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Industry 4.0 readiness assessment for apparel industry: A study in the Sri Lankan context

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***Abstract*: Sri Lankan apparel industry is the most significant and driving contributor to the country's economy by constituting a large portion of GDP. In the highly competitive apparel world, manufacturers search solutions for problems such as worker inadequacy while minimizing the human impact. Therefore, there is a need for apparel manufacturers to enhance value chain processes with the latest technologies. Industry 4.0 is the fourth industrial revolution that transforms the physical production into a combined cyber-physical production environment with IoT and decentralized intelligence. It enhances the process functions from new product development to logistics by providing real-time visibility of the production flow. Existing literature mentions the applications of Industry 4.0 in the apparel industry, but these have not addressed the issue of assessing the readiness for its adaptation in the apparel value chain process. Hence this scrutiny proposes a model to assess the current level of readiness of the Sri Lankan apparel industry to adapt Industry 4.0 technologies and practices. The model was developed based on a systematic review of literature with the industry experts' guidance. The factors that determine the readiness for Industry 4.0 within an organizational context were classified under four categories; People, Process, Technology and Data which were defined as readiness dimensions. The proposed model consists of five readiness levels from 0 to 4 namely: Stranger, Beginner, Intermediate, Advanced and Elite. This model enables managers to measure the readiness for adapting of Industry 4.0 in selected apparel value chain processes by using the specified minimum requirements under each dimension and level. The outcome of this study indicates that Sri Lankan apparel industry is in "Intermediate" level in terms of overall readiness with a value of 1.91 in the predefined readiness scale from 0 to 4.**

Keywords: *Apparel 4.0, Apparel value chain Industry 4.0, Readiness assessment, Sri Lankan apparel industry*

I. INTRODUCTION

Sri Lanka's apparel industry is one of the significant and driving contributors to the country's economy by contributing over $5 billion to GDP [1]. This industry has achieved rapid growth rates over the past few decades despite the increasing competition. Today, the apparel industry as Sri Lanka's primary foreign exchange earner accounts for 40% of the total exports and 52% of industrial product exports [2]. Since apparel is a human-centric industry, it has become a challenge for a small country such as Sri Lanka when compared to other regional players. At present, the major challenges faced by the industry are labour shortage, a record number of labour turnover, increases in wages and also loss of preferential treatments such as GSP+. As a result of that, apparel manufacturing organizations have to implement innovative solutions to overcome the challenges by enabling new technological developments. Therefore, these organizations have been left with the option of automating most of their processes [3]. Thus, the apparel manufacturers are in the initial step of transforming their factories into smart factories to find solutions to the aforesaid challenges by improving the productivity in both employees and operations.

The world has experienced three distinct industrial revolutions since 1800s. The first industrial revolution (Industry 1.0) was the usage of water and steam power for the invention of the steam machine. The second industrial revolution (Industry 2.0) was the period where the assembly line led to mass production and automation up to a certain extent. The third industrial revolution (Industry 3.0) was the rise of computer networks; robotics in manufacturing and the birth of the Internet, which is the game-changer in the ways that information is handled and shared [4]. The fourth industrial revolution (Industry 4.0) can be defined as an umbrella term for a new industrial paradigm that embraces emerging digital technologies: additive manufacturing, artificial intelligence (AI), autonomous robots, cyber-physical systems (CPS), Internet of Things (IoT), big data, augmented reality (AR) and creating the smart factory or in simple form the evolution of technology from embedded systems to cyber-physical systems [5]. Industry 4.0 empowers the businesses with improved control of the operation and allows leveraging real-time data to enhance productivity and processes improvements, which finally supports as driving forces for continuous growth within those industries.

