AI DIGITALIZATION AND AUTOMATION OF THE APPAREL INDUSTRY

AND THE HUMAN WORKFORCE SKILLS

by

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ABSTRACT

Artificial Intelligence (AI) digitalization and automation are transforming industries such as automotive, pharmaceutical and electronics at a blurring speed. As the technological pace of change in the apparel industry gains momentum, organizations across the apparel industry are facing a rapidly changing context for skills training and the development of the workforce.

The purpose of this research was to explore the impacts of AI digitalization and automation in regards to apparel industry processes, through objectives seeking to better understand how the transition to AI is affecting skill competencies required for the human workforce. As well, this research aimed to vision how to train the workforce and with what methods to train the workforce, in an effort to best prepare (both workers and businesses) for Industrial shift to AI and automation. The study adopted a qualitative approach, conducting semi-structured interviews with 21 participants from 5 different countries (USA, Sri Lanka, China, India, Hong Kong).

The study explored six research questions. While the results of this study were very comprehensive, the findings related to future apparel job functions will be highlighted. It was found that intellectual, innovative, and creative jobs will have a significant demand in the future of AI and automation. Results also showed that hard-skills (technical and digital skills) priority in skill-training of apparel employees, requiring a shift of focus from soft-skill training (management and behavioral skills). Findings from this study reveal significant collaborative opportunities between industry and academia, identifying and forecasting future skills requirements of the apparel workforce, and developing learning platforms to train employees on future skill needs. As well, findings suggest that sustainable and ethical practices are critical

within the emerging technology space, implementation of ethics regarding technology and sustainability as well as policies of accountability will be critical for the future of the apparel industry.

Chapter 1

INTRODUCTION

1.1 Background

The apparel industry is the world's most labor-intensive manufacturing sector and was a central momentum for industrialization in many countries (Nattrass and Seekings, 2018). Over the years, the apparel industry has evolved to be highly segmented, producing a wide variety of clothing and fashion products that change frequently with shifting style and season (Thomassey and Zeng, 2018). Disruptive trends that were on the horizon such as smaller quantities and shorter lead times, fast fashion, and the pressure of e-commerce are starting to become the norm for the apparel industry and its supply chain (Barrie, 2018). This presses the whole apparel manufacturing process to be incredibly complex and overwhelming to understand and manage.

In such complicated circumstances, industrial manufacturers regularly face complex and critical situations. The multifaceted nature of the apparel industry is challenging companies to deliver products faster, cheaper, and through more transparent and sustainable supply chains. In combination with the pace of change of the industrial needs, the speed of technological change is constantly and explosively accelerating. Traditional methods of industrial processes have not been able to efficiently handle the complex relationships with so many variables in today's apparel industry. (Thomassey and Zeng, 2018). As a result, efforts are being taken to seek and investigate new approaches including the use of Artificial intelligence (AI) techniques

in a variety of industrial applications (Thomassey and Zeng, 2018). Artificial Intelligence (AI) is defined as the property of machines, computer programs, and systems to perform the intellectual and creative functions of a person, independently find ways to solve problems, be able to draw conclusions and make decisions guided by data. A variety of practical industrial applications have proposed AI techniques such as Artificial Neural Networks (ANN), Big Data, Machine learning, and automation as an alternative approach for modeling such complex relationships. Numerous research studies have shown that AI techniques have the potential of providing superior solutions over traditional approaches (Guo et al., 2011).

The industrial landscape is at the beginning of the Fourth Industrial Revolution which is creating exponential changes to the way people live, work and connect with one another as a result of adoption of cyber-physical systems and connected machines that has the ability to interact, visualize the complete production chain and make decisions autonomously (Marr, 2018). It is the Era of Intelligence and Information, that is characterized by the fusion of technologies which are blurring the barriers between the physical, digital, and biological spheres (Otanez, 2017).

Consequently, the entry into the fourth industrial revolution is disrupting the businesses—big data, automation, advanced analytics and machine learning are set to dramatically transform how the apparel businesses operate (Alvanon, 2018). This AI environment has dramatically changed all industrial sectors, including the fashion industry. The fashion market will be optimized by developing data-driven tracking systems from raw materials to finished products and shops, proposing data-driven recommendations linking different production stages, design, and marketing services, generating new professional knowledge by learning from data, building data-driven

flexible manufacturing systems for small series productions, and exploiting new e-marketing methods (Thomassey and Zeng, 2018). Managers and practitioners in the Fashion and Apparel industry have to take into account the tremendous number of data to optimize their activities to be more profitable in businesses.

Garment manufacturing, which is one of the oldest human industries, has evolved through history with continuously adapting to the technology and society advances. Since decades, the fashion industry landscape keeps changing and requires enterprises' managers to continuously adapt their strategy with novel technological innovations. Brands and companies need to continue to evolve quickly, move faster, and be more innovative to meet the changing marketplace (Barrie, 2018). Currently, one of the most significant opportunities lies in the digitalization of the value chain. To pursue this opportunity, the typical Industrial policies recommend producing higher-value products (upgrading) while increasing labor productivity by creating a more skilled workforce with the advancement of technologies (Nattrass and Seekings, 2018).

Nevertheless, the adoption of AI features and processes into the apparel industry is very sluggish. Many factors conspire to implement all the available technology in the apparel industry complicated, including a vast amount fragmentation into small units across the supply chains and the presence of a knowledge gap (Barrie, 2018). Thomassey and Zeng (2018) mention that developing countries often do not have the skills to enter into higher value-added activities. All of the technological shifts are requiring a radical evolution of the workforce. According to a recent survey, one of the biggest complaints from brands and vendors is that they are having trouble hiring people with the right skills, with 62% saying they are struggling to fill specific

positions in the apparel industry (Alvanon, 2018). It is not just emerging technology that is challenging the industry to upskill current employees; the aging workforce and attraction of young talent into it is another pressing issue. Consequently, organizations across the apparel industry are facing a rapidly changing context for skills training and the development of their workforce.

Digitization of the workforce also poses a significant social responsibility risk in terms of the worker. Digitalization is defined as the integration of digital technologies into everyday life by the digitization of all possible information (Irniger, 2014), in contrast to Digitization, which is the action or process of digitizing; the conversion of analogous information (esp. in the later use of images, videos and text) into digital form. (Irniger, 2014).

Usually, for the apparel industry, entry barriers into garment work are low and attractive to many unskilled workers that would be forced out of jobs by AI. Statistics show that the current labor force of 3384 million in the Apparel Industry is facing an unemployment rate of 5.8% every year (Global Fashion Industry Statistics-International apparel). Over the last 25 years, apparel had the most significant decrease in employment among all manufacturing industries, with a decrease of 85 percent (Bureau of Labor Statistics, 2017). Therefore, training of unskilled workers to meet the needs of the evolving industry would be a tremendous step towards social sustainability by giving the workers the tools to transform with the AI digitalization of the apparel industry.

The AI digitalization comes with many opportunities while generating numerous challenges for the apparel industry. Rapid technology adoptions are hovering over the apparel industry due to the lack of research available to prepare the

industry to face the challenges. The purpose of this research is to better understand the digitally transformed workplace, to articulate the needs and requirements related to digitalization as well as to what opportunities exist in upskilling the current apparel industry workforce to meet perceived needs.

1.2   Justification

For the fashion and apparel industry, AI digitalization, while challenging, offers a tremendous opportunity. With the emergence of big data, fashion and apparel companies are faced with a new relationship between consumers, suppliers, competitors, and labor. It is vital for companies to enhance these data flows and relationships to optimize their production processes and decision making. Nevertheless, fashion and apparel companies do not widely use artificial intelligence (AI) techniques, primarily due to a few reasons. Those reasons have been identified as, 1) The scope of these methods is still unknown with acute research. 2) The implementation and set-up of AI algorithms on real data are too complicated. 3) The benefits cannot be identified due to the lack of relevant business models and research. 4) Lack of workforce with the right skills to implement new AI processes (Thomassey and Zeng, 2018; Nattrass and Seekings, 2018).

As the industry approaches the next industrial revolution, apparel businesses need to ensure that their workforces have the right technical skills in order to remain relevant and fit for the future, particularly as the current workforce ages (Alvanon, 2018). As a result, the apparel workforce is expected to continuously evolve faster, close the knowledge gaps to meet the needs of the changing marketplace. Training is happening within companies, but it is not enough to keep up with the lack of skilled

workers, and it is reported that there are high dissatisfaction rates with the content and modes of training provided (Alvanon, 2018).

Current fashion industry and apparel academic research must reflect the evolving field, in a collaborative effort with the industry, to overcome the challenges faced with the new technological adaptions. Currently, the task at hand is to comprehend what the full impacts of the AI takeover might be, how it affects the apparel workforce, as well as what actions might be taken to better prepare the workforce to meet the requirements inherent with technological changes in the apparel industry. A benchmark that illustrates the current positioning of the apparel industry worker and how she/he will be affected –given continuous AI development projections is timely. The results of this research will contribute to an evolving canon of literature on the impacts of technology innovations for the fashion and apparel industries. Beyond the literature, this research offers applied benefits, assisting at the industry level through technological strategies that might offer the unskilled apparel worker a competitive edge in the digitalized world as well as meeting the needs of an evolving industry. The findings offer recommendations on how the training programs might be structured to best prepare the workforce for the major digitalization of the apparel industry, thus retaining the jobs of the majority through upskilling. The overarching goal of this research is to contribute knowledge towards an efficient and productive apparel industry that is socially sustainable.

1.3   Objectives

The objectives of this research are:

1. To better understand the current status of the apparel industry processes and workforce.

2. To comprehend how the apparel industry's future should be aligned with the AI digitalization of apparel industry processes.

3. To anticipate how the apparel industry workforce needs to be trained and prepared for the anticipated technological changes.

1.4   Research Questions

In support of the stated objectives, the following research questions were posited:

RQ 1: What are the anticipated AI and automation artifacts in the future of apparel production and product development work-floor?

RQ 2: What job functions will artificial intelligence and automation take on and what will still require humans?

RQ 3: What are the specific future skills and competencies required of the fourth industrial revolution collaborative workforce?

RQ 4: What are the ways to minimize job loss through AI digitalization and automation?

RQ 5: What are the ideal training formats that maximize collaborative potential between the human worker and AI digitalization through job functions?

RQ 6: What are the social and sustainability impacts of AI digitalization and automation for the apparel industry?

1.5   Limitations and assumptions

The sources of the data collected were limited to five countries (USA, Sri Lanka, China, India, and Hong Kong), and it was assumed that the data gained through these interviews could be generalized. However, the AI digitalization and

automation of the apparel processes can have different impacts on different suppliers/

workforce in various geographic locations that are not covered by the research.

Chapter 2

LITERATURE REVIEW

2.1   Overview of Industrial Apparel Production

2.1.1   History of Industrial Apparel Production

Throughout Western history, fashion was reserved for only the wealthiest people like Queens, Kings, and aristocracy (Prins, 2017). Fashion was expressive and a way to show off the social class, whereas clothing was purely functional to keep people clean, warm, and protected. However, towards the beginning of the 20th century, manufacturing made fashion accessible to all upper and middle classes. The first patented sewing machine contributed to an exceptionally rapid fall in the clothing prices and a significant increase in the scale of clothing manufacturing (Idacavage, 2016). The combination of the sewing machine and industrial production lines helped push the ready-to-wear industry into the forefront. Men's clothing was the first type of clothing to be mass-produced (Prins, 2017). However, women's clothing lagged in terms of technology.

Standard sizing was the reasons that women's clothing took longer to reach mass-production than men's clothing (Prins, 2017). Since most women's clothing was dependent on the precise fit, and the technology was not developed enough to figure out the exact fit for mass production. Technology kept finding solutions to these problems while the industry went forward. Globalization led to another innovation, and fast fashion hit the scene around 1980 (Idacavage, 2016). Soon, fashion brands had to struggle to keep up with the increasing demand for affordable clothing, that lead opening of massive textile mills across the developing world, allowing US and European fashion brands to make millions by outsourcing labor.

Garment manufacturing eventually evolved to involves many processing steps, which can be categorized as pre-production, production, and post-production processes (Thomassey and Zeng, 2018). Each step of these processes has its own set of considerations and requirements that should be addressed and completed before moving to the next phase. Currently, apparel companies have to deal with a global and very competitive environment which is characterized by rapid changes, short life-cycle products, high volatility, low predictability, tremendous product varieties, short production lead times, increasing customer demand, and rising labor costs.

2.1.2 Apparel industrial upgrading

As consumers continue to change and become more sophisticated, fashion brands and suppliers are coming under increased pressure to supply for the demand (Alvanon, 2018). The industry practitioners are looking for many ways to upgrade the industry to make it more productive, thus more profitable. Thomassey and Zeng, (2018) mentions that industry upgrading helps to facilitate a 'high road' development trajectory where rising labor productivity accommodates wage growth without compromising profitability. This is especially important since the apparel and textile industries are very critical, especially for a few countries, in terms of trade, GDP, and employment. These industries provide opportunities for export diversification and expansion of manufactured exports for low-income countries that can explore their labor cost advantages and fill emerging niche markets and meet buyer demands.

The industry upgrading trajectories can be pro-labor, where there are rising average wages and employment (e.g., India and China) or higher average wages for fewer workers (e.g., Sri Lanka) (Thomassey and Zeng, 2018). Some policy analysts distinguish between economic upgrading and social upgrading. 'Economic upgrading'

is described as, encouraging firms to improve productivity and enter into higher value-added niches within value chains, and 'social upgrading' as improved working conditions skills development and higher wages (Fernandez-Stark et al., 2011). Social and economic upgrading is typically understood as a synergistic 'high road' to growth. Social upgrading incentivizes firms to upgrade their processes and products with technology advancements. However, higher value-added production is more skill intensive, thereby increasing the demand for technically skilled and better-paid workers. Lopez-Acevedo and Robertson (2012: 9) write that countries can enter at the simplest stages and gain experience that helps them move into complicated processes further up the value chain, these higher stages usually involve more skill and capital, and they may be associated with higher productivity and higher wages.

However, Keane and Velde (2008) mentions that developing countries often do not have the skills to enter into higher value-added activities hence will not be able to command a similar wage as the brands in developed countries.

Limitations for industry upgrading

The gender inequalities are higher in rural areas of developing countries, and thus, more technical and high skilled jobs are dominated by men than women. However, in the Apparel industry majority are women; thus, this has become one factor that impedes the successful technological upgrading of the industry. Tejani and Milberg (2016) provide evidence that industrial upgrading with skill intensification is biased against the employment of women, with potentially negative implications for female empowerment if female jobs are shed. Facing up to these challenges present

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opportunities for brands and their suppliers to rethink their businesses and find new ways to overcome these issues.

2.1.3 Apparel Production in the 21st century

The 21st-century consumer is continuously demanding immediate gratification. Today, with the fast fashion trend moving at a dizzying speed, the consumer has been significant for apparel businesses. With progressively increasing demands on personalization, the consumers are becoming more and more challenging to be satisfied (Thomassey and Zeng, 2018). Therefore, the apparel industry is undergoing a rapid shift with increasing global competition and random demand fluctuations. For apparel businesses, the accelerating pace of change has been all-consuming. Now, the apparel industry has to face challenges such as dealing with volatility and shifts in the global economy, competition from the online as well as Omni-channel, Value chain improvement and digitalization, decreasing foot traffic and offline retailing pressure (Barrie, 2018). While competing with fast fashion and facing pressure as retailers' close brick and mortar stores, the focus has shifted to the short-term strategies that will keep businesses thriving (Alvanon, 2018).

Fast fashion retailers work with manufacturers to produce clothes quickly for the consumer market (Nattrass and Seekings, 2018). These consumer pressures compel apparel manufacturers to continuously upgrade the performance of their production process to deliver the finished product within the shortest period of time and the lowest production cost (Thomassey and Zeng, 2018). Although consistent and optimal solutions are difficult to obtain under a fuzzy and dynamic manufacturing environment, they use increasingly sophisticated electronic monitoring systems to adjust volumes, and color (Caro and Martinez-de-Albeniz, 2015). A good example is

Zara; As of the early 2000s, they were able to design, produce and deliver a brand new collection and put it on display in its stores worldwide as short as in 15 days, which is a development attributing to the growth of new competencies in cheap-labor countries to manufacture intricately worked, high quality clothing (Nattrass and Seekings, 2018). However, with the globalization, the fashion supply chain is becoming more and more complex to be controlled.

The apparel industry is getting even more complicated with the Fast fashion trend starting to get coupled with mass customization. As the mass customization trend rising in the modern fashion industry, apparel manufacturing prompts large volume to small volume with more significant product variability, different to make-to-stock, no inventory of finished or semi-finished goods is available to buffer demand fluctuations (Thomassey and Zeng, 2018). The customization generates a high variety of products, and the production constraints make the formal mathematical modeling not possible. However, with the emergence of digital technologies such 3D body scanners and 3D virtual software, new opportunities are offered to researchers to develop new systems for the virtual evaluation of fit, wearing and comfort for the rapid adoption of mass customization (Thomassey and Zeng, 2018). Therefore, the survival of the apparel companies depends on their ability to respond quickly to order requirements and their flexibility in production operations, which increases the demand of advanced technologies for production prediction, management, and control.

Matthijs Crietee, secretary general at the International Apparel Federation (IFA), mentions that the main challenge and the first opportunity at the same time are to make the available technology work to take costs away from the supply chain (Barrie, 2018). Closer alignment between product development technology and

suppliers can unlock trapped value and help improve product innovation and quality, time to market, reliability, and execution. In the 21st century, a critical role in apparel manufacturing is to coordinate and manage the flow of material, the utilization of employee skills, equipment and technology, and responding to customer expectations (Thomassey and Zeng, 2018). Intelligence techniques and efficient computational tools for data mining will effectively deal with data related to uncertainties related to human factors, including consumer behavior, sensory quality attributes, and designer's knowledge. Therefore, the application of artificial intelligence techniques in all areas of production planning and control will make it possible to handle the experience in the area and enable improvement to meet the customer requirements.

