

**AN EXPLORATORY ANALYSIS ON IDENTIFYING THE
INFLUENTIAL FACTORS OF USING DIGITALIZATION
TECHNIQUES TO ACHIEVE A HIGHER SUPPLY CHAIN
EFFICIENCY BY SRI LANKAN APPAREL INDUSTRY**

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199171D

Research thesis submitted in partial fulfilment of the requirements for the degree of
Master of Business Administration in Supply Chain Management



Department of Transport and Logistics Management

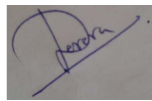
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Sri Lanka

August 2021

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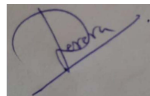
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The candidate has carried out research for the MBA in Supply Chain Management in the Department of Transport and Logistics Management of the University of Moratuwa under my supervision.



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ABSTRACT

The use of digitalization techniques has revolutionized the way of operating for many businesses today. It has become quite crucial for modern-day apparel manufacturers to use these techniques to cater to the highly customized needs of their customers with a minimum lead time to survive in the increased competition in the global market. Therefore, the apparel manufacturing firms constantly seek ways and means to improve their supply chain efficiency in terms of quality, cost, delivery, safety, and morale.

As most of the apparel businesses in Sri Lanka operate as a B2B business model with contract manufacturing agreements with renowned brands in the global market, many compliance requirements are being set by those giant companies just to improve their overall supply chain efficiency. Thus, the manufacturing firms are compelled to adopt various digitalization tools to cater to their customer's expectations. However, the implementation of aforesaid tools carries numerous benefits for all the supply chain partners.

The fashion and apparel (F & A) industry are one of the sectors which have largely implemented many of the digital applications into their operations during recent times. Whilst relishing numerous benefits, contemporary businesses also had experienced various negative implications after employing the aforesaid tools. The purpose of this thesis is to explore the various types of digital technologies which could be used by the F & A businesses, the potential benefits of those applications, and the possible challenges/risks to which they are exposed. In addition, this study would evaluate how those digital technologies could assist the B2B apparel manufacturing firms in improving their supply chain efficiency and enable them in data-driven decision-making.

Key Words: Digitalization, Fashion and Apparel Industry, Business-to-Business (B2B), Supply Chain Efficiency, Data Driven Decision-Making

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Last but not the least, many thanks would go to my wife and parents for the assistance provided me throughout this research project.

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LIST OF ACRONYMS

- AI – Artificial Intelligence
- AVR – Augmented Virtual Reality
- AM – Additive Manufacturing
- BDA – Big Data Analytics
- B2B – Business-To-Business
- CC – Cloud Computing
- RFID – Radio Frequency Identification
- RPA – Robotic Process Automation
- SQCDM – Safety, Quality, Cost, Delivery, Morale

1 CHAPTER – INTRODUCTION

1.1. Research Background

1.1.1. Introduction

The fashion and apparel supply chains are considered as one of the most dynamic supply chains in the contemporary business context. There is a rising trend of apparel customers constantly demanding better quality garments with mass customizations embedded and delivered within a shorter lead-time. As a result, many apparel manufacturers especially those who are in the South Asian region struggling to become competitive in the western markets they serve. In this context, it is quite useful to explore the ways and means that are available for them to optimize the supply chain efficiency whilst capitalizing on a minimum number of resources.

Supply chain optimization could be achieved in two ways; local optimization and global optimization (Lowe, 2019). Local optimization deals with optimizing a single function of a business without considering its effects on other functions. On the other hand, global optimization focuses on improving all the related functions together. In either way, the organizations would reap certain benefits such as better order fulfillment rates, demand planning, improved customer service, informed decision-making and healthier inventory control.

In recent years, digitalization has evolved to a greater extent which is now capable of assisting the decision-making activities at all levels of a business from operational to strategic. The term digitalization refers to the conversion of analog information, which is in the forms of text, images, pictures, or sounds into digital form that could be stored, processed, or transmitted using computers (Bloomberg, 2020). On the other hand, the term artificial intelligence refers to the simulation of human intelligence in machines that are programmed to think like humans and imitate their actions (Frankenfield, 2020). For instance, the functions such as visual perception, speech recognition, decision-making, and translation between languages are successfully performed using AI tools nowadays.

The apparel and fashion supply chains are comprised of a wide spectrum of players, raw material suppliers, manufacturers, customers, warehouse operators, and distribution centers, etc. The use of digitalization and AI technologies would help these players to optimize their respective functions. In this study, it is expected to explore on the application of these technologies and the level of impact it creates for apparel manufacturing businesses.

1.1.2. Apparel Sector of Sri Lanka

The export-oriented Sri Lankan apparel industry is comprised of more than 350 apparel manufacturers. The industry is largely dominated by three contract manufacturing entities which are commonly known as XYZ Holdings, ABC Apparel, and GHI Apparels (The researcher is yet to obtain the consent from the above companies to disclose their names in this study). Throughout the years, these apparel manufacturers have developed a strong reputation in the world for ethical manufacturing of high-quality apparel trusted by many global fashion brands. The apparel sector of the country contributes for about 44% of the national export revenue of the country and currently occupies nearly 990,000 employees (EDB, n.d.).

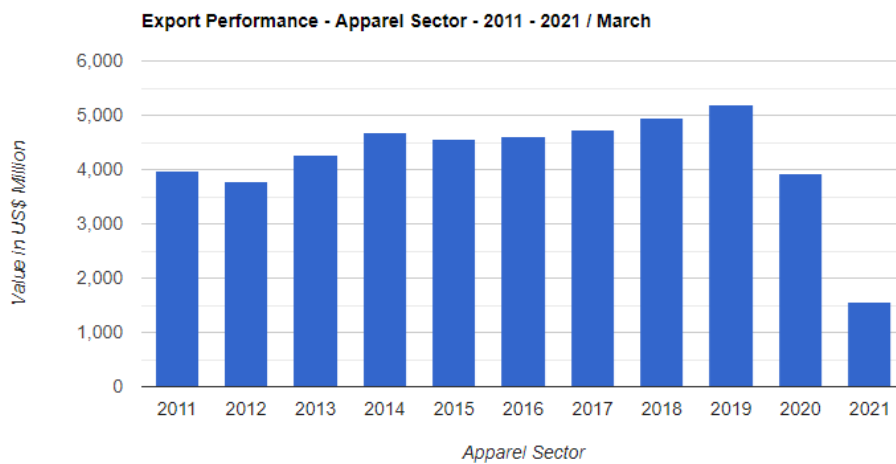


Figure 1: Annual Export Revenue from Apparel Sector (Source: Sri Lanka Export Development Board)

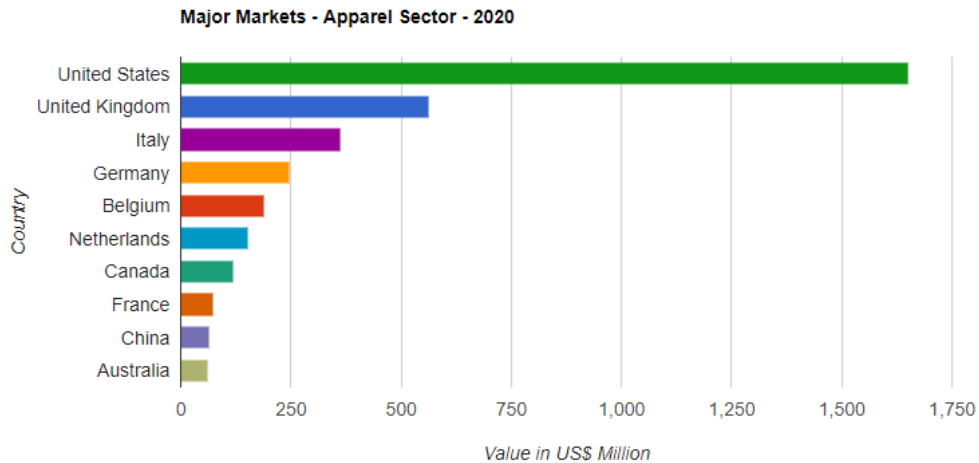


Figure 2: Major Markets of Apparel Sector in Sri Lanka (Source: Sri Lanka Export Development Board)

Although there is a significant contribution from the apparel manufacturing firms selected for this study to the country's economy, there is an ample number of small and medium-scale players who are also been in the business for a long time and trying to scale up their businesses. With the externalities created by the global pandemic and various other needs of the customers, the daily operations of the small and medium scale entities are heavily disrupted. In contrast, the large-scale manufacturers face insignificant impacts to their businesses due to market changes and the other companies must learn their best practices to improve their supply chain performance.

1.2. Problem Statement / Need for the Study

1.2.1. Research Gap

During the survey of the literature, it was noticed that most of the research work in this domain has been conducted after the year 2009 even though the digitalization methods have existed since 1989. Furthermore, the application of digitalization techniques has recently gained popularity in the fashion and apparel industry in the global context. Apart from that, it was also observed that there is a lack of applied research being carried out focused on the Sri Lankan fashion and apparel sector. Therefore, it is expected to validate the findings of the previous research work with the data gathered from the large-scale manufacturing entities in Sri Lanka.

1.2.2. Research Problem

In recent times, “digitalization” has become an increasingly important aspect of the apparel business. Most of the large-scale manufacturers in the country has begun to use technologies such as augmented virtual reality (AVR), radio-frequency identification (RFID), cloud computing, additive manufacturing, big data analytics, artificial intelligence (AI), and robotic process automation (RPA) to enhance the efficiency of their supply chains. As per the latest research findings, the organizations could use digitalization initiatives to determine how their product designs are made, how to improve the productivity levels of all functions, how to manage the product delivery channels and markets, etc.

There are numerous benefits achieved in terms of cost savings and time savings through the application of digitalization techniques. For example, with the use of robotics, the manufacturers could significantly reduce their production time whilst ensuring a higher level of output. In addition, the manufacturers who use digital platforms to track and trace the flow of raw materials are having a competitive edge over others as they could make relevant decisions based on real-time data. Another main challenge faced by the apparel-manufacturing firms is to find an adequate level of workers for the production due to high turnover. As a solution, they could invest in implementing AI system that has the capability of simulating certain characteristics of human intelligence and senses.

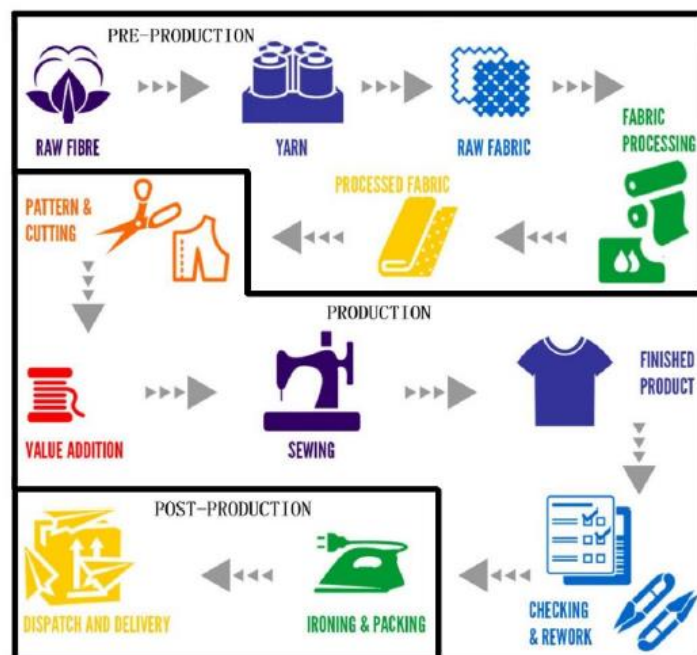


Figure 3: Apparel manufacturing activities (Source: Pattanachai, 2016)

Traditionally, the apparel manufacturing processes are highly labor-intensive which allows them to produce a wide variety of products with lower investments in fixed capital. In most cases, the manufacturers are not willing to invest to acquire digital assets due to cash flow issues or volatile consumer tastes. However, the efforts made by large-scale apparel manufacturers in Sri Lanka such as XYZ Holdings, ABC Apparel, and GHI Apparels on implementing digitalization tools are remarkable. As per the latest statistics, the above three companies are having the largest export market share and reported the highest apparel export revenue in the country. Therefore, it would be quite useful for the industry to understand the methods followed by these companies and the way they have overcome the challenges faced during the digital transformation.

1.3. Research Questions and Objectives

During the literature survey, it was observed that there are a limited number of research work being carried out focusing on the apparel sector of Sri Lanka on AI tools and their application. Therefore, the main aim of this study is to explore the contributions of digitalization and AI tools to improve the supply chain efficiency of the apparel industry of Sri Lanka. It is expected to validate the results of the previous research performed in this domain by replicating the tools and techniques used.

1.3.1. Research Questions

The following research questions are expected to answer with the findings of this study.

- RQ 1 Which digitalization techniques could be used by apparel manufacturers to improve their supply chain efficiency?

- RQ 2 How the digitalization tools could be applied to develop data-driven solutions using product-related data furnished by apparel manufacturers?

- RQ 3 What industry-specific challenges are faced by apparel manufacturers during the digital transformation process?

- RQ 4 What are the unique benefits that are enjoyed by the apparel manufacturers after the digital transformation?

The first two research questions are focused on identifying the current digitalization initiatives taken by the apparel manufacturers to improve their supply chain efficiency in terms of quality, cost, delivery, safety, and morale. The last two research questions seek information on possible challenges faced by the companies before and during the implementation and the benefits gained by the companies after the implementation of the digitalization initiatives.

1.3.2. Research Objectives

The following objectives are expected to achieve during the conduct of this study during the process of finding the answers for the above research questions.

RO 1 To identify and review the possible challenges faced by the apparel manufacturers when implementing the digitalization tools

RO 2 To assess the effectiveness of digitalization initiatives made by apparel manufacturers to improve the supply chain efficiency

The association between the research questions and the objectives could be illustrated as follows.

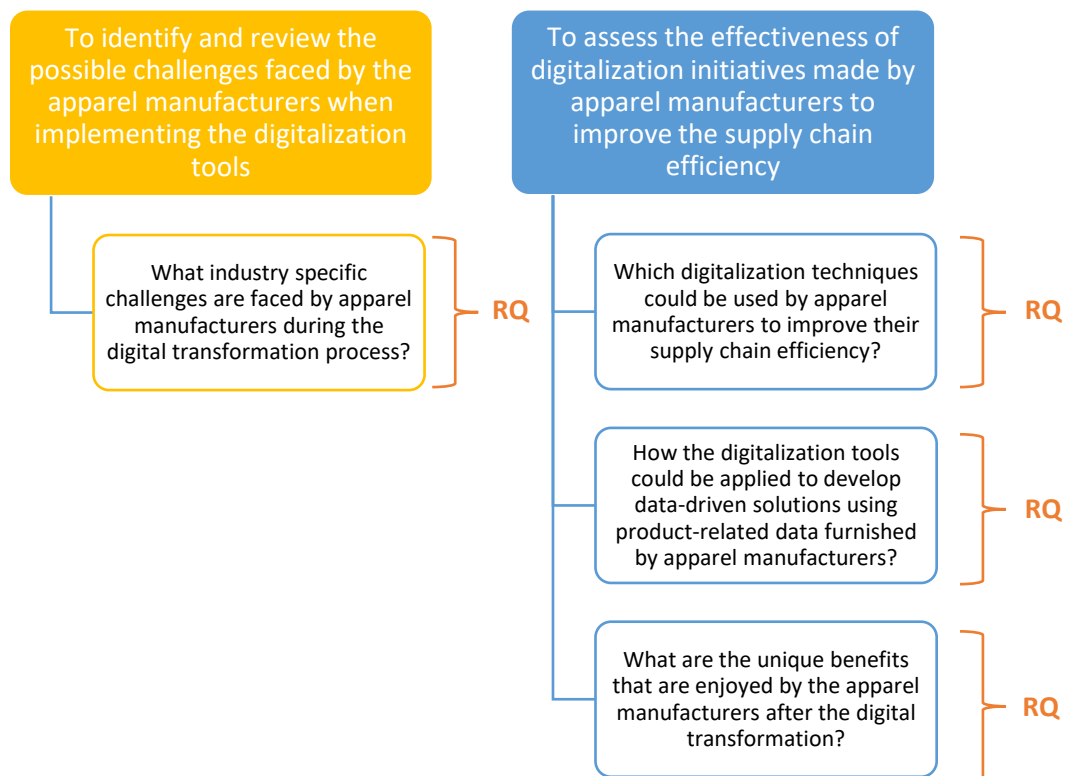


Figure 4: Association between Research objectives and questions

Primarily, the researcher expects to discover the available digitalization techniques that could be used by the apparel manufacturers to improve their supply chain efficiency. Subsequently, the different applications of the digitalization techniques would be studied whilst understanding the challenges faced by the companies when transforming their supply chains. Consequently, it is expected to discuss potential benefits which could be reaped by the companies once the digitalization techniques are implemented.

