Effect of industry 4 emerging technology on environmental sustainability of textile companies in Saudi Arabia: mediating role of green supply chain management

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Abstract

Purpose – The research objective was to check the impact of industry 4 (I4) technologies on environmental sustainability (ENS) with the mediating role of green supply chain management (GSCM) of textile companies in Saudi Arabia.

Design/methodology/approach – Data was collected from those respondents who were linked with management and also have knowledge of I4 technologies. The researchers distributed 500 questionnaires among respondents for data collection, 350 questionnaires were received, and used for analysis. The researchers employed the quantitative research approach and cross-sectional research design.

Findings – The results indicate that I4 has a positive effect on ENS and GSCM practices except for green purchasing where I4 has an insignificant impact on green purchasing. On the other hand, GSCM practices also significantly mediate between I4 and ENS except for green purchasing which has an insignificant mediating effect.

Practical implications – This study has a great theoretical contribution to literature as it provides strategic insight to managers as well as policymakers. From the perspective of resource-based view, this study is supportive to use I4 technology practices in GSCM. Furthermore, the current research suggests managers to implement I4 technologies and adopt the GSCM practices. These practices should be part of environmental strategies. The implementation of these practices will assist in building a strong reputation and satisfaction of customers and to fulfill the requisites of stakeholders.

Originality/value – The research was conducted with the extended framework of the mediating effect of GSCM between I4 and ENS of Saudi Arabia textile companies which are considered to be a pioneer study in the extant literature.

Keywords Environmental sustainability, Technology, Textile sector, Saudi Arabia
Paper type Research paper

1. Introduction

In the age of swift globalization and industrialization, the factor of sustainability continually gains attention all around the world (Goodland, 1995). According to Holden*et al*. (2014), sustainability is a development function that ensures that the needs of the

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current generation are met without jeopardizing the availability of resources for future generations. For decades, the business world is facing sustainability issues like social, economic and environmental aspects. Generally, traditional production and consumption methods are the main cause of extreme sustainability crises in result of resource shortageand environmental degradation. Indeed, the waste products under manufacturing process are causing extensive pollution which is harmful to the global environment (Ajwani-Ramchandani *et al*., 2021). The existing literature highlighted that the use of non-recycling sources in the manufacturing system, un-disposal and unsustainable practices harshly damage the environment (Bag and Pretorius, 2020). Similarly, it is required to implement green supply chain management (GSCM) to avoid environmental distortion, and economic and social misfortunes (Moktadir *et al*., 2020).

No doubt, it is a very challenging task to manage the numerous dimensions of sustainability as organizational transformation is required in the direction of sustainable practices adoption in manufacturing concerns (Kumar *et al*., 2022). For this reason, multiple sustainable practices like green logistics (GL) and green manufacturing (GM) have gained a lot of attention in concern with economy to attain sustainable performance (Blunck and Werthmann, 2017). Modern economy got a lot of attention and popularity in contradiction of the traditional economic practices due to the recycling and reuse strategy (Rehman Khan *et al*., 2022). These strategies focus on eco-friendly practices which moderate energy consumption and production loops, it helps lessen the problems of resource wastage andharmful emissions (Bahadori *et al*., 2021). Implementation of GSCM in production guarantees enhances functionality through the way of successful numerous sorts like maintenance, reuse and durability. The main purpose of GSCM is to reduce wastage in the production process, improvement in product usability and healthy eco-friendly practices (Kayikci *et al*., 2022). Recent studies highlighted that I4 technologies can lead to environmental protection by promoting GSCM in manufacturing concerns (Bag *et al*., 2021).

I4 technologies lead to a progressive transformation that was initiated with the entrance of digitalization. However, I4 technologies meaningfully impact business models, production systems and organizational strategies (Bagnoli *et al*., 2019; Büchi *et al*., 2020). Indeed, GSCM influence the organization's performance positively by providing security through regulatory actions (Harrison *et al*., 2015). GP is very helpful in the retention of existing valuable and experienced employees in the firm as result in the company can attain a competitive advantage (Carter *et al*., 2019). According to Rehman Khan *et al*. (2022), GSCM play a substantial role in attaining sustainable performance. Based on variations in the results of different GSCM, there is the possibility that different GSCM may show different impacts on firm performance (Namagembe *et al*., 2018). Based on these groundings, there is arobust need to analyze the influence of specific GP on a firm's sustainability and performance. Despite numerous studies contributed to economy and I4, but still, there is need to address these two concepts for in-depth analysis.

The existing body of knowledge rarely discussed the influence of I4 technologies on the globular economy to strengthen the environment (Rehman Khan *et al*., 2022). The previous studies mainly focused on the directly effect of industrial technology on environmental sustainability (ENS) but had little attention to the indirect effect of industrial technology on ENS (Umar *et al.*, 2021a). Moreover, previous literature also has major focused on the direct effect of GSCM practices on ENS (Umar *et al.*, 2021a) while having little attention to GSCM practices as a mediating variable between the relationship of industrial technology and environmental sustainability (Khan *et al*., 2022c). The GSCM was used as a mediating variable with following practices GM and GL while ignoring green purchasing and eco-design which are also GSCM practices (Umar *et al.*, 2021a) argued that in future studies these practices could be added between the relationship of I4 technology and ENS.