Limitations of the current apparel industry

In the Apparel industry, many skills have been outsourced to cheaper labor countries over the past 15-20 years. Technology advances are likely to mean fewer workers and lower wage bills. This means that there is a pressing need to train new talent into the local industry to restore what many views as dying skills (Thomassey and Zeng, 2018). Hence, this is a particularly urgent challenge for specialized skills like bra-making, hosiery, and pattern making in the apparel industry.

Alvanon (2018) survey found that like other sectors, the apparel industry sees learning and adapting to continuous technology developments as a critical business concern, but only 73% of business leaders rank employee learning as a crucial business issue indicating that the apparel industry may be lagging. As the pace of change continues to accelerate in the apparel industry, there is going to be an increased need for new skill sets and expertise to apply them in the modern world. Changing

technology is going to be a key driver in this as innovations like Cobots, robots that facilitate human working, emerge, people will need to understand how to operate them. This skill gap is a barrier to healthy technological upgrading of the industry to meet customer expectations.

2.2   Artificial Intelligence and the apparel industry

2.2.1   AI applications in the field of apparel

Today, data have become one of the most valuable ingredients for social progress and industrial innovations. Supported by applications of the Internet, the big data environment has drastically changed the everyday lives of people as well as the economic and business world (Thomassey and Zeng, 2018). Recently, these AI techniques have attracted much attention of researchers and practitioners in the apparel industry and have been implemented successfully to solve a broad variety of decision-making problems. AI advances are not just in manufacturing, but are being integrated across all departments, such as sales, marketing and customer service, product research and development (Daugherty and Wilson, 2018). The potential applications of artificial intelligence in the fashion and apparel industry cover a broad range including design support system, fashion recommendation systems, sensory evaluation, fashion forecasting, intelligent tracking systems, textile quality control, decision making in supply chain management and social networks, and fashion e-marketing (Thomassey and Zeng, 2018). The scope of potential applications of AI in fashion and industry is wide and has been intensively reported in the literature. A few critical applications in fashion and apparel manufacturing are discussed below.

Fashion Sales Forecasting

Fashion products emphasize a short-life cycle, and the demand is highly unpredictable with the complex fashion trends that usually make the sales forecasting in the fashion industry greatly challenging (Thomassey and Zeng, 2018). An accurate forecast of future demand will lead to proper retail inventory management. With the advancement of AI technology, both AI-based methods and some hybrid approaches were suggested in the literature to be more efficient for conducting fashion sales forecasting than statistical methods. Even though, Artificial neural network (ANN) models perform well to yield a high forecasting accuracy, these forecasting models take a very long time to achieve the forecasting task (Thomassey and Zeng, 2018). Other AI methods such as Fuzzy Logic model and Support Vector Machines (SMVs) have been developed to overcome this problem but with additional limitations such as instability and forecasting error respectively.

Marker making

Literature suggests that optimization of marker making process utilizing artificial intelligence techniques can reduce the working strength of the staff's as well as significantly improve the material utilization ratio and the production speed, leading to considerable economic profits to garment manufacturing enterprises (Thomassey and Zeng, 2018). Scheduling of spreading and cutting demands labor cost minimization, greater accuracy, faster throughput, higher fabric utilization, and correct cut-piece fulfillment. This subjective nature of human involvement cannot guarantee the optimal planning and scheduling of the manufacturing process (Wong, 2003). Some dynamic factors which occur internally and externally will make the schedule

complicated, creating a much harder problem to solve (Wong et al., 2005a, b). Effective scheduling is crucial to accommodate higher production fulfillments and low production costs. Computational intelligence can be used to handle this issue better than humans.

Garment quality control and inspection

Garment inspection is considered to be an essential stage of quality control that relies heavily on trained and experienced personnel checking finished and semi-finished garments visually (Thomassey and Zeng, 2018). This process is very time-consuming because of the variety of styles, sizes, and fabric used in the garments. Further, there are concerns over the quality standardization, that requires the inspection to be repetitive to reach a guaranteed satisfaction (Fung et al., 2011). However, manual inspection has limitations on identifying defects in terms of accuracy, consistency, and efficiency, as workers are subject to fatigue or boredom. Thus inaccurate, uncertain, and biased inspection results can often be produced. As a result, it is necessary to set up an advanced inspection system for garment inspection that can decrease or even eliminate the demand for manual inspection and increase product quality. Artificial intelligence techniques can be explored to ensure reliable and accurate quality control in industrial apparel manufacturing.

Seam and fabric sewing performance

In cut and sewn products, a seam is one of the basic requirements in the construction of apparel and has excellent significance in all apparel products. Seam performance is affected by numerous fabric mechanical properties with a combination

of their sewing parameters (Yildiz et al., 2013). Complex and nonlinear relationships between these properties draw exciting ANN models that can replace conventional statistical predictive techniques. Patric et al. (2007) and Hui and Ng (2005) experimented two different AI models to predict the sewing performance of fabrics in apparel manufacturing. Both models provided better guidance than experts in some areas when compared to actual sewing performance.

Sewing automation equipment/ Sewbots

      The knowledge of sewing machines is an essential aspect to contemplate by apparel manufacturers in order to produce high-quality garments and improve production efficiency (Thomassey and Zeng, 2018). The sewing parameters usually are being adjusted by "trial and error" at the beginning of the operation, as average values (Silva et al. 2004). Automation equipment is critical to improve the quality of apparel products and enhances key machine functions. In a research Barrett et al. (1996) did, the researches indicated that, given the ability to identify fabric/ply combinations online, the sewing machine could use predefined sewing parameters to adjust the sewing machine settings automatically.

      Many researchers experimented real robotized sewing environments and found out that robotic AI can robustly manage deformation of various fabrics while sewing; wrinkling and folding (Koustoumpardis and Aspragathos, 2007), and also curved edges with known/ unknown curvatures (Zacharia, 2012). The authors highlighted that this approach applies to any piece of fabric, and that achieved accuracy is promising for future use of industrial applications. Li & Fung's new robotics system that automates the sewing process requires only one employee to handle an entire

production line and can produce a t-shirt in just 22 seconds (Alvanon, 2018). Tianyuan garments are about to set up a fully automated t-shirt production lines based in Arkansas in 2019 that will take only roughly 4 minutes from fabric cutting to the finished product, and the personal cost for each t-shirt is going to be around 33 cents (Zhou and Yuan, 2017). Tang Xinhong, the chairman of Tianyuan Garments, mentions that "Around the world, even the cheapest labor market cannot compete with us". Thus, According to Alavanon (2018), businesses must prepare their workforces for the future of Sewbots.

2.2.2   Challenges for adoption of AI

Although there is growing excitement around what new applications AI will enable next, literature also covers some issues and limitations existing around wide AI adoption across the industry. Firstly, the cost of incorporating artificial intelligence in daily operations is quite very high, even though the further advancements in the technology in future might bring that down (Thomassey and Zeng, 2018). However, the investment and resources required to produce intelligent machines that can perform complex human tasks is too much of a risk to many apparel companies.

Moreover, AI interference in individual roles can cost jobs for a considerable share of the workforce (Future of work and skill, 2017). Hence, some critics lobby against extended AI implementation. The lack of confidence in an AI-based system will limit support for its use and likely preclude adoption, even when that adoption could provide significant benefits. AI adoption is also hindered by the possible creation of a skill gap within the companies where they will need to secure employees with the combination of skills and knowledge necessary to unleash the full potential of AI (Fu, 2018).

2.2.3 AI and the apparel worker

Rapid advancements in automation and the use of AI robots together with some reshoring of jobs in advanced economies might limit the job potential of the apparel manufacturing sector while creating the massive skill gap for AI brain power and talent (Future of work and skill, 2017; Fu, 2018). Today, AI systems are not just automating many processes, making them more efficient, but they are allowing people and machines to operate collaboratively in novel ways (Daugherty and Wilson, 2018). Currently, in order to fulfill customized orders and handle fluctuations in demand, employees have the option to partner with robots to perform new tasks without having to go through any processes or manufacturing steps manually. This is changing the very nature of work, requiring the workers to handle their operations in dramatically different ways. The traditional assembly line with a factory where robots are much smaller and flexible with the ability to work alongside humans. In contrast, now robots and other types of machinery are utilizing sensors and complex algorithms, that have the ability to sense their environment, understand, act and learn thanks to machine learning software and other related AI technologies (Daugherty and Wilson, 2018).

It is predicted that, by 2025, intelligence applications in work could account for 40% of productivity gains (Oxford Analytica Daily Brief Service, 2014). Further, it is forecasted that 'technological singularity' (when artificial intelligence surpasses natural intelligence) will be achieved by 2029. Due to these `smart` machines and IT automation, 47% of jobs in the United States are at risk from Computerization. Although artificial intelligence has been utilized in industry since the 1990s, its implementation and impact on labor have been confined to lower level, unskilled, or semi-skilled jobs (Oxford Analytica Daily Brief Service, 2014). However, the

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statistics show that even the jobs and employment prospects of educated professionals could soon be under threat following rapid advances in artificial intelligence (AI).

2.3   AI and Apparel workforce skill competencies

With estimates that the fashion and apparel industries are set to transform more in the next ten years than in the past forty (Deloitte Human Capital Trends, 2017), the new apparel landscape requires its workers to have fresh competencies. These technological shifts of the apparel industry demands a radical evolution of the workforce (Alvanon, 2018). As per the estimates, the U.S. economy will need 100,000 new information technology employees each year for the next ten years to match the skill requirements in the job market (The Atlantic, n.d.). Executives around the globe rank "reinventing careers and learning" as the second most critical business concern behind going digital, with 83% saying it is urgent (Deloitte Human Capital Trends, 2017). Companies need to take the required measures to ensure their workforce is fit for the future.

2.3.1   State of Apparel Industry jobs

2.3.1.1   AI and the skill gap

The apparel industry is in a war for talent, however not many candidates have the specialized skill set needed for the job. Currently, the biggest challenge for many apparel firms is the retirement of the Baby Boomer generation (Alvanon, 2018). The fundamental problems resulting from this are decrease of the production as manufacturers lose their experts and the loss of knowledge when people leave the job. In the Alvanon survey (2018), 38% of respondents highlighted retiring staff as a central concern. However, a global survey was conducted in 2017 to comprehend the

current sentiment around industry skills to identify whether there is a skill gap (Alvanon, 2018). They found out that while businesses in other industries are concerned about the emergence of automation and the technological displacement of workers, the apparel industry was more concerned regarding the perceived shortage of technical skills. This could mean that the apparel industry is lagging, preoccupied on the wrong affair.

A report by the Oxford Analytica Daily Brief Service (2014) mentions that firms that move first into the AI field make substantial gains in competitive performance over traditional organizations as data and intelligence have currently replaced capital as the most valuable resource. Although people worry that computer intelligence will take over the world, little do people notice that it already have (Ryder, 2017). As accurately mentioned by Ryder (2017), it is impossible to have a robust conversation regarding artificial intelligence (AI) without discussing about its impact on society; especially if machine learning may eliminate jobs. However, the real question would be whether the growing demand for AI talent will outpace the jobs AI replaces.

There is an estimate that 47% of all U.S. jobs are undergoing high risk of computerization in the next few decades (Kaplan, 2017). He projected that, by 2055, more than 50% of all work-related tasks would subject to automation. Therefore, this could mean that computers will replace human jobs at a much faster rate than new jobs can be created resulting in significant unemployment levels, not just at the lower end of the workforce, but also among knowledge workers including clerical and professional services (Oxford Analytica Daily Brief Service, 2014). This may, in turn,

feed the global phenomenon of rising income inequality and a 'hollowing out' of the middle class.

However, Kaplan (2017) gives a different idea about the loss of jobs to the automation wave. He mentions that although the new wave of automation, like previous waves, might reduce the need for human labor, however, it will make the remaining employees more productive allowing their companies to be more profitable. These profits will then find their way to employees, stockholders, and consumers (through lowering of prices). This newfound wealth will increase the demand for products and services, compensating for the lost jobs by employing a greater number of people. According to Kaplan (2017), the industrial history strongly supports for this view. Despite the centuries of advancements in automation and recurrent warnings of a jobless future, the total employment levels have continued to increase relentlessly. A recent analysis by Atkinson and Wu (2017) quantified the rate of job loss and creation in each decade ever since 1850, based on census data. It was found that 57% of the jobs that existed in 1960 no longer exist today (adjusted for the size of the workforce). Hence. the literature concludes that artificial intelligence will change the way that consumers live and work, continuously improving their standard of living while shifting jobs from one category to another in the natural capitalist cycle of creation and destruction.

2.3.1.2 Changing need of skills

As digitalization happens across the apparel supply chain, the workforce needs to contend with new skills including understanding big-data facilitated buying and merchandising, 3D design, automation, and more collaborative ways of managing product life cycles. Matthijs Crietee, Secretary General of the International Apparel

Federation, quotes "The faster the industry changes, the more important it is to have the right training available for all working in fashion. So, it is super important now, and we need more of it." (Alvanon, 2018, pp.7). As the dynamic demand for specific skills is being felt across industries, apparel organizations are investing in programs that empower the future workforce through job retraining (The Atlantic, n.d). Furthermore, even with overall concern, investment does not match the level of concern shown (Alvanon, 2018).

As a result, staff is also taking education into their own hands, with the emerging popularity of digital boot camps that are designed to help upskill individuals for new job roles. Organizations like General Assembly, Lynda, or Coursera look to bridge the skill gap between training and apparel business requirements (Alvanon, 2018). In a recent survey done, when the apparel industry workforce was questioned of what types of training were provided compared to what was required, more respondents selected technical training versus management or soft skills (Alvanon, 2018). There is a broader focus at the moment on improving leadership or soft skills—improving competencies around communication and collaboration. However, it seems evident that the apparel industry has different needs, with a demand for more technical training.

2.3.2 Training and upskilling the apparel workforce

2.3.2.1 Need for training of Apparel workforce

Training is not just a means of ensuring people stay up to date with currently required skills; it is a mean of retaining and attracting the best ambitious staff. According to the Alvanon (2018), 91% of managers recognize training as necessary

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for the professional development of their employees, while 88% of those surveyed stated it was essential for maintaining job employee satisfaction. This fact is proven by the LinkedIn Learning Workplace Learning Report (2018), as it mentions that 94% of employees would retain at a company longer if it would be willing to invest in employees' career development. Over half the respondents were concerned about the lack of training and growth opportunities, which is likely to have implications for their progression and retention.

Some employees are fearful of change and what 3D design and technology would mean for their jobs. For businesses as such, skill training will help these employees feel confident that their employers see a future with them. However, managers and employees have less knowledge on how to implement training in their daily jobs. This means training solutions need to fit into a busy workplace and be simple for managers to encourage. Managers play a significant role in assisting in facilitating training. According to the LinkedIn Learning Workplace Learning Report (2018), 56% of employees would prefer to spend some time learning if their manager led them to a training program or course to gain or improve their skills. There is an awareness of a need for more training, yet budgets are not matching the demand with increased investment (Alvanon, 2018). 70% of executives in the apparel industry believe that more investment is required for skill training, however only 38% plan to increase the stake for skill-training over the next two years.

Consequently, literature mentions there are concerns that graduates are not fit for work (Alvanon, 2018). Respondents of this survey stated that academics are not up to date with what is going on in the apparel supply chain, and universities are not educating individuals with the right skill sets. This is particularly evident in the

lingerie industry, that requires more expertise due to its complicated construction. These functional areas require more ongoing skill training, with technical design and product development ranking the highest. However, it is evident that there is a massive gap between what employees learn in school and what skills they need for real life in the factory.

2.3.2.2 Current State of Training in Apparel industry

Many apparel businesses are unaware of the challenges they are facing, with very few having a thorough understanding of their current skill gaps. Only 16% of managers surveyed in the apparel industry mentions that their companies have assessed the skills of their entire workforce (Alvanon, 2018). It was also found that only 49% of managers and 50% of employees said they had undertaken company sponsored training over the past 12 months. Likewise, the survey further describes that only 42% of managers and 38% non-managers are satisfied with the training programs that are currently being provided to them. The main reasons for dissatisfaction of training programs are the time required for training, the relevance of content, and the quality of the content of the training.

The main barriers and critical challenges to driving increased training investment are time and budget constraints for business leaders. For employees, time, lack of training opportunities, and management support are the biggest challenges (Alvanon, 2018). For many businesses, the lack of a precise method for measuring the effectiveness of training may be holding them back—while 38% look at employee satisfaction, 36% look at increases in productivity and 24% at KPIs. This suggests that there is no consistent way of measuring the success of training, and thus no way to justify further investment.

2.4   Summary of the Literature Review

In western history, fashion was once only available to the wealthiest of society. With the introduction of the first sewing machine, society witnessed a rapid fall in the clothing prices and a large increase in the scale of clothing manufacturing, making fashion available to all social classes. Soon, fashion brands had to look for ways to supply for the increasing demand for affordable clothing. This persistent demand, coupled with globalization, led to massive textile mills and apparel companies opening across the developing world, outsourcing labor. The garment manufacturing eventually evolved to function in a very competitive environment fueled by fast fashion, which is characterized by shorter product cycles, short production lead times, increased customer demand, and labor costs.

Today, 21st-century consumers are becoming very difficult to be satisfied with the increasing demand for customized apparel together with fast fashion. These consumer pressures compel apparel manufacturers to continuously improve their performance in order to deliver the finished product within the shortest period of time and the lowest production cost. As of the early 2000s, Zara, for example, was able to produce and deliver new garments in a mere 15 days, which is a development attributing to the growth of product development competencies in low wage countries. However, the new wave of mass customization demands smaller volumes with greater product variability, flexibility in production operations, which raises the need for advanced technologies. With the Forth Industrial revolution upon the apparel industry, the application of artificial intelligence techniques in all areas of production and planning will enable the industry to meet the magnified customers' expectations.

