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Study on the Use of Industry 4.0 technology for the Textile Industry Sustainable Supply Chain Process

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Abstract. This paper studies a sustainable closed-loop supply chain progress for the textile industry based on the Industry 4.0 technologies to facilitate data-driven decision-making and ensure sustainability, which is premised on the ability of the IoTs to capture real-time information from the different stages of the supply chain through the use of radio frequency identification tags and sensors based data. Block-chain and Big Data technologies application in the closed-loop supply chain will support tracking and enable supply chain traceability and provide secure means of recording information in the supply chain progress according to the findings in this paper. It implicates the Industry 4.0 technologies will facilitate sustainable supply chain process in the textile industry as it helps in data collection, analysis and information transmission.

Keywords: Industry 4.0 Technology; Sustainable Supply Chain Process; Block Chain; Big Data; Textile Industry.

1. Introduction

Towards the supply chain transformation to achieve carbon neutrality, the global environmental sustainability agenda cannot be fully actualized without considering the supply chain. Besides macroeconomic policies to financial attempts led by the government, the role of the firms in the supply chain, consequently leading to their high demands on the environment, cannot be overemphasized. However, Sustainable Supply Chain Process (SSCP) in Textile Industry is faced with the challenges from data collection, analysis, and information transmission, which involves the manufacturing and distribution of goods to their final destinations, as well as their usage and disposal. The Industry 4.0 technologies such as artificial intelligence, the Internet of Things (IoT), Big Data analytics (BDA), block chain and advanced robotics can prove their relevance and worth by collecting data on a large scale, thereby circumventing the complexity of the SSCP. Despite the rising attention on SSCP, the literature is still limited in terms of how these technologies can aid sustainability practices in supply chain process, especially in the textile industry. This study thus covers this empirical gap by examining the application of Industry 4.0 technologies to the SSCM in the textile industry.

2. Literature Review

As earlier inferred, the need to ensure an all-inclusive sustainable environment has resulted in the recent concentration of environmental regulators, government, and other stakeholders on the supply chain. This is tied to the fact that the supply chain, which expresses a complex structure of activities, from the production of goods and services to distribution, consumption, disposal, and re-usage, embraces huge environmental demand. As such, the concern about the ascertainment of sustainability in the supply chain is an ongoing debate in the literature, leading to a plethora of recent studies in that dimension. In other words, sustainable supply chain process has become a central empirical concept in recent years. Many studies are devoted to achieving it or how firms have been operating in a suite.

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SSCP is a complex system involving the management practice, the environmental consciousness, the economic awareness, and social performance with the concern on sustainability, which means the attainment of sustainability require the firms to declare their environmental and social performances, alongside their profits, even uphold the required standards by enforcing specific laws sometimes. For instance, a robust model that incorporates four factors, namely risk management, strategy, transparency, and culture, was developed by Carter and Rogers to capture sustainability in the supply chain [1]. While the strategic approach is meant to ensure that firms in the supply chain fit in sustainability ideology in their communal strategy, the risk management approach is concerned with the protection of the firms from different supply chain risks, such as disruptions to the distribution of raw materials, goods and services, higher prices, weak environmental and social performance, poor coordination of demand patterns, etc. For the transparency, it aims to ensure that all activities by the firms in the supply chain are made to comply with set down sustainability objectives, and the relevant information such as sustainability ideologies be shared with other partners, and the stakeholders for awareness. Finally, the culture dimension suggests that corporate culture should be strongly related to environmental and social practices.

After Carter and Rogers [1], the theories have been proposed over the last decade to address SSCP. They include the development of advanced algorithms for the appraisal and the selection of sustainable supply [2], the consequence of block chain technology on SSCP [3], and the evaluation of the determinants of sustainable supply chain practices [4]. More so, the latest review reveals that in SSCP field, the current hot area of research endeavor is game theory. In contrast, issues such as big data analytics in this field are just emerging. The authors disclose that most available studies pay attention to a specific area. For instance, Paliwal et al. [5] focus on the implication of block chain technology on SSCP. Others are concerned with the SSCP either in the global supply chains, automotive industry, manufacturing or tourism. Thus, the role of Big Data in achieving SSCP is just rising in prominence. Specifically, studies such as Bag et al. [6] and Hazen et al. [7] have argued that one of the suitable approaches to ascertain sustainability in the supply chain is by taking advantage of big data analytics. Their argument is informed by the ability of smart devices to collect huge amounts of data on a continuous basis, such that sophisticated analytics can be applied to big data. Then, the insight obtained from the analysis can be used to make informed decisions and create pathways towards achieving sustainability in the supply chain. Other benefits of the application of big data analytics in achieving SSCP include the encouragement of collaborative habits among the supply chain firms to promote ethical actions, promotion of information transmission and transparency through the integration of activities along the supply chain [8], comparison of historical environmental behavior with the current environmental actions to aid the forecast of future social concerns, monitoring of harmful activities that lead to unethical conducts [9], and the reduction of supply chain risks to arrive at sustainable social practices by firms [10].