According to industry experts' analysis, it is seen that when implementing Industry 4.0 in real-world enterprise environments, the problems faced are the lack of strategic guidance, poor acknowledgement on exceptionally complex Industry 4.0 ideas, the vulnerability of the results of Industry 4.0 applications with the matter of benefits and costs, failure to assess Industry 4.0 capability and lack of readiness of the company [6]. Concerning these issues, readiness assessment for Industry 4.0 becomes highly important, since a large number of organizations still struggle to initiate the transformation for Industry 4.0. An organizational readiness assessment uses a checklist, that is usually custom made based on the current situation at the organization and the parameters and requirements of the change or project that organization which desires to pursue [7]. Thus, an Industry 4.0 readiness assessment model helps organizations to decide their state of readiness in the adaption of Industry 4.0 technologies, distinguish the gaps and factors of

advancement for Industry 4.0 adaption, as well as paths for profitability improvement and advancement of achievable procedures and plans to perform outcome-based intervention projects.

The properties of existing Industry 4.0 readiness assessment models are different and there is no standard and well-accepted Industry 4.0 readiness assessment model [8], [6], [9], [45]. The existing models provide an analytical tool for evaluating an enterprise's current state of Industry 4.0 readiness, but most of the models do not contain a guide to upcoming steps within a certain roadmap to move up to higher readiness levels. None of the researches has fully elaborated sector-wide solutions for the apparel industry to assess the readiness for adaptation of Industry 4.0 in the apparel value chain process. Thus, the existing Industry 4.0 readiness assessment models demonstrate many weaknesses and drawbacks which trigger the need for the development of a new Industry 4.0 readiness assessment model. Thus, there is an urge for an Industry 4.0 readiness assessment model for the apparel industry, particularly in the Sri Lankan context.

The objective of this paper is to propose a readiness assessment model customized for the apparel industry with an assessment survey, in order to provide apparel manufacturing companies with a tool to measure the current state of readiness regarding Industry 4.0. Subsequently, this scrutiny measures the readiness for adapting Industry 4.0 within the Sri Lankan apparel industry using that proposed model and help to guide apparel manufacturers to move up the readiness ladder while maximizing operational performance. The remainder of the paper is structured as follows: the methodology applied for this study is described in the next section, section 3 elaborates the implementation of the readiness assessment model in detail, the analysis and the results are presented in section 4 while a comprehensive discussion of the findings is given in section 5. Finally, the closure of the paper is by presenting conclusions and an attempt to provide some perspectives on future research.

II. METHODOLOGY

The systematic review of the literature was based on the content analysis to gather the state of the knowledge on Sri Lankan apparel industry, Industry 4.0 and existing readiness assessment models in the context of Industry 4.0. The literature review was conducted according to the procedure proposed by Kitchen ham, [10] and the literature review protocol based on Popay et al., [11] to minimize the systematic error and bias in the screening of papers. Fifty-eight articles remained for qualitative synthesis and they were analysed. Through the systematic review of literature, the major challenges that the Sri Lankan apparel industry is currently facing when they compete with the global competitors were identified. Then a comprehensive review of innovative applications of Industry 4.0 in the apparel industry was presented. The existing Industry 4.0 readiness assessment models were evaluated in order to find the gaps that exist and to explore the strengths and weaknesses of each model using a set of evaluation criteria that were identified based on the literature and key points that need to be included in a standardized assessment model. Finally, the results of the systematic review of literature were used in the development of Industry 4.0 readiness assessment model for the Sri Lankan apparel industry. The readiness assessment model has been validated based on the suggestions and criticism from the industry experts who are representing different functional areas within apparel manufacturing companies in Sri Lanka. Finally, the refined model was used to implement questionnaires and to continue the research process. Three leading large-scale companies and one medium scale company were selected. These large scale and medium scale companies were selected based on their capability to concentrate on Industry 4.0 implementations with enough financial strategies, and also a limited number of companies were selected since the assessment process included several value chains processes, dimensions and sub-dimensions which had a huge expansion. Since different plants within the same company are having different levels, several plants from each company were selected for the sample of the study. Data was collected from the management of each functional area of these apparel manufacturing plants. In quantitative data analysis of the answers collected from structured questionnaires for closed-ended questions, the relevant readiness level represented in each answer was identified based on a score value assigned for each readiness level.

