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Potential challenges of collaborative robot implementation in Vietnamese garment manufacturing

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ABSTRACT

Collaborative robots (cobots) are a new significant technology in the integration of Industry 4.0 (I4.0) and Industry 5.0 (I5.0). Working alongside humans in open environments, cobots can boost safety and productivity. However, manufacturers are facing some potential challenges in adopting cobots, such as technological challenges, social problems, cost barriers, and labor issues. Vietnam has a great potential for outsourcing in the top supply chains for many famous fashion brands globally, with thousands of textile and garment factories. The purpose of this study was to explore potential challenges of cobot implementations in the context of Vietnam's garment factories from factory employees' perspectives. Data were collected from 29 garment factory managers in Vietnam. Findings revealed a rapid change in fashion trends and many unskilled workers may limit cobots' flexibility, precision, and innovation. Furthermore, cobot implementation is affected by the cost of cobots, infrastructure upgrades, and risks of possible failure in deployment. Cobot firms, application partners, technology programmers, and manufacturers need to discuss how to maximize cobots' benefits in diverse aspects of the garment manufacturing setting. These insights could boost the industry's economy and sustainability.

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1. INTRODUCTION

In the current era of the 21st century, Industry 4.0 (I4.0) has initiated a transformative revolution in the realms of science to provide manufacturers with a multitude of advanced strategies to expand their businesses. I4.0 encompasses a diverse range of emerging technologies that play a pivotal role in numerous industries, specifically robotics and artificial intelligence (AI) [1]. The transformation of current value chains and the emergence of new, innovative business models are attributed to the integration of intelligent production, logistics, networks, and the internet of things (IoT) in contemporary goods. From this novel infrastructure standpoint, many advantages and revenue opportunities may be realized [2]. AI, smart manufacturing, 3D printing and knitting, AR/VR, and robotics are the most important uses of Industry 4.0 in the fashion industry because they solve many serious problems, such as unmatched consumer demand and supply, and environmental pollution [3].

In relation to the advancement of robotics, collaborative robots (cobots) have gained widespread adoption across various industries, owing to their beneficial effects on profitability, safety, and sustainability. The cobots, a novel robot model based on Industry 4.0 technology, have the capability to collaborate with workers in an unrestricted setting, thereby minimizing errors and waste while enhancing productivity, agility,

and flexibility [4], [5]. Cobots assist manufacturers in minimizing operational expenses and waste, providing a secure and conducive work environment, and guaranteeing the safeguarding of employees' human rights [6]. For instance, BWIndustrie, a French industrial firm of moderate size, implemented cobots from Universal Robots for tasks such as machine tending, material disposal, and quality inspection [7]. The return on investment (ROI) was achieved in less than 12 months, and the annual profit climbed to 5.6 billion Euros [7]. Regarding the safety of coexistence between cobots and people in the same workspace, Franklin and his team classified cobots into four distinct categories: safety-rated monitored stop, hand guiding, speed and separation monitoring, and power and force restriction are all features included [8]. These systems are designed to detect humans and regulate the motion and speed of cobots. They automatically adjust the speed to either slow or full, or even halt. Cobots analyze the relative location, speed, and movements of humans and robots within the workspace to establish an appropriate separation distance for application purposes [8]. Meanwhile, clothing manufacturing employees face a lack of machine guards and other potentially hazardous situations to account for 38% of all industrial accidents [9]. In their discussion of the causes of workplace accidents in the garment industry, Calvin and Joseph [9] cited careless sanitation, uncomfortable working positions, excessive physical lifting, broken machinery, and a general lack of concern for employee and employer safety. Following thorough risk evaluations, specific safety regulations are imposed on cobots in an effort to reduce the occurrence of such accidents [10]. Any job that requires heavy lift or repeated motion can be completed by a cobot to assist in keeping workers away from potentially dangerous machinery, toxic materials, and tools with the highest risk of injury [11]. Besides, lessening casualties leads to a decrease in staff absence [11]. For instance, to guarantee the utmost safety conditions, cobots and people can collaborate without a safety barrier thanks to adjustments to the automated mode and safety sensors. Sensors and visual cameras on cobots activate if workers enter the work zone, allowing them to instantly halt, adjust speed, or both [10]. Therefore, manufacturers can improve the quality of their workplaces with the help of cobots by incorporating them into their investment plans and pushing for the integration of cobot applications and safety devices in the garment sector [10].