1.4. Research Scope

To ensure the feasibility of completing this research within a period of six months, certain scope and limitations are taken into consideration. The scope of this study would be limited to the three export-oriented contract manufacturing firms (B2B) operating in Sri Lanka and their approaches towards digitalization applications. This research it is expected to authenticate whether these large-sized apparel firms have been able to develop a unique competitive edge in their supply chains after following through a complete digital transformation process. Therefore, the findings of this study would be more specific towards the fashion and apparel industry that cannot be generalized.

Furthermore, to enhance the validity and reliability of this study it is expected to use the findings of the previous academic journal articles published only between the period of 2014 to 2020. There could be other trade and commercial-based journals and magazines published in the same area of interest that would not be considered for this study. Apart from that, the article search would be limited to three online databases and the study might not capture certain publications due to the use of carefully selected terminology as the search criteria of the literature survey. The research works published in languages other than English would be excluded from this study.

This research would not cover the areas of post-implementation security concerns, organizational cultural effects, technological implications, and the costs incurred by firms. It is only expected to study the challenges faced by the firms during the process of implementation and the effectiveness of using the tools to improve the supply chain efficiency. On the other hand, the conclusions drawn at the end of this study would be based on the empirical data collected only from a relatively smaller number of companies and secondary data gathered from a limited number of databases. Furthermore, the manufacturing firms selected for this research would be facing different business situations and higher

capacities in terms of infrastructure and people talent. Therefore, it might be required to carry out further research to extend the validity of the findings of this study when applying the concepts in other small and medium scale organizations. The results of this study might get changed if a more comprehensive data set is used.

To gain the highest level of efficiency in the supply chain, all the partners upstream and the downstream must be in line with the application of the concepts discussed in this study. Therefore, the other players in the apparel supply chain such as raw material suppliers, logistics service providers, distributors, retailers, and the end consumers are also required to adopt the same type of techniques to improve the overall supply chain productivity. Further studies might be required to assess the suitable approach to follow when implementing the digitalization techniques in other business operations in the same apparel supply chain.

1.5. Significance of the Study

The purpose of this study is to conduct a thorough analysis of the digitalization applications in the apparel supply chain. It is expected to unveil numerous opportunities and threats generated with the use of these techniques that would be valuable for both academics and practitioners in the industry. For instance, the researchers would be able to understand the conceptual transformation of apparel supply chains and develop theories whereas the practitioners would be able to learn how to use these tools effectively to produce competitive advantages, enhance product quality, minimize the overall supply chain costs, boost innovations, etc.

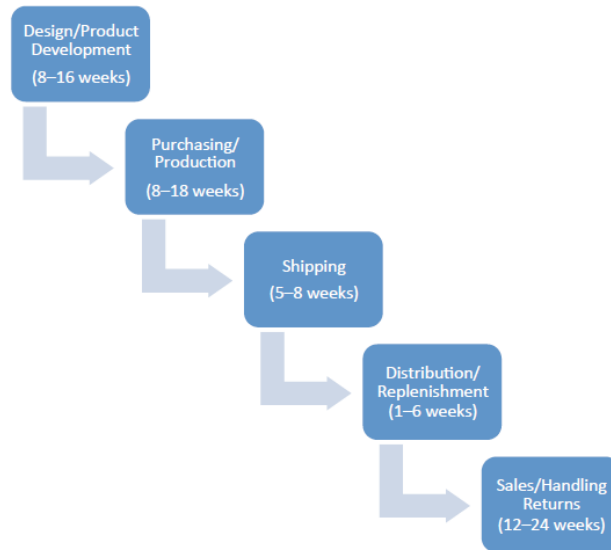


Figure 5: Traditional apparel supply chain (Source: Fung Global Retail & Technology)

In recent years, the apparel industry has gone through vast changes where order lead times have been drastically reduced, product varieties and complexities have risen, mass production has been fully replaced with mass customization of products, and most importantly the product life cycle has been reduced to a greater extent. Therefore, the need for a quicker flow of information has become an essential character for all the players in apparel supply chains. In this context, the industry has started to shift towards digitalization and automation to become competitive in the market. To cater the consumer tastes, the giant apparel brands in the world such as Nike, Adidas, Victoria Secret, H & M, Gucci, Zara, Hermes, etc. have already implemented a variety of digitalization techniques that has created pressure on their upstream and downstream supply chain partners also to fit into those initiatives.

From the perspective of the apparel manufacturer, numerous benefits could be achieved with the use of digitalization tools. Increased productivity levels, informed decision-making ability, real-time visibility towards the overall business operations, ability to tackle rapid changeovers, and ability to maintain an improved lead-time are some of the key benefits for manufacturing entities in the apparel supply chains. The use of these tools would also open the doors especially for contract manufacturers to develop long-term and strategic partnerships with their customers and they would be able to understand the potential long-term business integrations.

1.6. Time Plan

The proposed and approved time plan of this research is attached in the Annexure-1.

1.7. Chapter Breakdown

The structure of this thesis is outlined as shown in Figure-6

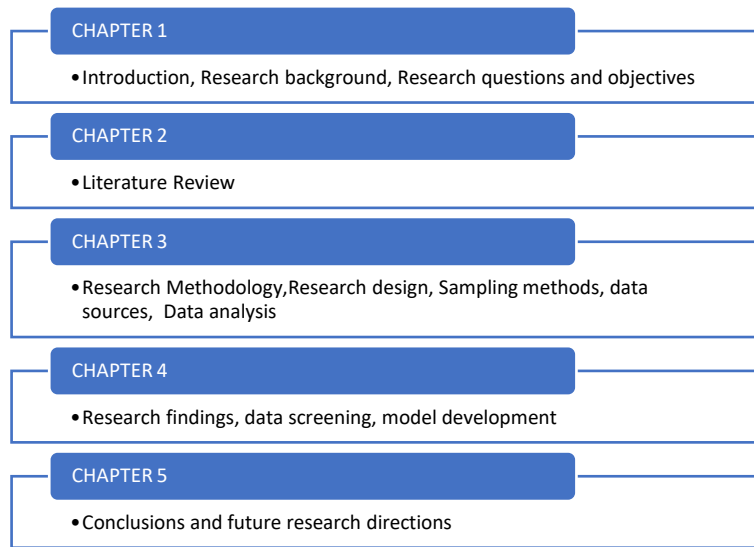


Figure 6: Structure of the thesis

There will be 5 chapters included in this thesis. Chapter 1 introduces the research topic and its background and develops the research gap, questions, and objectives. Chapter 2 provides necessary evidence from the previous studies conducted in the selected domain that would be tested in the Sri Lankan context. Chapter 3 provides an overview of the research design, methods of data collection, and analysis. Chapter 4 summarizes the findings of the survey and develops a model to understand the relationship between the variables of the research. Chapter 5 discusses the conclusions of the thesis whilst providing future research directions and the limitations.

2 CHAPTER – LITERATURE REVIEW

The purpose of this chapter is to provide a comprehensive review of relevant literature and build the foundation with the insights extracted from that literature to achieve the objectives set out in this thesis. Section 2.1 describes the context of the global apparel industry whilst discussing its evolution and the current challenges. Section 2.2 provides a summary of digitalization techniques successfully used by other apparel manufacturers in the world. Section 2.3 reviews various challenges faced by the apparel-manufacturing firms when implementing the previously mentioned tools. Lastly, section 2.4 discusses the benefits reaped by the apparel manufacturers who have implemented the digitalization tools into their processes.

2.1. An overview of the global apparel industry

Clothing is considered an essential feature of the whole of humankind that also has a long history of evolution. People use to wear different clothes to display various social, cultural, and demographic characteristics in society (Nayak & Padhye, 2018). Unlike in ancient times, the developments in fashion and trends have revolutionized the basic clothing patterns of the people in a significant manner over the years. The modern fashion and apparel industry represent one of the most dynamic sectors in the global economy that consists of highly unpredictable demand, shorter lead times, increasingly customized products, and high supply chain complexities. Due to rapid technological advancements and the developments in international trade, the industry has become highly competitive, and the market has fragmented into a myriad of niches that requires highly sophisticated supply chain operations to cater the customer needs (Jain, 2020).

The global economy has already gone through three industrial revolutions up until now. During the 18th century, the first industrial revolution has taken place in Britain that is known as the emergence of mechanization. In this era, people have started to use machinery to perform their required tasks and the agricultural era was replaced during this time. The second industrial revolution has taken place at the beginning of the 20th century where new sources of energy were introduced for the industry. The industrialists have started using electricity, gas, and oil as their main sources of energy during this period. In the late 20th century, the third industrial revolution has taken place and during this era, growth was

noticed in the industries such as electronics, telecommunication, and computers (Kaplanidou, 2018). At present, the fourth industrial revolution (industry 4.0) is in progress that has vastly disrupted almost all the industries in the world including the fashion and apparel sector.

Most of the organizations in the global context today are being digitally transformed by replacing traditional business practices. The term digital transformation refers to the fundamental transformation of the entire business through the establishment of new technologies powered by the internet and other digital platforms (Bloomberg, 2020). The need of implementing an automated solution has been in the mind of most apparel manufacturers in the world since the 1980s. However, the high labor-intensive nature of production with rapid changeovers in designs have led to delay in the industry is taking the digitalization journey for many years (Kaplanidou, 2018). As a result, the apparel supply chain had to face difficulties in achieving the expected productivity levels and quality in all aspects for many years. The introduction of digitalization and artificial intelligence techniques has revolutionized the industry in recent times, and it has become a critical success factor for many organizations (Nayak & Padhye, 2018).

2.1. Application of digitalization techniques by the apparel manufacturers

During this literature survey, it was noticed that many large apparel manufacturers in the world have also shown an optimistic view on adopting such techniques to improve their current business process. Most of the studies conducted in this domain have revealed identical results regardless of various methodologies followed by them. For instance, a systematic literature review of 149 research articles conducted in association with artificial intelligence in the fashion and apparel industry has evaluated the impact and significance of utilizing those tools in the last decades throughout the supply chain (Chandadevi, et al., 2017). The researchers have categorized the articles according to various AI applications used: Machine learning, Expert systems, Decision support systems, Image recognition, and Computer vision. A similar comprehensive review of research articles has been carried out in relation to the application of decision support and intelligent systems in the textile and apparel supply chains analyzing 77 articles by categorizing them into three basic segments: textile production, apparel manufacture, and distribution/sales (Alexander, et al., 2014).

Jain, 2020 has evaluated the effectiveness of employing big data and AI tools to improve the business operations of firms. The companies could use big data for activities such as trend forecasting, supply chain management, and the analysis of consumer behavior, preferences, and emotions (Jain, 2020). The researcher has primarily identified and classified AI techniques that could be used at various stages of the supply chain to improve existing business operations. Subsequently, the thesis presents product-related data used to create a classification model and design rules that can create opportunities for providing personalized recommendations or customization, enabling better shopping experiences for customers. This thesis also draws from the evidence in the industry and existing literature to make suggestions that may guide managers in developing data-driven strategies for improving customer satisfaction through personalized services. Finally, the study has shown the effectiveness of data-driven analytical solutions in sustaining competitive advantage via the data and knowledge already presented within the apparel supply chain.

Kaplanidou, 2018 has recognized the role of the dynamic capabilities in the digital transformation of apparel manufacturing firms. The researcher has conducted semi-structured interviews that are complemented with secondary data sources to examine the roles of dynamic capabilities and their influences in depth. Another research has been published by a scholar attached to a leading apparel research institute that emphasizes the importance of a holistic approach to digitalization and provides an overview of potential benefits that firms could achieve (Weinswig, 2017). The report further analyzes the four main stages of the apparel supply chain and illustrates how various types of digital technologies could be applied in each stage.

In summary, the application of digitalization tools would unveil many opportunities for apparel manufacturers as depicted below (Weinswig, 2017).

1. Market intelligence and characteristics

- Understand market trends by analyzing various types of data (AI)
- Monitor the actual consumer tastes and properties of the materials used for production (RFID)

2. Interactive designing and product development
 - Forecast projected demand for new products (AI)
 - Allow both designers and consumers to compare and test new designs in virtual platforms before the actual production or purchase (AVR)
 - Produce prototypes of new designs using 3D printing (AM)
3. Material grading and sourcing
 - Examine and identify material properties of garments and fabrics (AI / RFID)
 - Decide on best raw material suppliers and fabrics to use (AI)
 - Classify and grade garments and identify defects (AI / AVR)
4. Logistics and transportation
 - Engage in Just-In-Time production and better manage the supply networks (RFID / AI)
 - Manage the delivery arrangements and minimize delays (RFID)
 - Automate the processing of relevant shipping documents (RPA)
 - Access to real-time information on production or delivery (CC)
5. Production and waste elimination
 - Plan, monitor, and control production activities (RFID / AI / CC)
 - Optimize the material usage and reduce the amount of waste (AI / RPA)
 - Monitor the employee working conditions (production hours & overtime), occupational health and safety measures, and environmental impacts (AI / AVR / CC)
 - Automate the production activities (AI / RPA)
6. Customer service and support
 - Immediately respond to customer inquiries chatbots (RPA / AI)
 - Provide quick solutions to the customers as per their purchase history and recent product searches (AI)

2.2. Challenges faced during the implementation of digitalization techniques

Despite having numerous benefits in implementing digitalization tools, it also hinders certain challenges during and after the implementation process. For instance, the application of digitalization tools always requires continuous adaptation to new technologies, increasing volume of data, and consistent maintenance of the systems and platforms. A company that is

starting the digitalization journey would have to undergo many challenges, as they need to start from scratch.

Change management has been one of the major challenges faced by the firms that decide to take on digital transformation. Organizational change always creates anxiety, insecurity, and uncertainty among employees that will lead to high resistance to change (Kaplanidou, 2018). For instance, when intelligent robots and advanced technologies are introduced to work processes the need for human intervention becomes relatively lower and it results in feelings of insecurity among the staff. Therefore, the high resistance to change might become a barrier to the successful implementation of digital tools.

System adaptability is another key encounter faced by companies when implementing new digitalization techniques. For instance, the newly adopted tools need to be compatible with the current systems used in the company as well as the systems of suppliers and customers. The new technological tools would also require a change of competencies in staff and IT security (Buttner & Muller, 2018). It might require the firm to spend an extra amount just to bridge the compatibility gaps.

Digitalization initiatives always require a substantial amount of investment in IT infrastructure. Therefore, a small and medium scale enterprise might not be able to afford the required capital expenditure. Apart from that, digital technologies would enable all the connected devices to communicate automatically with each other whilst gathering, processing, and analyzing a large amount of data at once (Richter, et al., 2017). Therefore, once the digital platforms are in place it would further require extra protections against data security and privacy. This could become another challenge for most companies irrespective of their scale of operations.

Inadequate technical skills and expertise of the operational staff could be another challenge faced by the firms when they transform their operations digitally. Providing the staff with the required training and necessary guidance would consume a substantial amount of time until they get fully conversant with the new systems. The increased level of complexity at work might create a negative impression on the people who are not born into the digital world (Richter, et al., 2017). Furthermore, certain job roles require a high level of traditional skills such as work experience, intuition, innovativeness, and compassion. Therefore, during the

transformation period, the organizations might decide to overestimate the digital skills at the expense of traditional skills that would generate negative results in the end.

2.3. Potential benefits of implementing digitalization techniques

As per the previous studies conducted in the domain of digitalization and its application in the apparel sector, it has proven that the companies were able to gain numerous benefits in terms of cost-efficiency, process visibility, risk management, forecasting accuracy, etc. The following section explains the types of advantages that are available with each digitalization technology.

Artificial intelligence is known as one of the most researched technology in the global context. It represents a field of science that could simulate the characteristics of human intelligence and human sensory capabilities (Nayak & Padhye, 2018). The use of AI tools has revolutionized many disciplines such as engineering, medicine, production, and management. AI could provide superior solutions to various problems faced by the apparel-manufacturing firms such as increased number of production defects, high operational costs, and low productivity levels of the workers. In addition, this technology could be used in parallel with other digitalization techniques to achieve the highest level of optimization in the respective processes.

Amongst many other digital tools available, cloud computing could be seen as one of the most rapidly used techniques in the apparel sector. Cloud computing technology stimulates the new product development needs, reshaping the needs of the supply chain, and handling data analytics to optimize the production processes (Kaplanidou, 2018). The planning of production activities and raw materials, costing, order processing, sampling, and monitoring the final delivery have become effortless due to the use of cloud computing.

Augmented virtual reality is another important technology that could be used effectively by apparel manufacturers. AVR is a system that provides a range of services to its users such as picking materials directly from the warehouses without having a physical presence, sending repair and maintenance requests to relevant divisions automatically through mobile devices, and allowing access to real-time information about the work processes and procedures (Caricato, et al., 2014). In addition, the augmented reality tools could be used to provide virtual training to the workers concerning emergencies and reacting to machine breakdowns

(Kaplanidou, 2018). This could be seen as a positive feature in the technology that allows organizations to operate hassle-free especially during the times like the global pandemic.

