The role of sustainable supply chain activities as a pivotal factor in promoting green innovation: A case study in the Central Oil Company

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ABSTRACT

The key purpose of this research is to analyze the impact of the selected factors of the sustainable supply chain on the green innovations for the central oil company in Iraq. The study focuses on how different sustainable supply chain practices in the form of sustainable purchasing, sustainable design, sustainable transportation, and sustainable storage tend to influence the green innovation. A structural questionnaire was developed for the purpose of collecting the data. A total of 121 valid questionnaires were distributed within the company to gather data and address the existing knowledge gap in this field. The study applies both the descriptive and inferential statistics. For inferential statistics, Smart PLS 4.0 was used covering the measurement and structural model analysis. The findings show a significant positive correlation between the company's SSCM activities and green innovation. This suggests that sustainable practices within the supply chain are crucial for fostering innovation in both products and processes. The study emphasizes the need for the company to enhance its SSCM strategies, particularly in green purchasing and sustainable collaboration, to drive greater environmental innovation and meet future sustainability goals.

Keywords: sustainable supply chain, green purchasing, green innovations, green transportation,

INTRODUCTION

It is believed that the rise in global warming and related climate change along with the changing biodiversity is threatening the sustainability of the planet earth (Badr & Rl-Shazly, 2024; Shivanna, 2022; Verma, 2021). Therefore, for this strategic issue, several groups, including researchers, scientists, and professionals in the field of environmental management, have come together to find ways to protect the nature from increasing ecological threats. It is widely believed that irresponsible actions by humans and industries are significantly contributing towards the environmental harm and ecological damages (Lenox et al., 2000). As a result, it is important to realize that creating some sort of sustainable industries has become a primary objective for businesses groups in the contemporary environment where the environmental sustainability is a major concern (Le et al., 2023; Schaltegger & Wagner, 2011). Moreover, the

achievement sustainability requires organizations to focus on environmental concerns and adopt a phenomenon of going green (Bansal & Roth, 2000; Ramli et al., 2022).

The term 'green' has been regarded as the idea and the actions that aim to integrate environmental awareness into business practices (Polas et al., 2021). For this purpose, the notion of supply chain is an important part of operations management domain where it has a significant environmental impact, such as pollution, emissions, and health risks to the community (Rane et al., 2025). As a result, companies and business units are aiming to reduce their environmental footprints with the help of incorporating several green practices into their supply chain operations (Ekene Cynthia et al., 2021). This integration is known as green supply chain management (Sarkis et al., 2020), and it has become an important area of study in academics and is considered a key part of sustainability agenda as well.

By combining the above thoughts, the term green supply chain refers to a series of processes which are being considered and used throughout the lifecycle of a product starting from the design, production, and distribution to consumption and recycling for the purpose of minimizing its environmental impact (Beamon, 1999; Srivastava, 2007). Therefore, it is important to consider that green supply chain focuses on incorporating a range of green practices throughout the supply chain process, like from sourcing the eco-friendly materials to creating greener products (Komal S & Khandare, 2024). Therefore, such an approach is helpful in improving the operational efficiency, enhancing the company's image, along with increasing the market share, and driving revenue growth for the organization (Nozari et al., 2019) The theoretical foundation named resource-based view also aligns with green supply chain (Khan et al., 2022) because of the fact that it considers green practices as a unique and valuable capability that is difficult for competitors to imitate or copy. Additionally, the green supply chain enhances the ability of the organization to properly show its response towards environmental priorities, while improving the stakeholder relationships (Nozari et al., 2019).

Green innovation (GRI) is very important factor towards the environmental management (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Arenhardt et al., 2016). It has gained a considerable attention in recent years, specifically as the issue of environmental degradation becomes a growing threat to human survival. As a result, several organizations and communities around the globe are turning to GRI to both protect the environment while focusing on providing the support to the economic growth. Therefore, the achievement of environmental sustainability and economic profitability is crucial for businesses today (Fliaster & Kolloch, 2017). Additionally, GRI can help organizations gain sustainable competitive advantages (Hur et al., 2012). Now in the modern world, GRI has become a key tool for businesses to improve their market share while ensuring the concept of long-term survival in the marketplace. Another idea is that successful strategy for the green innovation can enhance the market position of a company, along with attracting the customers, offering the green services, and providing a competitive advantage too (Karimi Takalo et al., 2021). For these reasons, GRI has become a top priority for managers and researchers.