With steady improvement, Vietnam's manufacturing sector reached 25% of GDP in 2022 [12]. International economic integration was greatly aided by Vietnam's textile and garment industry, among other manufacturing sectors. Export turnover increased steadily from $30.5 billion in 2018 to $37.5 billion in 2022 [13]. Therefore, Vietnam's textile and garment industry, with its large workforce, faces both challenges and opportunities as it embraces Industry 4.0 [14], [15]. With a high degree of automation, deploying robots may reduce the advantage of vast human workers [16]. On the other hand, the I4.0 boosts textile and garment manufacturers' competitive capabilities through the use of new platform technologies like robots, biotechnology, cloud computing, big databases, the Internet of Things, 3D printing, and new material technology [17]. The Ministry of Industry and Trade of Vietnam highlighted the numerous benefits of cobots, such as enhancing productivity, improving output quality, and promoting the well-being of workers [18]. These are essential prerequisites for Vietnam to fulfill requirements for contemporary enterprises and maintain competitiveness [18]. For instance, garment workers consistently engage in overtime work to fulfill customer demands, resulting in an escalation of pre-consumer waste during the production process. Therefore, when workers work together with robots, the number of product defects may be reduced. This is because robots can work under pressure for extended periods without causing physical or mental harm to humans. Universal Robots, a well-known company that creates versatile cobot technology, expects the Vietnamese government to increase action plans in adopting new automated technology to the utilization of cobots across various manufacturing sectors, aligning with the advancements of I4.0 [19]. Universal Robots has successfully distributed cobots to Servo Dynamics Engineering and Tan Phat Automation JSC to fulfill the demand for cobots [19]. Meiko Trading and Engineering Co., Ltd has recognized the advantages of utilizing cobots to enhance productivity and ensure the safety of workers [19]. Within the fashion industry, textile and garment companies in Vietnam have made significant advancements in terms of production efficiency, operational time and cost reduction, and quality [20]. Thus, by investing in robots at all stages of production and providing advanced training for human resources, manufacturers can effectively implement Industry 4.0, maintain a stable employment rate, and fulfill the desired quality standards for orders [21]. In the near future, cobots can bring potential applications to the garment manufacturing industry to meet sustainable requirements.

Using innovative technologies to optimize productivity and achieve the demand for mass production is the main goal of I4.0 [22]. "Smart" manufacturing is a well-known objective that many industries aim to provide as much as possible [23]. This objective unintentionally limits humans' involvement in manufacturing [23]. Then, Industry 5.0 (I5.0) is coming to utilize the existing technologies of I4.0, focusing on the relationship between autonomous machines like cobots and the human role in manufacturing systems [24]. Cobots can work on repetitive, low-value tasks to allow workers to concentrate on advanced tasks that cobots cannot comprehend, due to a lack of human critical thinking skills [25]. This advantage will lead to an

