Key Factors for Designing a Green Supply Chain in Industry 4.0 for Egyptian manufacturing companies

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Abstract

This study aims to stand up and perform an empirical analysis of key embrace factors of green supply chain design in industry 4.0 to improve sustainability practices through tribble bottom line in Egypt. A mixed-method research design was used and included 30 online questionnaires, 10 remote interviews, and 33 exhaustive literature review materials. In addition, six key embrace factors of green supply chain design embracing in industry 4.0 were established. The results showed that these factors have a strong effect on enhancing sustainability performance and achieving Sustainable competitive advantage for Egyptian manufacturing companies.

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1. INTRODUCTION

1.1 Background

The impact of globalization on social, economic, and environmental aspects is causing market conditions to shift fast in today's society. In order to create a competitive advantage, modern manufacturing firms must concentrate on customer satisfaction and profitability (Ghobakhloo M. and Fathi M., 2021). It has become increasingly common for supply chains to compete against them other rather than against each other (Zhang Q., and Ma Y., 2021). When firms collaborate on fabrication and design, they are able to leverage each other's information and technologies to the benefit of the entire supply chain (Hopkins J., 2021). Several authors, (Enyoghasi C. and Badurdeen F., 2021) have stated that information exchange is essential for enhancing the performance of supply chains. There are numerous benefits for businesses when they collaborate and share resources across borders, and globalization is a crucial factor in this integration process (Aboelmaged M., 2018). Supply and demand in typical supply chain are often out of whack because of the increasing uncertainty and complexity (Enyoghasi C. and Badurdeen F., 2021). Supply chain management (SCM) has become increasingly important to the growth of firms, as it gives instruments to enhance the overall performance of firms along the supply chain (Ali S., Ali A., AlKilabi M., et al., 2021). Meanwhile, technological changes and new ideas play an essential role in the internal operations of businesses.

Supply chain design (SCD) is the vital contribution of SCM. As stated by Bai C. and Satir S. (2020), SCD is to identify the supply chain facilities (factories, distributors, logistics and channels, manufacturing processes, etc.) in order to satisfy customer requirements. This definition emphasizes the supply chain design's fundamental theme: facility development. Along with location, supply chain design entails considerations about how to allocate resources among phases of the process. Designing a supply chain also involves deciding on facility capacities as well as technological developments for the various components (Chowdhury M., Umme N., Nuruzzaman M., 2018).

Data collection and exchange are becoming increasingly important as the Fourth Industrial Revolution (Industry 4.0) gets under way, and it's already changing the face of the future (Mubarik M., Naghavi N., Mubarik M., et ai., 2021). Another big change that will happen because of Industry 4.0 (I.40) is that new business models, better manufacturing technology,

more jobs and better work organization will all be possible, as well as new jobs and better work organization. "Industry 4.0." This is when information and communication technologies are mixed with industrial technology. Many areas outside of the industrial sector could be profoundly impacted by I4.0 (Ghadimi P., Wang C., Lim M. and Heavy C.,2019). Digital manufacturing, network connectivity, information technology, and automation technologies are all part of I4.0. A variety of new technologies, such as the Cyber-Physical System (CPS), Internet of Things (IoT) and Augmented Reality (AR), are also being used by many businesses in order to enhance their goods and processes in order to increase production efficiency and productivity (Moktadir M., Dwivedi A., Khan N., et al., 2021).

The best approach to creating sustainability in industry 4.0 is the Triple Bottom Line (TBL), which focuses on transforming the business framework to enhance financial performance and measure the firm's social and environmental impact for a sustainable future (Ghobakhloo M. and Fathi M., 2021). Through TBL, a firm focuses on three key issues: planet, people, and profit. Although some firms have adopted key factors, the implementation level is low, and there is a need for increased usage. There is a recent shift in the approach to Supply Chain Management (SCM), which focuses on maximizing material and energy usage throughout the complex network of customers, producers, and suppliers (Zhang Q., and Ma Y., 2021). Thus, there is the need to either minimize or eliminate industrial wastes that reduce the efficiency of the production process and cause greenhouse effects that negatively impact the environment (Hopkins J., 2021).

The integration of Green Supply Chain Design (GSCD) in I 4.0 offers solutions to the environmental and efficiency challenges (Enyoghasi C. and Badurdeen F., 2021). Through the green operations, the supply chain is applied from the product design, purchase of the raw materials, manufacturing, distribution, and sale of the product (Mubarik M., Naghavi N., Mubarik M., et ai., 2021). Thus, certain factors focused on sustainability and Industry 4.0 (I4.0) should be established as a first step for a positive embracing of GSCD (Ali S., Ali A., AlKilabi M., et al., 2021). GSCD minimizes the release of wastes and entails increment inefficiency, increased customer satisfaction, reduced manufacturing costs, and enhanced the firm's performance (Chowdhury M., Umme N., Nuruzzaman M., 2018). Bai C. and Satir S. (2020) performed a case study and indicated that the Success Factors (SFs) of sustainability in manufacturing companies could enhance company's efficiency.

1.2 What's the problem?

Egyptian manufacturing firms are lacking in their ability to utilize cutting-edge industry 4.0 technology, which is the focus of this study. Green Supply Chains necessitate the incorporation of industry 4.0 technology by manufacturers. The purpose of this study is to identify the key Factors (KFs) that led to the embrace of the GSCD's I 4.0 initiative in Egypt. As a result of this, this study provides guidance on how to improve Egypt's sustainability performance in the context of Industry 4.0. There is a large quantity of study in the secondary literature and academic publications on the numerous important Factors. Unfortunately, they are not specific to Egypt or the Middle East, leaving a knowledge gap in Egypt. In addition, it is important to realize that Egypt, a "melting pot" of cultures, is distinct from other countries. Despite its significant Arab roots, it has also adopted western practices of diversity and inclusivity.