Green innovations or eco-innovation have been regarded as the processes with the core objective of creating some sort of new products and technologies which are being designed in order to reduce environmental risks like pollution and the negative effects of resource exploitation (Castellacci & Lie, 2017). For this reason, the idea of innovation is often divided into product or service innovation and process innovation, respectively. More specifically, the product or service innovation aims to improve the performance of products and services for

customers. On the other side, meanwhile, the idea of the process innovation aims to help in building the cost efficiency and organizational flexibility, which further contribute towards reducing the environmental risks (Albort-Morant et al., 2017; Kam-Sing Wong, 2012).

This study contributes to the modern literature in several different ways. Firstly, it aims to investigate the role of the green supply chain management practices by considering its different factors entitled green purchasing, sustainable collaboration, sustainable transportation, sustainable manufacturing, and sustainable storage towards the idea of the green innovations. A detailed review of the available studies indicates that although there is a rich literature on the field of green sustainable chain management practices, however, the available studies consider only couple of factors or dimensions of such practices where a very little attention has been paid towards the selected factors under present study. Moreover, the existing literature also seems less attentive towards the Central Oil Company in Iraq for which this research has provided both the theoretical and empirical evidence. The study findings show that there is a significant and positive effect of the factors like green purchasing, sustainable collaboration and manufacturing on the green innovations. The rest of the paper has been organized in the following way. Section 2 focuses on review of the studies, whereas third section captures the methodological debate. Section 4 covers the estimations and discussion, whereas last section concludes the study.

LITERATURE REVIEW

The literature provides some dangerous debate on the relationship between green supply chain management practices and green innovations, covering different regions and industries. Seman et al. (2012) believe that argue that growing environmental concerns from different stakeholders like those entitled as customers, buyers, communities, and government regulations have pushed business organizations to adopt green supply chain management (GSCM) and green innovation. Therefore, it is essential to develop plans, mechanisms, and work procedures that preserve and protect the environment from its negative impacts. These impacts pose a challenge to industrial organizations in how to transform these environmental aspects into into opportunities to improve the environment, enhance their environmental reputation, and embody ethical environmental commitment (Resent et al., 2023).

The reason is that there is a strong connection between GSCM, and green innovation and such a relationship is mainly connected to the idea when it comes to developing some sort of new eco-friendly products. However, there has been very little research on this relationship, which further hinders a clear understanding for both scholars, practitioners and decision makers. Their study has aimed to review the available studies that explore the linkage between the idea of GSCM and green innovation. The findings suggest that GSCM leads towards the green innovation. However, the paper also recommends that future research should consider a broader range of GSCM practices and factors along with collecting more empirical evidence to strengthen this relationship. Junaid et al. (2022) has strong believed that while sustainability clearly influences innovation, there is a lesser focus on how effective integrating sustainable supply chains is as a factor in determining the trends in the value of green innovations. Their study for this reason has discussed the information processing theory and the dynamic capability view, while proposing a research-based framework that connects sustainable supply chain integration, green innovation, and company performance, respectively. The researchers have collected the survey data and secondary data from annual reports of 296 manufacturing

companies across 19 sectors in the regional context of Pakistan. They used structural equation modeling (AMOS 26 and SPSS 25) to analyze the data. The results show that integrating sustainability within the company and with those of the suppliers and customers aims to encourage both of the green managerial and process innovations. Interestingly, the study findings indicate that green managerial innovation has a strong positive effect on the financial performance of the company. However, green process innovations have a negative impact on the performance outlook. These new insights are valuable for different stakeholders like the managers and researchers looking to better manage sustainable supply chains and green innovation .