AI digitalization and automation are now being integrated across all areas of the apparel industries. The potential applications of AI in the apparel industry cover a

broad scope including design support systems, fashion forecasting, intelligent tracking systems, textile/garment quality control and inspection, decision making, supply chain management, maker making, Seam, and Fabric sewing performance and Sewing automation equipment/ Sewbots. However, the cost of incorporating AI, not having the workforce with required skills are a few barriers that are hindering companies from going fully digital.

Consequently, technology advances are likely to mean there is a pressing need to train new talent and special digital skills required by the apparel worker. With emerging technology like cobots, robots that facilitate human working, labors will need to understand how to operate them. The industry upgrading policies rationalize that technological upgrading involves more skill, and developing countries often do not have these skills to command a healthy technological upgrading of the industry. Moreover, some literature points out that gender inequalities are dominant in the developing countries pushing technical and high skilled jobs to be dominated by men than women creating social sustainability issues.

However, it is predicted that 'technological singularity', when AI surpasses natural intelligence, will be achieved by 2029. For example, Li and Fung's new robotic system that automates the sewing process requires only one employee for an entire production line and can produce a t-shirt in just 22 seconds. Thus, statistics show that jobs and employment prospects of even educated professionals in the apparel industry could soon be under the threat of rapid advances in AI. With the retiring Baby boomer generation, production manufacturers are losing the expert knowledge in the industry, thus motivating apparel industries to go digital. All these technological shifts mean that computers will take over human jobs at a faster rate

than new jobs can be created; thus apparel industry needs a radical evolution of the apparel workforce to shrink the rates of unemployment in the future.

As the changing demand for specific skills is felt across the industry, companies are investing in programs that upskill the workforce of the future through job training. However, investment in job training does not reflect the urgency of the necessity. Managers are playing a significant role in assisting to facilitate training; a global survey shows only 38% are planning to increase the investment in training over the next two years. At the same time, there are concerns that universities are not graduating individuals with the right skill set.

A recent survey shows that only 42% of managers and 38% non-managers in the apparel industry are satisfied with the training that is being provided to them. The main reasons for dissatisfaction of training programs are the time required for training, the relevance of content and quality of the content of the training. The main barriers for increased investment in training programs are time and budget constraints for the businesses. For employees, time, lack of training opportunities, and management support are the biggest challenges. Furthermore, literature suggests that not having a clear way to measure the success of training, thus justifying the training investments are a key factor holding the businesses back in training their employees.

Chapter 3

METHODOLOGY

3.1 Research Questions

This research was aimed to understand the impacts of AI digitalization and automation in regards to apparel industry processes, how this change is affecting skills required of the human workforce as well as training required to meet the needs of Ai digitization and automation.

Primarily, this research seeks to understand how technology might influence future skills and job functions of the human apparel workforce and what can be done by the apparel industry, academia, countries, and individuals to prepare for the 4th industrial technological transformation. The following questions were posited:

RQ 1: What are the anticipated AI and automation artifacts in the future of apparel production and product development work-floor?

RQ 2: What job functions will artificial intelligence and automation take on and what will still require humans?

RQ 3: What are the specific future skills and competencies required of the fourth industrial revolution collaborative workforce?

RQ 4: What are the ways to minimize job loss through AI digitalization and automation?

RQ 5: What are the ideal training formats that maximize collaborative potential between the human worker and AI digitalization through job functions?

RQ 6: What are the social and sustainability impacts of AI digitalization and automation for the apparel industry?

3.2   Research Design

This research was conducted utilizing qualitative methods via in-depth, semi-structured interviews. This approach offers a deeper exploration of each research question, create openness in participants to expand their responses and to simulate respondent's individual experiences and feelings to build up a detailed picture of each scenario (Keller and Conradin, 2019).

Upon approval from the University of Delaware Institutional Review Board on February 19th, 2019, the researcher conducted interviews with professionals (executives, mid-level executives, and designers) from different apparel industry related companies throughout the globe. The interviews included questions from the topics, A) Understanding the current status of the AI digitalization and automation of the apparel industry processes, B) Benefits and limitations of AI digitalization and automation, C) Future of AI digitalization and automation in the apparel workspace, D) Social and sustainability issues involving technology advancements, E) Apparel workforce skills associated with AI-based technological developments and automation, F) Training of the workforce. Being a professional related to the apparel industry, being over the age of 18 and preferably having participated in some training offered by the employer were the criteria to participate in the research study. The interviews conducted with executives, middle-level managers, technicians, and designers were aimed at capturing data at different levels.

3.3   Research interview sampling and sample recruitment

The population of interest for this study were professionals (executives, middle-level executives, and designers) involved in the apparel business. Snowball non-probability sampling method (Blackstone, 2012) was utilized to solicit the

research sample for this study. Sample recruitment was globally focused in order to attain a holistic understanding of what AI digitalization and automation meant to apparel industry professionals from different geographical locations.

Snowball technique was applied via online (professional social media platforms, professional groups, and forums) in order to solicit participants for the study. A research participation invitation was drafted to recruit participants for the semi-structured interviews and posted on the professional social media network; LinkedIn and on public social media network; Facebook. The post briefly explained what the research study was about, what will make them eligible to participate, and how interested eligible professionals could sign up to participate in the study. Through the "sharing of posts" option on social media, the research invitation was shared by faculty and friends, which allowed it to circulate through a more comprehensive professional network. A Google form was created to make it easier for interested eligible participants to sign up for an interview, and the link was included in the research invitation post. A total of 3 participants signed up through this approach. The research participation invitation was also published in the Shimmy Technologies newsletter, in which many international apparel manufacturers were active subscribers. In order to look for potential participants, emails were sent out to professional contacts who were presumed to be potentially eligible participants. Through the referral method of snowball sampling technique, other eligible contact addresses were obtained through faculty, professors, and colleagues. Snowballing had an approximate successful response rate of 72%.

Ultimately, the research population included 21 industry professionals. Recruited participants had an approximately even gender distribution of 11 Females to

10 Males. Participants represented five countries, namely, the USA, China, Hong Kong, Sri Lanka, and India. All recruitments were apparel industry professionals over the age of 18 who had participated in training programs with an understanding of how industry trainings were carried out.

      Prior to the interviews, the interested eligible participants' consent was taken to participate in the research study by forwarding them the Informed Consent Form with the IRB approval. The Informed Consent Form briefed the participants about the interview procedure and other information such as risk/ discomforts and benefits of participation. It also mentioned how the interview would be audio-taped for subsequent transcription and analysis of data; however, assurance of anonymity was provided. Lastly, the Informed Consent Form provided the contact information of the University's Institutional Review Board for questions about the study and participant rights. Finally, a convenient time was scheduled with each eligible interested participant, either through email, utilizing the google form to sign up participants or using the app "Calendly" to book a time slot for the interview.

Table 3.1. Study participants' Geographical representation and Expertise.

Expert	Country	Expertise
1	USA	Retail and Technology
2	USA	Design and Product development
3	USA	Gender and Human rights
4	Sri Lanka	Product development and merchandising
5	USA	Innovation and 3D technology
6	USA	Customization, retail and fit
7	Sri Lanka	Design
8	Sri Lanka	Embellishment design innovation
9	USA	Supply chain
10	India	Digital Printing and Automation
11	USA	Supply chain
12	Sri Lanka	Design and Product development
13	Sri Lanka	Production planning
14	Sri Lanka	Textile design and Innovation
15	China	Supply chain and sustainability
16	Hong Kong	Research and Apparel solutions
17	Sri Lanka	Design, customization and 3D Technology
18	India	Human resource and training
19	USA	Technology and AI
20	China	Research and Innovation
21	China	Business Analytics and Planning

3.4   Data Collection – Semi-Structured Interviews

Data was collected through the responses received from the semi-structured interviewing process. The interviews were conducted from March 15th through April 2nd, 2019 by the Primary Researcher via telephone (for USA based participants) and other internet communication platforms such as Whatsapp, Skype, and Zoom (For International participants). A semi-structured interview protocol was designed to guide the interview process and address the research questions in the research proposal. The protocol outlined the general script to be used in the introduction and in concluding the interview along with the interview research questions and relevant follow-up questions/ probes. Follow-up questions allowed the researcher to avoid deviating from

the research topic during the semi-structured interviews (Bhattacherjee, 2012). At the beginning of each interview, the participant was greeted and offered a brief about the purpose of the study. Subsequently, the researcher briefly went over the Informed Consent Form and asked if the interviewees had any questions about the interview or the interviewer.

The interview generally started with basic demographic questions related to participant's carrier, such as how long he/she has worked in the apparel industry and what kind of roles/ positions they held. The purpose of the demographic questions was twofold. Firstly, those questions were expected to ease the participants in the interview process as well as to build a rapport with the participants (Bhattacherjee, 2012). Secondly, the demographic information was required to understand the research participant profile as well as to know what follow-up questions to ask depending on their experience in the apparel field. Generally, the flow of questions on each interview was dependent upon the participant's prior responses.

Interviews were conducted mainly in English for the ease of the data analysis. However, an exception was allowed to be made for some of the participants from Sri Lanka when they were more comfortable speaking in Sinhala (Sri Lankan native dialect). The principal investigator who conducted the interviews was fluent in both Sinhalese and English, so it was possible to carry out the interview in Sinhala when the participants wished to do so. It was expected that permitting participants to speak in their native dialect whenever possible helps them to open up more about what they want to express and also to develop a rapport with the interviewer. In addition to taking field notes, the interviews were also recorded electronically. Audiotaping was

done to ensure clarity and accuracy of data transcription and analysis. Interviews lasted a duration of 20 minutes – one hour per person.

3.5   Data Analysis and Validation

Thematic analysis approach was used for the data analysis, which is a widely used research method for semi-structured interview analysis. Braun and Clarke (2006) define Thematic analysis as "A method for identifying, analyzing and reporting patterns within qualitative data" (p. 79). The thematic analysis moves beyond counting exact words or phrases, but rather focus on identifying and describing both implicit and explicit ideas within the data, also known as, themes (Guest, Macqueen and Namey, 2012, p. 50). This method of data analysis allows extracting boarder and more profound meanings from data to foster trustworthiness in interpretations.

The first step in the thematic data analysis process involved transcription. The Interviews were transcribed word by word by the primary researcher. Sinhalese interviews were translated into English and scripted verbatim. The interview transcriptions were re-reviewed by the primary researcher to check for errors and to get familiar with data in preparation for further analysis.

After the completion of the data verification process, the interview scripts were coded using qualitative research software NVIVO 11.0 and searched for themes with broader patterns of meanings. Saldana (2014) defines "themes" as extended phrases or sentences that summarize the manifest (apparent) and latent (underlying) meanings of data. The coding was guided through considering each line/ phrase/ paragraph of the transcripts from the interview study while broadly keeping constant tabs on research questions to be answered in this study. New codes (themes) were added, and the description of initial codes was refined to include new findings as more transcripts

were analyzed. New codes were created for each time novel unexpected information appeared on data scripts, and this helped to uncover entirely new information regarding the topic of research. Consequently, a total of 34 principal codes were finalized with further sub-codes. Later, the themes were reviewed to make sure they fit the data obtained through the interviews.

The Constant Comparative method (Glaser, 1965) was employed to evaluate the analyzed data and find connections between emerging concepts, codes, and themes. Category construction was done as an attempt to cluster, the most seemingly alike themes into the most appropriate groups (Saldana, 2014). Thus, themes/codes were further grouped under the most appropriate categories as needed by each research question. The coding process was executed by the principal investigator alone to ensure coding consistency and to maintain coding reliability.

Chapter 4

RESULTS

This chapter contains the result of the study, arranged into six subsections. This section will disclose the significant areas related to the research questions as identified from the interviews.

4.1 "The future is Today": AI and automation in the Apparel Industry

The first subsection presents data uncovered on the broader view of the apparel industry's technological transformation, benefits, and limitations. This chapter will be essential to understand where the fashion industry stands today in terms of technology, in order to answer the six research questions of this study.

4.1.1 Apparel Industry technological transformation

'Liam was rushing to the design department to hand over the paper patterns to the technical design team. There were many pattern adjustments to do, so it consumed more time than he thought to fix them all by hand. He still needed to fax copy the paper pattern corrections to the factory in Bangladesh. Although he was not sure if they will make a mistake like the last time when putting all printed pattern pieces together on to the right scale. Liam knew by experience that they make so many errors when converting the pattern corrections to paper patterns on their side. He was quietly wondering if there was any other way to do this at all….'

The above scenario is outmoded, as there are multiple advanced procedures to do a pattern transfer to a supplier in today's context. However, this is a genuine snapshot of the apparel industry 20 years ago; according to Expert 5, one of the

research participants. Undeniably, the technology was not up to what the apparel industry experience today, and that assigned workforce with much manual work.

Since then, there have been many technological advancements in the apparel industry, especially in terms of automation and AI digitalization. Countless advanced machinery and digital software have been invented, which made processes much easier for the apparel workforce. Three participants (Expert 10, Expert 21, and Expert 19) attested to the fact that brands and suppliers alike have invested heavily on these new innovative technologies in the search for better ways to perform in the industry. This technological transformation of the industry has brought the product life-cycle to be much shorter from what is used to be; from 6 months to 2 weeks. According to Expert 16, 'it is a bit ridiculous for her.

"So, all the technology that we look at today when we go to a factory, you have to realize that 15 years ago only a very little existed." (Expert 16)

According to most participants, there is a consistent success rate in technology. Investments made are materializing fast, hence the interest in AI and automation currently. The industry is welcoming technology because "*it has truly become an innovate or die scenario*" (Expert 1). Technology is inevitable at his point, and it can be detrimental to not move along with it.

Expert 5 states that there is a very high rate of technology adoptions in the coastal areas of the USA, like Los Angeles and New York, although the rate seems to be relatively slower in the south where the garment industry was once strong, as well as the Midwest. Companies seem to integrate automation and AI technologies in a relatively short time seeing the benefits the industry would have. All participants approved that technology is a positive thing for the industry.

100% of participants agreed that technology should be an essential part of business; however, 85% of all respondents said that there were significant negative aspects of technology requiring further research. Indeed, there have been countless technological advancements in AI and automation; however, according to Expert 11, it is important to pay our attention to the ones that have been popular and been adopted largely.

According to 60% of respondents, technological platforms making a significant impact in the industry currently are automation, AI, and E-commerce. According to Expert 11, 15 years ago, it used to be internet and email, but now the apparel industry has conquered them successfully. Expert 11 wondered about the power that is still vested in MS Excel in the business world as it has been the dominant tool for business management- especially in the fashion and apparel industry since its adoption.

AI and machine learning techniques are widely being used in the retail space to manage their inventory and the floor. There has been tremendous progress in sourcing as well. Innovative brands like NIKE are focused on 3D prototyping rather than physical prototyping. Moreover, companies have started to explore 3D and digital printing options, and they tend to explore the use of robotics "sew bots" to cut and sew garments and footwear constructions. According to most respondents, the production sector has the potential to change exponentially in the next ten years; changes experiences most dramatically by many long-standing industry respondents.

"It is very positive for our industry; I do not think that we should be working without technology. The apparel industry needs to stay in pace with the rest of the

world in terms of technology for sure. It is precious for someone who used to grow up

in the industry with a ruler and an eraser" (Expert 5)

It was stated by a few participants (Expert 10, 15 and 21) that a high rate of

technology adoption is starting to be seen among the supply chain manufacturers and

sub-contractors (especially with the vertical manufacturers). The current apparel

manufacturers have a futuristic thinking pattern and identify the right trends. However,

Expert 10, an entrepreneur in India explained that when manufacturers in developing

countries are going to implement new technologies, the first would look at the initial

investment and financially compare the operational costs to understand if it will be

economical to use the human resources over the latest technology. "*It does not mean*

that we are never going to use that technology; it just means that now is not the time"

(Expert 10).

It is extremely promising that research centers are looming, which develops

technology solutions in collaboration with stakeholders of the apparel industry. The

research center in Hong Kong that particularly specializes in textile and apparel, assist

start-ups and graduate schools with technology solutions.

"Our research center is like a mini factory, only with more advanced systems

for manufacturing. We have 3D scanners, 3D printers and there are digitized systems

that can project the product to a computer screen. Also, we have many automation

too, so they are really good to support small scale businesses. If they don't have the

facilities to make the product they want, they can come to our research center to

explore and experiment" (Expert 16).

According to many participants, the apparel workforce is feeling very positive

about the inevitable tech transform and very keen to welcome the new changes. In the

technological revolution, the workforce needs to have the intuition to change parallelly with the evolving business requirements.

"I am not the tech-savvy person, so there is a part of me that wants to fight back against technology, but it is happening. There is not an option anymore. So the industry has to take a human-centered approach in implementing technology and make sure that no one is left behind" (Expert 3)

Experts 5 and 6 describe that technology is cost-effective, efficient, and the apparel industry needs to keep finding better solutions while moving forward. The consumers are knowledgeable than before, and this has generated numerous consumer demand variations; such as consumers prefer to utilize activewear to the professional workplace as well as to the pool. The industry needs to go digital and be technology driven in order to deliver solutions for increasing customer demands.

The next few subsections include research findings on notable technological advancements of the apparel industry.

4.1.1.1 Automation

When Expert 8 first entered the apparel industry in 2013, a fundamental laser cutting technique was available, which consisted of several processing stages involving about10 unskilled workers. He remembers that the manual process took a great deal of time to complete a single operation. However, the new Laser Bridge machine that was introduced to the company in 2015 helped his team to do seven techniques in a single operation cycle which reduced the manual worker involvement significantly.

Expert 16 from Hong Kong shared a similar experience on a digital printing plant that semi-automated. She described, when a standard digital printing plant could

generate an output of 2000 samples with 25 skilled labor working in 3 shifts per day, the new machines can run the production for 24 hours with a maximum of 3 workers creating an output of 3000 samples.