Therefore, below are the main research questions (RQs) that this study seeks to answer:

RQ1: What are the economic Key Embrace Factors in In Egyptian I4.0?

RQ2: What are the environmental Key Embrace Factors in In Egyptian I4.0?

RQ3: What are the social Key Embrace Factors in In Egyptian I4.0?

RQ4: What are the best practices for integrating and optimizing these multiple dimensions of sustainability into the supply chain design?

2. LITERATURE REVIEW

Supply Chain Management is the management of " a network of organizations that are involved in the various processes and activities that generate value in the form of products and services in the hands of the ultimate customer through upstream and downstream linkages." According to Gardas B., Raut R., Narkhede B. (2019), supply chain strategy, supply chain design, supply chain planning, and supply chain operations are all highly interconnected planning dimensions. Due to the fact that GSCD entails decisions about the structure of a value network (e.g. facility location and capacity allocation), it has a significant impact on the subsequent planning areas. GSCD decisions have a greater impact on a supply chain's environmental impact than tactical or operational decisions. As a result, this paper focuses on green supply chain design as a critical component of the green supply chain management concept in the context of I4.0 (Cochran D., and Rauch E., 2020).

GSCD is a subset of traditional supply chain design that incorporates economic, environmental, and social sustainability (Cabrera S., Pishchulov G., Sampaio P., et al., 2021).While the widely accepted definition of sustainability encompasses all three dimensions (Shao X., Liu W., Li Y., et al., 2021)., the majority of studies have focused on the economic and environmental dimensions, with the social dimension receiving far less attention to date (Jemai J., Chung B. and Sarkar B., 2020). Indeed, the literature has 'ignored' the social dimension (Zhang Q., and Ma Y., 2021). According to a recent assessment of different approaches for green supply chain management (Prasada D., Jabbour R., Gaurava K., et ai., 2020), in addition to 'the integration of the three dimensions,' 'the social factor is virtually entirely absent' from this research field. This paper demonstrates how economic, environmental, and social factors can be combined together for designing a Green Supply Chain in Industry 4.0 for Egyptian manufacturing companies.

I4.0 is a German initiative that combines manufacturing and information technology. Its goal is to increase productivity and operational efficiency by connecting the physical and virtual worlds (Enyoghasi C. and Badurdeen F., 2021). This connection is achieved through the use of technologically advanced manufacturing processes and equipment that communicate autonomously throughout the value chain. Thus, Industry 4.0 is an industrial approach based on three fundamental principles: (1) connected equipment and processes operate autonomously wherever possible, allowing horizontal and vertical integration across the entire value creation network ; (2) digitalization of product and service offerings, as well as end-to-end engineering throughout the product life cycle; and (3) innovative digital business models. I4.0 involves full communication between the various components of the supply chain, including companies, factories, suppliers, logistics, resources and customers (Moktadir M., Dwivedi A., Khan N., et al., 2021). Each of them adjusts its configuration in real time based on the demands and status of other members of the supply chain, allowing the inclusion of sustainable practices. Costs and pollutants, raw materials and CO2 emissions, for example, will be reduced. The computing component of Industry 4.0 includes self-organizing and decentralized cyber-physical systems (CPS) that connect and cooperate in real time with each other and with humans via cloud computing and the Internet of Things (IoT). Interoperability, virtuality, decentralization, real-time capacity, modularity and service orientation are the pillars of this collaboration (Chowdhury M., Umme N., Nuruzzaman M., 2018).

The business world is continuously changing and thus becoming more complex. The changing paradigm requires the integration of a supply chain that will enable the companies to adapt to

the new market and business environment (Aboelmaged M., 2018). Through the triple bottom line, the businesses are protecting the environment in which they operate, supporting people, and increasing their profit base (Enyoghasi C. and Badurdeen F., 2021). Therefore, It can be beneficial to develop a business case for I4.0 sustainability to demonstrate the economic, environmental and social benefits created by I4.0.

2.1 Economic performance factors

Supply chain economics has been extensively investigated and published (Snyder 2011). Historically, integrated supply chain design techniques have placed a premium on economic performance factors such as cost or profit, customer happiness, responsiveness, or service level (Ghobakhloo M. and Fathi M., 2021). Ali S., Ali A., AlKilabi M., et al., (2021) reviewed integrated approaches, including supply chain design, and found their distinguishing characteristics. In static single-period deterministic problems, the majority of publications reviewed used mixed-integer programming models with cost minimization as the desired objective function. Hopkins J., (2021) conducted a review of the literature and graded papers based on their supply chain performance. The study includes both qualitative performance criteria (such as customer satisfaction and supply chain flexibility) and quantitative performance elements (such as customer satisfaction and supply chain flexibility). Hopkins J., (2021) stated that the papers he analyzed concentrated primarily on one metric: cost minimization.

2.2 Environmental performance factors

The most frequently used environmental factor used to incorporate environmental considerations into supply chain design is the amount of CO2 or GHG emissions (i.e., carbon dioxide equivalent (CO2- e) created by a supply chain. Several environmental concerns raised in the SCM literature include greenhouse gas emissions, waste generation, energy consumption, water consumption and the use of hazardous and toxic substances in products (Jemai J., Chung B. and Sarkar B., 2020). Environmental performance factors could focus on air, water or solid waste in response to these issues (Shao X., Liu W., Li Y., et al., 2021). There are a large number of environmental factors that can be used as performance indicators (Vaio A., Palladino R., Hassan R., et al., 2020). Given the breadth of environmental performance factors, the issue of GHG emissions has been highlighted as the most pressing in the literature due to the significant consequences for ecosystems and human health, which resulted in the implementation of

several emission control regulatory policies globally (Chowdhury M., Umme N., Nuruzzaman M., 2018).