Roh et al. (2022) also focus on the similar domain of sustainable supply chain and green innovations while suggesting that global climate sanctions are likely to push supply chain partners to cut down on greenhouse gas emissions. In this context, the study has been exploring how the internal green activities like green managerial innovation, green supply chain management, and green innovation are helping the companies towards the improvement of their environmental performance. The research also looks at the role of intellectual property rights and examines how green GSCM acts as a mediator along with the sustainable marketing innovation as a moderator. The study has utilized the modern empirical estimation technique named structural equation modeling technique for testing the hypotheses with a data from 452 South Korean companies. The findings showed that green managerial innovation and intellectual property rights are playing their direct role towards the green supply chain management. on the other side, the green supply chain management and intellectual property rights also influence green innovation. Furthermore, the study confirmed the fact that green innovation has its positive role towards the environmental performance. It also highlighted the key mediating role of green supply chain management between intellectual property rights and green innovation, as well as the moderating effect of green marketing innovation between green innovation and environmental performance. based on the all of the given results, it is inferred that the study is contributing well towards the literature on clean production and environmental performance while taking into account the green market innovations too.

MATERIAL AND METHODS

This research collects the data from 121 individuals working in the Central Oil Company. The demographic factors along with the key variables of interest. This part gains its importance from the fact that it links the theoretical framework with practical application and provides quantitative evidence that enhances the strength of the results and contributes to formulating conclusions and recommendations of both practical and academic value. A questionnaire has been developed using the past literature covering the variables under the shadow of sustainable supply chain management and green innovations.

Table 1 indicates the results of the demographic characteristics of the research sample in the Central Oil Company, which numbered (121) individuals, indicating that the vast majority of workers are males at a rate of (95%) compared to (5%) females, which reflects the prevailing masculine nature in the oil work environment. The workers are also distributed in a relatively balanced age, as the category (36-45 years) reached the highest percentage (34.7%), followed by the category (46-55 years) at a rate of (27.3%), while the percentage of those under (35 years) reached (19.8%), and those over (55 years) (18.2%), which indicates the company's

reliance on middle-aged cadres that combine practical experience and job activity. As for the academic qualification, the largest percentage was concentrated in the intermediate and applied education categories, as the percentage of preparatory school and below reached 31.4%, technical diploma 32.2%, and bachelor's degree 32.2%, while the percentage of master's degree holders (2.5%) and doctorate (1.7%) was very limited, which reflects The applied nature of the oil sector and its reliance on technical competencies more than academic ones, while the distribution of years of service showed that the category (21-25 years) came first with (27.3%), followed by the category (16-20 years) with (25.6%), then the category (over 25 years) with (24%), and finally the category (less than 15 years) with (23.1%), which indicates high job stability and reliance on long-term cumulative experiences. These results together confirm that the work environment in the Southern Oil Company is predominantly male-dominated and relies on a middle-aged workforce with applied qualifications and extensive experience, with weak representation of women and high academic competencies, which enhances the stability of the company but at the same time reveals challenges related to gender diversity and research knowledge development.

Table 1: Demographic Factors

Variable	Details	Number	Percentage (%)
Gender	Males	115	95
	Females	6	5
	Total	121	100
Age	Under 35 years old	24	19.8
	36-45 years old	42	34.7
	46-55 years old	33	27.3
	Over 55 years old	22	18.2
	Total	121	100
Educational Qualification	Preparatory school and below	38	31.4
	Technical diploma	39	32.2
	Bachelor's degree	39	32.2
	Master's degree	3	2.5
	Doctorate degree	2	1.7
	Total	121	100
Number of Years of Service	Under 15 years old	28	23.1
	16-20 years old	31	25.6
	21-25 years old	33	27.3
	Over 25 years old	29	24.0
	Total	121	100

The descriptive output for the variables and their items is presented in Table 2 covering the mean and standard deviation. It shows that for the items of the sustainable purchasing, the mean values are 3.313, 3.802, and 3.77, reflecting an overall average score of 3.631. moreover, the values for the standard deviations are 0.805 on average, and for the rest of the items they are 0.712, 0.885, and 0.820. In sustainable manufacturing, the average mean is 3.289, with standard deviations ranging from 0.647 to 0.78. The items' mean values are 2.777 for reducing the negative impacts of manufacturing, 3.579 for sustaining operations, and 3.512 for using raw materials efficiently.