III. INDUSTRY 4.0 READINESS ASSESSMENT MODEL

A. Industry 4.0 readiness assessment dimensions

A systematic review of literature was conducted in order to identify the readiness factors highlighted by different papers and readiness assessment models and to provide a comprehensive, overall view of readiness factors for Industry 4.0. Thereby the intention was to develop a standardized readiness assessment model for Industry 4.0 which can be used to determine the overall readiness of an organization /industry. The identified factors were further reviewed and classified into four major categories: People, Process, Technology and Data. The classified readiness factors with their references and categories are shown in Table I.

TABLE I. FACTORS DETERMINING THE READINESS FOR INDUSTRY 4.0

Readiness Categories	Readiness Factors	References
People	Organizational strategy on the internal and external environment	[5], [6], [8], [9], [12], [13], [14], [15]
	Organizational strategy on technology implementation	[6], [8], [9], [13], [14], [16]
	Customer integration	[13], [17]
	Supplier integration	[12], [17], [18], [19], [20]
	Employee adaptability to skills and technology	[5], [18], [21], [22], [23], [24]
	Top management commitment	[12], [18], [19]
Process	Elements of organizational strategy (Vision, Mission, Goals, Action Plans, KPIs)	[6], [25], [26]
	Self-optimizing processes	[5], [16], [21], [25]
	Product integration with CPS	[8], [13], [23], [27], [28]
	Product innovation	[3], [5], [8], [13], [17], [27], [28], [35]
Technology	Integration of CPS	[17], [23], [25], [29],[30], [31], [32] ,[33] ,[34]
	Machine-system integration	[12], [23], [31], [40]
	Compatibility of IT systems with processes	[16], [23], [31], [35], [36]

	Autonomously guided work pieces	[31], [35], [37]
	IT system security	[9], [16], [21], [38]
Data	Real-time data analytics and decision making	[9], [23], [32], [33], [36], [39], [40], [43]
	Advanced algorithms	[16], [21], [34], [38], [39], [41], [42], [44], [54]
	Cloud-based data management	[5], [9], [17], [23], [31], [33], [39], [43]

These factors have been used as readiness dimensions for Industry 4.0 readiness assessment model for the Sri Lankan apparel industry. The identified readiness dimensions are further described in Table II.

TABLE II. READINESS DIMENSIONS

Readiness Dimensions	Readiness Sub-dimensions	General Description
People	• Organizational attitude on the internal and external environment • Organizational strategy on technology implementation • Customer integration • Supplier integration • Employee adaptability to skills and technology • Top management commitment	A culture of continuous improvement in which smart technology is viewed as the solution. Specialized roles and responsibilities drive toward predictable outcomes. Strategies towards having a set of skilful workforces who support and use new technologies. Change champions who understand the benefits of technology and influence the others around them. Smart and strategic partnerships. Real-time customer and supplier engagement throughout the product life cycle.
Process	• Elements of organizational strategy • Self-optimizing processes • Product integration with CPS • Product innovation	Processes that integrated data visualization into decision making for continuous improvement. Self-optimizing processes. KPIs that are required to run processes are being tracked. Planned processes in a proactive setting for predicting, forecasting, and planning future requirements. Innovative product development. Smart management system to run business operations throughout product development and innovation.
Technology	• Integration of CPS • Machine-system integration • Compatibility of IT systems with processes • Autonomously guided work pieces • IT system security	Intelligent applications to monitor and visualize critical operational analytics. Digitalized system integration with external entities to enable operational predictability and enhance customer relationship. Cyber-Physical Systems to improve agility responsiveness and accelerate the product life cycle. Mobility to schedule tasks and display KPIs.
		Adequate protection for all information available as electronic data.
Data	• Real-time data analytics & decision making • ML algorithms • Cloud-based data management	Utilized data analytics and visualization for real-time decision making. Automated KPI reports. Data gathering to predict future demand, performances and requirements for standardized decision-making process. Centralized data management with an open source collaboration.