increase in human participation, which can remove the fear of job insecurity and unemployment [25]. For example, DHL logistics applied cobots in the warehouse to support its staff not only by pushing heavy carts, but also by working alongside staff to assist moving quick-shipment orders [26]. Typically, Dorabot DoraSorter cobots can sort over 1,000 small parcels hourly and are installed in two Asian Pacific countries to help staff save time to work on value-adding tasks instead of walking long distances to complete orders [27]. Furthermore, in 2017, Amazon proved that cobots did not take over workers' jobs. Cobot applications in warehouses required more than double the number of employees compared to those in 2016 by hiring 2,500 full-time employees to fetch inventory with workers to keep abreast with the fast-moving process, which, in turn, increased output to pack and ship goods [28]. During the I5.0 era, workers are upskilled to guide cobots as cognitive laborers for mass personalization products. Especially, the I5.0 aims to bring green, sustainable solutions to the fashion industry by ensuring mass production quality [25]. Thus, cobots have massive, sustainable characteristics to significantly meet the I5.0 goals. The invention of cobots is a remarkable accomplishment of I4.0 and a crucial, sustainable strategy of I5.0 to mitigate potential drawbacks in the fashion sector. Cobots are accountable for enhancing production and establishing a novel interaction between workers and intelligent appliances.

While cobots offer various advantages for enterprises, their effective deployment depends on several factors, including the company's financial resources and the scale of production operations, ranging from small to medium to large. Technological obstacles still hinder the adaptability of automation [29]. The assortment of garment products, including various styles and sizes, undergoes seasonal changes and is closely linked to the adaptable manufacturing organization [30]. Current technologies have limitations in automating some garment constructions. Consequently, factory managers rely on the collaboration of workers with these machines to ensure adaptable operations and effectively attain intricate, extraordinary constructions [29]. Certain delicate textiles, such as silk, require the skill and accuracy of human artisans during the processes of drafting and stitching. Automated machines, such as robots, can efficiently manage mundane tasks, enabling workers to allocate more time toward specialized tasks. As a result, some challenges can come from technical sites that many manufacturers consider most.

The adoption of this new cobot approach may potentially generate controversy among qualified workers due to the need for them to acquire problem-solving skills, analyze failures, adapt to constant changes, and successfully complete new tasks, while cobots operate in collaboration with employees [2]. Worldwide, over 20 million jobs may be lost by 2030, due to the uptake of robots [31]. The implementation of advanced technologies like cobots in the garment industry could lead to both deskilling and upskilling of workers, as a way of addressing a decreasing unemployment rate [29]. Equally important, the abilities of workers play a crucial role in the deployment of cobots. For instance, repetitive stitching tasks must be decreased by applying cobots. Meanwhile, operating machines' tasks or complicated stitching tasks by upskilled workers are necessary to operate multiple machines in the production process [29]. Several brands have observed that the recruitment of skilled workers in machine programming and maintenance presents significant challenges, especially in developing countries characterized by low wages. Hence, the transition towards a technology-intensive industry has the potential to influence the outsourcing decisions of numerous brands, consequently affecting the labor resources throughout the fashion industry.

More to the point, the significant initial investment required for the implementation of innovative technology utilizing cobots poses a fundamental obstacle within the garment industry. Manufacturers often prioritize narrow profit margins and transactional relationships, which can lead to fear regarding large investments [32]. Investments exceeding six months' ROI are often restricted or declined due to a lack of evidence demonstrating their effectiveness. In addition, the fashion industry experiences a rapid proliferation of copycats [33]. Although cobots' applications can be customized, based on different garment manufacturers' requirements, competitiveness can push garment factories to duplicate cobots in some cases for better performance. For example, factory A asked for cobots to support delicate tasks in cutting sections and apply them successfully. Factory B only thinks of sewing cobots and has not considered this cutting cobot application. In this case, if factory B learns that factory A is successfully using cutting cobots, factory B may ask the cobot application company to create a cobot system utilizing the same programs as factory A and its partner had developed together. Therefore, non-disclosure agreement (NDA) is the most necessary bonding to avoid this problem between partners related to cobots and garment manufacturers. The goal of high comprehensiveness often results in significant investments in production automation. In order to demonstrate improvement, it is necessary for the factory to replace all machines in at least one production line. This is because efficiency cannot be observed with the assembly of a single sewing machine [27]. In addition, there is a substantial cost associated with employee training fees for the utilization of automated machines [34]. Retaining experienced workers is crucial in the long term as it helps prevent the need for retraining new employees in machine maintenance. As a result, key expenses can come from a cobot's cost, installation to meet specific machine areas, employees' training, maintenance, and other costs to operate the

cobots. Those costs also require long-term investment, including risks and benefits [35], causing potential challenges when applying cobots related to economic perspectives.