The above examples show how automation has increased the efficiency of the apparel processes. Automation can be defined as the conversion of a work process, a procedure, or equipment to automatic rather than human operation or control (Gerovitch, 2017). According to Experts 8 and 14, there has been a significant increase in automation technology implementation in the last five years and manual involvement has reduced a great deal particularly due to the two major weaknesses in the manual involvement of labor. Firstly, the manual processes are prone to many communication, and human errors, and the same mistake is possible to happen twice or more even in a scenario where labor is trained and educated. Secondly, manual involvement hardly can achieve the speed and efficiency that is accomplished through automated machinery. Therefore, if a process is prone to many mistakes, or output is less, or the speed needs to be increased, an automated solution would be the best bet to solve the issues.

The large-scale Asian vertical manufacturers have already automated their processes and have heavily invested in technology to gain the benefits of the new technologies. They have also incorporated research centers to their vertical structure to help them with R&D of these new processes and to find their solutions to increase efficiency. Expert 4 expressed his opinion that these technologies as of now, do not replace human workers; instead, they take the unnecessary work away from the workforce, optimizing the processes as well as giving the workers some time to do work that involves more thinking. Medium and Small level manufacturers, however,

do not usually want to be the initial risk takers in technology adoption, but they are interested in following once they see the practical technology benefiting the apparel processes. According to Expert 1, 12, and 16, it is possible that at some point in the future the apparel industry could be fully automated.

"You know if cars and airplanes can be made with 100% automation, why not a garment? One day it will come to that level for sure." (Expert 12)

Nevertheless, all participants felt mutual about the fact that automation and developments take a remarkably slower pace, especially in the apparel industry. According to the respondents, the apparel industry has proven to be one of the most resistant industry sectors for automation for decades, mainly because of cheap labor, complicated sewing steps with unique challenges to conquer such as handling very delicate products with smooth curves or soft materials. Hence, the industry needs many new developments still to be innovated in the next ten years to automate the apparel industry fully.

The following section discloses a few areas of the apparel industry where automation and AI technology have greatly influenced.

Manufacturing

As participants explained, the apparel manufacturing sector has a significant impact on AI digitization and automation. Many innovative changes are happening in the production floor as the research and innovation teams of factories are coming up with automated and semi-automated solutions such as Robotic arms and self-threading machines. Many high-level managers expose themselves to the cutting-edge technologies and machinery by visiting tech exhibitions over the world; especially in

China, Hong Kong, and Japan, which they later incorporate into the production process.

According to 7 participants (Expert 4, 7, 10, 12, 13, 17, and 20), the cutting department is already automated. Expert 13 explained that *"just about eight years ago, fabric cutting was done by hand, but now manual cutting methods of bulk manufacturing are replaced with automated cutting solutions*." These machines include automatic self-sharpening making human involvement minimal. At the initial stages, the automated cutting system needed one person to guide the machine over the fabric layers to inspect if the layers are properly cut. However, currently, according to Expert 12 and 13, most manufacturers have successfully replaced that by the Lectra automatic cutting system which does not need any human involvement. As Expert 7 mentioned, small and medium manufacturers were late to automate cutting, but they too drew level with the large-scale manufactures soon after.

With technology, the job functions in the production floor are changing.

"Job trainers; Earlier they had to fill papers, but now they have to record all the data on a tab" (Expert 12). This brings the apparel industry to a position where a rigorous skill building of its workforce is in need. This topic will be further discussed in Chapter 4 of the results.

Textile and Fabric

Expert 14, an innovation and product development manager in a leading Textile plant in Sri Lanka, offered his opinion on the substantial technological transformation in the textile industry, especially in the last five years. There have been

numerous innovations in processes where existing machines were replaced by better

upgrades, and manual involvement has become minimal in the last five years.

Due to the use of advanced technology used today, Expert 14 describes that

textile industry workers have more time and resources to focus on innovative textiles

such as breathable fabrics, extra-stretchable fabrics, chlorine resist, smooth handle

fabrics, and tactile feels. Even though the fabric suppliers just provided the fabric

hangers earlier in the industry, currently, they offer full fabric catalogs with trend

forecasts done using digitized trend forecasting. These developments of the textile

sector have helped a great deal to bring down the apparel product cycle by a

considerable margin. However, the effect of automation and AI was said to be

influencing the apparel sector more than the textile sector.

Design

In contrast to when the designers had to draw the fashion illustrations by hand,

the design landscape has gone through a massive transformation presently where

fashion illustrations have digitalized, and there are many software and AI apps out

there to help designers to illustrate (Ex: rough sketching on a digital drawing pad to

get the design on to a screen in the digital format, augmented reality).

Also, in earlier stages of Fashion design and product development, the

designers had to develop samples for all illustrated designs to be able to visualize

which ones to pick for bulk manufacturing; even if it was the same silhouette with

different colors and embellishments. However, today, the industry cannot afford any

redundant work in the design process; thus, digital software like CAD and Optitex EFI

are being utilized to visualize the specific designs. According to Expert 12, presently, the same silhouette is not developed twice, even in the CAD format.

"Sometimes they design with the 3D printing look to visualize these designs, and the designs look so real. So, if someone doesn't like it, it's just the matter of altering the design, and you don't have to do an entirely new sample for that. It has saved a lot of time and the cost of producing unnecessary samples." (Expert 12)

Technology is being impressively utilized also in design presentations, where everything is done on a digital screen as opposed to the physical mood boards, and fabric boards. As a result, Expert 17 explains that 3D designs of the garment can be viewed and the amendments can be done on the digital screen during the board meetings.

3D prototyping in design

3D prototyping has become extremely popular, especially in the last 2-3 years. Many participants agreed that the current trend is more into 3D design and development, in contrast to physical sample making. Instead of stitching a new sample to every fit comment or the slight changes of style by the designer, now the popular and efficient trend is to use 3D technology solutions like Optitex EFI, Browzwear, Clo design, and Marvelous Designer to cut down the additional time and unnecessary cost

According to the responses of Experts 12 and 17, there are few variations as well as different approaches to these different 3D modeling software. Optitex EFI is the oldest 3D prototyping software; however, it is described by Expert 17 to be an advanced application that can be only used by pattern making experts. Browzwear and Clo design were said to be similar to Optitex EFI but more user-friendly. Respondents

were more interested in Browzwear due to its' user-friendliness for both pattern makers and designers, and the profound pattern making skills are not required to operate the software.

Since software like Optitex EFI is not easy to be self-studied, most participants said that proper worker training is required on 3D prototyping.

"If we do not learn how to use 3D prototyping software at least within another one and a half years, we will lose the edge to other countries like China" (Expert 13). AI digitalization is pressurizing the businesses, pushing them to move forward. However, according to some respondents, 3D modeling comes with its own limitations. This will be discussed in detail in the 4.3 section; Limitations of technology.

Communication

The apparel industry has a supply chain that covers almost the entire world; thus, communication is a crucial division that has gone through a significant digital transformation to make fast fashion possible today. Earlier in the apparel industry, the primary forms of communication were the telephone and the fax machine. As Expert 11 describes, Tele-fax was supposed to be an advanced form of long-distance communication in the 1980s, and not many companies had that luxury. Samples would be sent through regular mail by the post office; thus, it took a couple of weeks or longer to reach the US from Europe.

Consequently, Expert 11 describes that the most significant inventions in terms of communication were internet and email, which upgraded many industries, including the apparel industry to the next level. However, email was not widely used until the

late 90s due to two main reasons. Firstly, under-developed countries did not have the internet facility for a considerable time, thus using email for communication was out of the equation although it was popular in developed countries. Secondly, people relied more on direct communication through telephone as they were not used to the new email system. Gradually, with generations advancing, emails took over as the primary form of communication of the apparel industry. This is a sound example of why most technologies in the industry are late to be adopted in the apparel industry with its widespread geographical distribution.

However, as of today, the industry uses SAP ERP systems for daily follow-ups instead of excels that were used 10 years ago. It has increased the transparency and the traceability of the supply chain enormously. With the communication transparency currently available for the apparel industry, brands and manufacturers have the traceability to know what spinning mill has spun the yarns used to make the fabric of any garment. Thus, the Expert 14's opinion is that it has relatively been straightforward to track down the root causes of many problems due to the availability of better communication and transparency. Additionally, these systems have eliminated the need for circulatory emails between the brand and the manufacturer, asking for information. Factory visits are becoming increasingly redundant as the required information is just pressing-a-few-buttons away, and "*there is hardly anything that cannot be solved through a video call*" (Expert 11).

Planning

Apparel industry planning has evolved from maintaining data in an MS-Excel sheet to digitalizing information on AI software. The main two sectors that typically

need to be planned in an apparel factory are the production floor and the sample room. However, according to Expert 13 presently there is a third planning module called "Executive Planning" that is being introduced to the apparel manufacturing facilities to progress the factories up to the required speed needed by the fashion industry. In the Executive-planning module, apparel executives' future work will be planned according to their skill level and available capacity. This is done using AI planning software.

Currently, the apparel industry executives are using Power BI to visualize planning data dynamically, so the necessity to send email reports to executives of different departments is eliminated.

Sample status records can be tracked by entering the bar-code to forecast when a style or a sample will be completed along with the general information on who is involved in stitching the garment. This was made possible through a bar-code scanning system.

4.1.1.2   Customization

"I met a big manager from MAS, he was telling me that we are moving towards customization right now. So rather than just doing bulk, they are trying to change the business model to manufacture for the demand." (Expert 10).

The fashion world is moving towards the next big topics of the industry, "customization" and "personalization". The apparel industry is a continuous evolution of what is happening in the fashion industry and visa versa (De vries, 2018). Many designers and entrepreneurs are looking for manufacturers that produce increasingly small MOQs (Minimum Order Quantity), and the apparel manufacturers need to cater to this need to stay in business.

Expert 17 and 19 stated that fortunately, large-scale apparel manufacturers are currently getting on board with small order quantities and customized design manufacturing. Unlike usual customer relationships, the customized-design manufacturing is communicated entirely on an online platform, and the "customer-manufacturer" relationship is very minimal due to being technology driven. Regardless of having design skills, customers can order the minimum order quantity online by selecting the preferred predefined silhouettes, embellishment options, colors, and fabrics, which can then be viewed on a 3D model.

"So you can view your garment in the print form or the solid form – with the prints and colors you added and with your logo. This is a 3D view. So it is like a 360 view. Once you confirm the order what we will do is, we will replicate the sample the way you have made it, and then we deliver it into your doorstep" (Expert 17).

In the apparel customization process, all initial prototyping is done using 3D modeling software. Any adjustments to the design are made on the 3D virtual samples, and only the finalized sample is physically stitched. Expert 17 explains that sample making is expensive and time-consuming where there are many involvements from the manufacturer's end (pattern making, stitching and fabric sourcing).

However, Expert 17 describes that the manufacturing sector does not yet promote 100% custom designs since the available technology does not still have the capability to support it enough to make a profit. However, if made possible through technology, 100% customization and personalization are going to be a grand solution to the fit issues of online sales. Large-scale manufacturers yet need to advance in technology, knowledge, and exposure to bring customization into reality.

4.1.1.3   Innovative Business Models

"If you talk to a new start-up, they will tell you about all these AI digitalization and automation. However, the interesting companies that you need to talk to are the old companies that have been in the industry for 40-50 or even 100 years! Because they will tell you, what they did differently to adapt to the changing industry. They haven't survived because they did the things the same way they did 50 years ago" (Expert 11).

Interestingly, seven participants (Expert 1, 3, 6, 7, 11, 13 and 20) talked about the need for business models to continuously evolve with the technology. Innovative business models have been a new topic of discussion which is being popular with the technological advancements. Business Model Innovation can be defined as the conscious change of an existing business model or the creation of a new business model that better satisfies the needs of the customer than the existing business models (Emprechtinger, 2018). Individual Innovative companies address the industry requirements as they evolve, by bringing in new ideas and concepts into the business. Expert 6 mentioned that, eventually, the large industry players pick the successful strategies and the whole industry evolves with time. For example, as explained in the previous section, there are apparel manufacturers who are integrating customization into their business models, by correctly identifying it as the next big trend in apparel manufacturing. Manufacturers are trying to explore their technological strengths in small order quantity manufacturing and manufacturing for demand instead of just bulk manufacturing, in an attempt to prepare for the foreseeable future. A great example, "Runaway Kit," an inspiring e-commerce platform for small batch manufacturing by MAS innovations in Sri Lanka, is one innovative novel business model among many others in the company (https://www.twinery.co/who-we-are/digital/).

According to the explanation of Expert 6, another example for business models lies in inclusivity and sizing. She mentioned that consumers who are not in the standard sizing category are tired of not having the right sizes and exciting styles to shop. The observers in the industry has identified and grabbed the opportunity to come up with new business models to address plus size clothing. Expert 6 further explained, "If other big manufacturers do not step up to address these new issues, they are going to get irrelevant." These new business models typically try to understand the industry from the consumer's perspective, thus have a very high growth rate as they are meeting the consumer demand. As a result, the large-scale industry players are acquiring and merging with these startups having patents, identifying the benefit of having concepts that are fresh to the market.

The apparel industry is digitally transforming in a blurring speed, and Expert 8 and Expert 15 states it is very tricky to predict what the future would be. Five participants highlighted diversification as a strategy that most manufacturers are currently interested in, to ensure their persistence through the unexpected industry changes. Rather than being fixated on to clothing manufacturing, Expert 21 stated that thoughtful manufacturers are exploring other booming markets.

However, a few participants mentioned that there are businesses who are not ready to change their business models, as change is generally repulsive. It was stated that this case was more familiar with SMEs.

"Happened to Nokia and Kodak- you know they were not ready to change the business model according to the market situation. No matter how big they were once, they just had to fall out from the business" (Expert 17).

4.1.2   Benefits and Opportunities of Tech

"Technology is great because it gives us many opportunities to rethink our processes" (Expert 1)

When considering the benefits of AI and automation, Expert 1 stated that the most notable one should be the opportunity that it has granted us to change the outdated ways and methods in apparel manufacturing. If technology is implemented right, the industry can re-correct the mistakes and solve the long-standing issues the apparel manufacturing process ever had.

Indeed, many participants expressed very mutual opinions on how great the AI and automation are in terms of achieving more efficiency, productivity, quality, as well as precise accuracy. Using technology, businesses can produce more and meet the customer demands better, while having the opportunity to bring down the costs of the products too. AI helps the industry to understand customer preferences better, (through a better customer connection and integration), granting an opportunity to satisfy the customers better with better products.

Some respondents (Expert 5,12, 13, and 19) described the advantages of 3D prototyping for the apparel industry. The 3D technology has eliminated the initial pattern correction rounds and the need to make physical samples, saving a great deal of time and cost for the manufacturers. It has become absolutely essential to survive in the fast-moving industry without falling behind in the game. Currently, there are many new brands in the apparel industry that cannot afford to have lots of sample iterations and physical prototype correction rounds. These new-comers typically offer low-profit margins to the manufacturers with the small order quantities; hence both parties prefer to use 3D modeling in replacement to physical samples. Expert 17 explains that, with 3D technology, no individual sourcing of fabric is required, instead "it is just a matter

of digitally playing around with different fabric and color options until you find the most appropriate one for the style". It will make less hassle for the designer, technical designer, pattern maker, and even the merchandisers reducing their excessive workload significantly. Due to this, Expert 10 mentions that, eventually, the amount of workload that humans have will reduce.

Over time, technology has helped to reduce the required workforce on specific operations. Expert 4 states that, in apparel factories, there are people dedicated to sample making, and that job can become obsolete in the future. 3D modeling has shrunken the sample making process from months to just a couple of weeks.

"For example, we signed an order with H&M for three styles and using Optitex EFI we could shrink the development process from 234 days to just 21 days. No samples went out to the customer; everything was done on Optitex EFI. In general case, many teams get involved, whereas in this case everything could be done by just three people; Technical designer, pattern maker, and the Optitex person. If Optitex person and the pattern maker were the same person, there would be only two people involved in the whole process" (Expert 12).

Another participant opinion was that AI and automation take all the unnecessary work away from human workers, leaving them time to involve in job functions that need brain-power. Expert 4 explains that the AI software ABBY which is being used in the apparel industry for data conversion from PDF to excel can do its work in five minutes while a human worker would take approximately three hours to complete the same job. Technology has granted the opportunity to optimize the worktimes while getting rid of all weaknesses of manual involvement of labor, such as

making mistakes and less-productivity. "I see that as a form of waste management" (Expert 4).

It should also be noted that how an automated factory can work up to 24 hours if necessary, to meet the customer demand with no rushing and pressurizing of the human labor to achieve unrealistic targets. The accuracy and precision of these automated systems too were mutually appreciated by participants. Research participants especially emphasized on the ability of the automated machinery to obtain the final product to be an exact replication of the sample developed; hence, no trials or tolerance approvals are necessitated. Therefore, most participants highlighted that it would be impossible to achieve the new industry trends such as customization, personalization, and fast fashion without the help of technology.

Technology has assisted the apparel industry in solving many social and environmental sustainability problems that the industry had to endure for a considerable time. This will be discussed in detail in Section 6 of Results. In conclusion, according to all participants, technology makes the processes much more comfortable and people's lives better.

4.1.3   Limitations of Tech

Although there are many benefits that AI and automation can bring about to the apparel industry, it is not yet perfected. Hence, according to the research interview findings, there are limitations to these technologies, some of which are very specific to the apparel field.

It was some participants' (Expert 1, 3, 4, 5, 14 and 20) opinion that, with the available technology, a machine cannot yet take over every aspect the apparel manufacturing process. This is particularly a result of numerous style variations of

apparel and the fact that technology has not been perfected to support the production of soft good items that drapes and have a flow to them. Thus, the industry yet needs to advance the automation technology for a robot to be able to pick up clothes made out of diverse fabrics. Moreover, AI have not yet been able to completely take over the design process and creativity.

"I don't think it will be easier for an AI to catch the creative process, so that's going to be like a final frontier for AI to replicate creativity" (Expert 3).