B. Industry 4.0 readiness assessment levels

Five readiness levels were identified based on the literature and guidance of industry experts. According to the accomplishment of readiness levels, a scoring method has been provided to measure the readiness level of each apparel value chain process and to analyse the overall readiness level within an individual organization among processes, compare among competitive organizations and assess the readiness level of the entire Sri Lankan apparel industry. A particular readiness level is determined based on the score range given to each level. Score value gained by a dimension is compared with the score range, and the readiness level on that dimension is assessed. The identified readiness levels are described in Table III.

TABLE III. READINESS LEVELS

Readiness Level	Score (x)	Definition
Level 0: Stranger	x=0	The level that Industry 4.0 is unknown/irrelevant to the functional area/factory and does not achieve any criteria for the development of Industry 4.0.
Level 1: Beginner	0<x<=1	The level that processes are primarily manual with semi-automated technologies and involved in Industry 4.0 by pilot projects. Investments are being allocated to implement Industry 4.0 strategies within a single part of the functional area/company. In-company information sharing is limited to a few parts of the functional area/company. Necessary skills required to expand Industry 4.0 are only found in a few groups within the functional area/company.

Level 2: Intermediate	1<x<=2	The level that computer-based technologies are available, but human-machine interaction is also still available. A strategy with a scale to measure the progress of implementation of Industry 4.0 principles is being developed. Investments are being allocated to implement Industry 4.0 strategies within a few parts of the functional area/company. The first step is being initiated to enable the information exchange process with business partners. Necessary skills needed to expand Industry 4.0 are possessed in many groups in the functional area/company.
Level 3: Advanced	2<x<=3	The level that automated processes without human intervention are available, but employees also interact as manual/semi-automated elements of the work with automated elements. A strategy with a scale to measure the progress of implementation of Industry 4.0 principles has been developed.
		Investments are being allocated to implement Industry 4.0 strategies within many parts of the functional area/company. The functional area/company is not yet integrated with its customers. Extensive efforts have already been made to expand the necessary skills needed for Industry 4.0 throughout the functional area/company.
Level 4: Elite	3<x<=4	The level that functional area/company is powered by IoT, computer technologies, complex data analytics and virtual manufacturing with little or no human intervention through autonomous decision making and self-optimization. A strategy with a scale to measure the progress of implementation of Industry 4.0 principles has been developed and is already monitoring the status. Investments are being allocated to implement Industry 4.0 strategies throughout the company and support the above activities. A System-integrated data exchanging process is conducted both internally and externally with partners of business throughout the functional area/company. In-house expertise needs to move forward with Industry 4.0 are available in all critical parts of the functional area/company.

IV. Results and Findings

First of all, it is important to highlight that not all results from the readiness assessment have been provided in this paper. The focus is to report the overall readiness of each manufacturing plant along with value chain processes. Finally, the overall readiness of the Sri Lankan apparel industry in adapting Industry 4.0 for each apparel value chain process was calculated and the overall readiness was assessed for Industry 4.0 in the Sri Lankan apparel industry. The mathematical equation used to calculate readiness values is mentioned below.

$$R_P = \frac{\sum_{i=1}^{n} R_{Di}}{n} \quad (1)$$

R – Readiness Value

P – Value Chain Process

D – Readiness Dimension

n - # of Readiness Dimensions

The readiness values calculated for apparel value chain processes of each manufacturing plant have been depicted in Table IV.

TABLE IV. READINESS ASSESSMENT IN APPAREL MANUFACTURING PLANTS

Plant #	Product Design	Supply chain	Planning	Manufacturing	Sales & Marketing	Readiness level of the Plant
Plant A1	2.07	1.38	1.92	1.78	1.31	1.69
Plant A2	2.13	2.08	2.21	2.19	2.24	2.17
Plant A3	2.54	1.47	1.77	1.84	1.59	1.84
Plant A4	2.56	1.75	2.69	2.11	1.67	2.16
Plant A5	2.36	2.21	2.46	2.53	1.99	2.31
Plant B1	1.83	1.96	2.29	2.11	1.64	1.97
Plant B2	1.75	1.96	1.58	1.62	1.97	1.78
Plant C1	1.66	1.65	2.00	1.84	1.73	1.78
Plant D1	1.59	1.40	1.78	1.20	1.55	1.50