2.3 Social performance factors

According to several review studies, practical modelling efforts that integrate the social dimension of sustainability in addition to environmental and economic objectives are virtually non-existent (Prasada D., Jabbour R., Gaurava K., et ai., 2020). Ghobakhloo M. (2020) conclude from a comprehensive review of the literature that "research on GSCM tends to focus primarily on environmental challenges, whereas the dimensions are often overlooked in empirical research on GSCM modelling". It has been argued that because social performance measures are difficult to capture and quantify, they cannot simply be incorporated into supply chain models (Jemai J., Chung B. and Sarkar B., 2020). However, social performance factors can play a crucial role in defining the selection choice factors that exist in Green supply chain design. Social indicators can have an effect on the optimal configuration of a supply chain in terms of social sustainability. For example, selecting socially responsible suppliers enables companies to avoid reputational damage caused by supplier social misconduct. This consideration can alter the ideal supply chain setup of a focal firm (Zhang Q., and Ma Y., 2021).

2.4 Research gap

1. While studies have been done on success factors of green supply chain management, there is limited research conducted on GSCD embracing in I4.0 (Mubarik M., Naghavi N., Mubarik M., et ai., 2021). Hence, there is the need for a study that provides a clear view of the integration of GSCD's KEFs in I4.0.

2. There are many companies in Egypt which consider I4.0 as a big challenge towards attaining sustainability. Ghobakhloo M. (2020) posited limited research studies on I4.0 and sustainability. Thus, there is the need to carry out a research study on the effectiveness of the (GSCDs) and their impact on the company's performance.

3. There is also lack of guidelines that focus on the three dimensions of triple bottom line in relation to the GSCD in I4.0 (Jemai J., Chung B., and Sarkar B., 2020). The area is unexplored to implement supply chain design decision support tools in practical applications or projects.

3. METHODS OF INVESTIGATION AND FIELD OF ANALYSIS

The research uses a mixed methodology, collecting data through questionnaires and interviews. Research questions, as well as research goals and objectives, require both qualitative and

quantitative approaches; thus, a mixed method approach was used in the study. It was decided to employ both approaches in order to maximize the benefits of each and to get a complete picture of the state of GSCD embracing within the context of Industry 4.0. The researcher concluded that the use of mixed methods would enable him (Creswell, 2009) to identify the KEFs of GSCD embracing in industry 4.0 in order to achieve sustainable competitive advantage (SCA) within the context of Egyptian manufacturing companies. Using a quantitative questionnaire would examine current perceptions of these factors across the organization, which could be followed up with semi-structured interviews with people involved in the embracing process to get their views on the impact of the factors on the process.

According to Creswell and Plano Clark (2011), the use of mixed methods helps increase internal validity by ensuring that the researcher is well-informed and that conclusions are reached with a thorough understanding of the firm. The mixed approach also provides external validity, as the research questions are asked in more than one context and persons. The questionnaire and interview questions were developed based on the results of the literature review, which also contributes to the development of internal validity (Creswell, 2009).

3.1 Data Collection

3.1.1 Reviewing Techniques

The researcher identified 33 articles from the three databases. A full table of the articles of systematic literature review showed in appendix I. Thus, the exhaustive literature review was done to explore the issues encountered by developing nations in managing sustainability and identifying the KEFs of GSCD embracing that using industry 4.0 technologies. The articles that have been recognized cover a variety of related fields, including management, marketing, operations management, industrial engineering, management science, and system design. Due to a lack of precise keywords describing the issue, we make a concerted effort to classify papers by examining their titles, abstracts, and texts. Typically, this stage is accomplished by directing attention to prominent journals, and conferences. This is not true for GSC and Industry 4.0, as this is a relatively new topic that emerged only a few years ago and the associated publication networks are still in their infancy. The period 2010–2018 is covered by a review of the literature using major scientific and general search engines, including Thomson Reuter's Web of Science, Taylor & Francis online, Elsevier's Scopus, Emerald Insight, and Science Direct (Elsevier).

The researcher reviewed and curated related research to achieve the goal of identifying key embracing factors for designing a GSC in Industry 4.0. The following summarizes the GSC and Industry 4.0 article review methodology:

1: Source identification (online platforms)

2: Keyword Research: The final list of keywords is, “Sustain, Sustainable, Sustainability, Green, Industry 4.0, Smart factory, Digital, Supply chain, Tribble bottom line, Egypt, textile industry, sustainable competitive advantage and Logistic”.

3: Taxonomy and analysis of journal articles

4. Issues and contributions include: SC, Sustainability, Industry 4.0, Features, Components and Technologies, and key Factors.

5: Survey results: degerming the key embrace factors as per appendix I.

3.1.2 Empirical analysis

This study's theoretical underpinnings were strengthened by an empirical investigation that combined qualitative and quantitative methods (Lauri M., 2019). Online questionnaires and interviews were used to collect primary data. Online questionnaire was chosen because it is highly flexible since it was administered through emails, telephones and online google form (Snyder H., 2019). In addition, this study used a distance zoom interview and skype, the interviewee gathered information from the participants with a proper contact in advance with them (Granikov V., Hong Q., Crist E., et ai., 2020). Furthermore, to get a clearer sense of the Key Embrace Factors, an empirical investigation was necessary. Survey data can be edited and analyzed with the help of SPSS, a program developed by the Statistical Package for the Social Sciences (Joslin R., Müller R., 2016). Therefore, an empirical study was conducted out using SPSS 21.0 in order to determine the key factors for the study.