In addition to the above, the use of additive manufacturing techniques could also be seen among the apparel manufacturing entities. It describes a technology that provides the possibility to shape 3D objects by adding layer-upon-layer with the use of any kind of material (Gibson, et al., 2015). In general, this technology is also known as 3D printing that brings many benefits to manufacturing firms. Additive manufacturing offers an agile, speedy, and flexible way of manufacturing items that helps the organizations to achieve speed to market, cost-efficiency, and ultimately gain a competitive edge over others.

The apparel industry has shown slow progress in adopting the robotics and automation technologies in history. However, it is witnessed that robotic process automation is rapidly being used in the apparel sector during recent times (International Labour Office, Geneva, 2019). Amongst many types of robots used in the industry, “sewbots” are having a long history that was used since 1980. It has been discarded from operations due to the diversity of processes and materials used for the production. As per expert opinions, the use of robotic process automation would bring ample savings for a manufacturing firm in terms of employment and production.

3. CHAPTER – RESEARCH METHODOLOGY

This study has followed three key data gathering methods; a systematic literature review (SLR), an empirical survey, and expert interviews to gather both qualitative and quantitative data. In other words, a mixed approach was adopted in this study to gather data that has both measurable and subjective judgment characteristics. The conduct of a systematic literature review has allowed the researcher to comprehend the existing knowledge from the previous studies and identify the gaps that need to be filled. With the conduct of the empirical survey, it was expected to collect more information from the academic and industry experts as well as from the Sri Lankan manufacturers. The data such as product-related, consumer preferences, and industry insights were obtained from the empirical study.

3.2. Research Design

This thesis was aimed at exploring the implications created by the digital transformation of apparel manufacturing firms. Primarily, it was expected to conduct a systematic review of the literature to understand how the manufacturing firms in other parts of the world have digitally transformed themselves. Subsequently, an exploratory qualitative case study was conducted focusing on three apparel-manufacturing firms in Sri Lanka who have taken several initiatives in recent times to transform their business towards digitalization. The survey was conducted after obtaining responses from various subdivisions of these firms which were specialized in manufacturing active wear, swimwear, intimate wear, fabrics, etc. to ensure widespread validity of the findings of the thesis. The relevant data for the empirical survey were gathered through a structured online-based questionnaire. Therefore, the research design was aimed to analyze both qualitative and quantitative data gathered from the survey.

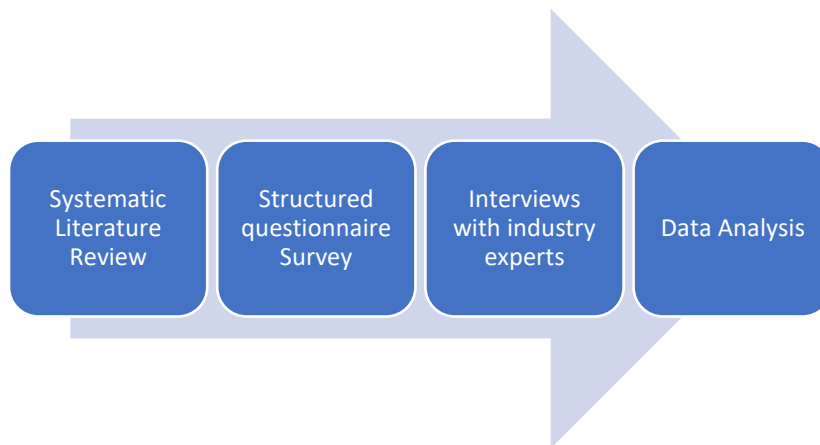


Figure 7: Data Collection Model

3.3. Selection of population and sample

3.3.1. Population

The population of this study represented the export-oriented apparel-manufacturing sector in Sri Lanka that is comprised of more than 350 apparel manufacturers. All companies in this population are engaged in contract manufacturing for leading apparel brands in the world such as Nike, Victoria's Secret, Adidas, H & M, etc.

3.3.2. Sample

To increase the validity and the feasibility of the study, it was expected to gather data from a sample of 150 executive level employees who are currently working in the selected export-

oriented apparel-manufacturing firms (targeting 50 employees from each company). The selection of the companies for the sample was purely based the characteristics such as the operational capacity, sales revenue and the number of employees. As per the most recent publications of the Export Development Board, Central Bank of Sri Lanka and the Sri Lanka Customs, the selected companies are among the top ten apparel-manufacturing firms in the country.

The data gathered were comprised of various information pertaining to the application of digitalization techniques by the companies such as types of techniques used, challenges faced by them, lead time changes and other potential benefits. The rationale behind selecting the executive staff for this study was to understand both front-line operational challenges and benefits they encounter with the implementation of the new technologies and to obtain the strategic level insights on the digital transformation.

Article #	A	B	C	D
Topic	A detailed review of artificial intelligence applied in the fashion and apparel industry	Big data management using artificial intelligence in the apparel supply chain	Towards Sustainable Textile and Apparel Industry: Exploring the Role of Business Intelligence Systems in the Era of Industry 4.0	Digitalization in the apparel manufacturing process
Context	Apparel Industry	Apparel Industry	Apparel Industry	Apparel Industry
Method of data collection	Systematic Literature Review	Systematic Literature Review	Semi-structured interviews	Semi-structured interviews & questionnaires

Table 1: Summary of methods followed by previous researchers

As shown in the above table, this study has followed a similar sampling approach as performed by the previous researchers to obtain the required data to conduct the studies in the same domain. It was witnessed that many of the previous researches have used systematic literature review method or empirical techniques such as interviews and questionnaires to draw the relevant conclusions. However, this study was conducted with a triangular analysis method that analyzed the findings of previous literature against the data gathered from semi-structured interviews and online questionnaire. The researcher was able to provide view that is more detailed for the readers after combining all three methods of data gathering.

3.4.Data Collection

3.4.1. Primary Data Sources

The relevant primary data for this study were gathered through the distribution of a structured online questionnaire to the above-selected sample in each company. It was expected to gather data regarding their experience in using digital tools, challenges faced by them during the implementation, and the objectives they aim to achieve by using the digital tools and the relevant initiatives. In addition, the researcher also expected to extend the validity of the questionnaire findings with the expertise knowledge gathered by interviewing senior management representatives of the above sample.

3.4.2. Secondary Data Sources

The secondary data sources represented the findings of the previous research publications. It was expected to screen 30 research articles that explain the application of digitalization techniques by various manufacturers. However, more priority was given to the 12 articles published for digitalization in the apparel industry.

3.5. Questionnaire

3.5.1. Overview

The questionnaire survey was developed based on the literatures that were reviewed during this study. The researcher has used similar questions used in the previous studies to test the impact of using digitalization techniques on customer communications, supplier communications, possible future challenges, overall productivity, and production and financial goals. However, the researcher has added the questions relating to manufacturing lead-time, impact of SQCDM on improving the supply chain efficiency and the number of employees as modifications for the survey instrument used for this study.

The questionnaire survey was comprised of 21 to 26 compulsory questions that are depended on the applicability of the digitalization techniques in the selected companies. As per the trial runs, the time consumed was 5 to 10 minutes to complete the whole questionnaire by the respondents. The finalized questionnaire used for this research is enclosed in Annexure-II with the relevant justifications for selecting each question.

3.5.2. Structure of the questionnaire – stage 1

The first 9 questions of the survey are focused on identifying the demographics of the respondents such as company name, work experience, work position, the function of work, type of garments produced, number of employees working for the company, number of employees in the functional area and whether they are currently using any digitalization techniques at their functions. Based on the answer selected for question 9, the respondents are directed to two unique sections named “the company has implemented digitalization techniques” and “the company has not implemented digitalization techniques”.

3.5.3. Structure of the questionnaire – stage 2

The “company has implemented digitalization techniques” section comprises 18 questions that include 6 Likert scale questions. The first two questions of this section would inquire about the types of digitalization tools used by the respondents and the main reasons for implementing those tools in their respective processes. The next three questions investigate the digital transformation process that the respondents have taken, the specific challenges faced by them during the transition period, and the ways they have overcome those challenges. Subsequently, the questionnaire explores more information on challenges faced by the company before the implementation of digitalization tools and the strategies taken to overcome them. The 6 Likert scale questions request the respondents to evaluate the effect of digitalization tools on 6 independent variables named as communications with customers, communications with suppliers, meeting the production and financial goals. Overall productivity, possible future challenges, and supply chain efficiency on a five-point scale (“1” as the lowest and “5” as the highest value). This section also includes two separate questions on checking the manufacturing lead-time before and after the digitalization initiatives. Apart from the above, this section expects to gather the respondent’s judgment on the company’s competitive position in the market and the company’s future directions in terms of digitalization.

3.5.4. Structure of the questionnaire – stage 3

The “company has not implemented digitalization techniques” section focuses on gathering data from the respondents who have not yet taken the digitalization journey in their processes. There are multiple types of questions in this section that investigate the reasons behind not implementing any digitalization techniques, manufacturing lead time, perception on threats for job security, challenges faced by the company, and the various other strategies followed by them to overcome the stated challenges. Furthermore, the questionnaire also examines whether the interest of both respondents and their respective companies in implementing digitalization techniques into the processes with necessary guidance and support.

3.5.5. Implementation of the survey and interviews

The questionnaire is developed using google forms and it is expected to distribute the same among the participants using social media and other electronic platforms. All responses of the participants are collected voluntarily and there would no inducements used to persuade them to take part in the survey. Furthermore, the participants of the interviews were selected with their prior consent and the relevant questions to be discussed were shared before the interview session.

3.5.6. Strategies for error control

To ensure that, the participants are sharing all the required information, the questions are made compulsory and various other techniques were used to minimize the inconsistency of the answers provided by them. Most of the questions are in multiple-choice, Likert scale, and checkboxes format which they could select answers from the given list. Apart from that, the email addresses of the respondents were recorded in the questionnaire that has enabled the researcher to filter out any repeated responses from the database. Furthermore, the expert interviews were held using Zoom software to enable the recording of the whole session which makes better accessibility for the references in later stages.

3.6. Data Analysis

A triangular analysis has been carried out for the relevant quantitative and qualitative data gathered through, the literature survey, online questionnaire, and expert interviews. In other words, the findings of the previous studies were used as the foundation for this study, and

those secondary data were validated using outcomes of the questionnaire survey and the expert interviews.

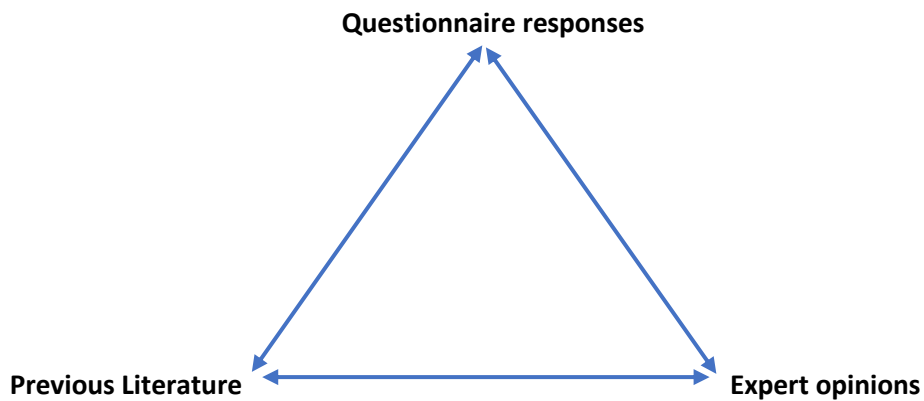


Figure 8: Triangular Analysis

To analyze the primary data gathered through the online survey, several statistical tools are used such as SPSS software and Microsoft Excel. The data analysis of this study would follow the structure as illustrated below.

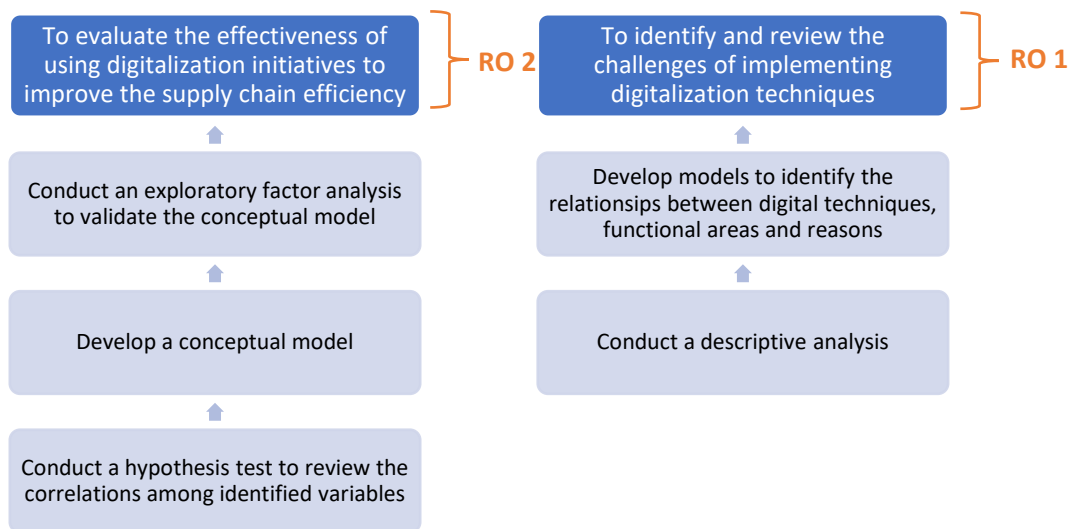


Figure 9: Data Analysis Model

3.7. Descriptive Analysis

The descriptive analysis of the data would be used to explain the basic features of the sample data through graphical and tabular forms. For instance, work experience, work categories, functional areas, number of employees, types of techniques used, and challenges faced during the transformation, etc. are some of the basic demographics that would be analyzed in the study. In addition, there are some other data collected from the respondents who have not yet

implemented the digitalization techniques in their processes that are expected to analyze during this study. Two models would be developed to identify the frequencies of using the techniques in different functional areas and to address the challenges faced when implementing different techniques in the existing processes. Furthermore, exploratory factor analysis and two-sample t-tests would be conducted to validate the conceptual framework developed in the study.

3.8. Conceptual Framework

Based on the literature review and the outcomes of the expert interviews, the following conceptual model has been developed by the researcher and the validity of the same would be tested in the Sri Lankan context using the data gathered from the selected three apparel-manufacturing firms.

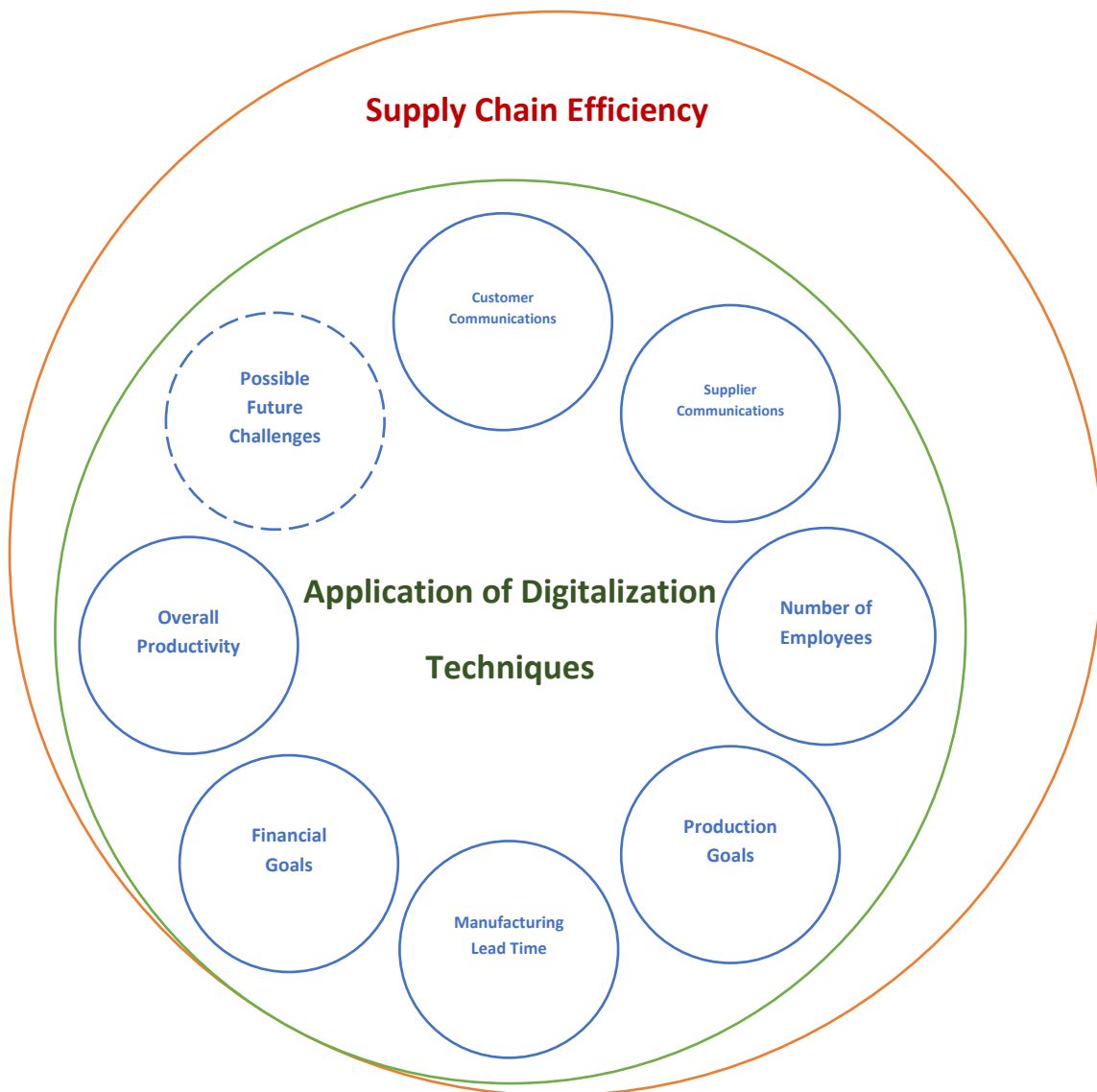


Figure 11: Conceptual Framework

As shown in the above diagram, the application of digitalization techniques could be seen as one of the methods used to enhance the supply chain efficiency. In other words, there could be numerous other methods used by the industry to improve the supply chain efficiency that are not discussed in this study. There are many influential factors which also impact on the use of digitalization techniques such as customer communications, supplier communications, number of employees, production goals, manufacturing lead time, financial goals, overall productivity, and possible future challenges. In addition, these influential factors could be categorized as latent variables.