Therefore, this study extended the research framework by adding two GSCM practices namely green purchasing and eco-design with the existing two practices GM and GL as mediating variables. Moreover, the earlier research mostly concentrated on these other industrialized regions (Khan *et al*., 2022c) meanwhile paying less consideration to emerge countries, particularly Saudi textile businesses. Therefore, the present research objective is to investigate the mediating effect of GSCM practices between the relationships of I4 technology and ENS of Saudi Arabia textile companies. This research has significance because the

existing studies have not discussed these factors in the literature. Importantly, the theoretical and practical implications of this study would be used for improving the practices for the advancement of ENS.

2. Literature review and hypothesis development

2.1 Green supply chain management

GSCM is useful for improving the quality of the environment in a better way (Tseng *et al*., 2019). It has become a requirement for the working of the modern industrial sector to improvethe performance of environment-friendly practices. Green innovation helps to improve green supply chain management, and the GM plays a key role in it (Haiyun *et al*., 2021). The advancement of the supply chain in a green way helps to reduce the utilization of resourcesthat are not good for the environment in either way (Badi and Murtagh, 2019). Furthermore, GSCM is a vast concept, but things are required to be discussed critically for the advancement of the supply chain in a green way.

2.2 Green manufacturing

GM is emerging in modern times for the sustainability of the environment (Karuppiah *et al*., 2020). For GM, the policies are developed to ensure that the employees are working in a green way by reducing the utilization of natural resources (Belhadi *et al*., 2020). Furthermore, GM is possible when the technology is utilized fairly to develop the manufacturing units in a more productive way to get the expected outcome in a green way (Mao *et al*., 2019). It helps to save the environment by less focusing on natural resources with production efficiency.

2.3 Green logistics

The role of logistics is critical in any business activity, but green logistics has become a demand of the environment (Yingfei *et al*., 2021). The utilization of technology to improve the GL is the appropriate way to achieve sustainability in the environment. It is based on the utilization of green resources in the reverse and forward flow of products by any industry (Zhang *et al.*, 2020). Furthermore, the share of information in a green way also is a way forward to the green environment and the sustainability of the environment (Jinru *et al*., 2022).GL helps to reduce the wastage of natural resources in the supply chain.

2.4 Green ecosystem

The ecosystem refers to the overall environment of any organization, and the green ecosystem demonstrates the GSCM in the environment (Enssle and Kabisch, 2020). When any industry has a green ecosystem, the functioning improves according to the green way.A green ecosystem developed or promoted by any industry is necessary to enhance the green environment (Langemeyer *et al*., 2020). Fair manufacturing helps to advance the green environment that is necessary for green advancement and its sustainability (Zhong *et al*., 2020). Green production and a green supply chain also help to achieve a green ecosystem.

2.5 Green purchasing

Green purchasing refers to the process of purchasing that has a less negative impact on the environment (Zhang and Dong, 2020). The way of green purchasing is improved when the products and purchasing process is compared to get the final product. The purpose of green purchasing is to protect the environment with core dimensions that are required to achieve sustainability in the environment (Amoako *et al*., 2020). Environmentally friendly products are purchased in the mechanism of green purchasing. The modern practices in the works are improving the efficiency of green purchasing for achieving sustainability in a better way (Nekmahmud and Fekete-Farkas, 2020).

2.6 Industry 4 technology

The I4 technology is based on the development of a modern system of cloud computing and analytics in the industrial sector (Zheng *et al*., 2021). This use of modern phenomena is required to improve modern technology dimensions. The availability of resources for modern technology can be enhanced over time when the designed technology based on robotic functions is used in any country for the betterment of the public and their welfare (Raj *et al*., 2020). The advancement of this technology is necessary to advance the facilities that are deliberately improved to support the industrial sector in the fourth revaluation (Bai *et al*., 2020).

According to Freeman *et al*. (2021), the resource-based view is the most famous theory that provides a strong base for ascertaining different resources and analyzing their roles in organizational performance. For better performance, it is the responsibility of management to investigate all resources and their link with multiple capabilities because resources matter a lot in productivity (Umar *et al*., 2021a). Furthermore, Ployhart (2021) reported that a firm’s performance depends upon the management of valuable assets as this art helps to improve the performance. Particularly, the firms should investigate all their resources to minimize the risk level in uncertain situations. In the global world, the high competition increased the value of different resources (Chong *et al*., 2021) and their efficient use to enhance the productivity. Therefore, it is mandatory for firm’s management to identify the value of available resources and their best use to achieve firm performance to compete with other firms in the market.