Table 2: Descriptive Results

Level	Description	Mean	SD
	Sustainable purchasing (average)	3.631	0.805
1	The company's purchasing processes are approved based on the necessary requirements for producing safe products.	3.314	0.712
2	Environmental considerations are considered as a basis for periodically evaluating equipment performance.	3.802	0.885
3	Purchases are based on data that ensures environmentally friendly production.	3.777	0.820
	Sustainable Manufacturing	3.289	0.691
4	The company seeks to reduce the negative impacts of manufacturing.	2.777	0.78
5	The company works to sustain its manufacturing operations.	3.579	0.647
6	The company uses raw materials efficiently to reduce costs, pollutants, and energy consumption.	3.512	0.647
	Sustainable Transportation (average)	3.284	0.757
7	The company seeks to reduce transportation costs without compromising its objectives.	2.727	0.617
8	The company selects transportation methods based on environmental decisions that focus on reducing energy use.	3.521	0.86
9	The company uses environmentally friendly transportation methods that ensure product preservation.	3.603	0.78
	Sustainable Storage (average)	3.554	0.779
10	The company works to ensure compatibility between storage locations and the type of stored material.	3.909	0.812
11	The company monitors storage and handling operations to ensure they produce minimal harmful emissions.	3.157	0.606
12	The company observes storage control systems during material storage.	3.595	0.891
	Sustainable Collaboration (average)	3.306	0.723
13	Sustainability is integrated and managed into the company's operations in a coordinated manner across all supply chain members.	3.595	0.85
14	The company's management adopts a proactive approach to collaborating with supply chain actors to develop more successful and innovative solutions.	2.818	0.664
15	There is trust among the stakeholders involved.	3.504	0.655
	Green Innovation (average)	3.635	0.365
16	Our firm is engaged in processes that reduce the emission of hazardous material.	3.851	0.147
17	Our firm is engaged in processes that reduce consumption of electricity, water, gas, and petroleum.	3.617	0.518
18	Our firm is engaged in processes that recycle, reuse, and reproduce material and decrease the use of raw material.	3.437	0.432

GRP; green purchasing, SUC; sustainable collaboration, SUT; sustainable transportation, SUM; sustainable manufacturing, SUS; sustainable storage, GRI; green innovations.

Sustainable transportation shows an average mean of 3.284, with standard deviations from 0.617 to 0.86. The mean values for the items are 2.727 for reducing transportation costs, 3.521 for selecting transportation methods based on environmental decisions, and 3.603 for using environmentally friendly transportation methods. In sustainable storage, the average mean is 3.554, with standard deviations ranging from 0.606 to 0.891. The individual items show mean values of 3.909 for ensuring compatibility between storage locations and materials, 3.157 for monitoring storage operations to minimize emissions, and 3.595 for observing storage control systems. Besides, sustainable collaboration has an average value of 3.306.

RESULTS AND DISCUSSION

Measurement Model Assessment

Table 3 shows the results of reliability and validity entitled as convergent validity. The variables of interest as shown in the Table 3 show that alpha values for all of these are above 0.70, giving a confirmation of the reliability. Similarly, the CR in terms of rho_a and rho_c for these variables are also above 0.70. additionally, for checking the convergent validity, the results are showing that variables named as GRI, GRP, SUC, SUM, SUS and SUT have their relative values as 0.798, 0.780, 0.645, 0.736, 0.667, and 0.791, respectively.