4. CHAPTER – RESEARCH FINDINGS

In this chapter, all the quantitative and qualitative data gathered from the selected sample were examined in detail. It was observed that a significant percentage (approximately 77%) in the selected sample represented the entities/functional areas that has successfully implemented various types of digitalization techniques. Therefore, the analysis has been conducted separately for the two groups who have implemented the digitalization techniques and who have not to recognize the underlying motives behind those initiatives. The content of this section is included with the analysis of demographic factors, interview data, hypotheses development and testing, exploratory factor analysis, and t-test analysis.

4.1. Data Screening

The researcher has developed a questionnaire using Google forms and randomly distributed the survey link among 150 executives working for the selected apparel firms using social media platforms and other electronic media. There were only 69 responses (46% of the expected total sample) received and all those responses recorded were anonymously and treated with highest level of confidentiality. Even though the response rate is lower than expected, the researcher has decided to proceed with the data already received due to research time limitations and the data set corresponded to a larger sample (more than 35). The response rates could be summarized as follows.

	XYZ Holdings	ABC Apparel	GHI Apparels
Expected number of responses	50	50	50
Actual number of responses	32	21	16
Response Rate	64%	42%	32%

Table 2: Response rate of the sample

To enhance the accuracy and the reliability of the findings, certain measures were taken to screen the data collected from the survey and the interviews. For instance, repeated responses received from the respondents were ironed out from the data set before starting the analysis. Apart from that, to eliminate the inconsistency of certain data the responses were reorganized with simple numbering and text formats. The interview data collected from the experts have also been recorded in a structured manner by following a standard set of questions.

4.2. Analysis of the demographics

This section would be comprised of numerous descriptive statistics and demographics such as company/product-related data and the individual respondent’s data. The company-wise data includes the types of garments produced, number of employees working for the company, lead-time, etc. The individual respondent’s data include their work position, work experience, functional area of work, etc.

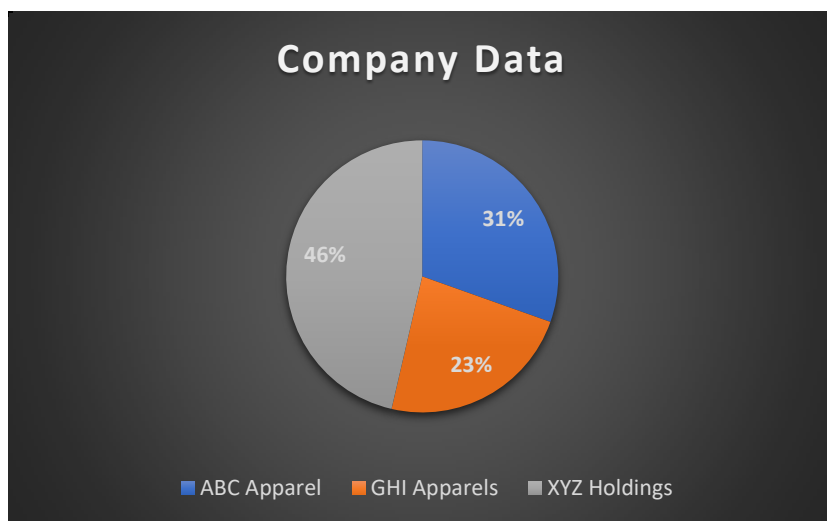


Figure 11: Company-wide distribution of the Sample

There were 69 responses recorded in the survey conducted using Google forms. As illustrated in figure 11, the sample carried responses from three different companies and there was a higher percentage of responses received from the respondents working for XYZ Holdings.

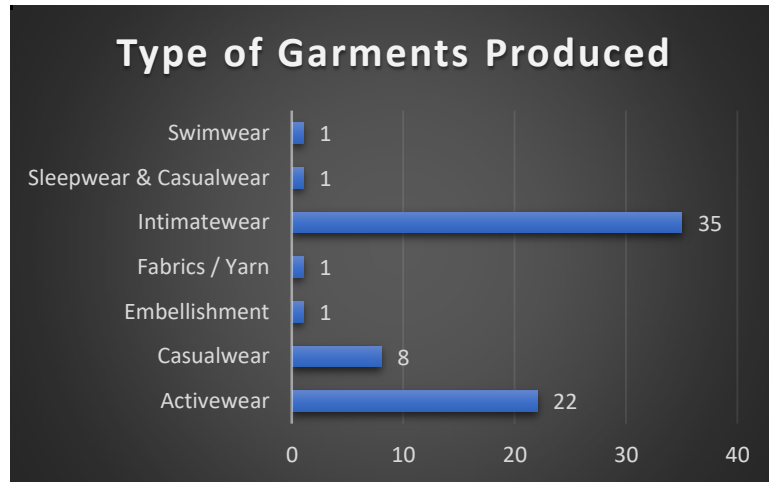


Figure 12: Type of garments produced

The subdivisions of the companies were categorized based on the types of garments produced by them. Most of the companies were engaged in producing intimate wear and active wear clothes as depicted in figure 12.

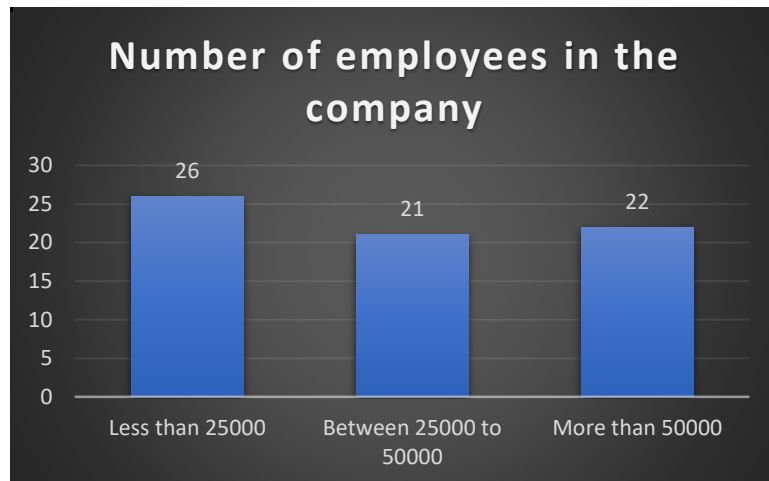


Figure 13: Number of employees working in the company

When considering the number of employees, many firms were having a workforce of less than 25,000 people that has encouraged them to adopt various types of digitalization mechanisms to achieve the required productivity levels.

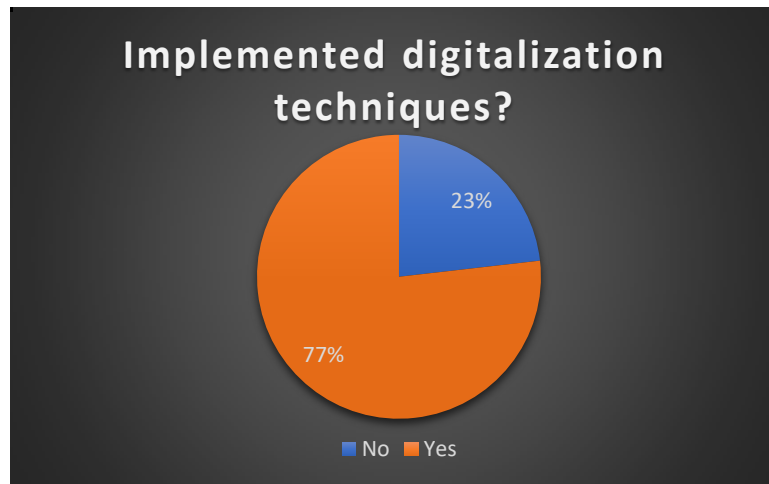


Figure 14: Implementation of digitalization techniques

As illustrated in the above chart, there were 53 out of 69 respondents have marked as they have implemented digitalization techniques in their processes.



Figure 15: Work position

The sample reflected the expected proportions of respondents from different work categories, which includes a higher number of participants from Executive grade as shown in the above diagram. This has enabled the researcher to gather data on the specific hands-on experience of the respondents.



Figure 16: Work Experience

There are around 65% of the respondents of the survey were having more than 3 years of experience in working for the selected company. This implies the level of knowledge and expertise they carry in their respective functions.

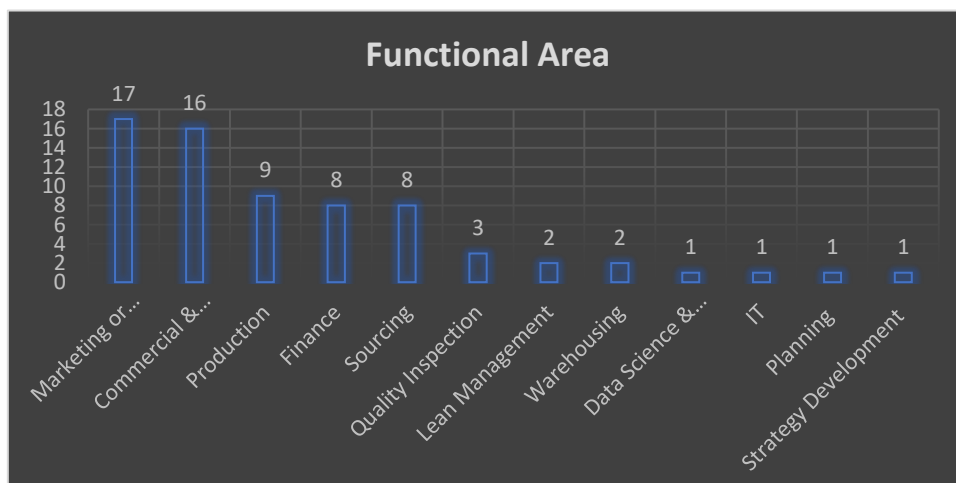


Figure 17: Functional area of the respondents

As shown in figure 17, there was a significant number of respondents working for the merchandising and commercial roles in the selected sample. These functions are generally known to be supportive functions of the company that facilitates the logistics and procurement of raw materials.

When considering the various applications of digitalization tools, cloud computing was marked as the most heavily used method by the respondents who have implemented the techniques. In addition, big data analytics and robotic process automation were significantly used by the entities as shown in figure 18.

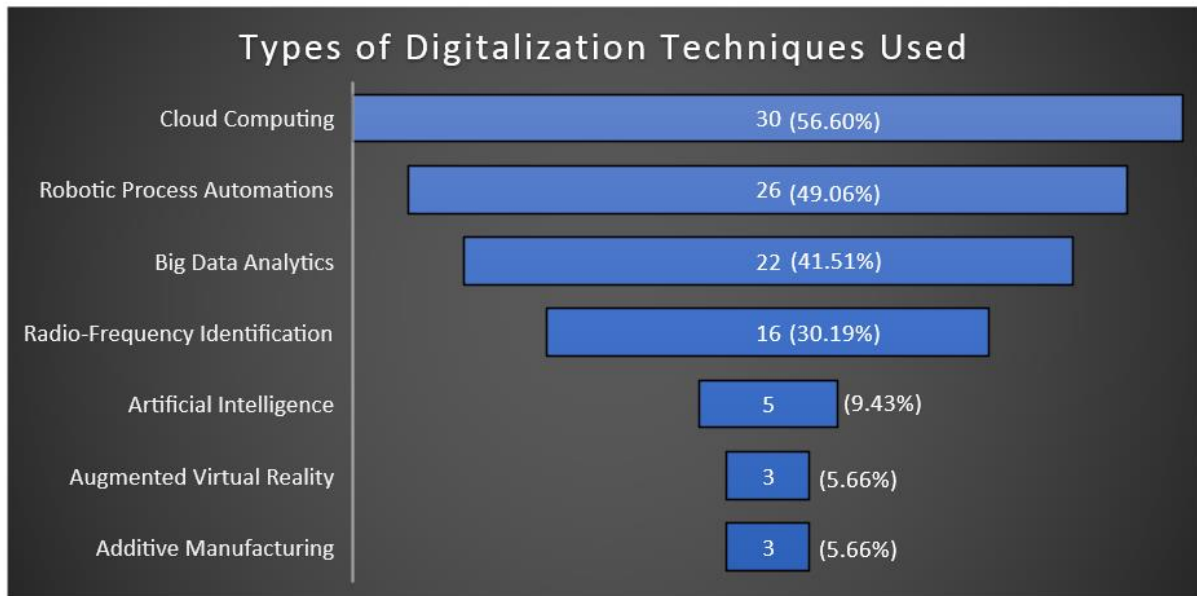


Figure 18: Types of digitalization tools used

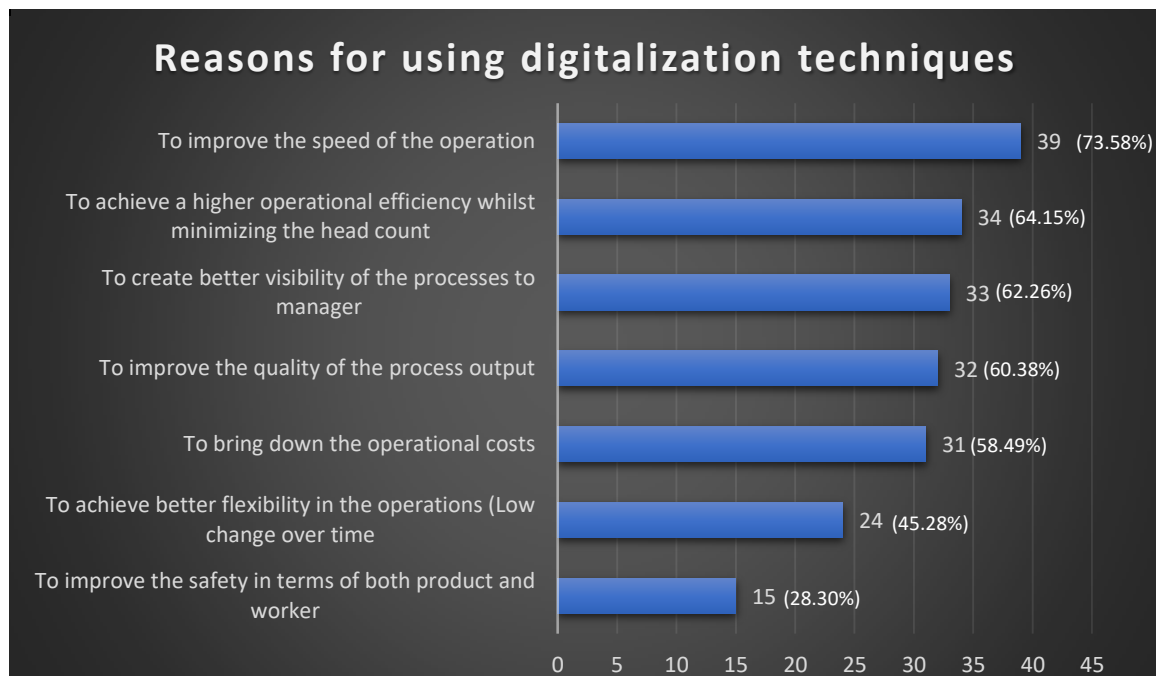


Figure 19: Underlying motives behind the implementation of digitalization techniques

There have been many reasons why the companies have decided to transform them digitally. Amongst the underlying motives, most of the entities were trying to speed up their existing processes using digital tools. As per the above diagram, an equal number of entities were aiming to improve the process visibility, operational efficiency, quality of the process outcomes and bring down the operational related costs.