We note that the available few studies that connect big data analytics with a sustainable supply chain have mostly concentrated on specific areas. With a specific emphasis on the manufacturing supply chain, for instance, Mageto [11] explains that big data analytics helps enhance the management of materials by making important information available, particularly in location, materials, quantities, and delivery d of goods. This, according to Ammar et al. [12] further strengthens the supply chain in holding exact dates inventories and how to control them efficiently, all of which eventually diminish the costs of freight. Extending the scope beyond manufacturing, big data analytics has been found important in aiding sustainability in other areas of the overall supply chain, such as logistics, inventory optimization, demand sensing, customer service, goods tracking, and quality control of production.

Studies have recently concentrated on the textile industry. Reviewing the literature on the social issues pertaining to the textile and apparel industry, Koksal et al. [13] believe that the firms in this industry should have collaboration with suppliers to mitigate social risks. For sustainability in the strategy of apparel products produced partly with recycled inputs, Yang and Dong [14] make a division between consumers that are environmentally inclined and those that are not. They uncover

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that the firm will attain a higher level of sustainability and profit if the consumers are skewed towards environmental consciousness. They further suggest that if too much cost is not involved in converting regular consumers to be environmentally conscious, the firm should proceed with the conversion through the provision of adequate sustainability information.

3. SSCP in Textile Industry

The supply chain process in textile industry covers the downstream and upstream. The upstream segment consists of all activities related to the manufacturing and processing of textile products and the downstream segment relates to all distribution activities through which the textile products reach the final consumer [15].

As shown in Figure 1, fibers production, ginning processes, spinning and extrusions activities, processing weaving and knitting, and garment production are the key activities where the life cycle of a textile product from the raw material production to the waste level is emphasized. As noted, the life cycle of a textile product begins from the production of natural Fibers by farmers and growers or synthetic fibers by the chemicals industry, through to the yarn formation, which occurs through Fiber preparation, texturizing, and spinning then to fabric formation through knitting, weaving, slashing, to the wet processing through dyeing, finishing and printing, to the fabrication stage through cutting and sewing, to consumption and finally to waste. At different stages in the life cycle, several resources utilized such as dyes, additives, chemicals, water, and energy are of significant environmental concern. Especially, water is used at nearly every stage in the textile product's life cycle, which leads the textile industry become the second highest consumer and polluter of clean water after agriculture.