Table 3: Reliability as Alpha and CR, and Validity using AVE

Variables	Cronbach's alpha	CR (rho_a)	CR (rho_c)	(AVE)
GRI	0.747	0.748	0.888	0.798
GRP	0.859	0.860	0.914	0.780
SUC	0.711	0.751	0.840	0.642
SUM	0.839	1.006	0.893	0.736
SUS	0.751	0.752	0.857	0.666
SUT	0.875	0.997	0.919	0.791

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The study loadings for the items are presented in Figure 2. As it shows, the values are 0.804, 0.850, and 0.917 for the SUM, followed by SUT with the values 0.946, 0.928, and 0.787, respectively. Additionally, for the SUS, the values are 0.821, 0.836, and 0.792, whereas for the SUC, the values are0.898, 0.848, and 0.632. for the last independent variable named GRP, the loadings are 0.889, 0.875, and 0.885. on the other hand, our main DV is green innovation as measured through three items. The items have a loading of 0.888 and 0.898. Wherever, the third item was removed due to lower value of the loading.

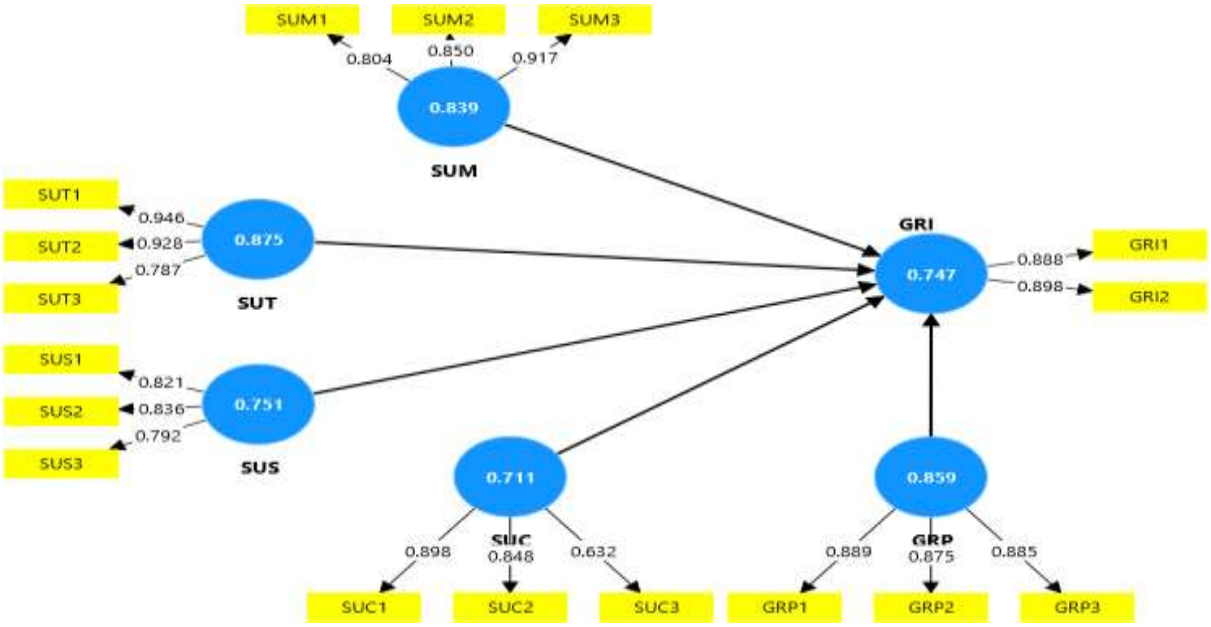

Figure 2 Output in terms of Loadings and alpha values

GRP; green purchasing, SUC; sustainable collaboration, SUT; sustainable transportation, SUM; sustainable manufacturing, SUS; sustainable storage. GRI; green innovations.

The study further investigates the discriminant validity by using the HTMT ratio as reported in Table 4. As it shows, the values in terms of matrix between the variables are well below 0.85, confirming that there exists a clear discrimination between these variables.