By following the resource-based view, the Internet of things (IoT), artificial intelligence, blockchain technology and cloud computing are considered most valuable for the organization to improve efficiency and performance (Bressanelli *et al*., 2018). The main purpose of I4 technology adoption is to replace the traditional practices of manufacturing in new and advanced production systems by introducing remanufacturing and recycling as ithelps to get better results (Saidani *et al*., 2021). The adoption of I4 technologies as well as the use of other resources like ecological awareness and knowledge, reverse logistics, and green human resource practices enables the firm to make superior performance and these findings are new in the literature (Aragão and Jabbour, 2017). In the same way, in cleaner manufacturing reverse logistics works as the crucial source because the whole system of manufacturing depends on it (Govindan and Soleimani, 2017). The technological resources have a very influential role in the implementation of reversal and GSCM in the firm for advance production. To improve the overall manufacturing system, modern technologies can be utilized to attain superior performance through different operations like artificialintelligence, green production, logistic practices, intelligent and advanced storage system, product traceability, inventory control, self-configured workplaces and muster control system and recycling and remanufacturing (Bag *et al*., 2021). Hence, in the formation of a competitive strategy technological integration along with ecologically friendly practices help to attain sustainable results.

2.7 Industry 4.0 and green supply chain management

Modern technological integration is focused on the fourth industrial revolution to attain sustainability in manufacturing concerns, particularly in the large industrial sector (Ben-Daya *et al*., 2020). Currently, many modern technologies are integrated to carry out production changes in manufacturing practices to advance efficiency and effectiveness (Secinaro *et al*., 2020). Specifically, in the modern era, I4 technologies are used to create value and sustainable goal development based on the cloud computing working system (Asiimwe and De Kock, 2019). Furthermore, the technologies of I4 are very useful for the industrial sector which are included cyber-security, IoT, AI, big data analytics (BDA) and blockchains, 3D printing, and other different things (de Bem Machado *et al*., 2022). Interestingly, both small- and large-scale organizations can adopt these technologies to transform the production process (Li *et al*., 2017). Furthermore, I4 technologies helped a lot in achieving sustainability and environmental protection by the manufacturing sector reported in literature (Kumar Mangla and Luthra, 2018). The past studies focused to adopt I4 to implement GSCM to lessen environmental adversities. For example, a green supply chain (GSC) could be efficiently managed by using IoT. As GSC has been assisted by Internet usage, helps to minimize harmful emissions and optimizes the response time (Mastos *et al*., 2021). Recent studies reported that the deficiency of modern technologies is the main hurdle in the implementation of circular economic activities (Sivageerthi *et al*., 2022). However, the use of I4 technologies also helped in decreasing the production waste as well as led to boost up consumption efficiency. Accordingly, I4 technologies assist in information management and facilitate the eco-friendly strategies.

I4 principles are enlightened in the existing literature which is very useful in the implementation of GSCM to improve eco-performance. According to Khan *et al.* (2022a), these features comprise modularity, interoperability, decentralization, service orientation, real-time capabilities and virtualization (Khan *et al.*, 2022d). The real-time capabilities assist in improved adaptation for demand and changes in energy supply; full and efficient utilization of resources leads to modularity; while the best utilization of local sources and available assets of the firm could achieve decentralization; interoperability augments the reduction in wastage and efficient machinery usage; virtualization mainly encourages the eco-friendly practices; service orientation leads to recycling and better use of final products (Carvalho *et al*., 2018). In this way, the entire features of I4 are very influential in the implementation of GSCM to improve the sustainability and performance of industrial sector.

In smart production advanced technologies like CPS, IoT and visual computing play a very critical role. Likewise, innovative human-machine borders could improve productivity, it also provides safety to workers (Ardanza *et al.*, 2019). Smart manufacturing is a very crucial factor in green production, the main purpose of smart manufacturing is to save the environment from pollution and worst situations. Therefore, it is proved that in the promotion of GSCM, I4 technologies have a very important role in inventory management, minimizing the wastage in the production process, allowing the innovation collaborations to boost up the performance of the firm (Szalavetz, 2019). Industry 4 technologies help a lot in the effective decision-making process, better planning and risk management through the collection and analyzing the data (Arunachalam *et al*., 2018). BDA is also helpful in operational performance improvement (Dubey *et al*., 2019).

I4 blockchain technology facilitates the GSCM, it assists the GL and related functions like traceability and transparency and improve protection and security (Böckel *et al*., 2021). The feature of traceability improves the logistic operations by the smooth flow of products. Blockchain technology improves the collaboration in activities and information accessibility among all supply chain associates (Rusinek *et al*., 2018). Moreover, the availability of data through blockchain technology prevents fraudulent activities like data tempering and false ownership (Khan *et al.*, 2022b). It is very important to tell that blockchain technology gives high security from fraud by management, employees and other parties. Sharma *et al*. (2021) stated that I4 technologies help to lessen environmental pollution and adversity, build-up social development, helps to enforce sustainable practices which further boosts economic outcomes and social development. Thus, based on above discussion it augmented that sustainable and GSCM tend to be promoted with the adoption of I4 technologies. In past literature, a few researchers studied the impact of I4 technologies on the modern economy to strengthen sustainable performance (Rehman Khan *et al*., 2022). In the past literature, there are no more studies available on the relationship between I4 technologies and GSCM. This study conceptualized I4 technology as the resource for environment sustainability, green manufacturing, green logistics, green ecosystem and green manufacturing green purchasing. Based on this literature and research gaps, the following hypotheses are developed.

H1. The industrial 4 technology has a significant effect on environmental sustainability.

H2. The industrial 4 technology has a significant effect on green manufacturing.

H3. The industrial 4 technology has a significant effect on green logistics.