The readiness assessment of the planning processes with readiness dimensions is presented using a radar chart in Fig. 1. The axis gridlines displayed in the radar chart present the readiness levels of the model as described in Table 2. People and Process dimensions have shown a huge variation in terms of readiness among manufacturing plants while Technology and Data dimensions have low variation compared to those two dimensions.

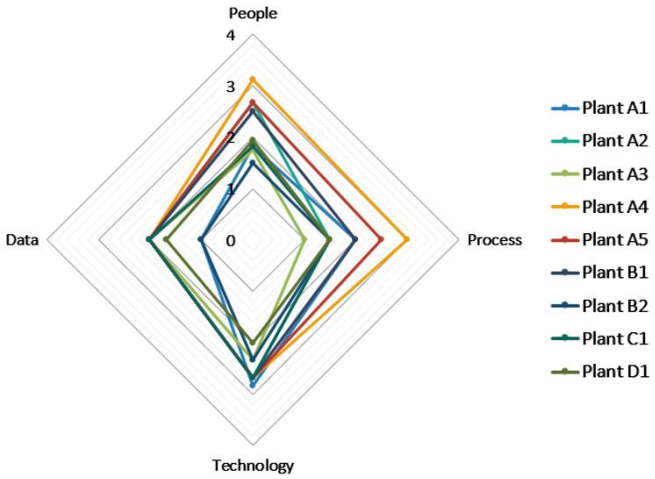

Fig.1. Readiness assessment of planning process

Hence, the variation of readiness among plants of the sample is displayed in Fig. 2. The figure describes the number of plants in the sample as a percentage against the variation of their readiness level in each dimension for the planning process.

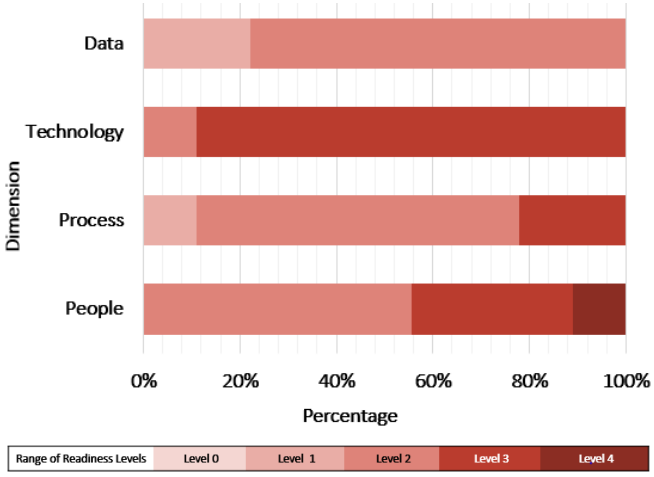

Fig. 2. Distribution of readiness for dimensions in planning process

V. Discussion

A. *Readiness assessment of value chain processes*

The reason for selecting the planning process for discussion that it is the process which has achieved the highest readiness with a variation between four levels. According to the Fig. 2, all the plants have improved their readiness up to “Intermediate” level or above it from People readiness. 56% of the plants were in the “Intermediate” level, where employees have improved skills for making judgements and decision making, and also where employees communicate with stakeholders once in a while to follow through on requests. Then 33% of the plants were in the “Advanced” level by enabling communication with stakeholders once in a while to follow through on requests and update the plan in a critical situation with the skills of employees to solve complex problems. Consumer interaction is up to a medium level at the product design stage. Those plants have fully skilled employees, but research skills are at a low level. Out of the four dimensions, only People dimension had 11% portion of the sample who got the readiness level up to “Elite” where they have acquired the maximum readiness level with employees’ skills for mathematical reasoning, analytical thinking and problem-solving. There is also communication with stakeholders early, often to follow through on requests and update the plan frequently.