Although professionals in the field are coming up with innovative technological concepts, fit related issues are still a large problem among fashion consumers. With online shopping getting popular by the day, Expert 6 states that it is quite unacceptable that the industry has a staggering 30% of product returns due to fit issues. The widespread criticism is that AI algorithms are not good enough to predict the consumer sizing precisely nor the right consumer preferences yet. When it comes to fashion, consumers like to change their styles and try out different new types of clothing styles often, but the online algorithms only seem to emphasize a distinct style for a consumer narrowing down the online selections.

When it comes to communication, Expert 11 explains that 90% of problems in the apparel industry are due to poor communication. The apparel industry is equipped with all advanced communication platforms, however according to Expert 11, both parties; brands and manufacturers somehow have to wait a good chunk of time to get an answer to an urgent question they are having. "*So although technology is all great, sometimes the fastest way to solve a problem is just pick up the phone and do it in the old fashioned way. And that doesn't only apply to communication*" (Expert 11).

Three participants expressed dissatisfaction about the currently trending 3D modeling software. According to their opinion, 3D modeling still does not cater to the needs of the industries which it is being appreciated by. The apparel industry uses 3D modeling for outerwear garments as well as intimate apparel. The fit of outerwear garments is not that critical, nor is the fit difficult to achieve through manual methods. However, when it comes to intimate apparel, 3D prototypes do not support the fit of the garments in most cases- so the physical samples have to be made, and fit has to be re-ensured with human models. The 3D modeling has not yet figured out a way to visualize draping of a molded bra or a wired bra on a body. Expert 17 stated that "*Since its intimate apparel, being able to express feelings about the fit is really crucial*". It becomes problematic as AI algorithms do not have feelings, nor they can replicate the subtle muscle movements of the human body with an intimate garment on. None of the 3D modeling software so far has been able to provide a reliable solution for intimate apparel, although 3D modeling would be of much more useful in intimate clothing than in outerwear garments.

Besides, technology can become a limitation is when it comes to the sustainability of the industry. AI digitization and automation indeed have the capacity to make the processes faster and to amplify the production output; however, there are many arguments currently about how more production leads to more wastage. Further, there are discussions on how the workforce will lose jobs due to technology significantly affecting the social sustainability of the industry.

Moreover, there were many arguments in the research interviews about how the apparel workforce will lose core skills due to the advancement of technology. For instance, if pattern making is to be automated, eventually, the core-skill of pattern

making will be lost. The downside of it is, if technology systems go down or if there is an error in the AI systems, core skills are necessary to identify and remedy the error Besides losing the core skills, technology can inhibit the creative thinking patterns of the workers, as human workers will settle with the output which the machine will provide and not giving a thought to advance the process any further.

4.2   Need for technology upgrades

Apparel production has been geographically distributed over many parts of the developing world as a result of low-cost labor. However, with economic development, as stated by Expert 10 and 13, certain established manufacturing countries have lost the advantage of cheap labor, and now are struggling with the challenge of achieving the cost and the production capacity to compete with the low-cost apparel manufacturers such as Bangladesh and Vietnam. It was most participants' idea that making the processes of these manufacturers more efficient with better technology is the unswerving way to survival in the modern world.

One major issue that manufacturers are facing is not having the right capacity to deliver for the demand, especially as a result of not being able to prepare for the uncertain future needs (Expert 13). However, if digitized data can be used to predict future orders, such as the number of styles for the next season or the number of production hours needed well ahead of time using machine learning, manufacturers can allocate their resource capacities accordingly for the future. This capacity would help to lower the cost by acknowledging what's coming and recruiting the right skills needed for future demands.

"For example, initially all the orders we got from USA customers required rubber overlock machines and our skills were concentrated there. But the industry

changed rapidly, and the styles started getting sportier, so we have to use Flat seam machines now. We are struggling because only now we started training our labor for that kind of sewing functions" (Expert 13)

Likewise, AI algorithms can be used to predict and forecast many things to help apparel manufacturing to help bring down the costs and to be better prepared for the dynamics of the industry. Things such as using machine learning to predict the HR labor turnover rates which are a massive issue for the apparel industry, optimizing machine layouts for each style, assisting designers to analyze the customers via consumer and market insight are few areas where AI digitalization can be used to bring about significant improvements to productivity and efficiency of the industry.

4.2.1   Tech in other Industries

Participants commonly agreed that the apparel industry is far behind when compared with the technological pace of other industries such as automotive, pharmaceutical, electronics and food. As stated by Expert 9 and 18, one reason for this is that labor in the apparel industry is relatively less-skilled, thus inexpensive when compared with the other sectors. As a result, manufacturers prefer using inexpensive labor to get the work manually done instead of expending to implement AI and automation. Secondly, automation processes that exist in other industries are perfected, whereas they are relatively emerging processes in the apparel industry (e.g. the capability for a robot to be able to do delicate handling of clothing materials). Given the apparel industry is churning out 52 micro-seasons per year (Lohr, 2016), number of variations and styles are grater, making it extremely challenging to fully automate the process.

"The companies who are doing really well in our industry are looking at the far better practices of other industries. So instead of hiring a bunch of people from our industry itself, they are used to the apparel process- so instead of that I am going to hire people from the automotive industry, aerospace industry or data analysts" (Expert 11)

Expert 11 expressed his opinion that it's high time for the apparel industry to be cross-disciplined, applying the knowledge of other industries to the crucial spots. He also mentioned that more thoughtful companies will take diverse expertise and multiple skills onboard in finding solutions to apparel related issues.

4.2.2 Lack of Technology

The Apparel Industry historically has been an exceptionally slow adopter of automation. It's not considered to be a very high-tech industry, with low barriers of entry allowing an ease of startup and managing. The existing technologies in the industry have an uneven distribution, primarily concentrating on the developed parts of the world (Expert 5 and 11). The rate of technology adoption in underdeveloped countries takes a comparatively slow pace due to the apparel industry being a labor-intensive industry dependent upon inexpensive labor. However, most participants agreed that tech accessibility even in developed countries is not satisfactory. When a new technology emerges, it won't be readily available to companies and professionals due to lack of accessibility or being expensive.

Industry professionals are trying to explore the use of robotics to cut and sew garments and build footwear, but it has a prolonged development rate. Most technologies haven't changed much during the last ten years although participants said there's a possibility of them changing in the next few years. Expert 11 expressed his

dissatisfaction about how we still depend on old software like Excel which are still the foundation of countless business processes.

"We started using Excel in 1985 when it was first introduced, and we still use it. The workforce is used to work off excel for 30+ years now and don't want to move to a better system. In fact, they use Ms-Excel to manage other better software. I hear them saying if I can export the data of this new app to an Excel sheet we are good" (Expert 11).

Lack of technology is especially true when it comes to SMEs (Small and Medium Enterprises). Most SMEs are not concerned about the latest technologies, and they are still dependent on the same existing traditional methods. Expert 7, a designer in a Medium sized manufacturing company explained that SMEs don't use digital pattern drafting software (i.e. Optitex EFI) or 3D modeling software even though their customer brands have invested in the software. SMEs are behind the regular pace technological investments making it hard for them to compete in the apparel industry and hence, are being acquired by larger companies.

Reasons to lack technology

As much as technology is gaining momentum, all participants agreed that it is moving forward at a snail's pace. This section discusses the reasons that could be behind the slow rate of AI and automation developments in the apparel industry.

It was of common opinion among the participants that apparel manufacturing process is difficult to be wholly taken over by machines due to the fact that apparel industry has unique challenges such as handling soft good items that are soft, flexible, having curves and a drape to them and the technology to support those are not

invented or perfected yet. In fact, it is not still possible for sewbots pick up clothes or textiles and run the whole process by themselves and many automation developments need to happen for that to become industry practice. Apparel has a lot of variations such as the number of styles and the number of changes per style which are much more than other industries like automobile or aerospace-engineering. Fashion trends change fast, and consumer behavior is very unpredictable. Apparel production does not involve a set protocol of process, in fact, the process can be unpredictable (i.e. lead designer making style changes in an untimely fashion such as just before the style goes to bulk manufacturing) an example of why automation is challenging for the Apparel industry. Technology can be most effective when there is a clear protocol for production, something that has yet to be developed for AI apparel processes.

Major apparel manufacturers are hesitant to use technology because labor is still the cheaper option (Expert 10 and 13). New technology is expensive, and manufacturers think it is disadvantageous cost wise, as they will have to add a higher value to each garment to cover the cost of the machines. Countries who are still using the low-cost labor strategy can deliver garments for a much lower price, and thus most Asian manufacturers are unwilling to adopt advanced technology as it wouldn't realize immediate profits for the company and make it harder for them to compete with countries with inexpensive labor. Expert 10 from India says, sometimes the taxes are too high for this new imported machinery and manufacturers are also discouraged by the initial investment they have to incur. Thus, they are still following the traditional ways of production and printing methods like screen printing and sublimation instead of digital printing to reduce the cost per garment. Opening their mindset to the modern

world is challenging, because "*there still is a bit of feeling of safety in the manual way of doing things*" (Expert 5).

According to Expert 11, apparel industry would only move to an AI solution or automation only if it becomes too complicated to handle with their existing methods or if it is a cheaper replacement or giving more considerable advantages over the current methods.

"If a forecast with an accuracy of 80-90% can be achieved using manual methods, there's no necessity to invest on an AI for now. If it is something far away in the future like 2-3 months ahead, they probably need an app because the uncertainty, variations, and parameters are high, but we don't really need an AI to predict something that is a week ahead.

You know when you have a headache, first you will get a Panadol, and you will only move to Panadine if Panadol isn't strong enough" (Expert 13).

Moreover, although some apparel manufacturers have been in the industry for over 20 years, data gathered over time has not been properly recorded in a structured way and the institutional knowledge has not been captured. Therefore, businesses don't have data in hand, even if they are ready to invest in data science and move to the next level. For instance, Expert 13 mentioned that, usually all data regarding an optimal machine layout for a style is discarded when an order is completed, because that's what they have been doing it for the past 20 years. Manufactures never realized the importance of data recording, so now when they get a new style that might be similar to a previous style that was completed, they need to come up with an optimal machine layout from scratch.

This lack of interest to adopt technology in one segment of the apparel sector has negatively affected the other sectors eager to adopt. Some experts concur that businesses can only have the optimal use of a technology when all aspects of the apparel supply chain are using it; a simple example would be email or internet. Ever since offshoring, the technology pace of the apparel industry has dropped to the rate of that of underdeveloped countries. Experts 5 and 11 explained that the whole industry is lagging behind the pace of AI adoption due to this reason.

Furthermore, participants' responses are explicit in the opinion that middle management of this industry does not like change. Some companies want to carry out the processes in a way they have been doing it from the beginning to preserve authenticity of brand identity. The companies with this "*historical baggage*" (Expert 5) do not trust the new technology, and it has prevented them from moving forward with automation and AI solutions.

A repeated complaint from the participants was that some technology platforms are not user-friendly or need maximum core-skills to learn how to function them. For example, according to Expert 12, the statistics of user licenses for Browzwear was higher than Optitex EFI, because Browzwear is relatively easy to learn and handle. Browzwear product teams were said to be very flexible and experimental in making the software customized to match each company whereas Optitex EFI didn't provide that facility to the users. Consequently, the level of customer satisfaction of technology companies can influence a company's' motivation to embrace technology.

Finally, it was frequently mentioned by participants that, lacking knowledge and skill in how to operate these software and machines are a huge reason behind why

technology isn't spreading as quickly as it should. Companies give more priority to day to day functions, and neglect upgrading workers' skills through pieces of training. This leads to not having the right workforce that knows how to appropriately adapt technology to the production to get the optimal results. This will be discussed in depth in the next few sections of the results.

4.3   Apparel workforce and state of skills

4.3.1   Current apparel workforce

State of skills

As Technological advances change apparel industry processes, the workforce supporting production will require an almost radical training relating to skills and competencies to remain competitive and relevant. According to the Experts 11 and 15, the industry workforce has shifted generationally, aging out (from the baby boomers to millennials), this change of demographics is influencing how apparel workers respond and adapt to AI and automation. Most baby boomers in the industry are 50+ years old and resistant to change. For the most part technology adoption is difficult for this generation.

The low barrier of entry that exists in the apparel industry with many opportunities for low skilled and unskilled workers. According to Expert 3, female garment workers in Bangladesh and Indonesia have never used a computer or a smartphone before. Without basic digital skills these workers are not competitive in a technologically advanced industry, one opportunity to maximize the cultural use of technology as a training mechanism. Expert 13's opinion was that in Sri Lanka the

computer literacy of unskilled workers was slightly better, and they display an experimental attitude towards digital knowledge.

"*The sewing girls use smartphones, so they somehow do understand how to check their efficiency and downtimes on the computer and we don't know how they really learned to do that. There are some people who know how to use a computer and maybe they taught their friends, or it was easier because it's a bit similar to smartphone and so they are not scared of technology*" (Expert 13)

In some instances, participants stated that manual labor is faster than labor with machine or software assist mainly because manual workers are not skilled in handling the new technology. Companies only seem to train the workers when the necessity arises; therefore, the industry is facing a knowledge gap in terms of basic digital skills.

Knowledge gap

It was the shared opinion of the interview participants that a knowledge gap is present among the apparel industry workforce. It is especially the case in apparel manufacturing as most workers are unskilled, and therefore, have limited skills in transitioning into technology-upgraded job functions (Expert 8 and 12). However, even the workers in higher level job positions such as designers, pattern makers, and technicians seem to lack skills required to handle the technological transformation of the apparel industry. Some participants (Experts 2, 10 and 17) criticized that the technology gap is more significant in academics, which is why the workforce is not delivering the right skills to the industry. According to Expert 2, US colleges considered it superfluous to teach certain skills like pattern making in depth, as pattern making was done by the overseas manufacturers ever since offshoring, leaving a lack of experts in the US apparel industry with the core skills.

Two participants (Expert 8 and 10) explained how difficult it is to find a qualified person with the right skills for a job position at the right time. Although most industry candidates of higher-level jobs do have degree qualifications, they have not gone that extra mile to improve their knowledge to know how to apply their knowledge in the industry.

"For example, when recruiting graphic designers, they only have graphic design knowledge but not the skill on how to apply that graphic to a garment. They would do nice graphic designs, but sometimes the print is not feasible to be done with the machine or not breathable when applied on to a t-shirt." (Expert 8)

Fundamentally, most people would either have the core-skills or the technological implementation understanding; but rarely both. It was the opinion of Expert 17 that core-skills are hard to be taught from scratch but teaching the relevant technology would be easier. According to her, "*Technology implementation or finding tech solutions are easier to be done when you know the subject better*".

However, currently there are cross-functional initiatives (such as 3DRC education sub-committee at PI Apparel) between manufacturers, educators and brands to co-develop common criteria. The industry is working on helping academia to understand what criteria are needed for graduates, helping factories understand what are brands looking for and co-collaborating and innovating along with multi-skilled industry professionals, so that the knowledge gap in the industry is being identified and remedied. The new generation is technologically more explorative than the older generation, and few participants expressed that the new generation of apparel professional has the capacity to absorb and adopt the tech talent if the right exposure is given.

4.3.2 Future apparel workforce

Future Job functions and skills

This section describes research participants' responses to the question regarding how would they anticipate the apparel job functions to change in the future with AI digitalization and automation. According to all responses, apparel job positions would drastically change in the future.

"I am not sure exactly what kind of jobs will exist in 20 years- but definitely not what I am doing now" (Expert 16)

According to the participants, a lot of manual processes will be automated and AI will be used to do certain job functions. However, 94% of responses shared the opinion that 100% automation of the whole process is impossible and at some point, human interaction is going to be necessary. According to Expert 4, at least 50% input for the apparel process will be from humans, whereas AI and machinery will take control of the rest. Expert 11's opinion was that the functions that need to be automated are tactical functions. According to him "*The important question is do we need to give machines or AI the 100% control?*". As the apparel industry has to deal with art, aesthetics, quality and understanding the customer, human interaction is going to be necessary for AI and automation not to become the root cause of another problem. In the future, Expert 11 expects significant human interaction to remain in design, consumer engagement, quality, strategic planning and high-end decision making in the future.

In the future, most participants expect humans to be more involved in the thinking process than the manufacturing process.

"It is going to be labor who are more technologically savvy that can either produce a better product than automation, and that can do something innovative and change how AI and automation are done. Alternatively, add to it or advance it." (Expert 2)

More intellectual and innovative job functions will remain, such as creating software that design or plan, programming, designing, innovation, and fabric selection. "*Or at least that's what I am saying now, who knows in a couple of years this software might pick the best fabric to whatever design you have*" (Expert 2). It was agreed by a few other participants (Expert 2 and 11) that the future job functions are going to be more cross-disciplinary. Thus, technology is also going to create more opportunities and new job positions for the apparel industry in the future. "*The apparel workforce will eventually have to adapt to these new jobs, not the other way around*" (Expert 3)

Conversely to the above opinions of participants, Expert 9 stands firm with the perspective that the apparel industry is not going to change much technologically and humans are going to be making clothes for a long time, although efforts will be made to automate it.

Design

Interestingly, all participants expect that designing would be hard to be 100% automated in the future; with 45% of participants assuming that to be impossible. Most participants mutually agreed to what Expert 1 articulated as *"it is going to be one of the final frontiers for AI to replicate human creativity*". The designer's job functions will however, be significantly reduced by AI digitalization leaving at least 50% the job to be "*very much human*" (Expert 1). Although things like trend analysis,

pattern making and color matching can be done using an AI, creating the initial idea/ concept, the aesthetic appeal of designs, feasibility studies of the designs, selecting the right fabrics, getting the designs done using the latest technology are going to need human interaction. Even if they get eventually digitalized, most participants said it would not be anywhere in the recent future.

"The *Automobile industry was automated long ago, but they still have designers and developers. Because you need creative people to do that initial part of the process. So, I think creative fields might survive automation"* (Expert 12).