H4. The industrial 4 technology has a significant effect on green eco-design.

H5. The industrial 4 technology has a significant effect on green manufacturing andgreen purchasing.

2.8 Green supply chain management and sustainable performance

The management of different firms implements the GSCM to attain sustainable performancein multiple dimensions. According to Joshi and Sharma (2018), to attain economic performance and environmental efficiency, GSCM have a very influential role because it involves environmentally friendly practices. No doubt, the traditional manufacturing systemis the main cause of ecological adversities due to unsustainable practices (Luthra *et al*., 2022). Therefore, GSCM have been adopted by modern firms to reduce the eco-problems by implementing recycling and remanufacturing practices (Yolmeh and Saif, 2021). The researchers indicated that GSCM help to eradicate the waste and harmful emission of gas by working on critical guidelines and policies (Konietzko *et al*., 2020). However, these practices especially pay for the reduction in wastage and improve the firm performance by adopting sustainability in work (Korhonen *et al*., 2018). Hence, GSCM boost the production capacity bythe way of efficient utilization of resources to achieve better enactment (Marques *et al*., 2021).According to past studies, the efficient use of energy resources and raw materials areimportant drivers of sustainable growth of the firm for achieving sustainability in theenvironment (Paulraj *et al*., 2017).

Accordingly, the sustainable and green production practices boost the material and product functionality and ensure maximum consumption in the improvement of the operational performance of the firm (Sehnem *et al*., 2019). However, most of the practices in GM include waste reduction, maximum resource utilization, pollution prevention techniques and remanufacturing, all these practices improve the economic as well as ecological performance or the organization to achieve sustainability (Cousins *et al*., 2019; Sarkis *et al*., 2020). Additionally, practices of green logistics concentrate on efficient processes, efficient transportation, sustainable packaging and reduction in destructive emanations. GM also enhances the economic performance of firms because it helps to use the resource in an efficient way that is appropriate to use these resources for better development of sustainability (Kim *et al*., 2021). Therefore, it is reported that GSCM like GL and manufacturing lead to an increase in the overall performance of GL and GM. Thus, it is concluded that GSCM have a positive and significant relationship with the sustainable performance of the firm.

Furthermore, GSCM influence the organization's performance positively by providing security through regulatory actions (Grewal and Serafeim, 2020). However, GP is very helpful in the retention of existing valuable and experienced employees in the firm as a result the company can attain a competitive advantage (Carter *et al*., 2019). Moreover, the social policies and pro-environmental activities enable the organization to increase and retain customers, which leads to an increase in the sales volume and market performance of the firm (Balatsky, 2019). Furthermore, proactive management of any firm that uses GSCM normally has easy

access to pro-environmental investors for fundraising. Employing pro-environmental fund, the rising cost of capital is significantly reduced which further enhance the profitability of the firm (Tashman *et al*., 2019). On the other hand, an opposing view is also available in the literature which stated that green initiatives have a higher cost of implementation and operations in the short run, which causes a negative influence on economic performance (Ambec, 2017).

The existing studies in the literature show mixed results on the value of GP for the performance of the organization. Accordingly, Jafarzadeh-Ghoushchi (2018) concluded that solitary internal management practices of the environment affect the firm performance in a positive sense. In the same way, Umar *et al*. (2021a) reported in the literature that there is a strong association between sustainable practices and different circular-economy practices within the organization. Furthermore, in a study by Rizki *et al*. (2022) based on the geography of Thailand it is shown that there is a significant relationship between green purchasing practices and the eco-performance of the firm. In contrast, Zhang *et al*. (2017) found a negative association between GSCM and the firm's productivity. Likewise, Khan and Qianli (2017) found a positive relationship between different GSCM and a firm's economic performance. Policymakers and practitioners should implement GP for innovation and sustainable development of firms (Wang and Yang, 2021). Moreover, GSCP also has a positive association with the profitability of a firm (Cloutier *et al*., 2020). According to Umar *et al.* (2021a) GSCM play a substantial role in attaining sustainable performance. Based on variations in the results of different GSCM, there is the possibility that different GSCM may show different impacts on firm performance (Namagembe *et al*., 2018). Thus, there is a robust need to analyze the influence of specific GP on firm's sustainability and performance. Theoretically, this research has considered green manufacturing, green logistics, green purchasing, green ecosystem as resources for environmental sustainability.

Based on this literature and gaps, the following hypotheses are developed. *H6.*

Green manufacturing significantly affects environmental sustainability.*H7.*

Green logistics significantly affects environmental sustainability.

H8. Green purchasing significantly affects environmental sustainability.

H9. Green eco-design significantly affects environmental sustainability.

H10. Green manufacturing significantly mediates between industrial 4 technology and environmental sustainability.

H11. Green logistics significantly mediates between industrial 4 technology andenvironmental sustainability.

H12. Green purchasing significantly mediates between industrial 4 technology and environmental sustainability.

H13. Green eco-design significantly mediates between industrial 4 technology and environmental sustainability.