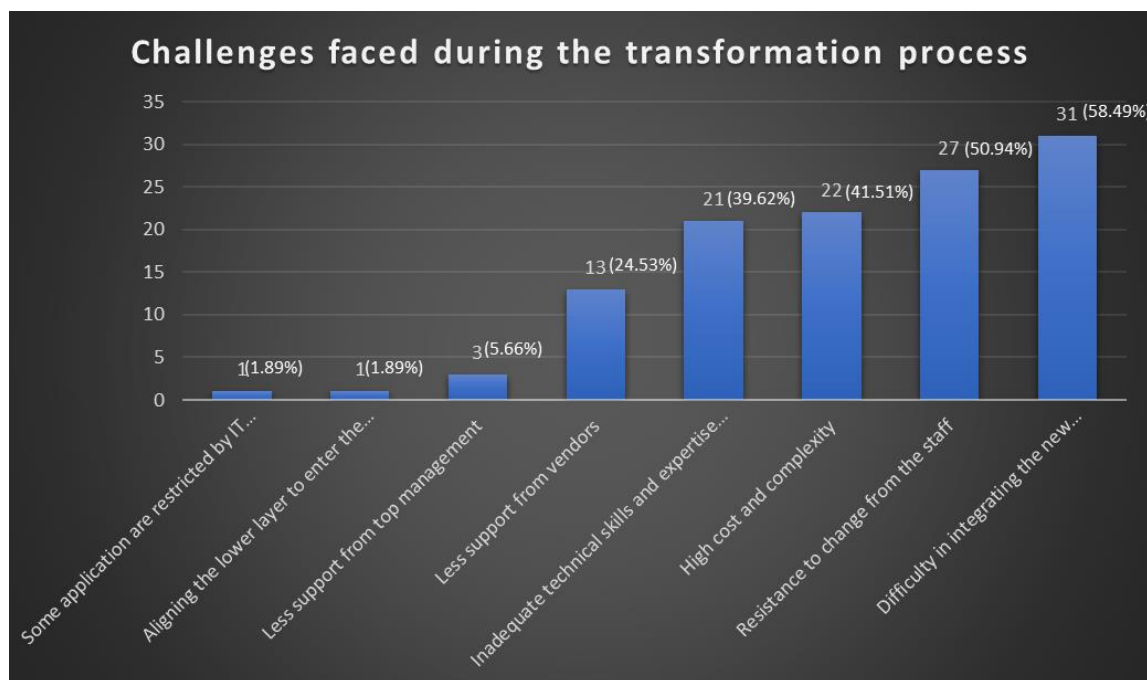


Figure 20: Challenges faced during the transformation process

The companies which were successfully implemented the digital techniques in their processes have gone through various types of challenges as depicted in the above figure. Most of them were facing difficulties in integrating the new tools with the existing infrastructure/platforms. High cost and complexity, the inadequacy of technical expertise and the resistance to change from the staff were the other key challenges faced by them. However, the companies have used certain strategies such as providing extensive training, sharing regular updates with the teams, strategic directions from the leadership, brainstorming sessions, lean management techniques, and error-proofing mechanisms to overcome the key challenges stated above.

There were numerous advantages have been gained by the companies with the digital transformation. Time savings, fewer human errors, improved work-life balance, reduced operational costs, improved visibility of the processes, accurate forecasts and predictions, lead time improvements, data-driven decision making, and improved focus on critical

activities were among the key benefits enjoyed by the companies. Majority of the respondents who marked as they have implemented digital tools in their processes believe that the company is in a better position when compared to their direct competitors in the market. Furthermore, they plan to introduce many other digital techniques such as warehouse automation, 3D printing, automated sewing, block chain, and predictive analysis tools that were not yet implemented in their processes.

In addition to the above, the researcher has analyzed few other descriptive statistics to examine the barriers, resistance, and competitive position of the entities/functions that have not yet implemented the digitalization techniques in their processes.

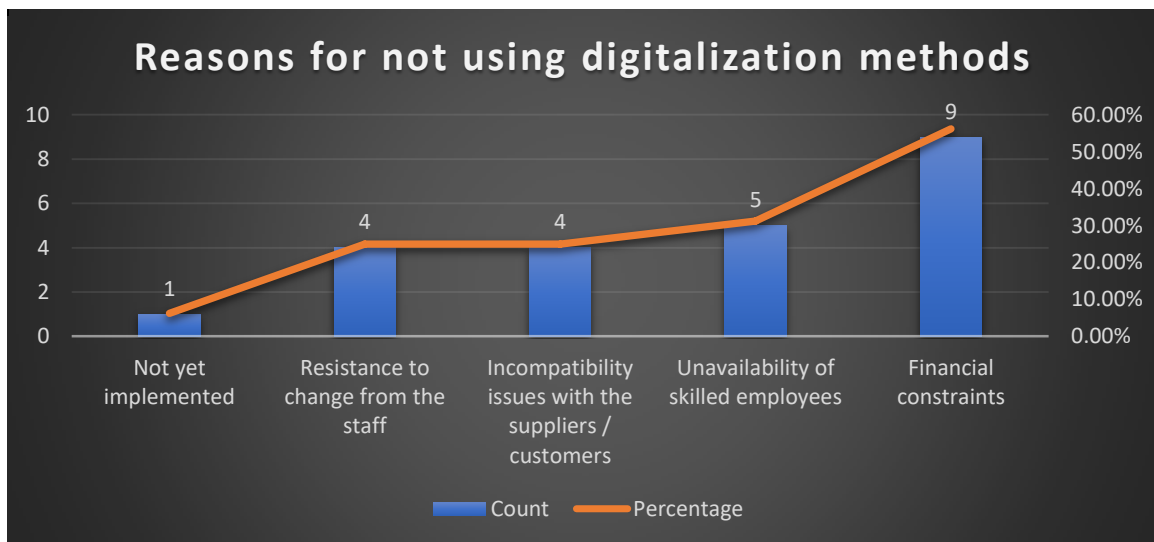


Figure 21: Reasons for not implementing the digitalization techniques

In fact, most of the digitalization techniques require a heavy investment and as shown in the above diagram, 9 out of 16 respondents have marked that they were facing financial constraints which hinders their digitalization journey. In addition, a higher number of respondents have marked staff resistance, unavailability of skilled employees, and incompatibility issues with suppliers/customers as the constraints in implementing digitalization tools in their processes.

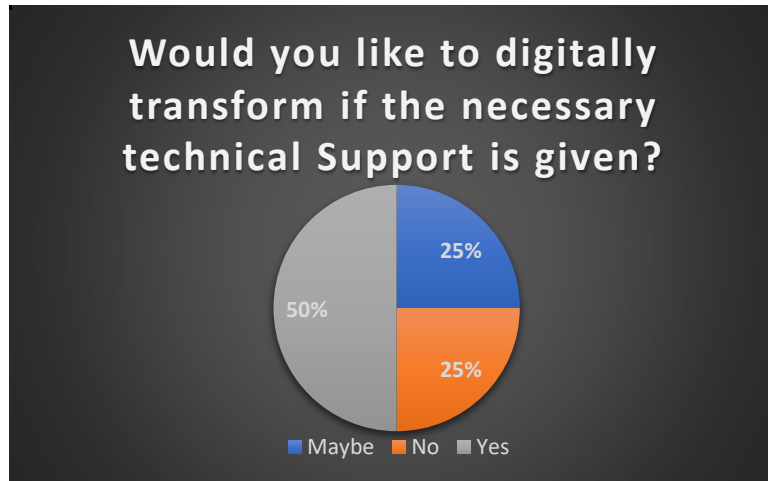


Figure 22: Shifting to digitally enabled processes if the necessary technical support is provided

As shown in figure 22, 50% of the respondents out of 13 have stated that they are willing to take on the digital transformation process if the necessary technical support is provided. However, there was an equal percentage of respondents who were either not willing to transform themselves or unsure whether they really need a digital transformation.

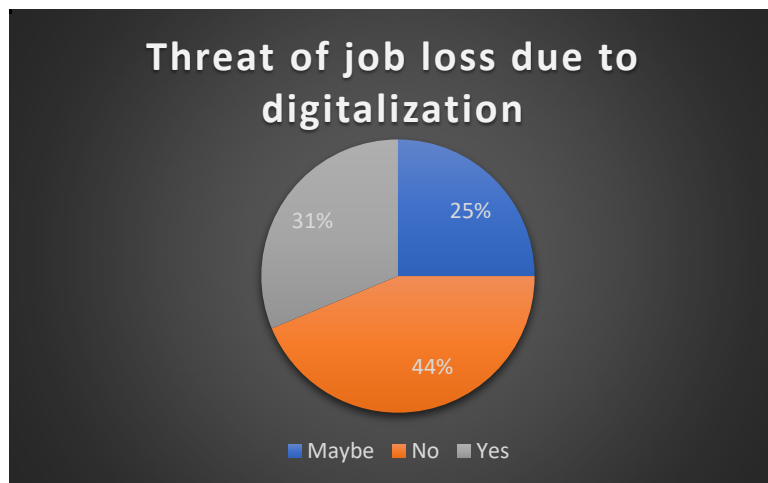


Figure 23: Threat of job loss due to digitalization

Even though the digital initiatives were still not implemented, 7 out of 16 respondents believe that they do not see any threats for their current occupations created by the digitalization. However, a significant number of respondents (69%) have marked that there can be a threat of job loss imposed with the introduction of digitalization techniques.

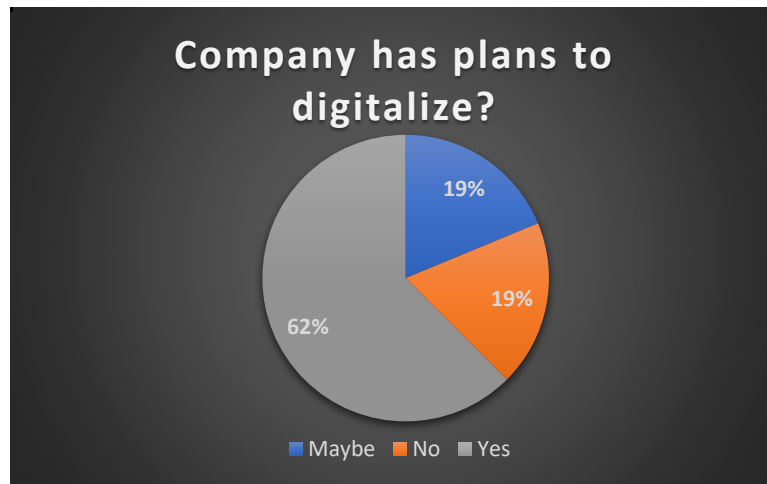


Figure 24: Company' view on digitalization techniques

As shown in figure 24, 62% of the companies which were not yet implemented the digitalization techniques have already put-up plans to take on the initiatives. This implies a positive impression the companies in the industry are having towards the capabilities and the opportunities offered by digitalization.

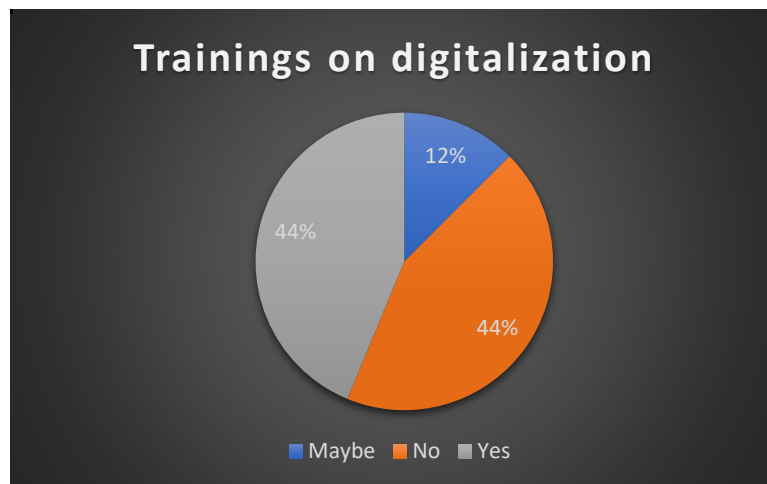


Figure 25: Company provides relevant trainings to staff on digitalization

Figure 25 represents an opposing view when compared to figure 24 where companies were not providing sufficient training for their staff on digitalization techniques even if they need to take on the transformation process. This could be resulted due to financial constraints or limited access to technical expertise they currently experience.

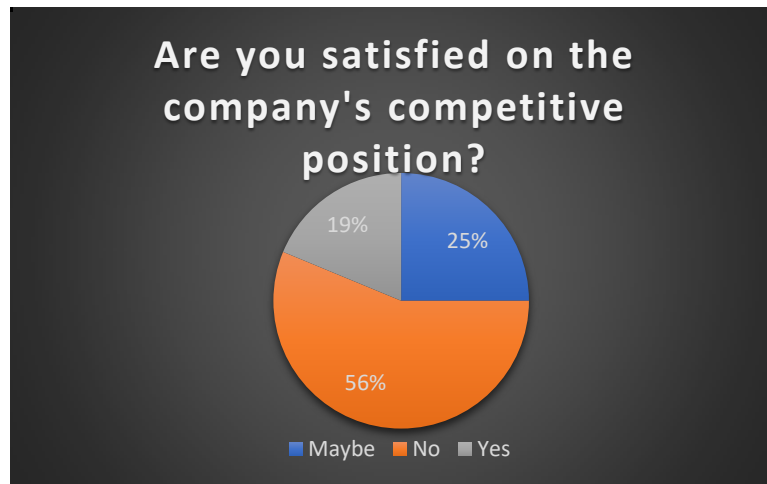


Figure 26: Company's position compared to competitors

As illustrated in figure 26, 56% of the respondents believe that their company position is not healthy in terms of digitalization when compared to their competitors. It implies that XYZ Holdings as an apparel manufacturer has already captured a better position in the market after going through their digital transformation process.

4.3. Expert Interview Data

To validate the findings of the survey results and to obtain a glimpse of market dynamics two semi-structured interviews were conducted by the researcher. The first interview was held with an experienced professional who represented the top management of XYZ Holdings, and the selection of the person was fully based on the person's industry exposure and the company's strategic directions on digitalization. During the discussion, it was noticed that there are four key supply chain challenges faced by XYZ Holdings during recent times. Firstly, they have been experiencing rapid growth of order volumes that require them to increase their capacities. Secondly, the company direction has been in place to handle the additional volume with the existing headcount although there is 5% to 10% year-on-year volume growth. Thirdly, all the teams are being obliged to maintain the highest level of accuracy in all activities whilst managing the extra workload. Lastly, whenever a new customer is added to their customer portfolio, they are required to adopt new systems and processes to their existing platforms that also have become quite challenging to manage the required changes.

XYZ Holdings has successfully converted most of its manual processes into fully automated systems using robotic process automation in both production and other support functions. In addition, the company's central finance division has started using artificial intelligence tools to assist the data analysis process. With the implementation of these techniques, the company has effectively addressed the implications created by the increased order volume.

In addition, the company has significantly improved its manufacturing lead-time when comparing the before and after periods of implementing the digitalization tools. For instance, the previous lead time of 14 days has been reduced to 3 days with the use of the above techniques which corresponds to almost 80% lead-time saving. Apart from the lead-time, the company has significantly improved the accuracy levels and quality of the process outcomes. Moreover, the tastes of the apparel consumer have been evolved largely where they demand mass customization instead of standardized products. For instance, the production of 100,000 PCs in a single batch of production has been replaced with the production of 500 to 750 PCs that needs to be delivered to different buyers located in various locations. XYZ Holdings has gained the capability to cater to these operational requirements of its customers with the use of digitalization as the overall efficiency levels do not change based on the number of transactions to perform.

It was also highlighted that they have faced many challenges during the digital transformation process such as sustainability of the deployed processes, technological changes in terms of programming languages and infrastructure, approvals from the top management, and adaptability of the digital tools with the existing systems such as SAP. However, they were able to manage these challenges effectively and continue to implement even more techniques in their processes as the company believes in improving the supply chain efficiency having the existing workforce. The accessibility of historical finance-related data, allowing the customers to check the garment fitness in virtual platforms and fast prototyping with the use of additive manufacturing techniques are in the pipeline of the future digitalization initiatives of XYZ Holdings.

The company adopts an agile supply chain strategy where they always adjust themselves according to the customer's requirements. For instance, whenever a customer demands faster delivery of garments the company changes its processes with the use of digitalization techniques that is also compatible with the customer's systems and processes. At the same

time, they mutually share the knowledge and the expertise with their supplier network to enable them also to use the above techniques in their respective companies. This approach has made XYZ Holdings successful in implementing the digital techniques without compromising the needs of its upstream and downstream supply chain partners.