3.2 Case selection

For this study, Egypt Chamber of Commerce and Industry (ECCI) is the source of data to identify ten manufacturing companies using I4.0 as a sustainable means to enhance production efficiency. Textiles and clothing are an important industry in Egypt. The objective of the 2020 sector strategy is to maintain a compound annual growth rate (CAGR) of 15% in order to increase exports from their current level of USD 2.6 billion to USD 10 billion in 2020 (S. E. Ibrahim and K. H. Ahmed, 2011).

ECCI 's vision for attracting new investments in the sector is:

- Strengthen the upstream supply chain;

- Put more emphasis on rapid delivery of garments to the European Union, allowing entry into a higher value-added market segment;

- Focus on the following various sub-sectors:

o Denim factories o Denim laundries o Intimate apparel o High-end knitters o High-end fabric and cotton manufacturers o Spinning and weaving mills.

Therefore, according to the objectives of the study, a textile manufacturing company was chosen as the case organization. The XYZ company was founded in 1970 and is based in Cairo-Egypt. It employs approximately 650 people over three shifts and generates annual revenue of $170 million. The organization serves a diverse customer base across the country but has yet to establish a brand internationally. Therefore, the management is constantly working to ensure that the products meet international product standards and are durable. Following a discussion with senior management, they agreed to help the author test the process for improving sustainability using their Industry 4.0 technology.

For the interview process, an expert group consisting of ten experts was convened. This included a senior manager, two project managers, a supply chain and operations manager, a research and development manager, and a warehouse and packaging supervisor. Each member of the group had an experience between 10 to 15 years; the two project managers and the head of supply chain had extensive experience in international business management, while the warehouse and R&D experts had previously managed green and sustainability initiatives.

3.2.1 Questionnaire structure

An empirical study was conducted to check the statistical establishment of all identified key embrace Factors to enhance sustainability in I4.0. A questionnaire was prepared based on a1–5 scale (i.e., 1 - strongly disagree and 5- strongly agree) (Granikov V., Hong Q., Crist E., et ai., 2020). The pre-testing of the questionnaire was done with the help of area experts who held large experience in this area within XYZ company. Based on their inputs, the language of some questions was amended and made simpler to understand. After the modification, a final questionnaire was prepared, and a small sample was used for pilot testing. The research team initially used a convenience sampling method for data collection but after meeting some respondents, they referred us to the company's staff who were working in the same area. After

following this process, the researcher was able to collect 30 respondents to conduct the empirical analysis, which is quite acceptable.

3.2.2 Bias measurement

When primary data is collected, it can be skewed by respondents' preconceived opinions. To minimize this, the researcher kept all responses and opinions anonymous (M. Saunders, P. Lewis, and A. Thornhill, 2012). To help respondents understand the study objectives, they were sent to them with a brief description of the study, so that they could spend more time completing the questionnaire and providing answers without bias.

3.2.3 Validity and reliability

SPSS 21.0 was used for reliability and validity testing. The researcher used reliability and validity tests to determine not only the accuracy of the data collected, but also the "quality of a measurement". This paper used Cronbach's alpha (α) and its recommended values to determine reliability (Joslin R., Müller R., 2016). If the factor loading of each variable is greater than 0.5, the data has convergent validity. Cronbach's alpha (α) was 0.720 in this study, indicating that the data was acceptable according to previous literature (Georgiadis G.and Poels G., 2022). If the factor loading of each item is greater than 0.5, the instrument demonstrates both internal consistency and convergent validity (Snyder H., 2019).

4. RESULTS AND DISCUSSION

4.1 Key embrace factors of green supply chain design in industry 4.0

Based on the analysis, the key embrace factors for the given companies were six (6). In regards the researcher used the below correlation matrix table 2 to determine the influence of these factors. Thus, since the results obtained illustrated that the correlation value was above 0.50, it was therefore concluded that the variables were essential in the process of integrating GSCD into Industry 4.0 since they had a high correlational rate.

Correlation Matrix							
		Resources	Pressure	Government and Corporate Support	Strategic alignment	Collaboration	Technology
Correlation	Resources	1.000	.605	.675	.573	.685	.704
	Pressure	.605	1.000	.723	.679	.815	.750
	Government and Corporate Support	.675	.723	1.000	.716	.785	.821
	Strategic Alignment	.573	.679	.716	1.000	.755	.730
	Collaboration	.685	.815	.785	.755	1.000	.805
	Technology	.704	.750	.821	.730	.805	1.000

Table 2. Correlation Matrix

4.1.1 User Experience and Pressure

The users of the GSCD are the various stakeholders who get to interact with the technology practices and the models developed daily. The way they interact with them and their experience from the industry give rise to the desire to implement the GSCD in I4.0. A force of pull and push characterizes the market environment (Vaio A., Palladino R., Hassan R., et al., 2020). Various players in the textile market exert their effect on the company. The various stakeholders such as the government, the society, the shareholders, the customers and regulating agencies, among others, exert pressure on the XYZ company compelling it to comply. Whenever a regulation is enacted, the regulating body has to come in between enforcing it and ensuring it is implemented. Thus, a regulation requiring that companies implement or adopt GSCD will compel the company to do so due to the inherent pressure. The external pressure comprises the customer, and the market demands force the company to embrace the GSCD. A good example is when the business partners pressure the company to adopt GSCD or stop the partnership. If the pressure is beyond the organization's control, the only option will be to embrace the sustainability practices (Jabbour A., Jabbour C., Foropon C., et al. 2018).