3. Research design and sampling

3.1 Measurement design

In this study, we selected the textile industry of Saudi Arabia for data collection. The purposeof the large firms' selection is that these firms are environmentally friendly and playing role inthe sustainability of the country. In 2020 data was collected for firms. We explained thepurpose of the study to respondents before the questionnaire distribution. The scale itemsused in this study for each variable are adapted from the existing studies in the literature. The validity of the scale items was already tested by the findings of source studies to ensure the items are reliable to be used in the current research. In this way, the questionnaire was finalized for this study.

3.2 Data collection process

Data was collected from those respondents who were linked with management and also haveknowledge of I4 technologies. We distributed 500 questionnaires among respondents for datacollection, and 350 filled questionnaires were received, so these questionnaires were used foranalysis. The research instrument was adopted from the study of Umar *et al.* (2021a).

3.3 Data analysis technique

In the present study, we used the PLS-SEM model for analysis because it is better as compared to "covariance-based structural equation modeling" (Hair *et al*., 2011). The PLS- SEM also handles the complicated and complex models containing a large number of predictor variables, structural paths and structures that are used in the analysis (Hair *et al.*,2019). Khan *et al*. (2020) and Astrachan *et al*. (2014) demonstrated that the problems of non- normal data can be handled easily by using PLS-SEM. To ensure consistent and accurate measures of the construct there are two stages by which the PLS path model is calculated, before making assumptions for their relations (Hair *et al.*, 2019). The first is "the assessment of the estimation (outer) model's reliability and validity" and the second is "the assessment of the structural (inner) model".

4. Results and findings

4.1 Measurement model

The evaluation of the measurement model has been done by using convergent validity and discriminant validity which are designed for PLS' reflective indicators (Hult *et al*., 2018). The construct reliability could be assessed from factor loadings, Cronbach alpha, composite reliability and average variance extracted. Among these criteria, the minimum threshold value for factor loadings is 0.5 or greater than 0.5 (Hair *et al.*, 2011). Table 1 and Figure 1 predicted values indicated that all values are greater than 0.5. In addition, the findings for constructs reliability and validity are explained in Table 2, where composite reliability and Cronbach's alpha are soundly established. According to Hair *et al*. (2011) the composite reliability and Cronbach's alpha value should more or equal to 0.7. Moreover, the results propose the convergent validity establishment. If the results show "average extracted variance (AVE)" more or equal to 0.5, the convergent validity is established (Hult *et al*., 2018). Table 2 predicted values show that all the values are greater than from above recommended values.

In addition, the construct's discriminant validity was established by Fornell and Larcker. In Table 3 the results of discriminant validity are presented which shows that discriminant validity is well established, meanwhile, the square root of AVE's every construct was greater as compared to other latent construct's correlations (Fornell and Larcker, 1981). These results indicate that the construct has discriminant validity.

	ECD	ENVS	GL	GM	GP	
	I4ECD1	0.879				
ECD2	0.924					
ECD3	0.862					
ENVS1		0.825				
ENVS2		0.83				
ENVS3		0.848				
GL1			0.672			
GL2			0.837			
GL3			0.876			
GM1				0.832		
GM2				0.9		
GM3				0.864		
GP1					0.951	
GP2					0.85	
GP3					0.733	
I41						0.814
I42						0.854
I43						0.861
I44						0.766
I45						0.833

Note(s): Acronyms: ECD-eco-design, ENS-environmental sustainability, GL-green logistics, GM-green manufacturing, GP-green purchasing, I4-industry 4 technology
Source(s): Table created by author

Table 1.
Factor loadings

Furthermore, by applying the "Heterotrait–Monotrait (HTMT)" the discriminant validity could also be calculated. Henseler *et al*. (2015) proposed the parameters for assessing the construct's discriminant validity. The value of HTMT should in between 0 and 1 (Henseler *et al*., 2015). In Table 4 whole values of HTMT are lesser than 1, which indicated that this construct holds resilient discriminant validity.

4.2 Structural model assessment In the next step of analyzing the outer model, we test our hypothesis. We used the PLS-SEM model for hypothesis testing. The results of this analysis are shown in Table 5. The outcomes indicated that I4 technologies contribute to environmentally sustainable and green supply chain management (GSCM) practices. Moreover, the result also shows that GSCM practices also add to environmental sustainability. It is shown that GSCM indicators have a significant and positive and significant impact on ENS. Green purchasing has an insignificant effect on ENS. Moreover, the indirect influence also shows that all the I4 technology also significant effect on environmental sustainability which indicates that GSCM indicators are important factors for ENS. These results are predicted in the following Table 5 and Figure 2.

The values of VIF should be lesser than 5. All the values in the test were less than 5, which shows the estimation model was not collinear. If the f^2 values are in the middle of 0.020 and 0.15, these show a minor impact on the "endogenous latent variable". The values show a moderate effect if its range is between 0.150 and 0.350. Values show momentous effects if these are 0.35 or greater. In our study, the values of f^2 are more than 0.024 which shows asignificant effect on construct validity. The study by Cohen (1988) stated that the value of $R^2$is considered significant if it is more than 26%. In Table 6, the dependent variable's relevance is ensured by the R^2 value.