The second interview session was held with an IT entrepreneur who provides numerous types of AI solutions to a wide variety of customers including apparel manufacturers. It is a startup venture, and it mainly offers SAAS (Software as a Service) solutions to its customers through a cloud platform where they could hire a standard AI solution with the required customizations by paying a nominal subscription fee. During the discussion, it was noticed that many companies have tried out implementing digitalization technologies into their processes by collaborating with the previously mentioned company and in most cases; they were failed due to inaccurate judgment of the deliverables required by the customers and the financial constraints faced by them. As a solution to address the heavy investments needs and the customized requirements of the customers, the company has come up with the SAAS model that has improved the usage, as it is highly affordable and user-friendly for any type of business. They are currently offering specialized AI solutions and edge computing to apparel manufacturers such as detection of quality defects in the fabric materials.

The interviewee highlighted the negative implications created by the COVID-19 pandemic such as increased logistics costs, lead-time pressure from the customers, and improved accuracy levels that have boosted the need for digitalization initiatives to be adopted by the Sri Lankan apparel manufacturers. For instance, when the number of defects reduced even by a trivial percentage, the apparel manufacturers would be able to reduce the number of reworks, product returns, lost orders, etc. which helps them to significantly reduce their operational costs. However, as per the experiences shared by the interviewee, the implementation of artificial intelligence techniques in apparel manufacturing companies involves a long process that requires a large amount of data and training with a minimum adequate level of data. In most cases, traditional businesses do not retain data in digital format which acts as one of the key barriers for digital transformation.

As per the interviewee's comments, developing a proof of concept for an AI solution would require a minimum investment of 20 million LKR, which is not affordable for many organizations in the apparel sector in the Sri Lankan context. However, even if an

organization has the capability of investing the capital, they struggle to find the required technical expertise within the organization to connect with the relevant service providers that could lead to misinterpretation of the requirements, and ultimately the whole investment becomes a failure once it goes live. Therefore, the potential customers could firstly use the SAAS solutions offered by the service providers to validate their requirements in the cloud platform and continue only if the requirements are being met. This could be seen as a positive feature of this solution that does not involve a heavy investment and the customer would receive the opportunity to test the product directly in the real environment without any need for a pilot run.

4.4. Model Development

To investigate the most used digitalization techniques in different functional areas and to understand the various types of challenges faced by them before implementing any digitalization technique the researcher has developed two models using the survey data.

4.4.1. FTR Model

The first model is abbreviated as the FTR model that stands for functional areas, techniques, and reasons behind the implementation of the tools. For the convenience of reference, each element of this model is coded as mentioned in the following tables.

Code	Description
R1	To improve the speed of the operation
R2	To create better visibility of the processes to managers
R3	To achieve a higher operational efficiency whilst minimizing the head count
R4	To achieve better flexibility in the operations (low change over time)
R5	To improve the quality of the process output
R6	To bring down the operational costs
R7	To improve the safety in terms of both product and worker

Table 3: Reasons behind the implementation of techniques

Code	Description
T1	Cloud Computing
T2	Robotic Process Automations
T3	Radio-Frequency Identification
T4	Big Data Analytics
T5	Additive Manufacturing
T6	Artificial Intelligence
T7	Augmented Virtual Reality

Table 4: Types of digitalization techniques used

Code	Description
F1	Commercial & Logistics
F2	Data Science & Analytics
F3	Finance
F4	IT
F5	Lean Management
F6	Marketing or merchandizing
F7	Planning
F8	Production
F9	Quality Inspection
F10	Sourcing
F11	Warehousing

Table 5: Functional Areas

The respondents of the selected sample represented 11 different functional areas of the company and they have been using 7 types of digitalization techniques in their respective processes. The following pivot tables and graphs used by the researcher to illustrate the relationship that exists among different types of digitalization techniques and the respective functional areas.

Functional Area	T1 Count	T2 Count	T3 Count	T4 Count	T5 Count	T6 Count	T7 Count
F1	13	10	3	9		1	
F2	1	1		1			
F3	3	4		2		1	
F4	1						
F5	1	2		1		1	
F6	6	3	4	5	1	2	1
F7	1			1			
F8	1	1	4	1	1		1
F9		1	2	1	1		1
F10	3	3	1	1			
F11		1	2				
Total Count	30	26	16	22	3	5	3

Table 6: Functions Vs Techniques (Count)

As shown in Table 4, the commercial & logistics function mostly uses cloud computing and robotic process automation in their operations. When considering the marketing and merchandising function, they largely use cloud computing and big data analytics in their process. The respondents were allowed to select more than one response for the types of digitalization techniques during the survey.

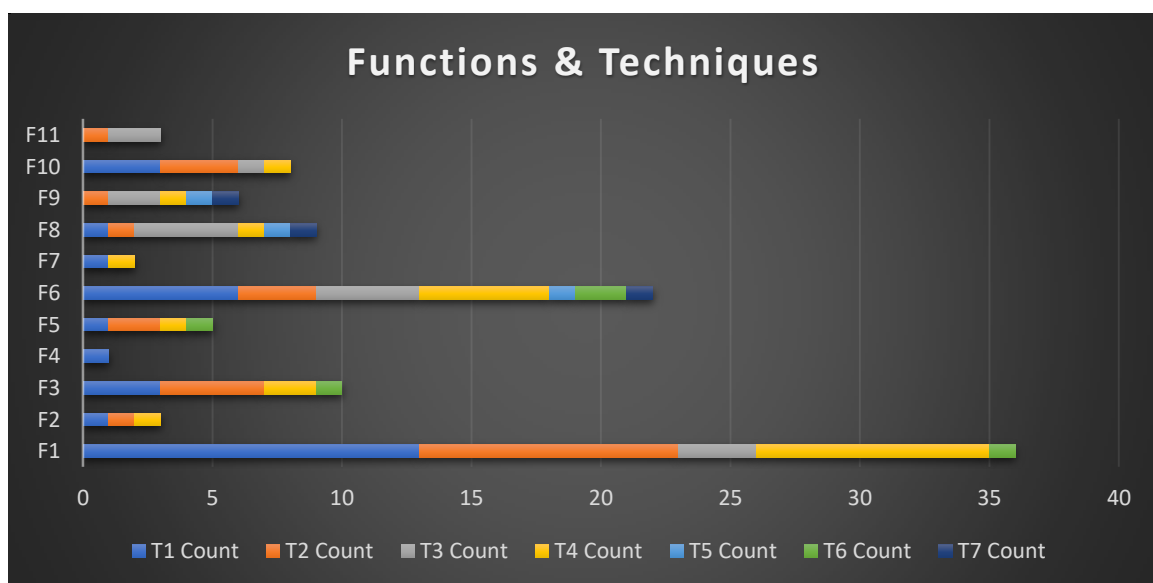


Figure 27: Functions Vs Techniques

When looking at the number of techniques used by each functional area, the sample data reflect 1 to 4 different types of techniques are utilized by each division.

Functional Area	1 technique	2 techniques	3 techniques	4 techniques
F1	3	4	7	1
F2			1	
F3	3	2	1	
F4	1			
F5	1			1
F6	4	3	4	
F7		1		
F8	4	1	1	
F9	2			1
F10	3	1	1	
F11	1	1		
Total	22	13	15	3

Table 7: Number of techniques used by each functional area

There were 15 respondents from the commercial & logistics divisions of the companies and as shown in table 5, 7 respondents have marked that they use at least three different types of techniques in their process.

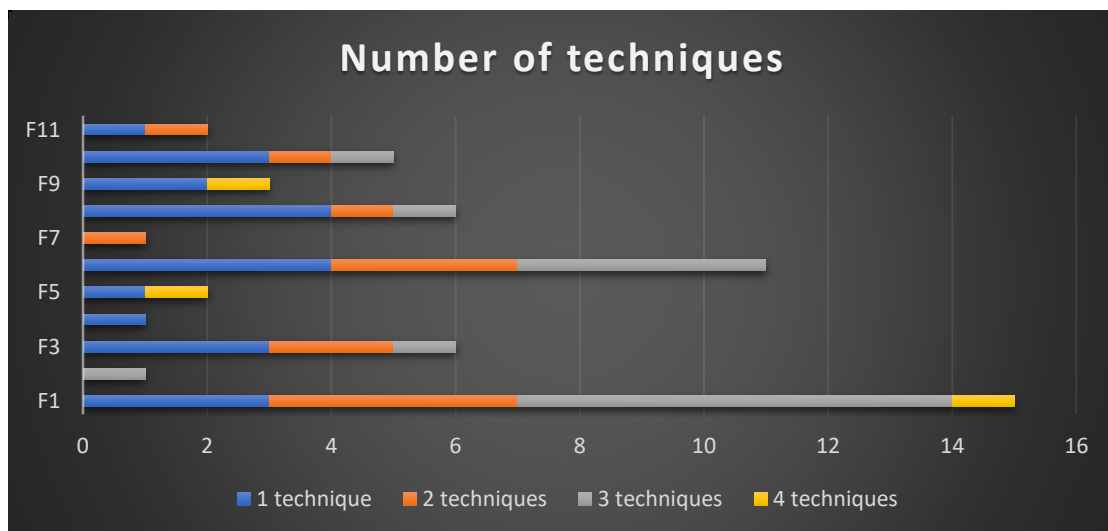


Figure 28: Number of techniques used

There were seven different types of reasons were listed in the questionnaire as the motives behind the implementation of digitalization techniques.

Functional Area	R1 Count	R2 Count	R3 Count	R4 Count	R5 Count	R6 Count	R7 Count
F1	14	10	12	8	13	11	5
F2	1	1			1		
F3	4	4	5	4	5	3	1
F4	1	1		1		1	
F5	2	2	2	2	2	1	2
F6	8	5	8	4	3	9	3
F7		1		1	1		
F8	2	3	1	1	4	3	2
F9	1	2	2	1	2	2	1
F10	5	3	3	1	1		
F11	1	1	1	1		1	1
Total Count	39	33	34	24	32	31	15

Table 8: Reasons behind implementing the digitalization techniques

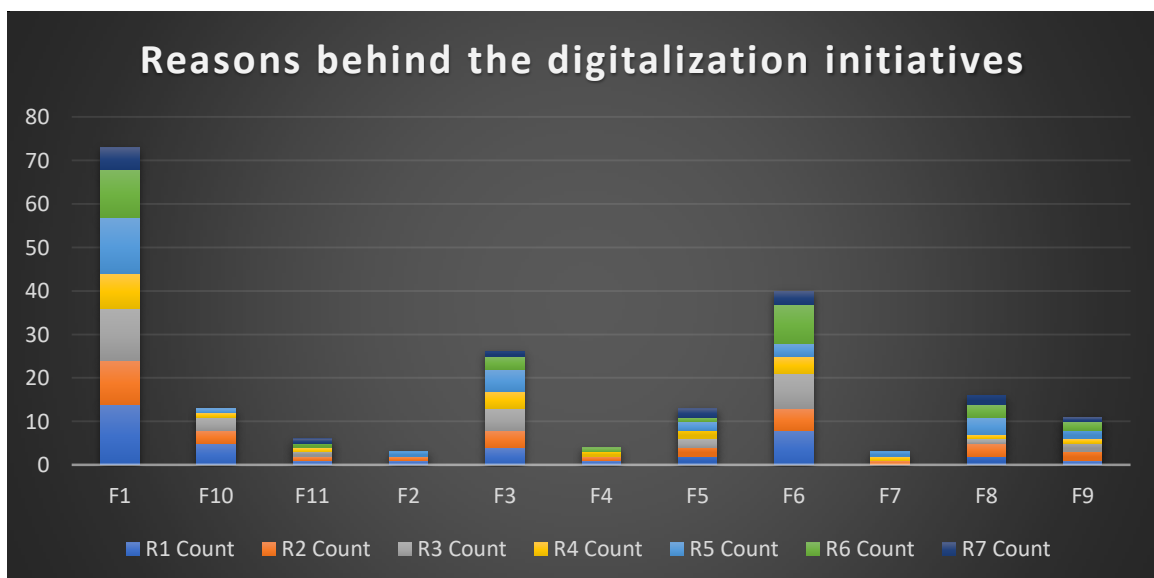


Figure 29: Reasons behind the digitalization initiatives

As per the above analysis, the top three reasons for implementing the digitalization techniques were to improve the speed of operations, enable better visibility for the management, and minimize the total headcount whilst improving the productivity levels. Further analysis has been carried out to understand the relationship between different types of techniques and the reasons for implementing the techniques as shown below.

	R1	R2	R3	R4	R5	R6	R7
T1	27	19	20	15	19	18	10
T2	24	18	20	14	18	14	7
T3	10	10	9	5	7	11	5
T4	17	16	16	10	16	12	6
T5	1	2	0	1	2	2	1
T6	5	4	5	4	3	4	2
T7	2	2	1	2	2	2	1

Table 9: Techniques Vs Reasons (Count)

	R1	R2	R3	R4	R5	R6	R7
T1	90.00%	63.33%	66.67%	50.00%	63.33%	60.00%	33.33%
T2	92.31%	69.23%	76.92%	53.85%	69.23%	53.85%	26.92%
T3	62.50%	62.50%	56.25%	31.25%	43.75%	68.75%	31.25%
T4	77.27%	72.73%	72.73%	45.45%	72.73%	54.55%	27.27%
T5	33.33%	66.67%	0.00%	33.33%	66.67%	66.67%	33.33%
T6	100.00%	80.00%	100.00%	80.00%	60.00%	80.00%	40.00%
T7	66.67%	66.67%	33.33%	66.67%	66.67%	66.67%	33.33%

Table 10: Techniques Vs Reasons (Percentages)

As depicted in table 8, a higher percentage of respondents have marked that they use big data analytics, cloud computing, and robotic process automation to improve the speed of their operations. The radio-frequency identification technique was used to bring down the operational costs in most cases. Artificial intelligence tools were used to achieve higher operational efficiency whilst minimizing the headcount. The additive manufacturing and the augmented virtual reality techniques were used for various reasons such as to bring down the operational costs and to improve the quality of the process output.

4.4.2. CT Model

The CT model is developed to identify the relationship between various types of challenges faced and the number of digitalization techniques used by the companies.

Code	Description
C1	Lower productivity level
C2	Increased number of defects/customer complaints about the process output
C3	Higher operational cost
C4	Reduced process visibility for the management
C5	Resistance from employees for digitalization
C6	Unbalanced workload
C7	Overnight workings

Table 11: Types of challenges faced by the companies

No of techniques used	C1 Count	C2 Count	C3 Count	C4 Count	C5 Count	C6 Count	C7 Count
0 techniques	3					5	2
1 technique	7				12	12	6
2 techniques	6	1	1	1	8	4	5
3 techniques	9				8	6	5
4 techniques	2				2	2	2
Total Count	27	1	1	1	30	29	20

Table 12: No of techniques vs challenges faced by the companies

As shown per the cross-tabulation shown in table 20, the highest number of challenges has been overcome using only 1 technique which implies the significant capabilities of the techniques and their contributions. However, to improve the lower productivity levels faced by the apparel manufacturers they have had to utilize at least 3 techniques as shown in the above table.

4.5. Exploratory Factor Analysis

With the use of an exploratory factor analysis tool in SPSS, it was expected to measure the levels of relationships amongst the declared variables and to assess the hypotheses developed above. To avoid the biases of the data, the researcher has filtered only the respondents who have marked as they have implemented digitalization techniques in their processes to run the exploratory factor analysis. As per KMO and Bartlett's test result shown in figure 30, the sample adequacy level is closer to one, which implies that the data set collected during this study could be used to conduct a meaningful factor analysis.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		
		.738
Bartlett's Test of Sphericity	Approx. Chi-Square	125.098
	df	15
	Sig.	<.001

Figure 30: KMO and Bartlett's Test

According to the results of the descriptive statistics shown in figure 31, the standard deviation values are less than 1 which implies that the data points of the sample distribution tend to be closer to the statistical mean values. Apart from that, the standard error values are also considerably low, and it describes that the mean value of the sample is closer to the population mean. Therefore, the results of the following factor analysis could be generalized for the population of this study.

	N Statistic	Range Statistic	Minimum Statistic	Maximum Statistic	Mean		Std. Deviation Statistic	Variance Statistic	Skewness	
					Statistic	Std. Error			Statistic	Std. Error
Communications with the customers	53	2	3	5	4.30	.096	.696	.484	-.490	.327
Communications with the suppliers	53	2	3	5	4.36	.086	.623	.388	-.426	.327
Achieve production and financial goals	53	2	3	5	4.53	.088	.639	.408	-1.030	.327
Overall productivity levels	53	2	3	5	4.53	.083	.608	.369	-.913	.327
Diagnose possible challenges in future	53	2	3	5	4.26	.101	.738	.544	-.468	.327
Supply chain efficiency in terms of safety, quality, cost, delivery and morale	53	2	3	5	4.53	.079	.575	.331	-.744	.327
Valid N (listwise)	53									

Figure 31: EFA descriptive statistics

Correlation Matrix

		Communications with the customers	Communications with the suppliers	Achieve production and financial goals	Overall productivity levels	Diagnose possible challenges in future	Supply chain efficiency in terms of safety, quality, cost, delivery and morale
Correlation	Communications with the customers	1.000	.722	.543	.343	.291	.363
	Communications with the suppliers	.722	1.000	.481	.455	.376	.427
	Achieve production and financial goals	.543	.481	1.000	.605	.351	.639
	Overall productivity levels	.343	.455	.605	1.000	.498	.451
	Diagnose possible challenges in future	.291	.376	.351	.498	1.000	.254
	Supply chain efficiency in terms of safety, quality, cost, delivery and morale	.363	.427	.639	.451	.254	1.000

Figure 32: EFA Correlation Matrix

When looking at the correlations between the variables, it was noticed that the highest level of positive correlation prevails between the customer communications and the supplier communications as depicted in figure 32. In other words, when the firms are engaged in a higher level of customer communications the need for supplier communications would also be increased. This indicates the level of connectivity with the customers as well as the suppliers by the apparel-manufacturing firms. The second highest correlation exists between the financial and production goals and the supply chain efficiency that denotes that whenever the supply chain efficiency is improved in terms of safety, quality, cost, delivery, and morale the achievement of financial and production goals would become much easier.