However, it was stated that the productivity and efficiency of the design process would increase with the help of AI. Designers will have to create the initial pre-defined concepts with design details that eventually could be put together by an AI or a person in the apparel customization process. Therefore, although the whole job position will not be automated, designers in a company will reduce in number. Additionally, it will become an essential need for designers to know 3D prototyping. It would be more convenient for the designers to take over pattern making using 3D modeling software, so the risk of the designs being altered by the hands of the pattern makers would not happen.

Future designers will be knowledgeable in cross-functional aspects of the industry rather than just being creative and being able to assemble the garment. In the future, most apparel job functions will be cross-disciplined, so designers must understand aspects of design related to materials, production, legal issues, compliance issues and environmental aspects.

Subsequently, Expert 17 expected the future design job position to be something similar to a "digital fashion designer" where the designer is involved in

more tech related aspects of designing like 3D prototyping, augmented reality and things like electronic devices in garments. The designer job position would have more integrations with other disciplines such as medicine, engineering, chemistry and even physics. Garments will be experimented to have more durability, be able to wear all seasons long, having antibacterial capsulations, or being reversible wear.

"Apparel would be something more than something that is just being worn, but a tool to help you with your day to day functions as well. So the digital fashion designer will have to be innovative and use technology and cross-disciplinary knowledge to be more of a problem solver than just an apparel designer." (Expert 17)

Manufacturing

Manufacturing, it was agreed upon by participants, will be the part of the apparel production process most likely to be automated in the future. Approximately 65% of participants agreed that 100% automation of garment stitching would be possible. All participants agreed that cutting would be fully automated because there are already machines in use. The use of machinery, the total number of human hours will reduce, gradually cutting down on human workers until the function is fully automated.

In contrast to that, 35% of the participants said production has the potential to get 80-90% automated and not 100%. It was stated that the 'sewing function' of the production floor could get entirely automated because by the time design hits the production floor all the changes are done, and it is just a matter of programming the stitch length, thread tension and the operation sequence. Thus, there will be programmers and machine technicians to handle that part of the production, in place

for the unskilled labor in production. Additionally, it was Expert 11's option that some human interaction should be there to inspect the quality of the final product as quality control.

4.4   Tech Threat

"There's always some kind of downfall to technology that we won't know until later. Yes, technology is a good thing, but we need to find solutions to the downfalls well in advance and move forward" (Expert 2)

Many research participants shared the perspective of Expert 2 regarding the future of AI digitalization and automation. 45% of the participants described the environmental aspect of technology. Most of them said technology was excellent in terms of certain environmental attributes (which will be discussed more in section 6 of results), a few of them (Expert 2, 15 and 17) also stated that automation and AI would contribute to fast fashion; producing more, and hence wasting more.

Furthermore, some businesses are going through challenging circumstances resulting from technology. Certain deep-rooted businesses are pressured to invest in technology and make economical shifts, in order to compete with new technologically advanced start-ups. Expert 17 describes this scenario as "the survival of the fittest; like evolution". Although this is not entirely an awful thing to happen, it does make specific businesses irrelevant in the apparel industry.

"The new digital embroidery machine that's been invented only uses white threads that will be digitally colored by absorbing dyes to match the artwork. So, multiple thread companies in the world will become irrelevant when this technology takes ground" (Expert 8)

Moreover, with technology, nearshoring and re-shoring can take place relocating the entire apparel industry back to the developed countries. Re-shoring is essentially the opposite of off-shoring, which can be defined as the act of bringing back off-shored manufacturing and other types of jobs to a country from which it was originally relocated (Market Business News, 2019). Re-shoring can put the under-developed economies through damaging circumstances, as apparel is the primary source of income of the majority of these countries. Additionally, automation and AI will significantly affect all human job roles, making some of them obsolete. Eventually, "headcount will be cut down" (Expert 18) creating an unemployment wave through many apparel manufacturing countries. In contrast, Expert 9 holds the perspective that apparel industry job loss due to tech will not be happening in the foreseeable future. The topic of job loss will be discussed more in the next section of this chapter.

It was 56% of participants' opinion that current research must be carried out to comprehend the implications of technologies for the future and technologies should be implemented in the right way not to create those implications.

4.4.1   Job Loss

77% of participants suggested that there would be a massive job loss resulting from automation and AI. Since most of the human job functions in the apparel industry can now be done using machines and AI, unskilled worker roles and redundant job functions of skilled workers are becoming automated, gradually cutting down the population of human workers in apparel factories.

"You know whenever we are introducing a new printing technique using new machinery, the workers are getting increasingly cut down. It saves us more workers, but the workers are losing their jobs" (Expert 8)

It was stated by the participants that the workers do not need apparel skills moving forward, but technical and computer skills are adequate to handle the new machinery and software. Hence, it would be challenging for unskilled workers to move to a similar area of work, as they have limited skills to transition to a job that might also be soon to automate. It was stated that these workers do not recognize the bigger picture of the industry, enough to be exposed and prepared for these new technologies to move to the next level of their job functions. This poses a social sustainability issue in the apparel industry. Expert 8 explained that it is impossible to keep both the jobs and the business, while the rest of the world moves forward with technology.

"It is really a tradeoff between losing the whole business by not moving with technology or losing jobs of unskilled workers due to moving with technology. Either way, these workers will lose jobs, but the latter option is better because at least the business will survive" (Expert 8)

According to Expert 16, "*There's this thing in China that we never had before, called unemployment*". Even though unemployment is the result, it is very likely for the industry to move forward in automation as factories do not have to pay salaries or deal with worker rights anymore. Expert 16 partly takes job-loss to be a positive thing, so that the "*low-cost labor will be calibrating out*". Presently, most countries face difficulties in finding low-cost labor too, as people consider working in an apparel factory as a job of lower social status.

"Where there's growth there is a losing end of it is as well right. That's how the universe revolves. Something has to go down for another thing to grow." (Expert 17)

Conversely, 35% of the participants thought that there would not be a job loss; instead, job functions will alter. As witnessed in history through many industrial revolutions, jobs continuously changed and evolved with technology but people never ceased to have jobs through each era. Hence, her idea is, it is safe to assume to be the same for the Fourth industrial revolution. Expert 9 is among the few other participants (Expert 11 and 21) who think apparel jobs will survive. However, he argued that even if the apparel cut-and-sew gets automated, there is always a supply chain that's going to have manual jobs for quite some time.

4.4.2 Minimizing the Tech threat

The perspective of the majority of participants was that countries, manufacturers, and individuals need to be aware of how the AI and automation are going to affect the apparel industry, and get prepared in advance. Collaboration and sharing of knowledge are going to be crucial in between the industry, academia, and governments to look for how it is going to affect human workers, environment, human rights and how to encounter them. More research is needed in this area to bridge industry experience with academic research in order to make so informed decisions, to develop an inclusive industry where no one is left behind through a human-centered approach to technology.

Academia and industry need to collaborate on acknowledging what skills will be required in the future and equipping the future workforce with those skills needed. Directing the workforce to be more digitally-aware is going to be as much important

as training and educating them in novel technology. Hence, policymakers and key-decision makers have a responsibility to educate respective parties and spread awareness in preparation for the possible future threats of technology. It is vital for the key decision makers in the industry, academia, and governments to make informed decisions by learning from the global mistakes, because "*sometimes we think we are doing the right thing, but really not*" (Expert 15).

However, the perspective of Expert 9 is that "*automation could be the greatest threat to society; I don't think we can actually do anything to prepare*".

Manufacturers

According to the interview participants, manufacturers' preparation for future technological transformation should be two-fold. Firstly, persisting in an industry with automation or re-shoring, and secondly, having a sustainable transition to AI and automation through managing the workforce.

Manufacturers need to embrace the global trends of apparel production while "futuring" through scenario building (5 years, 10 years) and preparing for possible scenarios. It is imperative to think strategically and get brands onboard with future technology-related projects. Manufacturers should be able to predict the future demands of the workforce and know what skills are going to be needed for the future so the best-suited recruitments and training programs can be carried out. Expert 13 states that business analysts in his company have not adequately recognized the future workforce needs, so they lack workers with the 3D modeling skills now.

"*If we identified that 3D modeling is going to be the future workforce need, we would have planned and trained people for it in advance. It is like people only learn*

combat when someone is coming to hit them, and we don't know what happened until

they hit and go!" (Expert 13)

As one significant impact of automation and AI would be re-shoring, it was the opinion of Expert 19 that overseas-manufacturers should start looking at their local markets and begin manufacturing for their own brands, in the probable-chance where re-shoring of manufacturing would reduce orders for them. If the local markets of under-developed countries do not have the purchasing power, another option would be to create their own local brands that target the international consumers. Additionally, high fashion markets like GUCCI, Channel have hand-made couture, hence Expert 17 thinks there is always going to be a value for hand-made clothing and accessories as that authenticity sometimes cannot be replicated by automation. Hence, it would make sense for the manufacturer to start investing in areas that are hard to be automated such as customized clothing manufacturing, hand-made couture and the circular economy. The circular economy has business opportunities such as recycling of materials and fixing and mending of clothing, instead of bulk manufacturing. Expert 17 states that it is currently not being done because the cost is too high for custom clothing manufacturing and the profit margin is low.

Expert 11 is emphasizing on the need for new business models by the manufacturers to survive the tech threat. Expert 13 thinks diversification is the best option for overseas manufacturers facing the tech threat of re-shoring due to automation. It is his opinion that diversifying into IT related areas and being apparel solution providers would make sense for the manufacturers. These manufacturers have 20+ years of experience, expertise, and knowledge, however, a newcomer to the

industry would take a considerable time to gain the expertise they have presently. Hence, he emphasizes the importance of storing the data properly for future reference.

"For example, we can make the design pack or the sample iterations needed for them to manufacture the product. These are the areas the amateurs in the industry will need help with because they don't have the experience or the expertise. Manufacturing knowledge we have can be applied to other industries too, and we have to invest in them. If we only try to market the mass manufacturing, we won't have a future" (Expert 13)

Few participants from Sri Lanka and India described how the manufacturers have identified the tech-threat of re-shoring, and currently are relocating in customers' countries or nearby countries that can be reached through the land, such as Mexico, Jordan, and Vietnam. Relocation would be immensely helpful to reduce the cost per garment by cutting down the shipping cost. Moreover, Expert 4 thinks that increasing productivity, trying to give brands more solutions and adding more value will help them to be in the manufacturing business for longer.

It is the responsibility of the manufacturers to make sure the workforce that the transition to the future of work with automation and AI is sustainable. Hence, some participants (Expert 3, 8, 15 and 16) think that manufacturers should figure out alternative arrangements for the workers instead of just laying them off. One option would be to shift the labor to similar or alternate operations when their jobs get automated.

100% of participants stated that educating and training the workers is crucial for workers to have a successful transition to the next level of their jobs. Directing them and educating them about their future jobs are also important so that they will

make an effort to develop required future skills. These will help a gradual transition to AI and automation as opposed to a random transition, which could be very unhealthy for the workforce.

4.5   Training and skill development

4.5.1   Tech Education

Tech education is essential to make the future workforce ready for the industry. However, 45% of participants thought that although the apparel industry has entered the fourth industrial revolution, academia curriculums are not up to date with what is going on in the industry. Expert 2 stated that academia updates very slowly and most schools still teach the same syllabus from 10 years ago. "*Now Photoshop and Illustrator are essential requirements for a designer right, but I never really learned them when I was at school 12 years ago. I had to learn them from my employer and by myself*" (Expert 2). According to her academia never moved in parallel with the industry.

Since the purpose of the university is to get students equipped with the tools they need to get a job, academia requires to have a much broader curriculum primarily reflecting on the industry's latest technology. Expert 11's opinion is that, if a fashion graduate does not have (at the very least) a basic sense of the latest industry trends like data analytics, PLM, 3D design, 3D prototyping, then the industry will not be interested in her, and she will not be competitive in the marketplace. Hence, Expert 6 suggests that academia should be able to understand and predict when the industry needs a particular skill in the future and make the graduates ready for it in advance. "*If*

they don't do that, what the students learn at school won't be there in the industry when they graduate" (Expert 6).

Additionally, Experts 5, 16 and 19 emphasized the fact that it is brands' as well as academia's responsibility to bring the industry experience to the research area and vise-versa. Furthermore, they mentioned that technology education should incorporate teaching students how to implement technology in an industry scenario. However, a few participants (Expert 5, 16 and 18) stated that most new companies now have started getting on board with various collaborations with universities to share the knowledge to close the gap between industry and academics.

It was also mentioned that it is not only school's obligation, but the students also have a responsibility to use the university infrastructure to get themselves equipped with the skills required by the industry. Expert 10 suggested that academia should give students many self-studies, so they would go out to the industry and identify the industry needs by themselves, thus feeling the pressure to educate themselves.

4.5.2 Industry Training

4.5.2.1 State of Industry Training

Executive Training

Among the participants, 44% were satisfied with their personal experience of apparel industry trainings. However, most of them mentioned that the majority of the skill trainings are on soft skills and only a few of the industry trainings are technical in nature. According to the popular responses, vertical manufacturers offer their employees better trainings more often than SMEs.

Expert 4 says that in the manufacturing sector of Sri Lanka, executives are given at least 4-5 trainings a year. According to him, the workers are individually evaluated by their senior management to know what skills they lack or require in the future by the company and are trained on those. The employees sometimes get to choose the training from a list of topics and thus get a say in picking their training. These trainings could be internal or external depending on the subject of the training. If the company has the necessary budget, some external trainings are conducted overseas. Further, executives go to global trade shows and technology exhibitions looking for new knowledge, technologies, and machinery for the factories. "*Almost once a year, I get to go to different parts of the world for different training programs"* (Expert 8).

Expert 13 stated that most trainings are on soft skills such as executive development, awareness on sustainability and labor rights, presentation, leadership and Negotiation skills. "*Only about 30% of the trainings are technical in nature like how we can improve this process, what are the technologies we can use to improve the product and etc*." (Expert 14). However, most participants said factories do train people if they introduce a new machine or software, but the training would be only when the skill necessity arises, not in advance. In some cases, they train only one or two people in the team assuming the knowledge would eventually diffuse to the rest of the team through them. However, Expert 14 thinks that IT knowledge among executives is not too bad and if given the proper training most have the capacity to grasp the skills instantly as they already know the manual way of carrying out the operation.

"*They do can handle a computer and can easily catch up with new software if we give them some training- they do have that talent to absorb and adopt skills. Five years ago, we introduced an ERP- SAP system. We only did a few training sessions, and people adopted really fast"* (Expert 14).

Conversely, 56% of the people are unsatisfied with the current trainings that are being offered in the apparel industry. Experts 7 and 17 agree that the apparel industry needs to give more attention to improving the hard skills of their employees such as the specific skills needed in operating machinery and software. It was said that SMEs lack all kinds of training in general. Most of the time training programs are postponed either because the budgets are cut down, or factories are always busy and *"every day there is a new firefighting"* (Expert 11). In some instances, companies would introduce a new technology or a skill very casually, leaving the rest of the learning to the employees. Additionally, Expert 14 mentions that employees do not get an idea of what the next level of their job function is going to be in these trainings for them to get prepared for the future. Expert 11 says that some companies think it is not their responsibility to elevate the individual skills of employees, but thoughtful companies will look into the skill needs of the workforce and train them to survive in the industry.

Non-executive training

The machine operators get an initial 1-3-month program to train on sewing skills needed to do their regular job functions, and sometimes on job development as well. Apart from this, mostly they are trained on things like how to improve their efficiency, lean manufacturing and how to manage work-life balance. Expert 18 says

that digital and computer skills are given to only those who need them; for example, the job trainers. "*Because earlier they had to fill papers, but now they have to record all data in a tab*" (Expert 18). Further, he has sometimes observed peer learning and training happening in the production floor within sewing girls with respect to technical and digital skills.

4.5.2.2 Effective training

This section discusses the responses of research participants on what they think would be timely and effective training approaches for the apparel industry. Many participants stated that the trainings should be a combination of both hard skills and soft skills. Hard skills are defined as a skill set that can be acquired through a formal education or training programs, and that can be quantified (Doyle, 2019). In contrast, soft skills are attributes and personality traits that can affect interpersonal interactions. In regard to the hard skills, the ability to operate new machinery and being soft skills are able to use a computer are going to be important for any job in the future (Expert 3). It was also mentioned that training workers on the sustainable and ethical implementation of technology is as important as educating them on technology.

Effective training should be designed to elevate the skill or to motivate employees to do better in the field. Factory visits to see technological solutions, visiting tech trades shows, looking at the global solutions were stated to be important training aspects of motivating the workers for technology-related training. 90% of participants mentioned that practical knowledge in a lab setting is essential where they get time to put their knowledge into practice and experiment with it by incorporating their ideas. It was also stated to be important that the person who is training the apparel workers to be knowledgeable in both the technology subject matter.

"Sometimes the people who do the tech trainings know how to navigate the software or the machinery well, but they have zero knowledge on apparel and how to apply the technology to the apparel. So, they can't understand nor provide the answers to the practical questions the employees have" (Expert 12).

Employees should be taught the full potential of specific technologies and give them the freedom and the opportunity to do their own problem-solving in the workspace. According to Expert 12, this is effective than research teams involving to solve the problems for them, so that they get to work their way around technology. It is also vital to make the employees mindful on the tech threat and what the next level of their jobs are going to be with the AI and automation, so they will be self-motivated in preparation for the future of the industry. Expert 6 thinks compensating employees for self-skill-training would be another good strategy to save time for the brands and factories and *"to get both done at once"*

Additionally, Expert 4 explained that, multi-skilling workers are important, so they can be shifted to alternate job functions if their job is under the threat of getting automated. Further, skill training should be designed recognizing the future forecasted skill requirements of the workforce, and the programs need to be continuously evolved to compensate for the needs of the future industry.