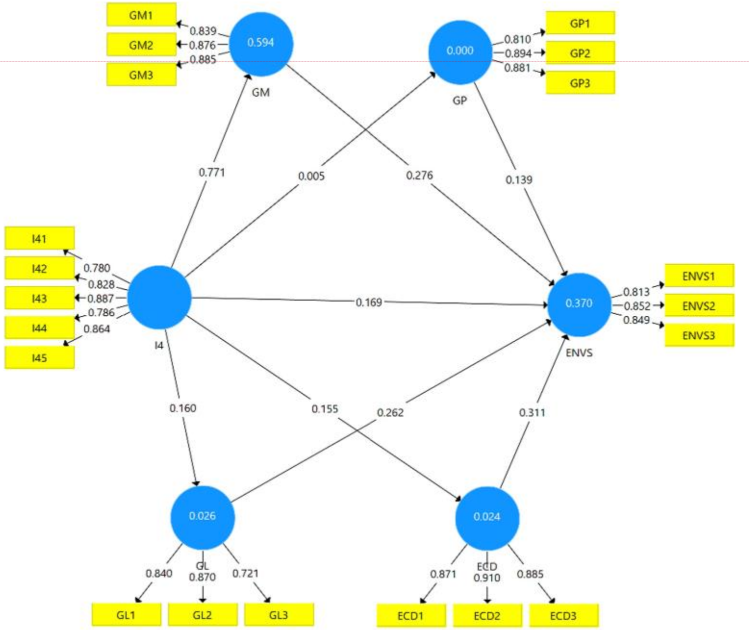

Figure 1.
Measurement model

Source(s): Figure created by author

Commented [H1]:

	Cronbach's alpha	Composite reliability	Average variance extracted
ECD	0.867	0.918	0.789
ENVS	0.789	0.875	0.710
GL	0.743	0.841	0.640
GM	0.834	0.9	0.750
GP	0.833	0.885	0.722
I4	0.886	0.915	0.683

Note(s): Acronyms: ECD-eco-design, ENS-environmental sustainability, GL-green logistics, GM-green manufacturing, GP-green purchasing, I4-industry 4 technology
Source(s): Figure created by author

Table 2.
Reliability and validity

Furthermore, the assessment of effect size was determined by f^2 values. The value of 0.02 is small, 0.15 is medium, and 0.35 is large for f^2. This study found that the effect size of I4 on GM, GL, GP, and ECD is medium. However, the impact of I4 is large on ENVS. Furthermore, thestudy found that the impact of GM, GL and GP is large on ENVS. However, the effect of ECDis small on ENVS.

Similarly, the predictive relevance of the study model was tested. It is determined by the results of the PLS Blindfolding test. The results for predictive relevance should be greater than zero. This study found the model has 79% predictive relevance which highlights that the

	ECD	ENVS	GL	GM	GP	
	I4ECD	0.889				
ENVS	0.533	0.838				
GL	0.456	0.428	0.813			
GM	0.279	0.272	0.139	0.867		
GP	0.368	0.284	0.096	0.023	0.862	
I4	0.155	0.135	0.160	0.771	0.005	0.83

Note(s): Acronyms: ECD-eco-design, ENS-environmental sustainability, GL-green logistics, GM-green manufacturing, GP-green purchasing, I4-industry 4 technology
Source(s): Table created by author

Table 3.
Fornell and Larcker

	ECD	ENVS	GL	GM	GP	I4
ECD						
ENVS	0.632					
GL	0.565	0.543				
GM	0.328	0.339	0.186			
GP	0.428	0.339	0.119	0.036		
I4	0.174	0.163	0.198	0.891	0.066	

Note(s): Acronyms: ECD-eco-design, ENS-environmental sustainability, GL-green logistics, GM-green manufacturing, GP-green purchasing, I4-industry 4 technology
Source(s): Table created by author

Table 4.
HTMT

	Original sample	Sample mean	Standard deviation	*T* statistics	*p* values
ECD → ENVS	0.311	0.309	0.052	5.947	0.000
GL → ENVS	0.262	0.265	0.045	5.805	0.000
GM → ENVS	0.276	0.278	0.068	4.088	0.000
GP → ENVS	0.139	0.141	0.049	2.873	0.004
I4 → ECD	0.155	0.156	0.060	2.581	0.010
I4 → ENVS	0.169	0.170	0.067	2.509	0.012
I4 → GL	0.160	0.161	0.057	2.801	0.005
I4 → GM	0.771	0.772	0.038	20.235	0.000
I4 → GP	0.005	0.004	0.052	0.093	0.926
I4 → ECD → ENVS	0.048	0.048	0.021	2.336	0.020
I4 → GL → ENVS	0.042	0.043	0.017	2.503	0.012
I4 → GM → ENVS	0.213	0.215	0.055	3.843	0.000
I4 → GP → ENVS	0.001	0.000	0.008	0.086	0.931

Note(s): Acronyms: ECD-eco-design, ENS-environmental sustainability, GL-green logistics, GM-green manufacturing, GP-green purchasing, I4-industry 4 technology
Source(s): Table created by author

Table 5.
Hypothesis results

model of this study has significance. However, this also reported that the further variables can contribute further to ENVS.