Apparel manufacturing plants, in terms of Process readiness in the planning process, have shown up a variation between three levels. All the plants have improved their readiness up to "Beginner" level or above it. Most of the plants amounting to around 67% were in "Intermediate" level, where the production plan is optimized up to some extent with real-time information updates. Then 22% of the plants were in the "Advanced" level by enabling their planning departments' processes to optimize the production plan with real-time information updates. The least number of plants (11%) were at "Beginner" level by facilitating their plants to update the production plan only in critical situations with manual intervention.

The results of the survey indicated that Technology readiness within the planning process was up to “Intermediate” level or above it. 88% of the plants were in “Advanced” level, where integrative, automate and transparent planning and scheduling systems are used. Simulation is used to find the optimal arrangement of critical resources for selected product categories for profitable products. These plants practise several cyber security solutions with strategies to remove security gaps in technology. Only 11% of the plants were in the “Intermediate” level by preparing for Industry 4.0 with the use of systems which require little manual adjustment to generate plans. Simulation is used as a trial case to find the optimal arrangement of critical resources for the planning process for profitable products within these plants.

The lowest readiness among four levels has been shown by the Data dimension where it has variation in its readiness only between two levels: “Beginner” and “Intermediate”. Most of the plants around 78% were at the “Intermediate” level, where demand forecasting is conducted using past data with simple applications, and then the past data on planning is used frequently for future planning and scheduling. Initial solutions already commenced in few areas for cloud-based computing, data warehousing and analytical purposes. Then 22% of the plants were at the “Beginner” level by enabling to forecast demand roughly using past data. Past data on planning are used by these plants for future planning and scheduling by computing manually. Initial solutions are being planned for cloud-based computing, data warehousing and analytical purposes.

The variation of readiness flows between four levels: “Beginner”, “Intermediate”, “Advanced” and “Elite” when considering the four dimensions in the planning process within the Sri Lankan apparel industry. Only the People dimension has improved their readiness up to "Elite" level and no other dimension has been able to move up to that level. The plants prepared up to the "Advanced" level were found only in the Technology dimension, followed by People dimension and finally in Process dimension. The highest number of plants were prepared up to "Intermediate" level and they were in Data dimension, following Process dimension, People dimension and finally in Technology dimension. Plants that were prepared up to "Beginner" were only found for Process and Data dimensions with the highest number of plants for Data dimension and then Process dimension.

B. *Readiness assessment of Sri Lankan apparel industry*

The overall readiness values of the value chain processes in the Sri Lankan apparel industry are presented using a radar chart in Fig. 3. The readiness of each value chain process is discussed below.