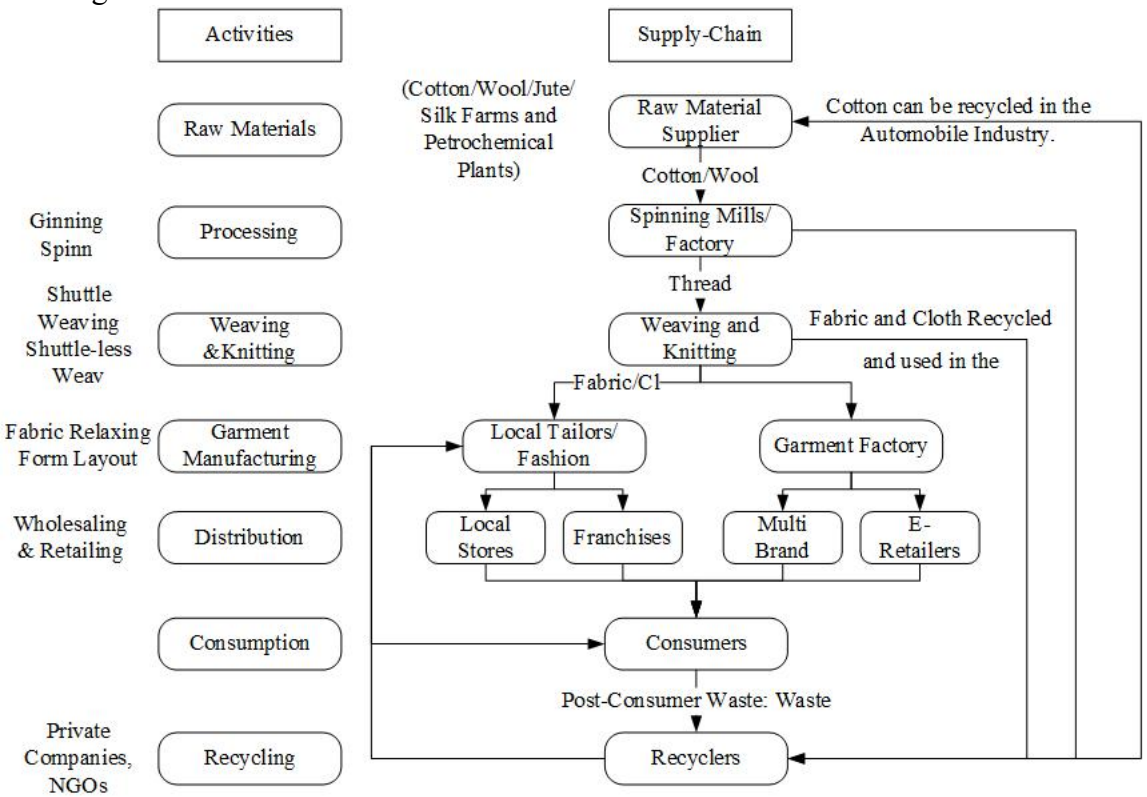

Fig. 1 Textile Industry Supply Chain Process

4. Integration of Industry 4.0 Technologies in SSCP

The integration of some of the Industry 4.0 technologies could facilitate data-driven decision-making in textile industry and ensure sustainability within the supply chain since the applications of IoT devices, block chain, big data, etc. are used to address these issues relating to

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sustainability. In the closed-loop supply chain, information regarding the origin of the material, composition, length, and color of the Fiber can be gotten from the Fiber producer, while information relating to the thickness, strength and humidity level is provided by the yarn spinning factory. Similarly, information about the production network and garment assembling is also provided, while information regarding the packaging and merchandising, transit and distribution are given at the wholesaling and retailing stage. The block chain and big data analysis can provide a secure and productive means of recording information about the actors and their actions in the supply chain which includes the time and locations of supply chain processes, operations, and transactions. In this section, we proposed a sustainable closed-loop supply chain process for the textile industry, integrating Industry 4.0 technologies (See Figure 2).

According to Tortorella and Fettermann [16], digitization of processes and implementing practices that use smarter equipment is a crucial success factor that is beneficial to productivity, the efficiency of resources, and the reduction of waste. The development of the industry 4.0 has been employed to restructure the supply chains towards creating digital networks in improving sustainability. The IoT's ability to capture real-time information from the different stages of the supply chain through the use of Radio Frequency Identification (RFID) tags and sensors-based data communication networks was highlighted by Pal and Yasar [17]. The need for big data-driven analysis to evaluate trust and behaviors in the supply chain was emphasized by Tseng et al.[18]. Also, the capability of the block chain to secure information collected at each stage of the supply chain gives the need for the application [17]. The integration of the Industry 4.0 technologies for SSCP in textile industry should follow the steps which are data collection, data processing, data storage and data mining.