5. Discussion

The research objective was to check the impact of I4 technologies on environmental sustainability (ENS) with the mediating role of green supply chain management (GSCM). The

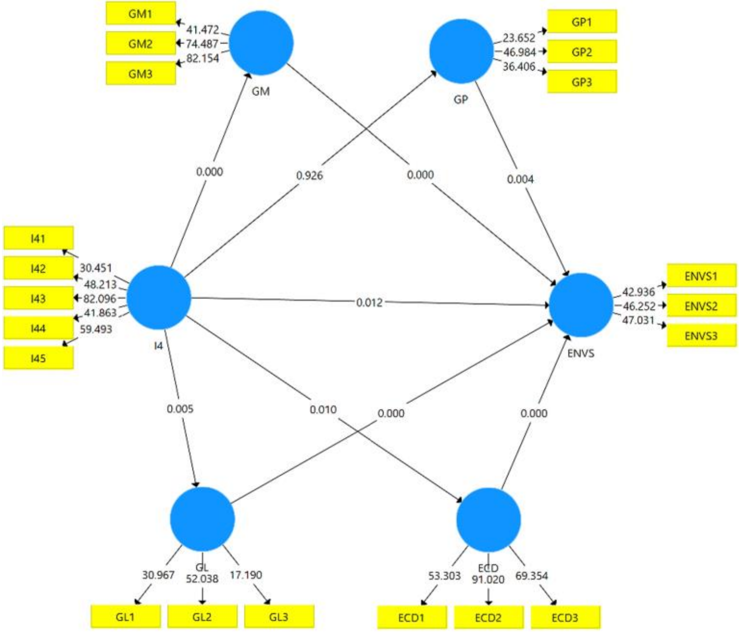

Figure 2.
Structural model

Source(s): Figure created by author

Table 6.
R-square values

	R-square	R-square adjusted
ECD	0.024	0.021
ENVS	0.370	0.361
GL	0.026	0.023
GM	0.594	0.593
GP	0.004	0.003

Note(s): Acronyms: ECD-eco-design, GL-green logistics, GM-green manufacturing, GP-green purchasing, I4-industry 4 technology
Source(s): Table created by author

objective results indicate that I4 technologies have positive as well as substantial influence on ENS. This indicated that time when technologies are improved then sustainability is also increased. These results are further in line with previous studies (Ejsmont *et al*., 2020). In addition, the present study also shows that there is a significant impact of industry I4 technology on GM. Our results are matching with those (Bag *et al*., 2021; de Sousa Jabbour *et al*., 2018; Frank *et al*., 2019) study's findings. The study of Wee *et al*. (2015) recognized certain types of technologies and affirmed that the use of these technologies gives many benefits to various manufacturing domains. As an example, the use of I4 technologies increases visibility as well as all-time access by augmented reality and virtual reality, the expanded capacity of offers for active repair and assessment, and maintenance by the way of monitoring which leads to getting maximum efficiency in the production process. Technology assists in the improvement of quality and efficient inventory management by the way of minimum cost and reduction in working time. The demand and supply forecasts are made by performing Big Data Analytics more accurately by having information about customers, suppliers, services, and products. The study of Umar *et al.* (2021b) indicated that

digital technologies have an impact on GM. For a better understanding of the capabilities of I4 technologies, divided these into front-end and based technologies. Smart manufacturing and smart working could be done by adopting front-end technologies by reshaping the manufacturing operations. In addition, GL are significantly impacted by Industry 4.0 outcomes of the study are consistent with those of (Bag and Pretorius, 2020; Torbacki and Kijewska, 2019). GL is benefited from I4 technologies and principles. Additionally, the relationship between machines and tiers of the supply chain adopting the real-time capabilities allows timely delivery and improvement in logistic routes (de Man and Strandhagen, 2017). In the study of Torbacki and Kijewska (2019), it is stated that for intelligent and efficient management of heavy transportation, delivery vehicles and areas, and parking lots I4 technologies play a very important role. Moreover, past research has also shown that in urban areas intelligent transportation adoption helps to reduce vehicle transportation (Torbacki and Kijewska, 2019). The functions of the management of vehicle routing, traceability of logics and collaborative logistics with the help of implementation of I4 technologies enable the GSCM in supply chain. In addition, the adoption and use of technology help to manage logistics efficiently and effectively. Delivering the information timely while using GL leads to enhance sustainability (Barreto *et al*., 2017). Moreover, I4 also has positive and significant effect on eco-design which results are supported with previous studies (Grajewski *et al*., 2015). In addition, I4 technologies are not significantly and positively effecting to green purchasing. This value indicates that I4 technologies are not having important roles to increase green purchasing in the textile sector of Saudi Arabia.

The results further indicated that there is a beneficial relationship between GM and ENS. Such outcomes remain consistent with those of (Abualfaraa *et al*., 2020; Afum *et al*., 2020). GMhelps to enhance the market share and profitability of the firm (Roy and Khastagir, 2016). Moreover, in the study of Sezen and Cankaya (2013) investigated Turkish manufacturing enterprises, present research findings indicated that green marketing seems to have an effect on ENS. GSCM also increase ecological performance by waste reduction, reducing the number of environmental accidents and lessening air pollution. The results of our study areconsistent with the previous research. In past studies, the various positive impacts of GM have been analyzed, for instance, discharge of liquids and wastes, substances, reduction in air emissions, enhanced energy efficiency, and best utilization of resources (Green *et al*., 2018; Namagembe *et al*., 2018). The results of our study are consistent with the past findings. Research on Brazilian enterprises (ISO 9001) predicted that the adoption of GM has a positive impact on the green performance of enterprises (Soubihia *et al*., 2015). The study of Green *et al*. (2019) confirmed that environmental performance has been improved by the practices of GM by eliminating the ecological impacts of manufacturing processes.