There is some empirical research on the utilization of cobots in various manufacturing industries, including automotive, nutrition, and electronics [1]. However, there is currently a lack of academic exploration regarding the application and impact of cobots on garment factories, specifically concerning employees' cognitive, social, and psychological perspectives. Research on the application of cobots in garment factories is currently in its early stages. Notably, previous studies [16], [36]–[38], primarily focus on providing an overview of cobots and their potential applications within the fashion industry. Owing to its extensive network of textile and garment factories, Vietnam presents a promising opportunity for numerous renowned global brands to engage in outsourcing. Hence, there exists a notable opportunity to comprehend the correlation between cobot factors and adoption intention in garment factories in Vietnam. Based on the above literature review, the purpose of this study is to explore the potential challenges of cobot implementations in the context of Vietnam's garment factories from factory workers' perspectives related to technical, labor, and economic concerns. Findings from this study will help academics better understand the elements utilized to make judgments about the deployment of cobots in the garment industry. Therefore, professionals in this industry may better develop production strategies to use cobots to satisfy the expectations of their businesses.

2. METHOD

This study was conducted to determine the potential challenges of cobot implementation in the context of Vietnam's garment factories. It elicited a range of potential difficulties that manufacturers can assume in the garment production process when applying cobots. The study involved a total of 29 participants who are currently employed or have previously worked in garment factories in Vietnam, where they held management positions. All participants exhibited a high level of proficiency in the English language. Approximately 90% of the participants possessed a minimum of four years of professional experience within the garment industry. Furthermore, they were employed in factories that boasted over 20 production lines and handled a monthly volume of 1,000,000 garments. Hence, it is imperative that their extensive experiences and visions encompass the entirety of the garment factories' construction process with diligent attention to detail. The participants were selected for the study through a snowball sampling method, which was based on the researchers' prior professional network in Vietnam.

When the Institutional Review Board (IRB) granted approval, the respondents were contacted twice via email over a period of 10 days. In the initial email invitation letter, the purpose of the study was explained, a hyperlink to the survey was provided, potential implications were acknowledged, participation was requested, and confidentiality was assured. The participants were instructed to access the survey by clicking on the provided URL. Approximately five days following the initial invitation, a subsequent email was sent to express thankfulness to those who had provided a response and to kindly remind those who had not yet responded to kindly complete the survey. Participants were provided with a survey link, which included an informed consent form embedded on the first page of their survey. The confidentiality of all participant information was ensured in accordance with the informed consent form, which clearly outlined the study's purposes. No associated risks were observed.

A series of questions were developed into two parts, based on relevant literature regarding adopting new technology. The initial section consisted of multiple-choice inquiries pertaining to professional backgrounds within the garment industry, the number of production lines and employees within their manufacturing location, and familiarity with collaborative robots (cobots). Subsequently, despite their level of awareness regarding cobots, the participants were provided with an introduction to the definitions and applications of cobots to establish an equal knowledge of these terms during the survey. It is believed that they were pondering the implementation of cobots in their factory. The following part covered open-ended inquiries regarding potential obstacles that might hinder the adoption of cobots within garment factories. These questions concentrated mainly on technical, labor, and cost-related considerations. The survey is expected to require approximately 20 to 30 minutes to complete. It was conducted online using the Qualtrics system to guarantee the confidentiality of participants' information.

