*

<table>
<thead>
<tr>
<th>Constraints Identified</th>
<th>Suggestions for Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly competitive market with price-sensitive products</td>
<td>Mass customization. Good communication with customers.</td>
</tr>
<tr>
<td>Lack of technical standards</td>
<td>Strengthen SITRA as the central organization for all medical device-related quality tests and standard compliance.</td>
</tr>
<tr>
<td>Lack of government support</td>
<td>Provide financial support and incentives for technology up-gradation and innovation.</td>
</tr>
<tr>
<td></td>
<td>Provide a digital platform that addresses all the documents and forms related to starting and expanding the business</td>
</tr>
<tr>
<td></td>
<td>Government procuring medical textile products from the Indian manufacturers</td>
</tr>
</tbody>
</table>
CHAPTER 5.

CONCLUSION

Summary and Discussion of Major Findings

This study first explores the structure and activities of India's medical textile value chain. Secondly, the study understands whether there are any challenges medical textile product manufacturers face that prevent them from attaining their full potential. Lastly, the study explores what changes can help these companies overcome the challenges. There are three research objectives: 1) to map the structure of the Indian medical textile value chain, 2) to identify constraints that prevent material, information, and finance flows throughout the Indian medical textile value chain, and 3) to explore feasible solutions to improve the performance of the Indian medical textile value chain. In-depth interviews with Indian medical textile professionals provided valuable insights and fulfilled the research objectives.

The Indian medical textile product industry comprises researchers, manufacturers, component suppliers, distributors, wholesalers, and retailers. The first step in the medical textile value chain starts with companies researching and developing products. Smaller niche companies do their research and development in India. SITRA does medical textile research and consults new entrepreneurs interested in entering the medical textile industry. However, India is mainly considered a manufacturing hub. Big companies that assemble products with imported textiles and technology do not do their research and development in India. The second step is manufacturing medical textile products. The three main medical textile product categories manufactured in India are (1) woven and knit products, (2) non-woven products, and (3) yarn products. Small-scale production is
typical in the medical textile industry. Distribution is the third stage in the value chain. In this stage, wholesalers are the leading distributors of products such as gowns, caps, bed sheets, curtains, uniforms, lab coats, and bandages. Yarn products like sutures are almost always distributed through pharmaceutical stockists and sold to hospitals. Implants and other class III products are sold directly to hospitals. For the fourth step, which is the agency, Indian manufacturers rely on agents for large orders. For exports, companies use sourcing or export agents to send orders. Once the products hit the fifth step markets, the products are sold by distributors, stockists, super stockists, and wholesalers. The retailer is the last step of the value chain. Retail products are self-explanatory or have simple instructions that do not require specialized training. Pharmacists are the retailers of medical textile products in India.

The Indian medical textile product industry is still developing and has several constraints. First, as with most developing countries, this study also found that Indian medical textile/textile product companies compete for price-sensitive products. The study found that the grey fabric manufacturers were catering to the apparel and upholstery industry and supplying to the medical textile industry. Medical textile products such as sutures and surgical bandage manufacturers concentrated exclusively on providing to the medical industry. Second, though the companies interviewed produced different medical textile fabrics and products, they had similar issues at the broad industry level. Most of the products manufactured were of lower technology products, and they competed with each other over price. Third, companies felt disorganization of expected standards related to medical textile products. They relied on overseas markets such as USA and European to manufacture quality products. Fourth, companies felt
unsupported due to the lack of a centralized organization governing the medical textile industry. Companies expect the Indian government to do more to make it easier for them to do business in the country. Finally, companies were hesitant to make further investments in the medical textile industry because they were unsure of their return on investments.

Some suggestions for the companies and government are given here. First, the medical textile industry is disorganized and needs to come under a single umbrella for efficient work. SITRA can be the much-needed umbrella for everything related to the Indian medical textile product industry. Moreover, SITRA can address all the understanding and dissipation of information about the medical textile industry. Industry growth depends upon the political environment. Second, an industry-focused government provides the macroeconomic environment, which supports and aids the industry. Incentives and financial support for high investments can help companies develop a niche and promote their products. Third, internet usage and online submission of all business-related documents will make the procedure transparent and faster. Fourth, assured demand for medical textile products will encourage small manufacturers to take more risks and invest in the medical textile industry. Fifth, low-technology products can create a niche with mass customization and partner closely with their customers. And sixth, companies may find it beneficial to cater to the demand of other sectors, which can help them to have stable orders.