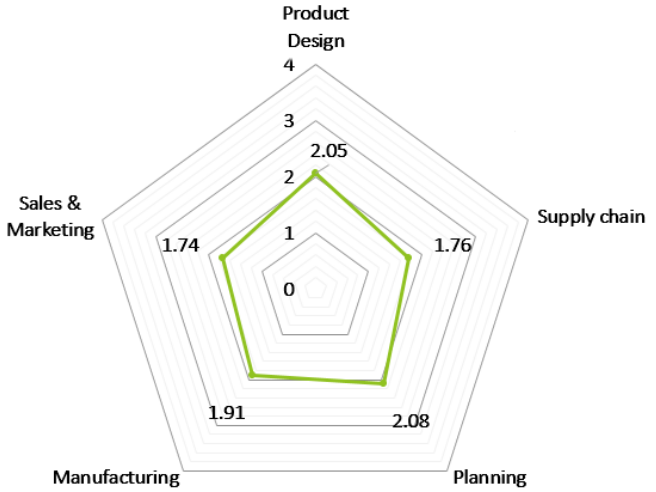

Fig. 3. Overall readiness in value chain processes

1) Product Design: The readiness level of the Product Design process is "Advanced" level (Level 3) with a readiness value of 2.05 which is the second-highest readiness compared with the other processes. It indicates that from People readiness, consumer interaction, product visualization are enabled at the product design stage. Employees have been fully skilled with creativity but research skills are at a moderate level. When considering Process readiness, most of the information, documents on new products are sent using cloud technology in a digital environment to other departments. Products show value from intellectual property (IP) licensing with smart clothing or wearable technologies in a considerable portion of the production. Sri Lankan apparel manufacturers develop prototypes using 3D printing up to a considerable level. Technology readiness is a critical point for each process and according to the current readiness, manufacturers use digital modelling for most of the garments. In terms of Data readiness, a high level of data usage can be seen for new product development processes. At the same time, pilot solutions have been implemented in a considerable proportion of the industry.

2) Supply Chain: The readiness level of the Supply Chain process is "Intermediate" level (Level 2) with a readiness value of 1.76. It indicates that from People readiness point of view, data transfer is among vital suppliers and customers. Employees are skilled in transactional tasks by the use of both manual and digital tools while top management has identified the possibilities for Industry 4.0 within supply chain functional area. From Process preparedness, these plants are maintaining supply chain processes that are partially incorporated among the organization, key vital suppliers and customers as far as data transfer. Improvements have been planned and commenced to reduce lead times for some materials. Sri Lankan apparel industry moderately responses to the changes in the market and shifts of customer needs. Technology readiness is a critical point for each process, and according to the current readiness enabling the visibility of site location, capacity, operations and inventory up to first level suppliers and customers is also critical. Supply chain applications are used by key suppliers and service providers. Data readiness in terms of Supply chain process indicates that initial solutions have been already commenced for cloud-based software, data warehousing and analytical purposes in few areas.

3) Planning: The readiness level of the planning process is at the "Advanced" level (Level 3) with a readiness value of 2.08 which is the highest readiness value compared to the other value chain processes. Regarding the People readiness, it is highlighted on enabling communication with stakeholders once in a while to follow through on requests and update the plan in a critical situation with the skills of employees to solve complex problems. Consumer interaction is up to a medium level at the product design stage. Those plants have fully skilled employees, but their research skills are at a low level. From Process preparedness point of view manufacturing companies have enabled their planning departments' processes to optimize the production plan with real-time information updates. According to the current Technological readiness integrative, automated and transparent planning and scheduling systems are used by these plants. Simulation is used to find the optimal arrangement of critical resources for selected product categories for profitable products. In terms of Data readiness, demand forecast uses past data with advanced applications. They maintain a large volume of data that can be used as input for planning. Pilot projects are ongoing in a considerable proportion within this functional context.

4) Manufacturing: The readiness level of the Manufacturing process is "Intermediate" level (Level 2) with a readiness value of 1.91. It indicates that from People readiness point of view, employee training is conducted using many digital tools. Employees are skilled up with easy tasks, repetitive tasks, watch and call and contribute to standardization in these plants. The production line is balanced manually and most of the data are collected on employee performance at this level. Customers have the ability to track the status of the product only at limited stages of the manufacturing process since these plants are still at "Intermediate" level. The top management has identified the possibilities for Industry 4.0 within the manufacturing process where they are responsible for. From Process preparedness, these plants are not using self-optimising processes but pilots are available in some advanced areas of the manufacturing process. Large scale production strategy is still in action with limited differentiation and medium level customization of production. Products can be tracked as it moves between a few processes in manufacturing within these plants. These plants have prepared for Industry 4.0 in the quality assurance part with the use of real-time applications for in-line quality testing. Since the Sri Lankan apparel industry still represents "Intermediate" level, 3D printing technology is at the conceptual level in the manufacturing process. Systems and machines are interoperable to some extent and few systems and machines are being able to upgrade. Few autonomously guided machines are available but not in use. In terms of Data readiness, the required data is collected real-time in a few areas. Varieties of data are used to control processes. Initial solutions already have been commenced in few areas for cloud-based software, data warehousing and analytical purposes. At the same time, employee performance reporting is partially covered by real-time data collection on few parts within the manufacturing process in the Sri Lankan context.