4.5.2.3   Self-Training

Participants stated that there are many opportunities out there to help apparel industry workers to elevate their own skills. Currently, some NGOs and many online platforms like "YouTube" provide free training for those who are interested. Expert 14 says many industry workers do self-training consciously or unconsciously to survive in the industry. "*After all, I never learned Photoshop or Illustrator in my school, nor I*

got any proper training by my employer. I somehow learned them by myself while

working in the industry. So, it's also your own responsibility to find your way to

survive" (Expert 14). Most participants agreed that if they were to train themselves, it

majorly would be hard skills. Many of them expressed their interest in topics such as

3D printing, 3D modeling, Innovation, digital printing and data analytics to self-learn.

However, Expert 6 and 18 think that not many people in the apparel industry

take self-trainings that are technically related. According to them, roughly around 0.5-

5% would do self-studies, but many would not do it unless they are forced to. The

small numbers are particularly due to the fact that many workers lack motivation,

time, industry awareness, and money. Expert 3 thinks it is unfair for the industry to

expect employees to train on their own since they do not make enough money for it

and some do not have the right opportunities available for them.

4.6   Sustainability impacts of AI and Automation

4.6.1   Social Sustainability

Social sustainability covers much ground from fundamental human rights to

cooperate governance; however, Expert 3 and 11 agree that "sustainability" is a very

ambiguous concept meaning different things to different people. As a result, it is very

worrisome if the apparel industry is having a sustainable transition to automation and

AI. Participants think technology can negatively influence global apparel industry

workforce in two significant ways; Automation and re-shoring.

Firstly, with automation in apparel factories, there will be massive

unemployment of the workers. Some companies consider this job loss of employees

not to be their responsibility and they have not given too much thought to the worker

rights. Expert 3 described how manufacturers seem to think that it is the governments' responsibility to support the citizens who lose jobs and to find them an alternate living. Therefore, they have not taken an active stance to make sure that employees take a sustainable transition to future jobs. However, Expert 3 does not approve of this.

"*What I mean by a sustainable transition is, as automation is going to impact worker access to jobs, and financial security, when considering business and human rights framework- I personally feel that businesses have an obligation to ensure this transition which is a basic human right.*

Also, going back to the UN guiding principles, it is really the business's obligation to mitigate social risks caused by the business." (Expert 3).

Few participants stated that companies in other industries seem to be taking the situation more seriously than the apparel industry, mainly because other industries have long been automated and they do not have to deal with a vast unskilled workforce. Hence, it is crucial for the apparel industry to have a gradual transition to automation and AI, as opposed to an abrupt transition. Expert 14 also believes that due to automation, people will eventually lose their core-skills and become "*slaves of machines and AI*". Hence, it is essential that automation and AI have to be implemented by taking a human-centered approach.

Secondly, with automation, a lot of production will be shifted back to the US and Europe (re-shoring), leaving a considerable impact on countries like Bangladesh, Indonesia and Vietnam whose economies are mainly dependent on apparel exports. Expert 20 states that Europe has already taken most of the manufacturing back to the European region. This will exceedingly influence the developing apparel manufacturing economies and the general social life of the citizens. Expert 15 says

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that, as Asian apparel manufacturing countries are mostly under-developed and most of their infrastructure and the workforce are built to support the apparel industry, an abrupt transition to another industry is going to be extremely challenging. Hence, the governments of these countries have a major responsibility to look at the potential risks and to plan for the future in advance. However, Expert 10 says most governments are not yet aware of this risk, and eventually, educated people and investors will leave the country looking for opportunities, and this will create acute conditions in under-developed countries.

The opinion of Expert 4 was that, with re-shoring, overseas apparel manufacturers should lower their profit margins and provide better products and solutions to compete with automated factories. However, Expert 18 and 20 stated that even if re-shoring never happens, the jobs are going to be eventually invaded by automation; therefore, manufacturing countries should develop additional capacities.

On the contrary, a few participants (Expert 13, 16 and 20) mentioned the numerous positive social benefits to technology. According to Expert 13, apparel factories have started micro-managing executive workers, in response to achieving fast fashion targets, this is frustrating to the executives. However, with automation and AI digitalization, work will be streamlined; thus, the factories will not need to rush people to achieve unrealistic deadlines. Moreover, Expert 16 mentions that it is getting increasingly difficult to find low-cost labor in China now, because of society's negative attitude towards blue-collar jobs.

"So eventually the industry will become to a position where people are not proud to say that they are working in an apparel factory. So, thinking from that

*perspective I think it's a good thing that robots can do the dirty work and some of the high skilled roles will hand make the garments for individual customers" (*Expert 16).

In some instances, new technology can take dangerous jobs away from humans, such as dealing with chemical dyes and sandblasting for denim. Hence, machines can take over these kinds of jobs that workers do not want to commit, bestowing them with better jobs and better lives.

Gender in Tech

As females dominate 80% of the apparel industry workforce, the research included a question to understand if gender could be a barrier to social sustainability when it is coupled with technology. Eleven interview participants (Expert 1, 2, 4, 5, 8, 10, 13, 14, 16, 18 and 21) believed that gender would not be a problem for the sustainable technological transformation of the apparel industry. Four (Expert 6, 9, 15, 20) participants thought that slight gender bias could be seen in the industry for tech-related positions, but it will not play a significant role in the future as many females, especially in the new generation, are adopting technology at a very high rate to get tech savvy. Expert 6 states that "*Especially the young women in American society think that gender should not be restricting them, and on the other hand companies just want smart people.*" Expert 16 describes how China is a traditional country; however, there are many women leading tech positions; in some instances, exceeding men.

However, five participants (Expert 3, 11, 12, 17 and 19) describe that gender could be a significant issue in the industry's transition to technology, increasing the economic inequalities between men and women. *"Women have continued to be under-represented in certain areas and eras, and technology is one of them*" (Expert 6).

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Expert 3 highlights how the concept of "Digital Divide" can create a gender disparity between men and women in access to technology, especially in developing countries. Males have more experience in utilizing technology and the internet, whereas women have lower accessibility to technology. In some countries, family members have prohibited the use of the internet and smartphones for women in their families for safety reasons. Expert 12 describes that certain cultural norms and mental barriers act as the foundation creating this gender disparity. These cultural norms can have a major impact on women's digital skills, making this topic very much relevant to the sustainability and social responsibility of the apparel industry.

Expert 12 states that this gender bias towards males is prevalent among Asian management when recruiting for tech-related job positions. "*Even if you go to the production floor, supervisors are mainly male"* (Expert 12). Unless the industry makes an effort to move against these cultural norms that create a digital divide, women are not going to get the same opportunities as men for a sustainable technological transformation of the apparel industry.

4.6.2 Environmental Sustainability

According to many participants, there are going to be numerous environmental benefits generating from automation and AI digitalization. Technology helps to create less waste as it can considerably reduce the amount of water and electricity consumption through making the processes more efficient. "*If everything is automated you do not need lights on the floor*" (Expert 6). AI-based 3D technology has eliminated the need to create samples, saving resources as well as reducing the carbon footprint through the avoidance of shipping and freighting. Expert 17 describes that in certain instances, many fabrics meters are sourced to make the physical samples which

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later have to be destroyed if the designer does not choose that fabric for the bulk; which currently have been able to overcome through 3D modeling. The carbon footprint has also reduced a great deal due to reduced customer visits, as most of the difficulties are solved through video calls. Additionally, technology has diminished the need to do the paperwork for recording purposes in the factories. Further, many business models relating to the circular economy have been possible owing to the latest technologies. With automation, it has been possible to have a circular process to bring the materials back to production again.

Chapter 5

DISCUSSION

The purpose of this study was to comprehend the current and future impacts and opportunities of AI digitalization and automation of the apparel industry in regards to the human workforce. The results gathered through a series of industry-professional interviews offered insight into the six research questions proposed in this study. This chapter discusses and analyses the results of the study relevant to individual research questions, as well as cross-case analysis.

5.1   General Discussion

The primary objectives of the research were achieved through significant results of this study, industry guided data which better clarified present and future scenarios of how AI and automation will affect skill competencies required as well as job functions of the apparel workforce. The contents discussed by the experts built upon and support findings in the literature. For example, the literature suggested that the demand for technical trainings are greater than soft skills training among employees. Expert participants support this view, suggesting that what might be most effective is a combination of both hard-skills (technical and digital skills) and soft-skills (management and behavioral skills).

Expert interview discussions on skill training highlighted the importance of peer-to-peer training in technology skill building; a new concept that builds upon the literature. "Peer learning" encompasses a broad range of activities (Eg: discussion seminars, privet learning groups, peer assessment) that often suggest a two-way

reciprocal learning activity (Boud, n.d). It is proven that peer-to-peer learning can yield many positive results, including higher engagement, increased confidence, improved competency, and overall higher achievement and greater productivity in terms of learning outcomes. According to the findings in this study, the apparel industry lacks skill training is due to the limited resources (Eg: time and budget), and limited specialists who are knowledgeable on both the technology and subject matter. Peer-to-peer training, however, would be an effectual strategy to train workers on technology by utilizing a very little time and budget. In an environment where a trained worker is involved in training the peers on technology, more subject related problems can be solved with greater relevance to the field and with more productive engagement. The trained employer has a better prospect of learning more when they take on the role of a trainer while allowing an improved peer-to-peer relationship as well.

The findings make it clear that currently, there's more focus in the industry for bridging the skill gap through new technologically-savvy recruitments. Building on the literature, however, filling the skill void shouldn't be only about attracting new entrants, but also about retaining the expert staff (who are more experienced in core-skills) by developing talent and skills in emerging areas including AI and 3D technology. Training the expert staff will also help to retain the core-skills, which was found to be a losing focus in the current apparel industry. In the attempt to gain the new technological talent, findings implied the necessity to retain the core-skills. Core-skills can be defined as the basic functional and employability skills that enable an apparel worker to create or develop a product or an outcome without exercising technology (Eg: Manual pattern making skills, manual embroidery skills). Core-skills

were stated to be essential to innovate and to problem solve critical situations. For example, if the outcome of a pattern making algorithm does not adequately satisfy the design, a pattern maker will have to utilize manual methods to create the required patterns. Improving the effectiveness of the AI algorithms will need a combination of high-level core-skills and digital skills as well.

A direct interrelation to co-skills can be seen with literature stating the lack of skills in the lingerie industry, that require more expertise due to its complicated constructions (Alvanon, 2018). This information directly relates to the findings regarding the glitch in 3D technology to reliably respond to figure-hugging lingerie designs. It seems that due to the malfunction of the 3D technology, core-skills are in need. This proves that when technology fails to provide the precise solution, core-skills becomes the problem solver and the innovator that override the AI algorithms. However, findings suggested that it is increasingly challenging to find the experts with traditional core-skills due to the technological revolution, and thus it can be assumed that people with both core and digital skills will have a massive demand in the future.

This study successfully identified the future job functions and skills that will be essential for an AI digitalized and automated future of the apparel industry. According to the findings of this study, the future of the apparel industry will be dominated by more intellectual and innovative job functions. Jobs that are related to Information technology, Data science and programming are going to be the thriving job profiles for the next decade. The findings also suggested that creative job functions and competencies are uniquely human and will be a final frontier for AI to capture, in this scenario, designers will remain while their job functions will be more digital in nature and cross-disciplined. The findings resonated with the literature when

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indicating that skills in 3D technology will be an essential job requirement for the designers. Having cross-discipline knowledge and the skills to work with data is going to be handy for the designers as well as the other future work roles in the industry.

In alignment with previous literature and the findings of this study, is the knowledge of both positive and negative risks of technology regarding social responsibility and worker rights. Negative aspects of job loss will materialize only if an abrupt technology transformation unsettles the industry. In one scenario, apparel workers who lack time and resources will be unable to stay relevant and speed with the industry skill requirements and competencies. In another, more beneficial scenario, the rate of adopting technology is relatively slow and tolerant in terms of supporting skill adjustments in existing jobs, this evolution providing opportunities to several stakeholders in the industry. However, the creation of new employment is an opportunity to eliminate poverty and create a better life through socially acceptable job positions for the garment workers. Therefore, faster the skill adjustment is a more sustainable option for the worker.

5.2   Conclusion

There are two main conclusions of this study. Firstly, while AI digitalization and automation to is inevitable in the apparel industry in the next decade, critical emphasis must be on the sustainable implementation of technology. With the apparel industry mindset focused on achieving the next best technological developments at a blurring speed, ethical and the sustainable best practices are not priorities, resulting in negative impacts to apparel workers. Optimistically, the implementation of Automation and AI solutions should provide solutions to industry issues, as opposed

to creating new problems. The implications of technology must be analyzed and considered before adopting them to the working environment, while taking the necessary measures to avoid all negative consequences that it might cause presently, or in the future.

Secondly, this research study concludes that apparel industry skill training must address the current and future technical and digital skill requirements of the workforce. It was found that currently, most skill-trainings are either focused on soft-skills or presently required technical/ digital skills, but less focus is given to future skill requirements of the industry. The apparel industry will move faster with AI adoption and automation implementation if the workforce is readily equipped with the next set of skills that will be demanded by the evolving industry. It is imperative that industry and academia collaborate to develop best practices in terms of skill competencies so that entry level workers (recent graduates) have relevant skills to enter into the workforce. As collaborators, they need to accurately forecast the next crucial industry skill-set and get prepared for it in advance through the right skill-development of the current and future workforce.

5.3   Limitations and Future Research

As with all academic research, this study has certain limitations and must be highlighted. First, in terms of geographical representation, the study was limited. The study sample included twenty-one interview participants from five different countries (USA, Sri Lanka, China, India, Hong Kong), and the quantitative representation from each country was unequal. While the current participants' geographical distribution did allow for the gathering of rich qualitative data, future research could be built upon

the information gleaned in this study with qualitative data gathered with a much broader representation of major apparel producing countries.

Secondly, the quality of the sample was narrowed down due to the snowball sampling approach. The sample scope could have been improved to include a much broader expert base. The expert participation did not cover academia, even though "tech education" was a major topic most of the experts touched on, to discuss future skill training needs. As well, two experts mentioned the importance of interviewing experts from other disciplines, such as automobile designers and aero-craft technicians to understand how the automation of different industries has affected the jobs of their respective industrial sectors. Therefore, the future extension of this research could utilize a more comprehensive selection of experts of cross-disciplines, though sourcing them through snowball sampling approach would be a challenge.

The qualitative approach of the research was a hindering factor to statistically determine the relationships between different influencing factors (Eg: Company size Vs. skill training, Geographical location Vs. technology adoption). Along with the series of interviews, a survey tool would have been beneficial in quantifying the data. Future research is suggested to take an approach that will combine both quantitative and qualitative instruments to analyze direct and indirect relationships among different factors in the framework.

Moreover, the technology's relevance to business ethics was a topic that was unexplored in this study. Owing to the immense social power of technology, ethical issues are always in play (Vallor and Green, 2018). Although certain research questions were designed to gather information on Sustainability impacts of AI digitalization and automation, direct expert opinion on ethical relevance would have

expanded the results to touch on the best practices to incorporate ethical business attention, reflection and decision making in the context of technology implementation. As business ethics is a pervasive aspect of technology practice, it is a suggested landscape for future research.

As suggested by the general discussion of this study, peer-to-peer training on digital and technical skills is highly potential but an unexplored area of research. It would make sense for future research to delve into the depths of peer-to-peer digital skill training to investigate the effectiveness and the related constraints. Similarly, it was found in this study that implementation of automation and AI digitalization is challenging for the apparel industry due to the constant altering of design styles at the last minute and due to lack of set-guidelines and deadlines for the apparel production process. Technology can be most effective when there are clear protocols for production, something that yet has to be developed for the apparel process through future research.

5.4   Implications

The results of this research are beneficial for apparel brands, manufacturers, sub-contractors, and workers to accurately identify the benefits and implications of AI and automation technologies. The results can assist these entities in determining and implementing the proper strategic decisions relating to AI and automation developments, worker training, and future skill recruitment. The research study also revealed and highlighted the necessity of properly stored knowledge and data for a future of technology; which is a lacking area in the apparel industry resulting in the

sluggish AI digitalization. It will motivate the brands and suppliers to have proper data structures for data storage for the future of AI.

Finally, Sustainability implications and Technology threats of AI and automation that are revealed in this study would be an excellent resource for government and business policymakers to acknowledge the significant costs and risks of implementing AI and automation in a less than optimal way.

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Appendix A

HUMAN SUBJECTS PROTOCOL

University of Delaware

Protocol Title: **AI digitalization and automation of the apparel industry and upskilling the workforce**

Principal Investigator
Name: Anuththara Gangoda
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Advisor (if student PI):
Name: Professor. Kelly Cobb
Contact Phone Number: 302-831-4475
Email Address: kcobb@udel.edu

Other Investigators:

Investigator Assurance:

By submitting this protocol, I acknowledge that this project will be conducted in strict accordance with the procedures described. I will not make any modifications to this protocol without prior approval by the IRB. Should any unanticipated problems involving risk to subjects occur during this project, including breaches of guaranteed confidentiality or departures from any procedures specified in approved study documents, I will report such events to the Chair, Institutional Review Board immediately.

1. **Is this project externally funded?** ☐ YES **X** NO

    If so, please list the funding source:

2. Research Site(s)

    ☐ University of Delaware

    X Other (please list external study sites) **Research will be conducted remotely from February 20th- March 30th , 2019**

    Is UD the study lead? **X** YES ☐ NO (If no, list the institution that is serving as the study lead)

3. **Project Staff**
Please list all personnel, including students, who will be working with human subjects on this protocol (insert additional rows as needed):

NAME	ROLE	HS TRAINING COMPLETE?
Anuththara Gangoda	**PI/Interviewer/Data Analysis**	**Yes**
Kelly Cobb	**Advisor/ Data Analysis**	**Yes**

4. **Special Populations**
Does this project involve any of the following:

Research on Children?   **No**

Research with Prisoners? **No**

If yes, complete the Prisoners in Research Form and upload to IRBNet as supporting documentation

Research with Pregnant Women? **No**

Research with any other vulnerable population (e.g. cognitively impaired, economically disadvantaged, etc.)? please describe

Many apparel factory workers (except the executive level workers) in Sri Lanka are from poor rural families; therefore, some apparel workers being interviewed could be economically disadvantaged. This study focuses on mid-level management and design teams.