4.1.2 Strategic Alignment

One reason that compels XYZ company to embrace sustainability measures in industry 4.0 is to align itself strategically in the market and thus gain a competitive advantage over others in the industry. There is a growing awareness about the environmental effects of the pollutants

and contaminants released by the industries. Companies in the same industry are in competition to outdo the rivals (Simões, Barros, & Soares, 201. Thus, the company induces competitive pressure on each other, thus driving the necessity to seek competitive advantage by embracing a GSCD that gives it greater leverage. Companies fear losing their competitive advantage, forcing them to develop strategies to embrace and implement GSCD (Wenge Zhu W. and He Y., 2017). Therefore, competitive pressure compels firms to align themselves strategically in the market. Strategic alignment is thus an important factor determining whether a company will adopt new technology such as those affiliated with GSCD. Thus, businesses are more concerned about adopting sustainability measures in their supply chain networks. To ensure sustainable development, an organization must consider sustainability issues since they aid in accomplishing viable and competitive performance. Sustainable practices grant the company a new brand image by implementing strategies that resonate well with society. Thus, the company gains a greater competitive advantage that places it in better positions than its competitors (Bhui R., Lai L., Gershman S., 2021).

4.1.3 Finances and Resources

Finances and resources are essential in implementing an initiative such as GSCDs in industry 4.0. Without the resources, nothing can be actualized. The GSCDs are expensive, and for a company to adopt them, it must have the financial muscles. Resources enable a company to achieve a competitive advantage (Cabrera S., Pishchulov G., Sampaio P., et al., 2021). Finances are the most Key Embrace Factor in adopting sustainability projects in industry 4.0. Finances are resources needed to set up the frameworks for sustainability projects. It cannot succeed without the money required to develop or embrace the green supply chain design. Therefore, it is the main factor in the decision-making process of related projects. Human beings are also the resources needed to implement green supply chain designs. The machines interact with human beings as they perform work in the company. Human beings must interact effectively with the technical machines used in industry 4.0 and enhance sustainability practices. They must have the required skills and knowledge needed to operate the GSCDs otherwise; they will not be useful in the organization. Workforce knowledge and expertise in the management of resources as a key embrace factor of GSCDs in industry 4.0 (Chang H, Wong K. and Chiu W., 2019). This illustrates that the human resource must be useful by possessing the required knowledge and expertise.

4.1.4 Government and Corporate Support

The corporation and the government approved the implementation of a project. Sustainability and management are intertwined since it is an imperative aspect of the organization's mission statement (Ali S., Ali A., AlKilabi M., et al., 2021). As a result, top management and leadership arise, who must support its implementation. Therefore, the managers and the corporate team perform critical work in influencing whether the projects will be adopted or not. Implementing the green supply chain designs and other sustainability strategies and practices must be supported by the top leadership and management in an organization (Ghobakhloo M. and Fathi M., 2021). Managers influence the flexibility of the employees and the adoption of the green initiative in an organization. Besides, the government supports adopting sustainable practices through various means such as regulatory frameworks. For instance, the regulatory bodies in the government can compel organizations to take responsibility for the end products of a product. Related laws and regulations have been adopted to ensure that firms ensure societal and ecological sustainability (Mubarik M., Naghavi N., Mubarik M., et ai., 2021). The policies developed by the government and the company must be supportive enough to facilitate the implementation of GSCDs. Therefore, government and corporate (management) support is a significant KEF of GSCD in industry 4.0 in Egypt.

4.1.5 Collaborations

Collaborations are also central towards enhancing GSCD in industry 4.0. The collaboration of customers, suppliers, sellers and producers in an industry is a noble requirement to adopt sustainable supply chain practices. The supply chain members must collaborate to develop processes, technologies, and products that push for the implementation of social and environmentally friendly practices and technologies (Ghadimi P., Wang C., Lim M. and Heavy C.,2019). This indicates that the business organization affiliated with the company can compel the suppliers to embrace sustainable initiatives that aid in the reduction of greenhouse gas emissions and enhance the supply chain design. Collaborative partnerships go beyond the industry and its supply chain since they can include the research institutes, universities and agencies (Gardas B., Raut R., Narkhede B., 2019). Such agencies and institutes facilitate better research that develops and designs better evidence-based and effective technologies in driving sustainability in an organization. The design requires extensive research to ensure that effective outcomes are attained (Jemai J., Chung B., and Sarkar B., 2020). As a result, partnership with learning and research institutions is a haven for success as it provides an invaluable associated pool of resources that lead to the identification of the best design to drive industry 4.0. Various

universities in Egypt have started hosting incubators for start-ups. They seek to work with the private sector to develop and address challenges using targeted solutions, infuse the local ecosystem, and harness talent and expertise.

4.1.6 Technology

Information technology is a success factor in adopting GSCDs in industry 4.0. Information technology can be classified as a resource necessary to implement sustainable supply chain designs (Aboelmaged M., 2018). Technology is also an important resource in the success and embrace of the GSCDs in industry 4.0. Industry 4.0 is technology-intensive, implying that many technologies and machines must attain sustainability. For instance, adopting lean manufacturing, a green supply chain design, requires integrating technology for sustainability purposes. This indicates that information technology is an important resource required to implement the GSCDs in industry 4.0. The development of infrastructure and information technology (IT) based facilities is a key success factors in adopting GSCDs in industry 4.0 (Mubarik M., Naghavi N., Mubarik M., et ai., 2021). This identifies infrastructure as resources that are required for the implementation of the green supply chain designs. The GSCDs cannot be implemented without the infrastructure, and the initiative would not succeed.