Total Variance Explained

Component	Total	Initial Eigenvalues		Extraction Sums of Squared Loadings		
		% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.293	54.890	54.890	3.293	54.890	54.890
2	.883	14.716	69.606			
3	.806	13.439	83.045			
4	.448	7.462	90.507			
5	.364	6.070	96.577			
6	.205	3.423	100.000			

Extraction Method: Principal Component Analysis.

Figure 33: Total Variance Explained

As per a general rule of thumb in exploratory factor analysis components that are having Eigenvalues greater than 1 are most likely to represent the real underlying factors influencing the dependent variable. As shown in figure 33, only component 1 denotes a value greater than 1 and it indicates that the customer communications contribute the highest level for the application of digitalization techniques in the processes.

The scree plot diagram (as shown in figure 34) also visualizes the same output of the total variance table where only one component out of 6 has a value greater than 1. In other terms, components from 2 to 6 are categorized as weak factors which do not significantly influence the dependent variable.

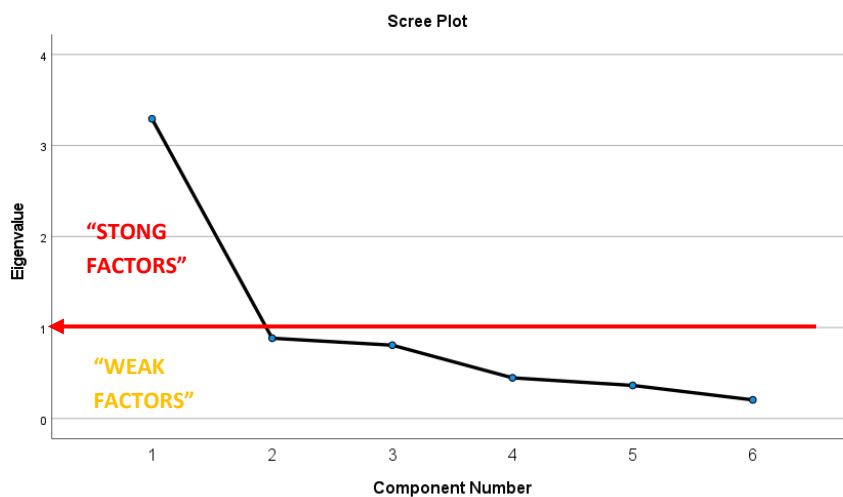


Figure 34: Scree Plot Diagram

Communalities

	Initial	Extraction
Communications with the customers	1.000	.555
Communications with the suppliers	1.000	.621
Achieve production and financial goals	1.000	.689
Overall productivity levels	1.000	.571
Diagnose possible challenges in future	1.000	.352
Supply chain efficiency in terms of safety, quality, cost, delivery and morale	1.000	.505

Extraction Method: Principal Component Analysis.

Figure 35: Communalities

Another key output of the exploratory factor analysis is the communality chart shown in figure 35. As per the rules in the EFA method, the variables that are having extraction values less than 0.40 do not significantly contribute to measuring the underlying factors. Therefore, the application of digitalization techniques does not support the organization in diagnosing possible future challenges as per the extraction result shown in the table.

The component matrix output of the exploratory factor analysis explains how each component is measured by the various underlying factors. As per the component matrix depicted in figure 36, only one variable is having a value greater than 0.80 which is the achievement of production and financial goals. Therefore, it could be concluded that digitalization applications have the highest influence over the achievement of production and financial goals of the company.

Component Matrix ^a		Component 1
Achieve production and financial goals		.830
Communications with the suppliers		.788
Overall productivity levels		.756
Communications with the customers		.745
Supply chain efficiency in terms of safety, quality, cost, delivery and morale		.710
Diagnose possible challenges in future		.593

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Rotated Component Matrix^a

a. Only one component was extracted. The solution cannot be rotated.

Figure 36: Component Matrix & Rotated Component Matrix

4.6. T-test Analysis

To compare the results of the two segments of respondents selected for the study (digitalization techniques implemented and not implemented) two separate t-tests were conducted by assuming unequal variances. The following assumptions have also been considered to improve the accuracy of the test results.

Assumption 1 - Number of working days per week is considered as 5 days as the factories are not operating on weekends unless if there is an urgent shipment to be delivered

Assumption 2 – Average lead time is calculated as no of working days per week * (lower bound of the lead time + upper bound of the lead time)/2

Assumption 3 – Average number of employees working in the functional area is calculated as (lower bound of no of employees + upper bound of no of employees)/2

	<i>Application of digitalization techniques</i>	<i>Current Manufacturing Lead Time (days)</i>
Mean	1	21.094
Variance	0	98.911
Observations	53	48
Hypothesized Mean Difference	0	
df	47	
t Stat	-13.9977682	
P(T<=t) one-tail	1.102E-18	
t Critical one-tail	1.677926722	
P(T<=t) two-tail	2.20468E-18	
t Critical two-tail	2.011740514	

Figure 37: T-test results of average lead time (digitally transformed functions)

	<i>Application of digitalization techniques</i>	<i>Current Manufacturing Lead Time (days)</i>
Mean	0	21.875
Variance	0	61.25
Observations	16	16
Hypothesized Mean Difference	0	
df	15	
t Stat	-11.18033989	
P(T<=t) one-tail	5.649E-09	
t Critical one-tail	1.753050356	
P(T<=t) two-tail	1.12973E-08	
t Critical two-tail	2.131449546	

Figure 38: T-test results of average lead time (functions which have not digitally transformed)

According to the t-test results of the average manufacturing lead-time depicted in figure 37 & 38, the companies that have not transformed digitally showed a slightly higher mean value compared to the companies that have digitally transformed their functions. Since the p-value of the two tests is less than the standard significance level ($\alpha = 0.05$), it could be concluded that the difference between the mean values is statistically significant.

	<i>Application of digitalization techniques</i>	<i>No of employees</i>
Mean	1	20.26415094
Variance	0	31.31349782
Observations	53	53
Hypothesized Mean Difference	0	
df	52	
t Stat	-25.06236301	
P(T<=t) one-tail	5.32424E-31	
t Critical one-tail	1.674689154	
P(T<=t) two-tail	1.06485E-30	
t Critical two-tail	2.006646805	

Figure 39: T-test results of average number of employees (digitally transformed functions)

	<i>Application of digitalization techniques</i>	<i>No of employees</i>
Mean	0	11.75
Variance	0	71.66666667
Observations	16	16
Hypothesized Mean Difference	0	
df	15	
t Stat	-5.551869578	
P(T<=t) one-tail	2.77041E-05	
t Critical one-tail	1.753050356	
P(T<=t) two-tail	5.54083E-05	
t Critical two-tail	2.131449546	

Figure 40: T-test results of average number of employees (functions which have not digitally transformed)

As per the t-test results depicted in figures 39 & 40, the mean values of the two segments have a substantial difference. On the other hand, the p-value of the tests is less than the standard significance level ($\alpha = 0.05$) considered for this study. Therefore, it could be concluded that there is a significant difference between the mean values of the two samples tested.

4.7. Hypothesis Test Results

Based on the following summary of the findings, a hypothesis test was conducted to ascertain the relationships between variables selected for the study.

Variable	Exploratory factor analysis	T-Test Analysis	Result
Customer Communications	Eigenvalue – 3.293	-	Significant positive relationship
Supplier Communications	Correlation against customer communications – 0.722	-	Significant positive relationship

Production and financial goals	Principal component analysis extraction value – 0.689	-	Significant positive relationship
Overall Productivity	Correlation against achieving production and financial goals – 0.605	-	Significant positive relationship
Diagnose possible future challenges	Principal component analysis extraction value – 0.352	-	Weak positive relationship
Supply chain efficiency in terms of SQCDM	Correlation against achieving production and financial goals – 0.639	-	Significant positive relationship
Number of employees	-	Mean difference – 8.514 P Value – less than 0.05	Significant positive relationship
Manufacturing lead time	-	Mean difference – 0.781 P Value – less than 0.05	Significant negative relationship

Table 13: Summary of findings

Hypothesis 1

H0 The application of digitalization techniques does not improve the organization's communications with the customers

H1 The application of digitalization techniques improves the organization's communications with the customers

According to the EFA results, the communication with the customers has shown the highest Eigenvalue among the selected variables and therefore, it could be concluded that the application of digitalization techniques improves the organization's communications with the customers.

Result – Null hypothesis is rejected

Hypothesis 2

- H0 The application of digitalization techniques does not improve the organization's communications with the suppliers
- H1 The application of digitalization techniques improves the organization's communications with the suppliers

As per the EFA results, the communication with the suppliers has shown the highest correlation with the communication with the customers. Hence the digitalization techniques improved the communications with the customers, it could be concluded that the communications with the suppliers would also be improved with the digitalization techniques due to high correlation value.

Result – Null hypothesis is rejected

Hypothesis 3

- H0 The application of digitalization techniques does not contribute the organization to achieve its production and financial goals
- H1 The application of digitalization techniques contributes the organization to achieve its production and financial goals

The highest extraction value and the component matrix value were indicated in the variable of achieving the production and financial goals. Therefore, it could be concluded that the digitalization techniques contribute to the organizations achieving their production and financial goals.

Result – Null hypothesis is rejected

Hypothesis 4

- H0 The application of digitalization techniques does not improve the organization's overall productivity levels
- H1 The application of digitalization techniques improves the organization's overall productivity levels

The achievement of production and financial goals and the overall productivity level has shown a strong positive correlation during the EFA. Since the digitalization techniques contribute for the organizations to achieve the production and financial goals, it could also be concluded that it improves the organization's overall productivity levels.

Result – Null hypothesis is rejected

Hypothesis 5

H0 The application of digitalization techniques does not support the organization to diagnose possible challenges in future

H1 The application of digitalization techniques supports the organization to diagnose possible challenges in future

The diagnosing of possible future challenges has shown the lowest correlations as well as the extraction value during the exploratory factor analysis. Therefore, it could be concluded that the digitalization techniques do not support the organization to diagnose possible challenges in the future.

Result – Null hypothesis is accepted

Hypothesis 6

H0 The application of digitalization techniques does not improve the organization's supply chain efficiency in terms of safety, quality, cost, delivery, and morale

H1 The application of digitalization techniques improves the organization's supply chain efficiency in terms of safety, quality, cost, delivery, and morale

The supply chain efficiency in terms of safety, quality, cost, delivery, and morale has shown a strong positive correlation against the achievement of production and financial goals during the EFA. Therefore, it could be concluded that the application of digitalization techniques improves the organization's supply chain efficiency.

Result – Null hypothesis is rejected

Hypothesis 7

- H0 The application of digitalization techniques has no effect on improving the organization's manufacturing lead-time
- H1 The application of digitalization techniques has a positive effect on improving the organization's manufacturing lead-time

According to the results of the t-tests obtained from the digitally transformed and not transformed functions, there was a significant mean value difference between the two segments. In other words, the application of digital techniques has a positive effect on improving the organization's manufacturing lead-time.

Result – Null hypothesis is rejected

Hypothesis 8

- H0 The application of digitalization techniques does not depend on the number of employees working in the functional area
- H1 The application of digitalization techniques depends on the number of employees working in the functional area

As per the t-tests conducted for the two segments of survey respondents, it was observed that the mean value of the number of employees has a significant increase in the digitally transformed functions. Therefore, it could be concluded that the application of digitalization techniques depends on the number of employees working in the functional area.

Result – Null hypothesis is rejected

5. CHAPTER – CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

The purpose of this study was to review the effectiveness of the digitalization techniques for the apparel manufacturing entities to boost up their supply chain efficiency. There were four research questions outlined at the beginning of this thesis, which focused on investigating different types of digitalization techniques that are available for apparel manufacturers, numerous applications of those digital techniques, various challenges faced by the firms during the digital transformation, and the unique benefits reaped by the firms after successful implementation of the digital techniques. This chapter is expected to comprehend the research findings and to draw the relevant conclusions comparing the results with the previous research findings using the outcomes of the hypothesis tests and the exploratory factor analysis. In addition, it is expected to discuss the limitations faced during the conduct of this study and unveil the potential future research directions. It would be useful for the scholars who are interested to probe more in this research domain.

5.1. Summary of the Research Findings

This study was conducted with the aim of achieving two specific objectives characterized as evaluating the effectiveness of using the digitalization initiatives to improve the supply chain efficiency and reviewing the challenges encountered during the digital transformation. A comprehensive and systematic literature review was conducted to lay a solid cornerstone for the study by identifying the various types of digitalization techniques used by the apparel industry. There were 7 different types of digitalization techniques, and the respective applications were identified and evaluated in the literature review. To make the results of this study more reliable and precise two types of primary data were gathered to validate the outcomes of the literature review using a structured online survey and expert interviews. There were 69 responses collected through the online survey that received the employees working for three leading apparel-manufacturing firms in the country. The interview sessions were conducted with two professionals working in the apparel industry and the IT industry.

The researcher has utilized both quantitative and qualitative approaches to analyze the data collected in this study. There were 77% of survey participants have implemented the techniques and most of them were using robotic process automation, cloud computing, and

big data analytics in their respective functions. Improving the speed of operations, visibility and operational efficiency were among the major reasons for using the digitalization techniques. In addition, the highest numbers of participants have faced compatibility issues in technologies and resistance from the staff during the digital transformation process. However, the respondents have marked as their companies are further investing in digitalization techniques targeting warehouse automation, 3D printing, automated sewing, block chain, and predictive analysis tools.

The respondents who represented the companies that have not yet implemented the digitalization techniques (23%) have marked financial constraints and the unavailability of skilled employees as the major reasons for not transforming themselves. However, it was observed that the companies and the employees both were having a positive feeling towards digital transformation as the data gathered on employment risk, training the staff, and technical support showed a higher percentage of constructive responses. Therefore, based on the survey demographics it could be concluded that the companies that have already gone through the digital transformation would continue to upgrade themselves whilst the companies that are not yet taken any digital initiatives would also be transformed soon.

During the interviews held with the two industry experts, it was understood that the apparel supply chains are going through various changes such as increased order volumes, customer pressure on reducing the lead-time, increased product customizations, company policies on maintaining a stable headcount even after the volume growth, system adaptability and the sustainability of the deployed processes, etc. However, the companies have proven that they could effectively tackle these challenges with the use of digital tools in their processes. For instance, XYZ Holdings was able to save 80% of their previous manufacturing lead-time only through the utilization of the digitalization mechanisms. Furthermore, both interviewees have highlighted the benefits that could be gained by the successful implementation of digital tools. Improved visibility and better forecasting ability, reduction in product rework and returns, rapid prototyping of the garments and virtual fit-on options, minimum lead time and quick change over time, improved work-life balance, reduced operational costs, etc. are some of the benefits highlighted during the discussions. Furthermore, the companies operating on a small scale and having financial constraints could use the SAAS solutions offered by the digital tool vendors which do not involve high investment in technological advancements.

There were two unique frequency models were developed by the researcher that was named as FTR model and the CT model. The FTR model illustrated the distribution of the digital techniques used among various functional areas of the company and the techniques were compared against the underlying reasons for using them. The model has highlighted that the highest usage of techniques was among the commercial and merchandising divisions of the companies that represented the sample. Robotic process automation, cloud computing, and big data analytics were the most used techniques in the sample. The highest number of techniques was used to speed up the operations and to enhance visibility. CT model describes how the companies have overcome the unique challenges faced by them by using digitalization techniques. As per the results of the analysis, the resistance of the employees for digitalization and the unbalance workload were addressed using only one technique out of seven.

5.2. Research Limitations

There were certain limitations identified by the researcher during the conduct of this study. Firstly, the number of responses received for the online questionnaire was limited to 69 responses that were initially targeted for 150. To validate the results drawn from the analysis, further analysis might be required, which could represent a larger population. Secondly, the data gathering was limited to three large-scale apparel-manufacturing firms in the country, which would require expanding further to other small and medium-scale firms. On the other hand, data that are more specific would be required to understand the unique needs of different clusters of the selected group of companies. Furthermore, the needs of the individual functions might also differ from one to another. For instance, the requirements of the intimate wear producing entity might be completely different for the requirements of the active wear producing entity.