Data were collected through an online survey using the Qualtrics system. The first part of the quantitative data was analyzed using Statistical Package for the Social Sciences (SPSS™) version 28.0, and descriptive analyses, including frequency and percentages, were conducted. The second part of the data was analyzed qualitatively. The researchers coded, classified, and analyzed the qualitative data following the guidelines of thematic analysis [39]. First, the researchers carefully reviewed the completed responses and identified key terms for each answer. Following that, the researchers proceeded to apply codes to the excerpts, subsequently organizing the codes into subthemes based on keywords that used a similar or

identical meaning. Third, based on themes, interpretations were made to obtain findings that fit well with the challenges manufacturers assumed in implementing cobots.

3. RESULTS AND DISCUSSION

3.1. Sample characteristics

Thirty-three employees (N=33) who are currently employed or have previously worked in garment factories received an invitation to take part in the online survey. After four incomplete responses (13.13%) were excluded, 29 responses were obtained, resulting in a response rate of 87.87%. These 29 responses remained valid for the purpose of data analysis. All participants in the study held positions of management or higher in the factories (n=29).

3.1.1. Sample demographics

The sample's demographic profiles (n=29) were categorized based on gender, work experience, and the size of the factory where they are currently employed or have previously worked. The survey participants consisted of 41.38% females and 58.62% males. The majority of respondents had work experience greater than 10 years (93.11%). Most participants, specifically 79.31%, reported being employed in factories with a production capacity of less than 100 lines. More than half of the respondents were working in garment factories, which can produce over 1,000,000 garments monthly (51.72%).

3.1.2. Knowledge of cobots

In the sample size of 29 participants, approximately 75.66% of the respondents demonstrated familiarity with the term "cobots," while 68.97% of respondents possessed knowledge of any cobot companies globally. Furthermore, approximately 75.86% of respondents had heard "cobots" through friends, co-workers (68.97%), YouTube (68.97%), or others (LinkedIn, Facebook, technology events, websites, newspapers, and news on television). Due to the limited adoption of cobots in garment factories in Vietnam, a significant majority of respondents, specifically 65.51%, have not had the opportunity to engage with this emerging technology.

3.2. Potential challenges of collaborative robot implementation in garment factories

Based on the research questions, the responses were classified into three main themes: technical perspective, labor perspective, and economic perspective. The "technical" theme delved deepest with 6 subthemes, while the "labor" theme had 3 subthemes, and the "economic" theme had 5 subthemes. All 29 participants, coded from P1 to P29, were analyzed through this framework. These emerging themes are summarized in Table 1 for further analysis.

Table 1. Qualitative theme summary

Main themes	Subthemes	Participants
Technical	Flexibility of cobots	P1 to P15, P17 to P19, P21, P23 to P25, P27, P29
Technical	Accuracy of cobots	P2, P5 to P10, P18, P20 to P24
Technical	Standard and specifications of cobots	P2, P4, P14 to P16, P26 to P27
Technical	Innovation of cobots	P14, P18, P20
Technical	Copycats of cobot applications	P24
Technical	No concerns	P28
Labor	Cobots can take jobs in factories	P1 to P16, P18 to P21, P23 to P25, P27 to P29
Labor	Knowledge and skills to work with cobots	P1 to P5, P10 to P16, P19, P25, P27
Labor	No concerns	P17, P22, P26
Economic	Cost of cobots	P1 to P15, P18 to P21, P26 to P29
Economic	Cost of the warranty, upgrades, stability, and maintenance	P2 to P20, P23 to P28
Economic	Cost of training	P2 to P19, P21, P22, P25
Economic	Cost of environmental sustainability: How cobots can be recycled at the end of use	P12
Economic	No concerns	P1, P29