5. **RESEARCH ABSTRACT** Please provide a brief description in LAY language (understandable to an 8th grade student) of the aims of this project.

This study focuses on understanding what are the impacts of the Artificial Intelligence (AI) takeover would be for the apparel industry, how it would affect the apparel workforce and what needs to be done to better prepare the industry and the workforce for the anticipated technological changes in the apparel industry. Overall, the primary purpose of this study is benchmarking to understand where the apparel industry is now, and where the industry and the apparel workforce is supposed to lead with the continuous industry AI adoptions.

Research questions for the study are as followed:

1. **What job functions will artificial intelligence take over and what will still require humans?**
2. **What are the anticipated AI artifacts of the future in the apparel production and product development work-floor?**
3. **What are the social and sustainability impacts of AI for the apparel industry?**
4. **What are the ways to minimize the job loss through AI digitalization?**
5. **What steps can be/ are taken to close the knowledge gap in the apparel industry?**
6. **What are the best ways to train the workers to get the best out of AI digitalization of job functions?**

6. **PROCEDURES** Describe all procedures involving human subjects for this protocol. Include copies of all surveys and research measures.

The aim of this research is to understand the impacts of the AI developments in the apparel production process and how it has changed the need of the workforce skills and the approach of technical trainings. The research design would take the form of semi- structured telephone/ internet interviews with approximately 10-15 workers (executives, mid-level management and design teams) of MAS Pvt Ltd, Sri Lanka, Bangladesh and Indonesia. MAS is the largest chain of export apparel manufacturer in Sri Lanka, mainly exporting to USA and other countries. The interviews will include the topics of A) Understanding the current status of the AI digitalization of the apparel industry processes, B) Benefits and limitations of AI developments, C) Future of AI digitalization in the apparel workspace, D) Social and sustainability issues involving technology advancements, E) Apparel workforce skills associated with technological developments, F) Training of the workforce. Interviews will be conducted mainly in English for the ease of the data analysis and consistency; However, if the Sri Lankan workers are more comfortable speaking in Sinhala (Sri Lankan native dialect), they will be allowed to do so, and the interviews will be conducted in Sinhalese. These interviews will later be translated to English by the PI. PI will be the interviewer and is a Sri Lankan citizen whose fluent in both Sinhalese and English. In addition to taking notes, the interviews will be recorded and will last a maximum of 45 minutes per one person. This will be taken place through telephone and other internet-based communication tools like Skype, Viber and WhatsApp, according to participants' convenience. Participants will be given the choice to decide if they prefer to do video or audio interviews. Video interviews will be encouraged since it can develop a comfortable and friendlier environment with the interviewer and will open the environment to get honest answers. Besides having participants being over the age of 18 and have participated in some type of training offered by the employer, there are no other criteria for the workers to participate in the research study. The interviews with executives will be more technical and are aimed to understand the macro/micro/ external/ internal constraints of the AI digitalization of the apparel process and the skills of the workforce. The semi-structured interviews with the non-executive mid-level managers and design teams would be less-technical and would mainly focus in finding the out about the trainings available to them and their perception towards adopting the digitalization of the processes.

7. **STUDY POPULATION AND RECRUITMENT**
Describe who and how many subjects will be invited to participate. Include age, gender and other pertinent information.

The research population would include 10-15 executive/ non-executive workers, who will be interviewed for a maximum of 45 minutes. The participant recruitment of executives will be done ahead of time by sending emails to the executives with related posts (Eg: Information technology manager, Product development manager, Design executives, etc.) to get their consent for the participation in the research study.

The non-executive worker recruitment will be done through snowball sampling of the workers under different executives/ managers. The non-executive workers will be notified ahead of time regarding the research study and would take their consent to participate in the interviews through their managers in written format.

Approximately equal amounts of executive and non-executive workers will be recruited roughly with an even gender distribution among the population. All recruitments will be over the age of 18 and preferably have participated in training programs conducted by the employer.

Attach all recruitment fliers, letters, or other recruitment materials to be used. If verbal recruitment will be used, please attach a script.

Initial introductions to the organizations will be made through Sarah Krasley, CEO of Shimmy Technologies,NY, and then the following script will be used as an email. Script is as follows:

Hi XXXX,

I want to thank you so much for your willingness to work with us and coordinate the interviews for our research. We are excited about what this study could show us about what makes the biggest impact.

We are wanting to have interviews with you and approximately 1-2 non-executive workers under your supervision in order to gather the data that is needed for our research. We would prefer if these workers have previously completed some kind of a training given by the employer, and they should be over the age of 18. We would appreciate it a lot if you can send us the names of the workers who would like to participate in our study, and we will send an official agreement form with all the details included about our study (*This paragraph will be included in emails to senior executives*).

We are hoping to limit the interviews approximately to 20-45 minutes and will be asking questions mostly about the current and future AI digitalization of the apparel industry processes and the skills of the workforce and the trainings you have been participated in. Your responses will be confidential; data will be analyzed and reported in aggregate form. During the interviews you may choose to stop participating at any time. There are no risks involved with this study.

If you have any questions, comments, or concerns, please feel free to let us know! Again, thank you so much for working with us. We are looking forward to hearing from you!

Describe what exclusionary criteria, if any will be applied.

- **Workers should be above the age limit of 18**
- **Workers must work daily in product development or some area of design development for the company.**

Describe what (if any) conditions will result in PI termination of subject participation.

None.

8. **RISKS AND BENEFITS**
List all potential physical, psychological, social, financial or legal risks to subjects (risks listed here should be included on the consent form).

No risks are anticipated.

In your opinion, are risks listed above minimal* or more than minimal? If more than minimal, please justify why risks are reasonable in relation to anticipated direct or future benefits.

N/A

(*Minimal risk means the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests)

What steps will be taken to minimize risks?
During the interviews, questions will be skipped if the question makes the participants uncomfortable.

Describe any potential direct benefits to participants.

There are no potential direct benefits to the participants.

Describe any potential future benefits to this class of participants, others, or society.

It is anticipated that the results of this research would benchmark to assist brands and companies to better prepare for the adoption of AI in the apparel industry. The findings will give recommendations on how the new training programs can be structured in a way to prepare the workforce for the major digitalization of the apparel industry, thus retaining the jobs of majority through upskilling.

If there is a Data Monitoring Committee (DMC) in place for this project, please describe when and how often it meets.

NA

9. **COMPENSATION**
Will participants be compensated for participation?
No

If so, please include details. **N/A**

10. **DATA**
Will subjects be anonymous to the researcher?
No

If subjects are identifiable, will their identities be kept confidential? (If yes, please specify how)
Yes
No names of individuals participating in the interviews will be recorded. Only the names of the apparel manufacturing plants will be used in publications.

How will data be stored and kept secure (specify data storage plans for both paper and electronic files. For guidance see
http://www.udel.edu/research/preparing/datastorage.html)

In addition to writing notes for each interview, with the permission of the participants, interviews will be electronically recorded using a phone recorder and the English translation will be transcribed verbatim. Both the paper and electronic data will be kept secure. The student will not keep the data after transcribing and no individuals will be identified by name. Electronic files will be kept in protected files belonging to Professor Kelly Cobb on a secure University network. The paper copies and tape recordings will be stored in a locked file cabinet in Professor Kelly Cobb's office.

How long will data be stored?

Approximately three years

Will data be destroyed? **X** YES   ☐ NO (if yes, please specify how the data will be destroyed)
Paper copies will be shredded and tape recordings will be deleted and then destroyed. Any electronic files will be deleted and data will be scrubbed.

Will the data be shared with anyone outside of the research team? **X** YES   ☐NO (if yes, please list the person(s), organization(s) and/or institution(s) and specify plans for secure data transfer)

Shimmy Technologies, NY. Interview scripts transcribed to English and detailed data analysis results might be shared with Shimmy Technologies. However, the data shared with Shimmy Technologies will only disclose the name of the Apparel manufacturing company, but the names and identities of individual informants will not be disclosed.
Eg: Informant No.1 from MAS Pvt Ltd, Sri Lanka.

How will data be analyzed and reported?

Data will be analyzed using qualitative data analysis techniques through deductive and inductive methods.

11. **CONFIDENTIALITY**
Will participants be audiotaped, photographed or videotaped during this study?

All interviews will be audiotaped/ video taped in order to ensure clarity and accuracy of data transcription and analysis.

How will subject identity be protected?

Names of the individuals interviewed will not be recorded and the data will be organized by a coding system for the workers being interviewed.

Is there a Certificate of Confidentiality in place for this project? (If so, please provide a copy).

No

12. **CONFLICT OF INTEREST**
(For information on disclosure reporting see:
http://www.udel.edu/research/preparing/conflict.html)

Do you have a current conflict of interest disclosure form on file through UD Web forms?

Yes, the faculty advisor does.

Does this project involve a potential conflict of interest*?

* As defined in the University of Delaware's Policies and Procedures ,a potential conflict of interest (COI) occurs when there is a divergence between an individual's private interests and his or her professional obligations, such that an independent observer might reasonably question whether the individual's professional judgment, commitment, actions, or decisions could be influenced by considerations of personal gain, financial or otherwise.

No

     If yes, please describe the nature of the interest:

N/A

13. **CONSENT and ASSENT**

_**X**___ Consent forms will be used and are attached for review (see Consent Template under Forms and Templates in IRBNet)

____ Additionally, child assent forms will be used and are attached.

__Waiver of Documentation of Consent (attach a consent script/information sheet with the signature block removed).

____ Waiver of Consent (Justify request for waiver)

We prefer to use modified informed consent because of the barriers we have observed that can be created between the interviewee and the interviewer as a result of the requirement for formal documentation, especially in international settings. The informed consent scripts attached reflect this and will be used at the beginning of each meeting.

14. **Other IRB Approval**
Has this protocol been submitted to any other IRBs?
No

If so, please list along with protocol title, number, and expiration date.

15. **Supporting Documentation**
Please list all additional documents uploaded to IRBNet in support of this application.

Protocol Form
Informed Consent Form
Interview script

Appendix B

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

Title of Project: Impact of AI digitalization of the apparel industry and upskilling the workforce

Principal Investigator(s): Anuththara Gangoda, University of Delaware

You are being invited to participate in a research study. This consent form tells you about the study including its purpose, what you will be asked to do if you decide to take part, and the risks and benefits of being in the study. Please read the information below and ask us any questions you may have before you decide whether or not you agree to participate.

WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to understand what the impacts of the Artificial Intelligence (AI) takeover would be for the apparel industry, how it would affect the apparel workforce and what needs to be done to better prepare the industry and the workforce for the anticipated technological changes in the apparel industry. Overall, the primary purpose of this study is benchmarking to understand where the apparel industry is now, and where the industry and the apparel workforce is supposed to lead with the continuous industry AI adoptions. You will be one of approximately 15 participants in this study. You are being asked to participate because your carrier experience in the apparel industry.

WHAT WILL YOU BE ASKED TO DO?

As a part of this study you will be requested to answer a list of questions about your daily job functions, technology that you experience in your job, and your skills and training experiences. There will be a maximin of around 15 interview questions where you can answer with your experience and give your opinion on. The interview will be conducted remotely through telephone and other internet-based communication tools like Skype, Viber and WhatsApp, according to your convenience. You can decide if you prefer to do video or audio interviews. Your participation in this study will take up to a maximum of 45 minutes. Prior to the interview, you can decide if the interview takes place in English or Sinhalese.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

The researcher does not expect your participation in this study will expose you to any risks different from those you would encounter in daily life. All questions will be guided by the interviewer.

WHAT IF YOU ARE INJURED DURING YOUR PARTICIPATION IN THE STUDY?

There are no possible risks of participating in this research study. You can choose to skip the questions if you don't feel like answering any of them, or you can terminate the interview at anytime you want.

WHAT ARE THE POTENTIAL BENEFITS?

There are no potential direct benefits to the participants.

HOW WILL CONFIDENTIALITY BE MAINTAINED? WHO MAY KNOW THAT YOU PARTICIPATED IN THIS RESEARCH?

During the interview, in addition to writing notes, with the permission of the participants, interviews will be electronically recorded using a phone recorder and the English translation will be transcribed verbatim. Both the paper and electronic data will be kept secure. The findings of this research may be presented or published. The researcher will make every effort to keep all research records that identify you confidential outside the research team. However, the names of the apparel manufacturing plants you work for, will be used in the publications. The data and results of this study may be shared with Shimmy Technologies, NY.

The confidentiality of your records will be protected to the extent permitted by law. Your research records may be viewed by the University of Delaware Institutional Review Board, which is a committee formally designated to approve, monitor, and review biomedical and behavioral research involving humans. Records relating to this research will be kept for at least three years after the research study has been completed. After the research completion, paper copies will be shredded, and tape recordings will be deleted and then destroyed.

WILL YOU RECEIVE ANY COMPENSATION FOR PARTICIPATION?

There will be no compensation for the participation in this study.

DO YOU HAVE TO TAKE PART IN THIS STUDY?

Taking part in this research study is entirely voluntary. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. Your decision to stop participation, or not to participate, will not influence current or future relationships with the University of Delaware.

At any time, if you decide to end your participation in this research study, please inform the interviewer.

WHO SHOULD YOU CALL IF YOU HAVE QUESTIONS OR CONCERNS?

If you have any questions about this study, please contact the Principal Investigator, Anuththara Gangoda, at +1 (417) 619 8050 or anugan@udel.edu OR Research Advisor, Kelly Cobb, at kcobb@udel.edu

If you have any questions or concerns about your rights as a research participant, you may contact the University of Delaware Institutional Review Board at hsrb-research@udel.edu or (302) 831-2137.

Your signature on this form means that: 1) you are at least 18 years old; 2) you have read and understand the information given in this form; 3) you have asked any questions you have about the research and the questions have been answered to your satisfaction; and 4) you accept the terms in the form and volunteer to participate in the study. You will be given a copy of this form to keep.

Appendix C

IRB APPROVAL

UNIVERSITY OF DELAWARE

RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE: February 19, 2019

TO: Anuththara Gangoda, MS. in Fashion and Apparel design
FROM: University of Delaware IRB

STUDY TITLE: [1360947-1] AI digitization of Apparel Industry and upskilling the workforce

SUBMISSION TYPE: New Project

ACTION: DETERMINATION OF EXEMPT STATUS
DECISION DATE: February 19, 2019

REVIEW CATEGORY: Exemption category # *(2)*

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will put a copy of this correspondence on file in our office. Please remember to notify us if you make any substantial changes to the project.

If you have any questions, please contact Renee Stewart at (302) 831-2137 or stewartr@udel.edu. Please include your study title and reference number in all correspondence with this office.

cc:

Appendix D

RESEARCH INTERVIEW SCRIPT

Introductory script

    Interviewer: Hi. How are you?

    Interviewer: Which language do you prefer to speak? English or Sinhalese?

    Interviewer: My name is Anu Gangoda. I am conducting this research as a part of my master's program in University of Delaware. This research will mainly focus on the AI digitalization of the apparel industry in relation to apparel workers skills. You can tell me if the questions make you uncomfortable, and you can choose not to answer/ skip questions if they do so. Also I want you to know, you can terminate taking part in this interview anytime you want.

    Before we begin, do you have any questions regarding the interview, or about myself?

    (Then the interviewer will begin to ask the interview questions. Depending on their job position, the interviewer will choose to ask all of the questions below or choose to eliminate some. This will be a semi-structured interview, therefore depending on their responses additional probing questions will be asked which are relevant to the topic of the research).

Interview Questions

1. How long have you been working in the apparel industry?

2. What roles/ positions, have you held in your carrier in the apparel field?

3. What are your usual job functions like?

4. How have those functions changed over the last XX years?

5. Over the period of time in your career, what are the technological developments that you have seen in your field of expertise?

6. Have these new technologies impacted how you do your daily job functions? Can you describe your experiences?

7. What are your thoughts on AI based apps and automation taking over the jobs in other industries? How do you see these shaping the fashion industry?

8. What functions of your job can be automated, and what functions will still require human interaction? What will your new job position will be, considering that the above functions are digitalized?

9. Do you see technological digitalization of the apparel industry as a good thing or a bad thing? Why?

10. How do you think you can prepare yourself for the AI digitalization and automation in the industry?

11. Have you noticed a presence of a knowledge gap when recruiting workers? (For executive level workers)

12. How often do you get trained for your job sponsored by your employer? What do you have to do in the training programs/ what do you learn? Do you find them useful to do your job functions better?

13. How do you think the training programs in your field should be, in order for them to be more effective?

14. Do you take any effort to train yourself without your company's involvement? What kinds of trainings do you do?

15. What would you like those trainings to be like?

Finishing Script

     Interviewer: Do you have any questions for me? Thank you so much for participating on our research. The information you provided will be a valuable resource for us to get accurate results. If you have any more information for us regarding the questions I asked you or the topic of our research, please email at anugang@udel.edu. Thank you again and hope you have a great day!

Appendix E

How Digitization and Automation is going to Change the Apparel Business!?

Take some time to tell us about it

Hello!

I am Anu Gangoda, a master's student of the department of Fashion and Apparel Studies in University of Delaware, researching in collaboration with Shimmy Technologies, NY, to increase our understanding of how digitization is going to affect Apparel manufacturing environment and worker skills. If you are an executive, middle management personal, designer or a technician related to the apparel industry, you are in an ideal position to give us valuable firsthand information from your own perspective. This will be a short telephone interview of a maximum of 30 minutes.

The final results of this research will be published as a thesis and a report, and your name will be included in the report upon your approval. Your knowledge and opinion will be a valuable addition to our research.

If you have any questions, please do not hesitate to ask at anugang@udel.edu!

Thank you!