Apart from that, the researcher was able to filter a limited number of articles from the previous studies conducted in the same domain as the articles published in English after 2014 were only selected for the study. In addition, the researcher has also experienced few biasness of the data gathered which resulted by the higher number of responses received from XYZ Holdings and higher representation from few individual functions. Therefore, the findings of this study might needs to be revalidated after gathering higher number of responses in the future researches.

Furthermore, it would be required to obtain data from other partners in the apparel supply chain to validate the findings of this study, as the manufacturer only cannot enhance the supply chain efficiency by himself. Due to the time limitations, this research was only limited to basic analysis methods and the same could be extended further with a higher volume of data in future.

This study has only focused on three companies that have successfully implemented digitalization techniques in to their processes. However, it would also important to study on the failed attempts of the companies that would explain completely different segment and it might contribute further for this research domain.

5.3. Future Research Directions

This study was an exploratory attempt that lays the foundation or the developing ground for many other related studies in the same domain. The possible research extensions might include different clusters / products / experienced professionals in the sector with a larger sample. The sample size of this study was limited to 69 respondents which could be further increased and revalidate the results. On the other hand, the costs, and the investment capital requirements act as one of the deciding factors for many organizations when it comes to digital transformation. Therefore, it would be helpful for small and medium scale firms to understand the pathways available for them to start their digital journey with less capital investment. For instance, the “software as a service model” might be the future of digitalization that does not require heavy investments at the beginning. Therefore, further research could be carried out for the SAAS model and its effects in promoting digital transformations.

Furthermore, this study was focused only on three apparel-manufacturing firms that would not explain the unique challenges faced by the small and medium scale firms. Therefore, the same study could be replicated focusing on the lower business scales. Another important suggestion for future research would be to extend the same study for other apparel supply chain partners such as raw material suppliers, logistics service providers, financial service providers, customers etc. which would assist the organizations to achieve better results by improving the efficiency of the overall supply chain.

In addition, the concept of digital transformation is a broader concept that could be followed by many other industries in both the manufacturing and service sectors to upgrade their businesses to the next level. Therefore, it is important to test the findings of this study in the other sectors that are having different business models.

5.4. Conclusions

There were 8 hypotheses developed based on the literature review and the industry expert opinions. Customer communications, supplier communications, achieving production and financial goals, overall productivity level, identifying possible future challenges, supply chain efficiency, manufacturing lead time and the number of employees working in the functional areas were the independent variables tested against the dependent variable of digital transformation. The analysis was carried out using exploratory factor analysis and t-test analysis. As per the exploratory factor analysis results, the possibility of identifying the future challenges using digitalization techniques showed a trivial effect and the researcher has concluded that there is no impact on the independent variable. However, the exploratory factor analysis results proved that there are significant relationships exist between all other variables and the use of digital techniques.

A t-test analysis was conducted to evaluate the level of relationship that exists between the digital transformation, the lead time, and the number of employees. As per the test results, the p-value of both variables was less than the standard significance level considered for the study which implied that the variances of the mean values are significantly important. Therefore, it was concluded that whenever the companies are digitally transformed it generates a positive effect on the manufacturing lead-time. On the other hand, whenever the number of employees is higher in the functions, the need for digital transformation would also be high. Based on the t-test results the alternative hypotheses developed for lead-time and the number of employees was also being proven and accepted.

This research has explored the influential factors of using digitalization techniques focused on improving the supply chain efficiency by the Sri Lankan apparel-manufacturing firms. This is a first time study in Sri Lanka and the researcher was able to deliver numerous contributions with the completion of this project. For instance, the researcher has developed a conceptual framework after evaluating the findings of the previous researches published under the same domain. The researcher has analyzed the relationship exist among few

additional variables which were not being evaluated previously such as digitalization techniques and the manufacturing lead time, number of employees and the supply chain efficiency. In addition, there were two models developed during the study to understand the application of various types of digital techniques in different functional areas and those applications were linked with the underlying root causes for transform themselves.

Digital transformation is a vital process for many contemporary organizations in the world today. The apparel sector is becoming increasingly competitive due to the reduced lead times, changing fashion and lifestyles, cost efficiencies gained through the smart manufacturing processes, etc. Even though there are only a few big players in the industry have invested in the digital transformation, the requirement would become essential for many companies to survive in the business. The transformation process requires the organizations to go through a tiresome process including the change of mindset of people, training, investments in additional IT infrastructure etc. However, the benefits that could be achieved with the transformation outweigh the initial expenses and the other required investments. Therefore, it is advisable for all the apparel-manufacturing entities to initiate the process for digital transformation at the earliest opportunity.

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ANNEXURE-1

Research Timeline

Quarter		Q4				Q1				Q2				Q3																
Month		Oct-20		Nov-20		Dec-20		Jan-21		Feb-21		Mar-21		Apr-21		May-21		Jun-21		Jul-21		Aug-21		Sep-21						
Research Phase	Activity/Week	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	
PHASE ONE	Brainstorming of ideas for potential research areas	█																												
	Selection of the research area			█																										
	One page document submission																													
	Refine the research topic with research coordinator																													
	Preliminary literature review																													
	Preparation of Research Proposal																													
	Verification of proposal with research supervisor																													
	Final submission of the Research Proposal																													
	Research proposal presentation																													
	Receive evaluation of Research Proposal																													
PHASE TWO	Apply necessary amendments to the Research Proposal																													
	Secondary literature review																													
	Preparation of Preliminary report of the Research Thesis																													
	Preparation of the questionnaire format																													
	Verification of report content & questionnaire with research supervisor																													
	Interim Presentation of the Research																													
	Data Collection - Questionnaire																													
	Data Collection - Expert Interviews																													
	Data Analysis																													
	Completion of the research thesis with findings and conclusions																													
Submission of thesis for examination purposes																														
Final Presentation - VIVA																														
Apply the revisions highlighted by the panel																														
Submission of the Final Thesis Report																														

ANNEXURE-1I

Questionnaire Form

5/31/2021

Digitalization and its applications in Apparel Manufacturing Sector of Sri Lanka

Digitalization and its applications in Apparel Manufacturing Sector of Sri Lanka

Thank you for taking your valuable time to respond to this survey. The aim of this study is to understand the implications created after the use of digitalization tools by apparel manufacturing companies in Sri Lanka. Digitalization refers to the use of techniques such as Artificial Intelligence (AI), Radio-Frequency Identification (RFID), Additive Manufacturing, Robotic Process Automation (RPA), Cloud Computing, Big Data Analytics and Augmented Virtual Reality (AVR). The relevant data gathered through this survey would be treated as highly confidential and anonymous and will only be used for university research purposes. Thank you

* Required

1. Email *

2. Please enter your company name *

3. How long you have been working in the company? *

Mark only one oval.

- Less than a year
- 1 - 2 years
- 2 - 3 years
- More than 3 years

Justification for using the questions

The email addresses were collected during the questionnaire to recognize duplication of data

Company name data were used for the purpose of categorization

Work experience data were collected to interpret as a demographic

<https://docs.google.com/forms/d/1DjK48K2EQwn5XRp-Qeqz56WDLg9sHcN1Nkos50peUj/edit>

4. What is your position/role in the company? *

Mark only one oval.

- Executive Level
 Managerial Level
 Senior Managerial Level
 Other: _____

Company & Product Information

5. Which of the following types of apparel is produced at your company/cluster? *

Mark only one oval.

- Activewear
 Intimatewear
 Casualwear
 Swimwear
 Fabrics / Yarn
 Other: _____

6. How many employees are currently working at your company/cluster? *

Mark only one oval.

- More than 50000
 Between 25000 to 50000
 Less than 25000
 Other: _____

Justification for using the questions

Work position data were gathered to categorize the responses and compare against the expected sample

Cluster data were gathered to categorize the sample representation

Workforce data was used to interpret as a demographic of the sample

7. In which functional area do you work? *

Mark only one oval.

- Sourcing
- Production
- Commercial & Logistics
- Warehousing
- Marketing or merchandizing
- Quality Inspection
- Other: _____

8. How many employees are working in your functional area? *

Mark only one oval.

- 1 to 5
- 6 to 10
- 11 to 15
- 16 to 20
- 21 or more
- Other: _____

9. Are you currently using any digitalization techniques in your functional area? *

Mark only one oval.

- Yes
- No Skip to question 28

Company has implemented digitalization techniques

**Justification
for using the
questions**

Functional area information were gathered to understand the link between digital tools and the functional needs

Number of employees working in the function was checked to understand whether the level of workforce impact on using digital tools

Question no 9 directs respondents to two separate paths based on their digital experience

10. Which of the following technologies are currently being used in your manufacturing process? *

Check all that apply.

- Cloud computing
 Additive Manufacturing
 Big Data Analytics
 Robotic Process Automations
 Artificial Intelligence
 Radio-Frequency Identification
 Augmented Virtual Reality

Other: _____

11. What reasons do you think that will have the highest influence over the implementation of new technological tools? (You can select more than one reason if applicable) *

Check all that apply.

- To improve the speed of the operation
 To create better visibility of the processes to managers
 To achieve a higher operational efficiency whilst minimizing the head count
 To achieve better flexibility in the operations (Low change over time)
 To improve the quality of the process output
 To bring down the operational costs
 To improve the safety in terms of both product and worker

Other: _____

**Justification
for using the
questions**

Type of techniques used as a descriptive statistic of the selected sample

Reasons for implementing the digital tools were used as a descriptive statistic of the selected sample

**Justification
for using the
questions**

5/31/2021

Digitalization and Its Applications in Apparel Manufacturing Sector of Sri Lanka

12. Can you describe the digital transformation process? (process/ transition time/resources/organizational changes etc.) *

13. What challenges did you face during the digital transformation process? (You can select more than one challenge if applicable) *

Check all that apply.

- High cost and complexity
- Less support from vendors
- Less support from top management
- Inadequate technical skills and expertise of the operational staff
- Difficulty in integrating the new digitalization tools with the existing systems/platforms
- Resistance to change from the staff

Other: _____

14. How did you overcome the challenges during the digital transformation process? *

The digital transformation process explained by the respondents were discussed as qualitative data

Challenges faced were discussed as a descriptive statistic of the selected sample

How the respondents have overcome the challenges were discussed as qualitative data

15. What were the challenges faced by the company before implementing the digitalization techniques? (You can select more than one challenge if applicable) *

Check all that apply.

- Lower productivity level
 Increased number of defects/customer complaints about the process output
 Higher operational cost
 Reduced process visibility for the management

Other: _____

16. How did you overcome the above stated challenges? *

17. Do you think the digitalization techniques would help the organization to improve communications with the customers? *

Mark only one oval.

	1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Definitely

Justification for using the questions

Challenges faced before the digital transformation is used as a descriptive statistic

How the respondents have overcome the challenges were discussed as qualitative data

Question no 17 checks whether there is any relationship between using digital tools and customer communications

18. Do you think the digitalization techniques would help the organization to improve communications with the suppliers? *

Mark only one oval.

1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Definitely

19. Do you think the use of digitalization techniques helps the organization to meet the production and financial goals? *

Mark only one oval.

1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Definitely

20. Do you think the use of digitalization techniques helps the organization improve the overall productivity levels? *

Mark only one oval.

1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Definitely

21. Does the digitalization techniques assist the organization to diagnose possible challenges in future? *

Mark only one oval.

1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Definitely

Justification for using the questions

Question no 18 checks whether there is any relationship between using digital tools and supplier communications

Question no 19 checks whether there is any relationship between using digital tools and production goals

Question no 20 checks the relationship between using digital tools and productivity level

Question no 21 checks the relationship between using digital tools and identifying future challenges

22. Does the use of digitalization techniques helps the organization to improve the supply chain efficiency in terms of safety, quality, cost, delivery and morale? *

Mark only one oval.

	1	2	3	4	5	
Not at all	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Definitely

23. What are the main advantages which you were able to enjoy after implementing the new technologies? *

24. What was the average manufacturing lead time of the company/cluster before implementing any digitalization technique? *

Mark only one oval.

- Less than 4 weeks
- 4 - 5 weeks
- 5 - 6 weeks
- More than 6 weeks
- Other: _____

Justification for using the questions

Question no 22 checks whether there is any relationship between using digital tools and supply chain efficiency

The benefits attained by the respondents after using the digital tools were discussed as qualitative data

Lead time data collected to compare the before/after changes

**Justification
for using the
questions**

5/31/2021

Digitalization and its applications in Apparel Manufacturing Sector of Sri Lanka

25. How do you compare your current manufacturing process with your direct competitors? *

26. What is the current manufacturing lead time of the company/cluster after implementing the digitalization techniques?

Mark only one oval.

- Less than 4 weeks
 4 - 5 weeks
 5 - 6 weeks
 More than 6 weeks
 Other: _____

27. Do you think that the company should invest more on implementing new digitalization techniques which were not yet implemented? If so, can you name them and describe the reason for investing? *

Company has not implemented digitalization techniques

Question no 25 is used to gather a qualitative data to understand the respondent's view on company's competitive position

Lead time data collected to compare the before/after changes

Question no 27 gathered qualitative data pertaining to future plans of the respondent's company

<https://docs.google.com/forms/d/1DJK48X2EQwn5XRp-Qeqa56WDLg9eHcN1Nkx50peU/edit>

28. What are the main reasons of not implementing the digitalization techniques in your functional area? (You can select more than one reason if applicable) *

Check all that apply.

- Unawareness
 Financial constraints
 Resistance to change from the staff
 Unavailability of skilled employees
 Incompatibility issues with the suppliers / customers

Other: _____

29. If the necessary technical support is provided, would you accept to shift to a new process enabled with digitalization techniques? *

Mark only one oval.

- Yes
 No
 Maybe

30. What is the current manufacturing lead time of the company/cluster?

Mark only one oval.

- Less than 4 weeks
 4 - 5 weeks
 5 - 6 weeks
 More than 6 weeks
 Other: _____

**Justification
for using the
questions**

Reasons for not implementing the digital tools were discussed as descriptive statistics

Question no 29 checks the respondent's willingness to use the digital tools

Lead time information is used to compare the changes after deploying the digital tools

31. Do you think that there is a threat for job security with the introduction of digitalization techniques to the process? *

Mark only one oval.

- Yes
- No
- Maybe

32. What are the challenges currently faced by the company? (You can select more than one challenge if applicable) *

Check all that apply.

- Lower productivity levels
- Increased number of defects/customer complaints about the process output
- Higher operational costs
- Reduced process visibility for the management

Other: _____

33. What are the strategies taken overcome the above stated challenges? *

Justification for using the questions

Question no 31 gathered the data pertaining to the respondent's view of job security

Challenges faced before the digital transformation is used as a descriptive statistic

How the respondents have overcome the challenges were discussed as qualitative data

**Justification
for using the
questions**

5/31/2021

Digitalization and its applications in Apparel Manufacturing Sector of Sri Lanka

34. Does the company has any plans to implement digitalization techniques into the processes? *

Mark only one oval.

- Yes
- No
- Maybe

35. Does the company provide any specific trainings relating to digitalization techniques and its applications to the employees? *

Mark only one oval.

- Yes
- No
- Maybe

36. What challenges do you think that the company would likely to face if a new digitalization technique is implemented into its processes? *

37. What are your suggestions to overcome the above stated challenges? *

<https://docs.google.com/forms/d/1DJK48XGEQwn5XRp-Qeqz56WDLg9eHcN1Vkos5OpeU/edit>

Question no 34 checks whether the respondent's company has any future plans to use digital tools

Question no 35 checks whether the respondent's company provides specific training for the staff on using digital tools

Question no 36 & 37 gathers qualitative data pertaining to the respondent's view on possible challenges faced when using the digital tools

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38. Do you think the current manufacturing process is good enough when compared with the direct competitors of the company? *

Mark only one oval.

- Yes
 No
 Maybe

39. What technological changes do you propose to the company to become more competitive in the market? *

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Google Forms

<https://docs.google.com/forms/d/1DJK48X2EQwn5XRp-Qeqz56WDLg9eHcN1Nkos5OpeU/edit>

**Justification
for using the
questions**

Question no 38 checks the respondent's view on the company's competitive position

Question no 39 gathers qualitative data pertaining to respondent's suggestions on technological changes required for their company

ANNEXURE-III

Interview Questions

1. Please give a brief introduction about the company (number of staff, key customers, operations etc)
2. What were the burning issues faced by your company in terms of supply chain efficiency?
3. What were the underlining motives behinds the implementation of digitalization tools?
4. What was your company's lead time saving after implementing any digitalization initiatives?
5. What were the main challenges faced by you when implementing the digitalization tools?
6. Other than the lead time, what are the other benefits gained by your team after implementing the digitalization tools?
7. What are the benefits do you think the digitalization techniques have offered to your customers?
8. What are the benefits do you think the digitalization techniques have offered to your suppliers?
9. Do you think that the supply chain's safety, quality, cost, delivery, and morale can be improved using digitalization techniques? How?
10. Do you think that the company should invest more on implementing new digitalization techniques which were not yet implemented? If so, can you name them and describe the reason for investing?