The present study analyzed the relationship between eco-design and environmental performance, and the results showed that there is a significant relation between green eco- design of the firm. The study of Sezen and Cankaya (2013) has shown similar results. In green eco-design results are achieved by green and eco-friendly practices. In this way, manufacturing firms could be successful in a win-win strategy by adopting the GSCM. A study by Abdul-Rashid *et al*. (2017) revealed that eco-design has a significant impact on environmental performance. According to Wang and Yang (2021), eco-design advances working conditions, and cleaner production and improves the quality of life of members. In addition, there is a significant impact of GL on ENS. These results are also confirmed the outcomes of (Baah *et al*., 2020; Centobelli *et al*., 2018). GL helps to efficient utilization of energy resources, and minimum wastage of material improves operational efficiency which leads to lower prices and enhances customers satisfaction. So GL improves a firm's environmental performance (Razzaq *et al*., 2021). In addition, the elements of GMP were studied in BRICS member countries by Shouket *et al*. (2019), findings of the current research indicated that GL makes sure to have a positive influence on ENS. Empirical research by Khan *et al*. (2018) in the context of industrialized nations of Europe found that logistic practices have a great impact on ENS. The results show that improved logistic practices fuel economic development as well as impact the ENS. The global environment could be badly affected without the implementation of sustainable strategies and policies (Yin *et al*., 2021). However, green purchasing also has a positive and significant effect on environmental performance which is also supported by previous studies (Grajewski *et al*., 2015). In addition, indirect mediating influence also indicated that GSCM practices considerably mediate between I4 technology and ENS except green purchasing which is not significantly mediating between I4 technology and ENS.

6. Conclusion

The main purpose of this study was to examine the impact of I4 technologies on GSCM for environmental sustainability (ENS). We collected cross-sectional data from different textile companies in Saudi Arabia by using a questionnaire survey. We selected these firms having great concern and impact on ecological system disturbance and socio-environmental problems in the country. In this study, PLS-SEM was used to test the hypothesis. This study meets the standards of convergent and discriminant validity. The variance Inflation Factor value suggests that there was no issue with "common method bias". This model also has predictive relevance. Moreover, the study indicates that I4 has a significant and positive impact on ENS. Finally, the analysis shows that I4 practices have a positive relation with GL, there are GL and manufacturing except green purchasing. In addition, the findings also revealed that GSCM have a positive impact on ENS. On the other hand, the mediating effect of GSCM also significantly and positively effecting between I4 technologies and ENS except for one practice of green purchasing mediating effect.

7. Implications

This study has a few significant theoretical implications in the literature as it provides strategic insight to managers as well as policymakers. The implications of this study were not comprehensively discussed by the studies before this research work. From the perspective ofa resource-based view, this study has provided statistical evidence to use of I4 technology practices in GSCM. Moreover, this study added to literature by building a new and comprehensive research model which statistically analyses the effects of I4 technology on green purchasing and green eco-design. Interestingly, these two variables were also recommended from previous studies and gaps in knowledge (Umar *et al.*, 2021a). Therefore, this study was conducted on the textile sector of Saudi Arabia and gaps in the knowledge are addressed. Moreover, this study also extended the body of literature with the mediating effectof GSCM on ENS especially in the context of Saudi Arabia by providing this relationship with empirical data. From the practical perspective, the research will assist decision-makers in encouraging manufacturing firms the adoption of GSCM, to make hard regulations and policies for implementation in manufacturing enterprises to attain sustainable goals. Practically, it is very helpful in the implementation of such regulations if the government charges dense penalties in case of disobey, and unhealthy manufacturing operations and activities. Furthermore, the current research recommended managers to implement I4 technologies and adopt the GSCM practices. Accordingly, these practices should be part of environmental strategies. In accordance, the implementation of these practices will assist in building a strong reputation and satisfaction of customers and to fulfill the requisites of stakeholders.

8. Limitations of the study

The current study has some limitations which could address in future studies. First of all, we collected data only from the textile sectors, in future studies the whole manufacturing sector can be chosen for data collection for in-depth results. Next, we conducted our study on quantitative data, so future studies can be based on qualitative data. We applied the PLS-SEM for analysis, in future research more advanced techniques can be applied for the analysis of data. Further, we analyzed the effects of I4 on four GSCM practices while future research may identify an influence of I4 technologies at remaining GSCM in perspective of resource-based view. In the future the researchers can also study the influence of I4 technologies on paperless, smarter and green Human Resource Management (HRM) and practices. In the last, further studies can be conducted in other countries for contribution to literature because this research was conducted on the textile industry in Saudi Arabia is a developing nation that limited the scope of research, therefore, future research could be conducted on other developed economies to check the variations in the results.

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