3.2.1. Technical perspective

About 82.76% of the participants (n=24) addressed a technical concern about the flexibility of cobots. The variety of styles, materials, and sizes change seasonally and are attached to manufactured products. Some tiny panel stitching and complex garment constructions require workers' professional skills to ensure product quality. So, factory managers must rely on skilled workers to maintain intricate operations. Cobots can efficiently manage mundane and repetitive tasks, thereby allowing workers to allocate more time and attention towards specific tasks. Participant 1 stated, "There are a lot of uncertain steps happening during

garment manufacturing; somehow, cobot's standard procedure without flexibility is difficult to apply in the apparel industry." Participant 2 mentioned, "I consider whether cobots can handle the different materials, small items, and complex constructions." A technical concern also brings fears about the accuracy of cobots for 44.83% of total participants as managers. Factory managers do not know potential issues that can occur during operation, since cobots are a new technology. There have not been many factories applying them previously to predict the risks of cobot usage. Participant 6 also mentioned, "For example, if any missing stitches happen while assembling pieces, workers will stop immediately and fix the machines before moving to the next step. However, I am not sure if cobots can realize this to stop. So, this is one small issue among a ton of other issues that I can predict for sewing machines. Since cobots are new to me, I cannot fully understand the risks that cobots can make. To ensure everything, I must run the pilots with cobots for at least three months." If any products have problems, these issues may affect the delivery date and customer trust. About one-quarter of participants (24.14%) stated the standard and specification of cobots might not be compatible with the core data of factories related to orders, such as garment patterns or constructions in old programs. Participant 4 indicated, in some cases, garment factories want to reuse data on garment patterns. They prefer to input this data into old computer programs to cobot software to produce garments instead of making new programs to save time. Therefore, cobot programmers must clearly understand the data on garment features to help manufacturers transfer data from old factory programs to cobot software without missing data or errors. Around 10.34% of participants were concerned about the innovation of cobots. Participant 14 noticed, "Many factories are using 3D printing and pattern making. So, I do not know whether cobots can be matched to those innovative programs." Participant 18 said, "Factories have a variety of innovative industrial machines to complete the entire process. Cobots can work with humans. However, I am unsure if cobots can match those innovative industrial machines." Participant 20 addressed, "In the fashion industry, a ton of industrial machines bring valuable benefits in reducing the cost of the product. For example, there is one machine making a back pocket on pants in 30 seconds. How long does this step take when collaborating with cobots? How many steps can cobots do in making a T-shirt compared to industrial machines?" As a result, technical concerns can come from many elements related to the speedy changes in fashion, the complication of garments, the ambiguous know-how about cobots and other related innovative machines, and the misunderstanding in cobot deployments between cobot partners and garment manufacturers.

Regarding the technical concerns mentioned previously, cobots' flexibility, accuracy, and innovativeness are developed and customized based on the unanimity of cobot companies, application partners, technology programmers, and customers. Different arm size options and the end effectors of cobots allow customers to discuss with technical engineers to repurpose cobots to work on a new task and fill a gap in the manufacturing line. Each arm size can have a different payload, degree of flexibility, and footprint depending on the job's features, like UR3e, UR5e, UR10e, UR16e, UR20, and UR30 [40]. For example, in the warehouses of garment factories, manufacturers can use the "Cobot lift" of Universal Robots to carry fabrics and accessories up to 45 kg [41]. Besides, this "Cobot lift" can attach different grippers to lift various materials like sacks, boxes, and buckets [41]. Universal Robots noticed that one of the cobots' most flexible common attachments is grippers that adapt to a range of tasks with delicate to tough materials [42]. There are hundreds of different types of grippers, such as magnetic grippers or vacuum grippers [40], which can be switched out to transform cobots into a different version. For highly delicate fabrics like silk or satin, soft grippers with magnetic functions or vacuum grippers can determine stitching or grabbing. Moreover, to deal with the speedy changes of orders in garment factories, manufacturers can use different grippers to ensure the flexibility of cobots and the quality of products. In general, it is recommended for manufacturers in developing countries to establish close collaborations with brands to engage in discussions regarding technological advancements and devise more effective machinery strategies that align with the volume of orders and prevailing fashion trends. Then, manufacturers can discuss with cobot companies and developers to design cobots that can match well with their production lines. Most of the above technical concerns can be resolved if all parties related to cobot applications make it clear to each other to customize cobots in the best way. Cobots' flexibility is highly valued, since there are a variety of options that manufacturers can choose to design cobots, depending on budget, level, factory, and facility size.