**Implications**

This study is the first attempt to identify the structure and activities of the Indian medical textile; hence the findings provide academic and managerial implications.
Firstly, due to the study's exploratory nature, it attempts to show a real-life picture of the Indian medical textile product industry. This study's main contribution is introducing the Indian medical textile value chain in academia. Multinational companies can use the value chain structure of the Indian medical textile product industry to compare it with other countries competing with India in medical textile manufacturing. Developed countries can look at this research and see the Indian medical textile product industry diversify their supply chains. India can be an alternative manufacturing hub to other countries like China which controls most medical textile manufacturing. Secondly, previous studies have focused on the medical devices industry, where medical textile/textile products are only mentioned broadly (Datta & Selvaraj, 2019). But this study has attempted to classify and understand the medical textile value chain. The value chain structure of the Indian medical textile product industry is a new addition to the existing literature.

This study also has managerial implications. The interviews with industry professionals provided real-world information. The researcher analyzed this information to identify the problems in the Indian medical textile product industry to compete in the global market. First, SITRA can work with other countries like USA and Europe to develop medical textile standards that are easier to implement by Indian manufacturers. Secondly, companies can strategize their investments according to the current and future trade environment. Third, multinational companies like Johnson and Johnson and 3M can leverage their existing manufacturing bases in India to develop advanced technology products in India. The fourth implication is government related. Companies need an industry and trade-friendly atmosphere to thrive. However, several government policies
can directly or indirectly hinder a company's growth. This study pointed out the issues which required government intervention. The government can address the needs of the manufacturers and provide them with appropriate solutions. Some articles have been published (Indian Institute of Technology Delhi, 2020) on how efficient the Indian medical textile product industry is. However, the ground reality shows that the industry is still struggling and has a long way to go.

**Limitations and Future Studies**

This research has some limitations. First, the researcher could not travel to do in-person interviews due to government restrictions on travel which limited the sample size used for the qualitative study. The interviewees were Indian respondents during the Covid-19 pandemic. A larger sample size would provide more comprehensive information. Visiting a factory gives a personal touch to an interview, and the respondents are more trusting. Second, the interviews were conducted over the phone and via video calls. When recruiting respondents, there was a lack of trust in this methodology. Respondents were hesitant to divulge information over the phone. In-person interviews would have resulted in a much larger sample size and a much more intimate open conversation with the respondents. Third, the responses were at an industry level, and further studies can find more specific company-level constraints. Studies can focus on each type of player to understand the medical textile industry in-depth. Other studies can be done at the individual company level to understand the in-depth experiences of firms.
APPENDICES

Appendix A: Recruitment Email

Dear __________,

My name is Poonam Parab. I am a graduate student at the University of Rhode Island, United States of America, working with my faculty advisor, Dr. Ji Hye Kang (Ph.D.), in the Department of Textiles, Fashion Merchandising, and Design. We want to invite you to participate in a study being conducted by the University of Rhode Island on the Indian medical textile product industry. Your company has been identified as an important part of the medical textile industry in India, and your input will provide valuable information for the study.

The purpose of this research is 1) to map the structure of the value chain in the Indian medical textile product industry, 2) to identify constraints that prevent material, information and finance flow throughout the Indian medical textile value chain, and, 3) to explore feasible solutions to improve the performance of the Indian medical textile value chain.

The study will include an in-depth interview of 19 open-ended questions and would take approximately 1 to 2 hours. It will be conducted over an online meeting platform like Zoom or WhatsApp at a mutually convenient time. Participation in this study is voluntary, and you will not be paid any compensation or benefits should you wish to participate. The results of the study will be made available to you (if you choose to receive them) after the study has been published.
The eligibility requirements of the study are 1) Interviewee should be in a managerial or decision-making role, 2) Interviewee must be working in a company which has been identified as part of the medical textile industry, 2) Interviewee must be above 18 years of age.

This research has been approved by The University of Rhode Island’s Institutional Review Board. If you have any questions about this research, please feel free to contact me at +1 615-678-2048 or poonam_parab@uri.edu. You may also contact the Principal Investigator of the study Dr. Ji Hye Kang (Ph. D), at +1 401-874-2881 or by email at jhkang@uri.edu. Please let me know your willingness to participate in this research so that I can send you the consent form and proceed with the next steps. Thank you so much for your consideration.

Sincerely,

Poonam Parab
BIBLIOGRAPHY


https://cdsco.gov.in/opencms/opencms/en/Medical-Device-Diagnostics/Medical-Device-Diagnostics/index.html

Dependence in India. Economic and Political Weekly. Economic and Political Weekly.


IANS. (2022, March 28). India set to weave Technical Textile story with large scale investments. New Delhi, New Delhi, India. Retrieved from Ummid.


Myers, J. (2022, August 11). These will be the world's most populous countries by 2030. India.