Table 4: HTMT Ratio

Matrix	Heterotrait-monotrait ratio (HTMT)
GRP <-> GRI	0.110
SUC <-> GRI	0.057
SUC <-> GRP	0.379
SUM <-> GRI	0.062
SUM <-> GRP	0.107
SUM <-> SUC	0.038
SUS <-> GRI	0.485
SUS <-> GRP	0.463
SUS <-> SUC	0.542
SUS <-> SUM	0.042
SUT <-> GRI	0.224
SUT <-> GRP	0.180
SUT <-> SUC	0.276
SUT <-> SUM	0.053
SUT <-> SUS	0.289

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The measurement also helps to investigate the discriminant validity by using the variance inflation factor (VIF) of the items in the model. As in Table 5, the values of VIF for the items

are all within acceptable ranges, indicating no significant multicollinearity. The VIF values for GRI1 and GRI2 are both 1.552, indicating low multicollinearity. For GRP1, GRP2, and GRP3, the VIF values are 2.305, 2.077, and 2.146, respectively, suggesting acceptable multicollinearity levels. The values for the SUC items range from SUC1, 2.061, and SUC2, 1.919, to SUC3, 1.167, all falling within an acceptable range. SUM1, SUM2, and SUM3 also show no concerns regarding multicollinearity with values of 2.206, 2.170, and 1.741, respectively. For SUS1, SUS2, and SUS3, the VIF values are 1.710, 1.726, and 1.318, respectively, and are well within the acceptable range. Finally, the VIF values for SUT1, SUT2, and SUT3 are 2.887, 3.093, and 1.910, respectively, all of which are within acceptable limits. Therefore, the VIF values suggest that multicollinearity is not an issue, confirming the discriminant validity of the measurement model.

Table 5: Variance inflation factor

Items	VIF
GRI1	1.552
GRI2	1.552
GRP1	2.305
GRP2	2.077
GRP3	2.146
SUC1	2.061
SUC2	1.919
SUC3	1.167
SUM1	2.206
SUM2	2.170
SUM3	1.741
SUS1	1.710
SUS2	1.726
SUS3	1.318
SUT1	2.887
SUT2	3.093
SUT3	1.910

GRP; green purchasing, SUC; sustainable collaboration, SUT; sustainable transportation, SUM; sustainable manufacturing, SUS; sustainable storage. GRI; green innovations.

Structural Model Results

Initially, the structural model results are provided using the R-square and its adjusted value in Table 6. The value of R-square is 0.812, reflecting a strong explanatory power of the model. It indicates the amount of variance in the main DV which is GRI as determined by set of exogeneous variables in the model. The results given confirm the fact that, overall, all the independent variables are strongly determining the change in the green innovations. However, the adjusted value is more suitable in terms of developing some strategic policies regarding the improvement in the green innovations.

Table 6: R-square and Adj. R square

	R-square	R-square adjusted
GRI	0.812	0.808

The path coefficients (Table 7) show the impact of the selected independent variables on the main DV of the model which is green innovations. As it shows, the green purchasing has a positive impact of 0.725 on the GRI. It means that considering all the variables are constant, a 1% change in the value of GRP is causing a positive change of 0.725 in the value of GRI, reflecting the highest value of the coefficient. The strong relationship between green purchasing and green innovations suggests that higher levels of sustainable purchasing directly contribute to the promotion of green innovations. This normally occurs through the title of procurement strategies which aims to prioritize sustainable and eco-friendly products, which further support the adoption of green technologies and practices within organizations. The same is the case in the present study where the green purchasing is promoting green innovations.

Table 7: Path Coefficients

Paths	Original sample (O)	Standard deviation	T statistics	P values
GRP -> GRI	0.725	0.049	14.668	0.000
SUC -> GRI	0.204	0.05	4.085	0.000
SUT -> GRI	0.021	0.029	0.707	0.480
SUM -> GRI	0.115	0.017	6.765	0.000
SUS -> GRI	0.016	0.036	0.439	0.661

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For the second variable, named sustainable collaboration, the results reflect a positive impact of 0.204 on GRI, with a T statistic of 4.085, which is indicating statistical significance outcome. This indicates that stronger collaboration among stakeholders can boost green innovations. In addition, sustainable collaboration (S-COL) influences GRI by facilitating the exchange of knowledge, resources, and best practices, which drive innovation and sustainability initiatives within firms. The collaboration between supply chain partners, regulators, and stakeholders creates an ecosystem where green innovations can flourish, with shared expertise supporting the development of sustainable solutions. On the other hand, sustainable transportation shows a weak but positive effect on GRI, with a coefficient of 0.021 and a T-statistic of 0.707, which is not statistically significant.