3.2.2. Labor perspective

When it comes to labor challenges, the participants of biggest concern was cobots could take over workers' jobs in the factories, leading to increased unemployment for lower-skilled workers. Almost 90% of the participants (n=26) agreed that training workers should play an essential role in improving workers' knowledge and skills to work with cobots. Participant 4 mentioned, "Cobots can help labor costs in the long term, but cobots can occupy jobs from humans, especially in developing countries that need more jobs like Vietnam." Participant 14 presented, "It will reduce manpower directly impacting the employment for

workers, especially low-cost workers." The second concern is the knowledge and skills to work with cobots as 51.72% of participants responded. In Vietnam, most workers have a low academic level. So, their ability to learn new things might be limited. Participant 10 indicated the knowledge to operate the cobots and Participant 11 also had the same opinion on the academic level to control cobots. Participant 25 was concerned about "How to make the collaboration the most challenging because the know-how of workers about cobot is zero. How long does it take to train one worker to be professional in using cobots?" However, about 10.34% of participants had no concerns about any labor challenges. The above labor-related concerns are understandable, when considering the importance of workers in developing human resources and the economy of a country, especially in a developing country like Vietnam.

I5.0 is a significant approach and is underway to bring back the human touch to manufacturing, due to its mass personalization [43]. Mass personalization asks for mass-customized products for which only human care can leave unique marks and human craftsmanship [43]. So, cobots are deployed to enhance workers' tasks to be quicker and more accurate, instead of replacing human jobs. Thus, cobots can replace workers when those workers can only work on repetitive basic tasks [44]. Cobots can realize and understand the human presence which industrial programmable machines cannot [35]. Critical thinking tasks and personalization are worker's tasks, while cobots focus on mundane, labor-intensive jobs in the human-cobot working environment. Besides, a bottleneck in production can easily occur, due to workers' absence, physical limitations of workers, human-induced production problems, and the need to remove, repair, or rework to fix quality defects. In this case, cobots can support the workstation to relieve workers to solve bottlenecks [35]. A skilled workforce in the I5.0 is expected to have higher standards for handling skilled tasks related to technology, management, and society [45]. However, in the garment industry, the number of low-skilled workers is enormous as a controversial issue. They work for garment factories in developing countries because the jobs do not require high knowledge and skills. In this situation, if these low-skilled workers are not willing to upgrade their ability and skill sets to adapt to the requirements of I5.0, their position will be eliminated. Therefore, garment factories should have careful labor strategies in upskilling and deskilling the low-skill workers to avoid an increase in unemployment in the integration between I4.0 and I5.0 [46]. This process takes time since these workers' physical and mental abilities might be limited in learning new things. As a result, the garment industry can move slowly in the integration of I5.0 compared to other automotive industries. Overall, I5.0 is a good signal that emphasizes human craftsmanship in personalized products, where low-skilled workers can put their efforts into producing something special and sustainable, such as patchworking art in clothing or sculpturing on handbags.