4.2 Theoretical contributions

One of the strongest contributions in this study is to enrich academia on the most important KEFs that companies can use in the process of integrating GSCD into Industry 4.0 and increase awareness of SCA (Mubarik M., Naghavi N., Mubarik M., et al., 2021). In which, there is no study highlighted the concept of KEFs of GSCD embracing in I4.0. The study also provides a group of various key embrace factors of GSCD in I4.0. Based on the findings, the six embracing factors lead to a significant effect on the level of sustainability performance in I4.0 in Egypt (Jabbour A., Jabbour C., Foropon C., et al. 2018). This will assist the stakeholders involved in the integration process of GSCD in I4.0 to focus on the priority ones. This study successfully demonstrated an interlink between the TBL, KEFs of GSCD and SCA in the industry 4.0 (Wenge Zhu W. and He Y., 2017).

The following points highlight important research contributions:

• The results of this research will advance knowledge on the subject of strategic roadmap for GSCD in Industry 4.0 and its potential applications in the Egyptian textile industry. XYZ Company has adopted the Green Supply Chain initiative as part of its Industry 4.0 strategy to

improve the efficiency of its performance in providing services to customers, businesses and government agencies.

• The study analyzes in depth the factors critical for the design of a green supply chain in Industry 4.0. The study establishes a guideline for future researchers and experts to use in planning future projects. It focuses on critical adoption factors for successful project deployment, allowing readers to better understand the importance of GSCD adoption in Industry 4.0 project planning.

• The study strengthens the theoretical foundations of GSCD adoption in Industry 4.0 projects and provides a theoretical guideline for companies to plan, build, deploy and popularize the adoption of GSCD in the project of industry 4.0.

5.0 CONCLUSION

The enrolment of new technologies in Egypt is relatively minimal since the country is developing and thus cannot be compared with the developed ones (Al-Ayouty I., Hassaballa H, and Rizk R., 2017). However, the government and the existing organizations are putting a lot of effort into ensuring that the industry 4.0 is adopted and that the KEFs are considering. The identified six KEFs were singled out from a spectrum of factors and thus formed a critical aspect in the success of the GSCD embrace in the selected industry 4.0 company (Vaio A., Palladino R., Hassan R., et al., 2020). To solve the current issue, the study uses a new combination of empirical analyzes via questionnaires and interviews. First, the study conducts an empirical analysis to determine the most important adoption factors affecting sustainability. Later, the key Embrace Factors identified (as per appendix I) were supplied and tested in XYZ company with the aim of increasing sustainability and international competitiveness.

KEFs of GSCD in industry 4.0 enhance one of the Triple Bottom Line factors: the economy through creating sustainable value, opening up new business model opportunities, increasing turnover, enhancing security, reducing operational costs, and increasing efficiency and profit (Jamwal et al. 2021). Besides, it also has a huge impact on the market share and supply chain. The social sustainability dimension of TBL is also influenced KEFs of GSCD in industry 4.0 through employment, reduction in accidents, improvement in working conditions, improvement in living conditions for communities, and better collaboration among stakeholders (Jamwal et al. 2021). Also, the environmental sustainability dimension of TBL is influenced by KEFs of GSCD in industry 4.0 through the promotion of circular economy, reduction of global warming, energy consumption and resource consumption, reduction of industrial waste, and reduction in

the use of non-renewable sources and energy consumption. These findings reveal that KEFs of GSCD in industry 4.0 is critical in enhancing sustainability in all three dimensions of TBL.

5.1 Practical contributions

The highlighted KEFs of Green Supply Chain Design enhance a company's Sustainability Performance through Triple Bottom Line, as explained by the natural resource-based view of the company. It interacts with the natural environment to create a competitive advantage (Chang H, Wong K. and Chiu W., 2019). This is because sustainable development initiatives such as pollutants removal and prevention of waste products reduce costs, and efficiency becomes enhanced in the entire supply chain (Chowdhury M., Umme N., Nuruzzaman M., 2018). Once the efficiency is enhanced and costs are decreased, the company gains greater leverage than others. Besides, it has superior value for its customers that are better than its competitors, thus giving it a Sustainable competitive advantage (Cabrera S., Pishchulov G., Sampaio P., et al., 2021).

The following points highlight important practical contributions:

•The results of this study are extremely encouraging from a practical point of view, as they corroborate the theoretical postulates concerning the factors affecting the success of the implementation of e-government in the textile industry in the context of the 'Industry 4.0.

• A case study from Egypt shows how sustainability goals can be considered.

• The factors identified and discussed in the analysis section of this document would be extremely beneficial in developing standard operating procedures and in planning new projects for designing a green supply chain in Industry 4.0 in Egypt .

• The research examines how involving management and all stakeholders in the change process benefits GSCD's adoption of Industry 4.0. It includes anecdotes shared by managers and employees who have worked on Industry 4.0 projects with GSCD and the insights they shared. All of this could serve as a starting point for further research and benchmarking by various organizations with regards to the design of a green supply chain in Industry 4.0.

5.2 Limitations

This study was conducted in Egypt. However, other countries around the world can benefit from the current results by adjusting the factors ranking level with the advice of professionals in I4.0. On the other hand, the articles classified in this literature review rely heavily on the results of academic reviews. Adding more industry reports in the future may help improve the

results of this analysis. In addition, the researcher designed a closed questionnaire to facilitate the collection of the necessary information; however, data collection was difficult as many companies were unwilling to contribute due to privacy concerns; Additionally, the researcher have assured our respondents that the data will not be shared with any government office or non-governmental organization.

APPENDICES

Appendix I : Comprehensive Key Embrace Factors for Designing a green supply chain in I4.0.