5) Sales & Marketing: The readiness level of the Sales & Marketing process is "Intermediate" level (Level 2) with a readiness value of 1.74 which is the lowest readiness value compared to the other value chain processes. Regarding People readiness, the reengineering process of the organizational culture and structure has been initialized as suited for customer engagement. Employees are skilled up with few basic skills required for Industry 4.0 in sales and marketing, and knowledge sharing about Industry 4.0 is conducted within the sales & marketing functional area of these plants. From Process preparedness, these plants have enabled the communication channel integration and cooperation of them with accomplices up to a medium level. At the same time, these plants are maintaining a medium level of integration between campaign systems and sales channels. When considering the results of the study on Technology readiness few pilot projects have been initialized on triggering technologies for a few advanced operations in the sales and marketing process. IT security solutions are initialized for data exchange with business partners which is a crucial requirement that is needed to be fulfilled before adapting Industry 4.0. Data analytics tools are used at a medium level to measure sales performances and data-driven administrations are offered with least consumer integration. Initial solutions have been already commenced in a few areas for cloud-based software, data warehousing and analytical purposes within the sales and marketing process.

The overall readiness level of the Sri Lankan apparel industry is 1.91 calculated by taking the average value of the five apparel value chain processes which equally contributed to the readiness assessment. Thus, it revealed that the Sri Lankan apparel industry is in level 2: "Intermediate" level according to the developed readiness assessment model. Thus, the Sri Lankan apparel industry is in a situation where computer-based technologies are in use, but human-machine interaction is still available. A strategy with a scale to measure the progress of implementation of Industry 4.0 principles is being developed. Investments are being allocated to implement Industry 4.0 strategies within a few parts of the functional area/company. The first step is being initiated to enable the information exchange process with business partners. The necessary skills needed to expand Industry 4.0 are present in many groups within this apparel industry.

The Sri Lankan apparel industry further needs to move up in this readiness ladder in order to settle down with the highest readiness before adapting Industry 4.0 technologies and practices. Industry practitioners can improve this readiness up to the next level by establishing automated processes which are without human intervention and by training employees to develop manual/semi-automated elements of the work with automated elements. A strategy with a scale to measure the progress of implementation of Industry 4.0 principles has been developed. Investments are being allocated to implement Industry 4.0 strategies within many parts of the functional areas. Finally, they can expand the necessary skills needed for Industry 4.0 throughout the company with the extensive efforts of top management. It is essential to pay attention to all the readiness sub-dimensions, readiness dimensions and apparel value chain processes equally to comprehensively prepare for Industry 4.0.

VI. Conclusion and Future Work

The study presented here aimed to develop a readiness assessment model customized to measure the readiness for adapting Industry 4.0 within Sri Lankan apparel industry with an assessment survey to provide apparel manufacturing companies with a tool to measure the current state of readiness regarding Industry 4.0. The model enables to assess the readiness up to different stages: the readiness of sub-dimensions, dimensions, apparel value chain processes, individual plant, a given apparel manufacturing company and finally the overall readiness of the Sri Lankan apparel industry as an average. The developed model is able to provide guidance to the apparel manufacturers, in order to identify their current state of preparedness and actions that should be taken to improve the readiness up to next level as a self-assessment tool, for five apparel value chain processes namely, Product Design, Supply Chain, Planning, Manufacturing and Sales & Marketing. This will be able to enhance the operational performance within this industry while solving the problems that the Sri Lankan apparel industry is currently facing when competing with the other regional players.

Since this study has considered a sample of nine apparel manufacturing plants which belong to four companies: including both large and medium scale companies, the sample can be further expanded to conduct more generalised readiness assessment. Future studies can aim at diversifying the proposed model to enhance the scope of readiness assessment with weighted readiness dimensions and to create comprehensive activity plans according to the companies' current readiness level. Further, this model can be applied in other geographical contexts to assess the readiness for Industry 4.0 in the apparel industry.

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