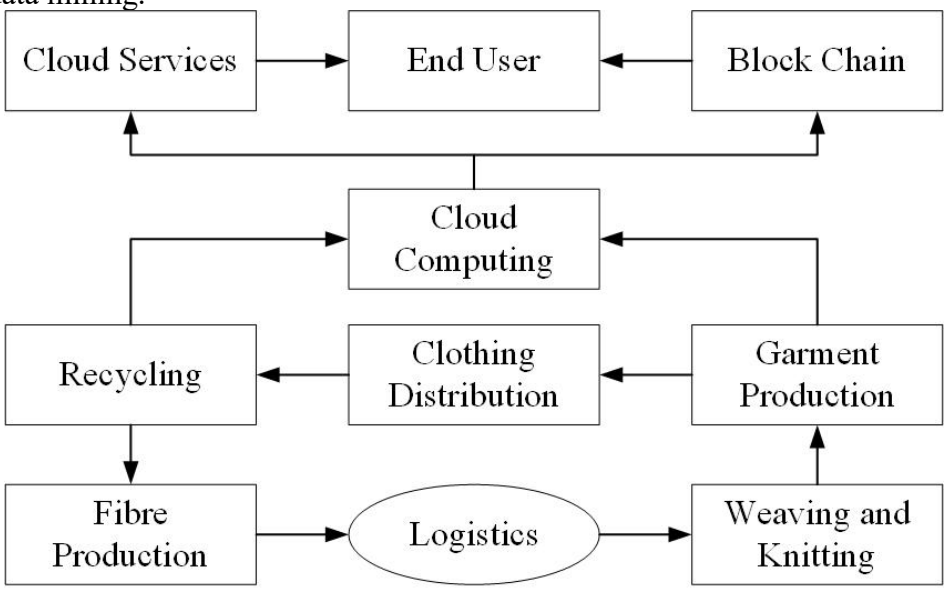

Fig. 2 Close-loop Supply Chain with Industry 4.0 Integration in Textile Industry

4.1 Data Collection with Industry 4.0 Technologies in SSCP

The information to be collected varies with each actor and the activities performed in the supply chain. The first one is the raw materials or Fiber manufacturer, including the data on yarn spinning, weaving, knitting stages and the information of the supplier of the Fibers. At the garment manufacturers' stage, information includes grading, pattern making, nesting, marking, cutting, sewing, quality inspection, pressing, and packaging. At the stage of clothing distribution and sales, the information of the wholesalers and retailers are involved. It is important to note that logistics activities are required at every stage of the supply chain [19].

The internet of things has the ability to capture real-time information in the supply chain. IoT is also defined as the communication between machines, devices, and equipment in which their virtual personalities and capabilities are obtained due to advancements in technologies. Data relating to

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movement and activities in the supply chain are detected by sensors and then sent to the system for processing automatically. In collecting the information discussed in the previous section, several tools can be used to achieve this aim. RFID is very popular and effective for SSCP in textile industry. During the whole data-collecting process of the supply chain, the RFID tags can be used and attached to products or their packs which could be the bobbins, containers, and cloth hangers. This tag attached to products helps store information relating to the products, the process of manufacturing, logistics operations, and others mentioned earlier, which are collected by RFID tags readers positioned in strategic places at the factory. The RFID tags send information to machines as a command after the sensor reads them. The sensor can also send information as a command to those that will convey the products to the shipping point, after which the product is scanned again by another sensor once it gets to the shipping point.

4.2 Data Storage with Industry 4.0 Technologies in SSCP

The aim of the data storage is for the end-users. The availability of these data makes it possible for the end-user to know the supply chain management of the textile industry and identify firms that are not contributing to environmental, social, and economic sustainability. The cloud computing technologies and block chain provide storage capability for the data collected across all stages. The block chain is referred to as a Distributed Ledger Technology (DLT) through which transactions are recorded securely. As a protocol which allows users to collect data into blocks and link them into a chain, the block chain helps to manage and distribute the information and at the same time provides security to the data by ensuring that no one tampers with the data collected.

In the context of data storage, data extraction is a key issue which should be concerned. In order to extract the data which has already been stored in the chosen database, product embedded information devices (PEID) could be used, which includes barcodes, smart sensors etc. For example, a technology referred to as smart label or smart tags can help to obtain the necessary data embedded in supply chain actors via block chain process using RFID algorithm. Additionally, the use of smart phones and other smart censoring devices can identify the textile data at any stage of the supply chain which could make the goods-tracking and inefficiency-reducing become available.

Data storage methods to be utilized include structured, unstructured and semi-structured methods. For the structured storage method, the Distributed Database System (DDBS) is recommended as the location of the different actors in the supply chain is diverse, cutting across not just countries but also continents [20]. In storing unstructured data, NoSql is to be utilized as it is more flexible due to the type of information that is extracted. Semi-structured data will utilize XML. XML is an abbreviation for extensible markup language, and it can be used to store semi-structured datasets that can’t be structured into columns and rows but still contain vital.