S/N	Key Embrace Factors	Industry 4.0 technology	Criteria	Source article
1	1. Government promotions and regulations 2. Economic benefits, Attracting foreign direct investment 3. Improving Quality 4. Education and Training system	Cyber physical system	Ecological	Bhanot, Rao and Deshmukh (2015)
2	1. Collaboration and transparency among supply chain members 2. Management support and effective governance 3. Development of infrastructure and information technology (IT) based facilities 4. Competitiveness 5. Improved information sharing system and resource development 6. Reduction in waste and improved cost efficiency	Manufacturing industry	Ecological, Economical and social	(Sunil Luthra & Garza-Reyes, 2019)

	7. Workforce knowledge and expertise in managing resources 8. Government supportive policies 9. Adoption of innovative business models			
3	1. Energy prices 2. Market share 3. processing and manufacturing times for technology 4. effect of customer satisfaction	Additive manufacturing	Ecological	(Hamid Afshari & Jaber, 2019)
4	1.Collaborative partnership 2.Information technology, 3.Top management support 4.Human resource	Intelligent logistic	Economical	(Talib & Hamid, 2014)
5	1. (network) Collaboration with research institutes, agencies and universities 2. Access to external information and knowledge, including technology support services 3. Material production (incentive to innovate, to use less material and decrease the cost) 4. Technological and management capabilities within the enterprise	Transport and Logistics Services ICT Adoption	Ecological, Economical and social	(Triguero, Moreno-Mondéjar, & Davia, 2013)

	5. Energy prices 6. Market share 7. Increasing market demand for green products 8. Existing regulations 9. Future regulations imposing new standards 10. Access to existing subsidies and fiscal incentives			
6	1. Collaboration with partners 2. Mutual trust 3. Green business understanding 4. Planning and implementation 5. Standardizing and integration 6. Activation of supporting for GSC 7. Strategic use of IT	Transport and Logistics Services ICT Adoption	Ecological, Economical and social	(Kim & Rhee, 2012)
7	1. Competitive advantage 2. Pressure/encouragement by customers 3. Regulatory compliance 4. Costs reduction 5. Monitor environmental performance	Additive manufacturing	Ecological, Economical and social	(Walkera, Sisto, & McBain, 2010)
8	1.Management leadership 2.Readiness for organisational change 3. Training and capacity building	Manufacturing	Ecological	(Jabbour, Jabbour,

	4. Strategic alignment 5. Top management commitment 6. Empowerment 7.Teamwork and the implementation team 8. Project management 9. Organisational culture 10. Communication 11.National culture and regional differences			Foropon, & Filho, 2018)
9	1. Digitisation of supply chain activities 2. Promoting knowledge management in supply chain 3. Management engagement towards sustainability adoption	Additive manufacturing	Economical, and Ecological	(Yadava, et al., 2020)
10	1. Governments and regulatory authorities. 2. collaboration and information sharing 3. Competitive advantage	Additive manufacturing	Ecological	(Ghobakhloo, Iranmanesh, Grybauskas, Vilkas, & Petraitė, 2021)
11	1. collaboration among interested parties 2. Communication 3.Automation and cooperation	Internet of Things (IoT)	Economical	(Adebanjo, Laosirihongthong,

	4. Training and professional development 5. Well established ecosystem			Samaranayake, & Teh, 2021)
12	1. Top management commitment + Strategic alignment 2. Employees' empowerment + Knowledge sharing + Effective communication 3. Internal innovation process 4. Data-centered solutions + Consistent data flow 5. Interdisciplinary and holistic integration + Life cycle 6. Customer and supplier integration 7. Governmental and institutional pressures 8. Valuing R&D/Research Centers	Big data	economic, Ecological, and social	(Machado, Scavarda, Caiado, & Thomé, 2021)
13	1.Communication and cooperation 2.Leadership and experiences 3. Quality 4. Employees and Flexibility 5. Finance 6.Plans and deadlines	Internet of Things (IoT)	Ecological	(Vrchota, Řehoř, Maříková, & Pech, Critical Success Factors of the Project Management

				in Relation to Industry 4.0 for Sustainability of Projects, 2021)
14	1.Government legalization 2. Societal considerations 3. Supply chain members' collaborations 4. Ecological considerations in organisations' policies and missions 5. Technology development and process innovation 6. Training 7. Community welfare and development 8. Green design and purchasing 9. Ethical and safe practices 10. Reverse logistics and waste minisation 11. Competitiveness and brand image considerations 12. Economic consideration 13. Investment recovery	Automobile industry	Social, Ecological and Economical	(Luthra, Mangla, Shankar, Garg, & Jakhar, 2018)

	14. Customer involvement and encouragement			
15	1. Strategy (Human resource and management, financial position, company position) 2.Top management (manufacturing vision, top management commitment, financial circulation) 3.Organization (benefit of technology, employee knowledge, alignment of organization and business, benefit of technology, organization structure) 4.Technology (facility and infrastructure, human and technology resources, technology in use) 5.Environment (business planning, vendor development, external pressure)	Advanced manufacturing technologies	Economy and Ecological	(Sukathong, Suksawang, & Naenna, 2021)
16	1.User experience 2.Collaboration	Biometric systems	Economical	(Borgianni, Rauch, Maccioni, & Mark, 2018)
17	Business, Technology, Sustainable Development, Collaboration and Management Strategy	Internet of Things (IoT)		(Manavalan & Jayakrishna, 2018)

18	Financial condition	Advanced manufacturing technologies	Economical	(Singh, Garg, Deshmukh, & Kumar, 2010)
19	1. Financial availability 2. Support and commitment of top management 3. Tactical and strategic factors	Advanced manufacturing technologies	Economical	(Rahardjo & Yahya, 2010)
20	1. External pressure 2. Government/Political Directives (Local and national) and their agencies 3. Technology infrastructure 4. Potential for innovation	CNC, CAM, FMS and robotics	Economical	(Simões, Barros, & Soares, 2018)
21	1.Organizational 2. Environmental contexts 3. Competitive pressure	E-SCM	Ecological	(Lin, 2014)
22	1. External 2. Internal 3. Societal 4. Committal	Green manufacturing	Ecological	(Govindan, Diabat, & Shankar, 2015)
23	1.Top management commitment 2. Government initiatives 3. Green sourcing 4. Green design 5. Green operations 6. Green packaging	Logistics	Ecological	(Routroy, 2012)