3.2.3. Economic perspective

Equally important, the managers had concerns about the cost of cobots. Almost 80% of participants addressed they prefer under $30,000 for each cobot. However, they could consider the price depending on the return on investment (ROI), labor costs, and how many steps cobots can apply in the process. For example, Participant 29 noticed the value of each cobot should be equal to the salary of 20 workers in five years maximum. Meanwhile, cobot companies need to commit to the benefits, including increasing productivity and quality by 30%. Participant 15 identified, "Compared to other industrial machines currently, the price of cobots can be higher and competitive. If cobot companies can commit to ROI or ensure an increase in productivity in a specific period, the factories will be willing to adopt cobots." Another idea came from Participant 21, "Each factory has different levels and backgrounds. So, it is good to set up the trial production lines collaborating with cobots to prove the benefit of cobots before buying cobots." Significantly, 93.10% of participants agreed that warranty, upgrades, stability, and maintenance should be available until they can easily maintain cobots by themselves and ensure the quality of cobots. Participant 20 noticed, "The price is not a concern if the warranty and upgrade of cobots are maintained while running cobots." Participant 16 addressed, "If cobots stop working for any reason, the fixing period can cause a delay in completing orders. So, the factory must also set up backup production lines all the time to avoid any issues. The budget for keeping these two things at the same time is a concern. The cobots company should think about building trust in cobots for manufacturers paralleling to the cobots price." Moreover, the cost of training was 79.31% of participants' responses. Manufacturers must pay for employees normally during the training period, although employees cannot work to make the products during this time. Also, managers think of long-term training programs and employee benefits that collaborate with cobots to maintain experienced labor resources and save time in future training. For example, participant 18 mentioned if employees who received training resign, there should be replacement employees to continue with the tasks and training to upskill the quality. The cost of training employees is enormous and requires a long-term investment. Participant 29 noted, "Most garment workers in the production lines in Vietnamese factories do not have high education and quick understanding of using technology. The training process will take longer and needs to be as detailed as possible to ensure workers understand. So, the training cost may increase significantly." Finally, 3.44% of participants paid attention to how many benefits cobots can bring to environmental sustainability and how

cobots can be recycled at the end of use. Participant 12 called this concern, "How much the friendly environment cobots are getting involved in and how easily we can recycle cobots at the end of use."

Overall, costs involving the implementation of cobots are complicated with many of the above-mentioned factors, since it is connected to human benefits. Pizon *et al.* [35] mentioned the business scale and type, the company's features, and its financial capabilities are crucial when making decisions to invest in any machinery or technology [35]. In garment factories, there should be a proper analysis based on the current situation in the factories to purchase cobots to work with workers. Manufacturers can consider the comparative analysis between goals, the volumes of products, and market offerings to decide on purchasing cobots. The cost of cobots, the costs of training employees, the infrastructure upgrade to match with Cobot implementation, and even the risks involving the failure of deployment are affecting cobot purchasing [35]. Especially in garment factories, the cobot implementation is more complicated than in other industries, due to the volume of low-skilled workers and the fluctuating change of products. To keep the workers' resources, manufacturers should ensure the income of workers during the training process to allow them to focus on learning how to use cobots and their retention after upskilling their ability [46]. If not, factories will continue retraining the laborers, and it will take a longer time for cobot adoption. Besides, garment production changes seasonally to fit customers' demands. So, cobot applicators and programming may need to be updated to the changing operations in the production line. Moreover, the cost of warranty and maintenance should be discussed clearly between garment manufacturers and cobot's parties to ensure cobot's activities last a long period. This point will improve the relationship between manufacturers and cobot partners to adapt cobot applications in the long term when needed.

4. CONCLUSION

Cobots have not yet been widely implemented in the apparel manufacturing setting in Vietnam. Moreover, the fashion industry continues to change rapidly, depending on the trends, style, and customer demands. Also, there are many lower-skilled workers in the garment industry. These factors impose limitations on the benefits of cobots in the context of apparel production. Therefore, it is necessary to develop and modify cobot practices to enhance flexibility in technical settings and ensure affordability, considering the scale of companies involved. Besides, if cobot companies, application partners, technology programmers, and manufacturers can discuss maximizing the advantage of cobots in diverse situations in factories, the spreading of cobot implementation in Vietnamese garment factories will increase significantly. Finally, worker training programs in cobot implementation are necessary to balance the workforce and integration of new technology in I5.0. Hence, garment manufacturers should prioritize this pivotal aspect to guarantee effective cobot adoption strategies. These findings will facilitate the industry's growth, both in terms of economic growth and environmental sustainability.

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