4.3 Data Processing with Industry 4.0 Technologies in SSCP

The data processing in SSCP of textile industry covers the cleaning, integration, reduction, and transformation of textile information according to the preference of the data user. Correcting inaccurate textile information is the key requirement in data cleaning process [21]. Additionally, the data integration process requires the data processors to unify and amalgamate information that has come from diverse sources to give data users a unified view of the activities in the supply chain [22]. Since the integration of information need to become a uniform view, the data reduction process is important. Data reduction in the supply chain is the conversion of information of the textiles from raw form to a corrected, ordered and simplified form, which requires the data processor to develop an easier to understand depiction of the result of the analysis carried out at various levels and examine all information gathered, identifies incomplete, incorrect, inaccurate or irrelevant information and replaces, modifies or deletes the bad data found.

Big data can be utilized in data processing of textile industry within a computational framework which looks like a model for current analytics across different stages and levels in the supply chain. The proper utilization of the computational framework will help to optimize results obtained from

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the analytics process if data processing is context-dependent [23]. This statement means that the data is required to be processed according to the needs and requirements of the data users. In another word, the information required to make decisions or recommendations based on the evidence available should be gotten through the information garnered concerning the textiles. Hadoop, Storm, MapReduce, Flink are the popular computational frameworks utilized in the supply chain due to the need for sustainability in the supply cycle process where real-time data-driven decision making is needed to reduce the effect of wrong environmental practices in the textile supply chain cycle.

Although Hadoop is the most popular and most utilized computational framework, it tends to process data in batches, requiring clustering, split into smaller processing jobs all in an indexed and arranged manner amongst many other processes before results can be gotten [24]. Comparatively, Apache Storm is alternative for the textile industry to concern which is used to process high velocity of data in real time, boosting its ability to process over a million records per second per node using a cluster of modest size [25]. The supply chain in the textile industry consists of resourcing materials, processing or manufacturing the garments, transporting products to warehouses, selling points or consumers and finally storing the textiles. The Storm framework can contribute to quality assurance, preventative measures in manufacturing, reduces plant downtime for textile manufacturing activities. For Storing and selling activities, Storm can contribute to preventing shrinkage of the textile and eliminates stock-outs with its advanced algorithm at the same time optimizing pricing, offers and advertisements [26]. Concerning transportation, Storm monitors the drivers and riders, supports vehicle health by recommending preventive maintenance while offering optimized routes and more economic pricing through optimization of the pricing system utilized.

4.4 Data Mining with Industry 4.0 Technologies in SSCP

For the SSCP in textile industry, the data mining process embeds various procedures of analysis of the available data, including extracting different patterns, similarities and differences. Machine learning, statistics, and various database systems or methods that are particularly applicable to the data extracted are often utilized for data mining which needs the extraction and segregation of large datasets.

In the decision-making tree procedure of the data mining process, tests on attributes of the textiles are attached to the internal nodes of the decision tree structure, and the outcome of the test is denoted by each branch [27]. The decision tree will be used to group textiles based on differences recognized after a test is carried out on the qualities of that textile. The use of different data mining procedures ensures that supply chain actors can choose whichever is most economical, efficient, and effective in the supply chain process.

5. Conclusion

Nowadays, industries, end consumers, governments and policy makers start to pay more and more attention to the impact of SSCP because of the awareness of the environment and society responsibility. For the textile industry, SSCP is also a key issue. The application of the industry 4.0 technologies for the textile industry shows the way where sustainability can be achieved through data collection, data storage, data processing and data mining. These technologies can help to track the activities at each stage of the supply chain in the textile industry and solve the complexity consequently. In detail, the internet of things devices can capture real-time information such as the origin of the raw materials, location of the materials, type of Fiber, chemical composition, pattern making, cutting and logistics activities in the supply chain. The cloud service and block chain improve the data storage ability. Additionally, the block chain can also improve the traceability, security and transparency of the data stored at each stage of the textile supply chain. Therefore, the importance of the industry 4.0 technologies is one that should not be overlooked in the supply chain

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of the textile industry. Conclusively, manufacturing industries should look more into the industry 4.0 technologies and apply them to the supply chain if sustainability is desired.

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