	7. Reverse logistics 8. Environmental management system 9. Green innovation 10. Customer awareness			
24	1. Customer requirements 2. Competitive pressures 3. Resource conservation opportunities	environmental management systems (EMS)	Ecological and economical	(Pun, Hui, Lau, & Lewis, 2012)
25	1. State rules and regulations 2. Customers 3. Internal motivation 4. Firm performance	Big data	Ecological	(Agan, Acar, & Borodin, 2013)
26	1.Business efficiencies 2. Innovation 3. Cost 4. Brand positioning 5. Business communication	Ecodesign technology	Ecological	(Santolaria, Oliver-Solà, Gasol, Morales-Pinzónad, & Rieradevall, 2011)
27	Financial benefit, Supply chain requirement, Stakeholders, Supply chain requirement, Customers, Environmental conservation, Market trend, Competitors	CNC and robotics	Ecological, economical, and social	Dornfeld et al. (2013); (Dornfeld, Yuan, Diaz, Zhang, &

				Vijayaraghavan, 2012)
28	Internal motivations, Customers, Market trend, Competitors, compliance with regulations, Company image	Green technology	Ecological	Agan et al. (2013);
29	Company image, Market trend			(Deif, 2011)
30	Competitors, Market trend, internal motivations, Employee demands, customers, Stakeholders, Financial benefit, Company image	Standardized management systems.	Economic	(Searcy, et al., 2012)
31	Financial benefit, Company image, Compliance with regulations, environmental conservation, market trend	Advanced manufacturing technologies	Ecological	Gabzdylova et al. (2010) (Gabzdylova, F.Raffensperger, & Castka, 2013)
32	Supply chain requirement, Stakeholders, Green innovation	Sensors	Economic	(Zhu & Sarkis, 2011)
33	Customers, Financial benefit, internal motivation, Competitors	Automative	Ecological	(Wu & Wirkkala, 2019)

Appendix II : Interview questions

Interview on the Key Factors for Designing a Green Supply Chain in Industry 4.0 for Egyptian manufacturing companies

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The interview is being conducted solely for research purposes, and your responses will be used exclusively for that purpose. Your personal information and responses will remain secure and confidential throughout the process. All confidential information will be treated with the utmost care and will not be disclosed.

General information:

Position:

Experience:

Email address:

The following data are required in order to assess, analyse and optimise your company's supply chain network design.

1. What is the purpose of your decision to implement Industry 4.0 in your business?
2. In your opinion, how important is designing green supply chain(s) in Industry 4.0 for your company?
3. What do you think is the most important environmental factor for embracing a green supply chain design in I4.0?
4. What do you think is the most important social factor for embracing a green supply chain design in I4.0?
5. What do you think is the most important economic factor for embracing a green supply chain design in I4.0?

6. Could you please identify any other factors that you consider important in the integration process? And would you specify the aspect (environmental, social and economic)?
7. Do you think all of the factors you've highlighted have a strong influence on sustainability performance? And What competitive advantage(s) do you currently have?
8. What are your expectations for the future to gain a sustainable competitive advantage? from the point of view of cost saving, ecological effects, etc.?
9. Would you like to share any additional information that might be useful for this study?

Thank you very much for your time and effort.

Appendix III: Questionnaire

Questionnaire on the Key Factors for Designing a Green Supply Chain in Industry 4.0

A questionnaire is prepared based on a1–5 scale (i.e., 1 - strongly disagree and 5- strongly agree)

It is estimated to take only 15- 20 minutes to respond to all below questions

Overview

This questionnaire aims to cover Key Factors for designing a green supply chain in industry 4.0 to improve sustainability practices through tribble bottom line.

The questionnaire includes the following two parts:

Part 1. General Information

Part 2. Key Embrace Factors

Part 1. General Information

Years of Experience:

Position:

Part 2: Key embrace factors

1. Financial resources and budget availability are an important organizational resource required for GSCD embracing in Industry 4.0.
2. Senior management allocates adequate resources and time to design a green supply chain.
3. The purpose of GSCD embracing in Industry 4.0 is to offer convenience to the users.
4. The trust of users on Green Supply Chain is important for the GSCD embracing in Industry 4.0.
5. Senior management has a clear vision for the Designing a Green Supply Chain.
6. Egyptian Government creates awareness of the need for the Green Supply Chain among managers and employees.
7. Strategies are adopted to ensure that employees do not consider Industry 4.0 a threat against their authority.
8. Aligning the use of Industry 4.0 with the performance measurement system is important to achieve GSCD embracing in Industry 4.0.

9. Communicating the embracing progress is important to ensure the effectiveness and sustainability of Designing a Green Supply Chain in Industry 4.0.
10. Your company offers open communication channels to employees, and stakeholders for GSCD embracing in Industry 4.0.
11. The rapid changes in Industry 4.0 technology make the entire system obsolete and everything needs to restart from ground zero.
12. Training is provided for employees who lack the technological competence required for Designing a Green Supply Chain in Industry 4.0.
13. employees encouraged to be creatively involved in the decision-making process for Designing a Green Supply Chain in Industry 4.0?
14. Does the implementation of GSCM practices improve your company's overall transparency to your stakeholders?
15. What are the following effects of your environmental practices on reduction of emissions and waste in all stages of the supply chain?

    Air emissions,

    Management of waste materials

    Purchasing and Production,

    Inbound logistics, outbound logistics and reverse logistics

    Others

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