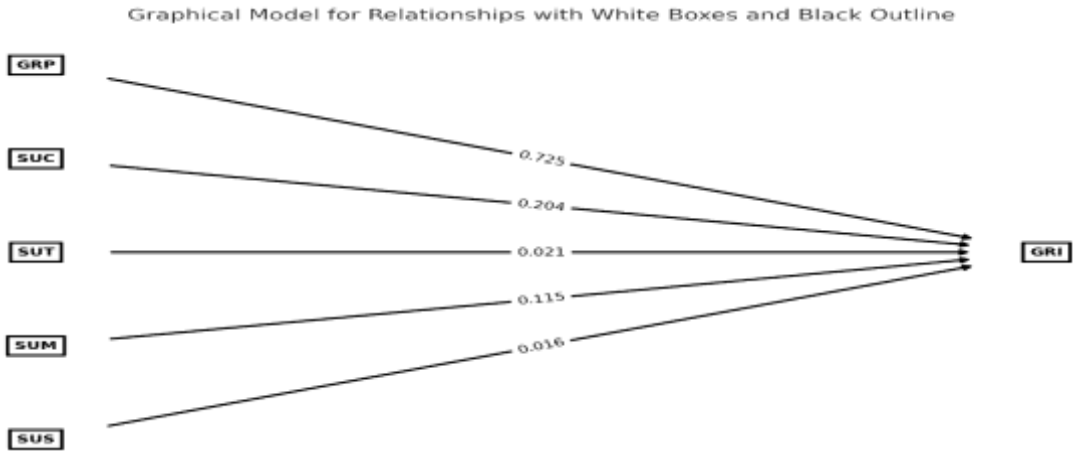

Figure 3 Path Model with Coefficients

GRP; green purchasing, SUC; sustainable collaboration, SUT; sustainable transportation, SUM; sustainable manufacturing, SUS; sustainable storage. GRI; green innovations.

The other results also provide some interesting output. For example, the sustainable manufacturing has a coefficient of 0.115 and a T statistic of 6.765. it means that like other dimensions of sustainable supply chain, the green manufacturing also reflects a productive role towards green innovation. This relationship can be expressed by exploring the associated channels too. For example, the impact of sustainable manufacturing on green innovations occurs through the adoption of energy-efficient technologies, waste reduction strategies, and resource optimization. Therefore, with the help of improvement in the manufacturing processes it is stated that central oil company can create an environment where green innovations are more likely to be developed and adopted over a longer period of time.

Sustainable storage named as SUS has the reflected the lowest impact on GRI with a coefficient of 0.016 and a T statistic of 0.439. this t-value has cleared the fact that the impact on GRI is not significant on statistical grounds. This implies that sustainable storage has little direct impact on green innovations in this model. However, it may still influence GRI through indirect channels, such as energy-efficient storage systems or reducing waste in storage operations. These factors might not be strong enough to show significant effects in the current study, but over time, more efficient storage practices can contribute to broader sustainability goals and encourage green innovations.

CONCLUSION AND SUGGESTIONS

This empirical study is focusing on the Central Oil Company in Iraq while emphasizing the importance as well as the need of the sustainable supply chain activities in boosting the green innovation. The study has applied quantitative method of data collection and analysis by using the PLS-SEM technique. The results show that green purchasing has the highest impact in determining the green innovation where 1% increase in such purchasing is leading towards a big rise in green innovation. This suggests that when the company puts more effort into sourcing sustainable products from the suppliers, it directly supports the development of environmentally friendly solutions in the form of green innovations which indeed a good ecological sign. Additionally, the factor entitled as sustainable collaboration also has a positive effect on green innovation. However, its effect is not as strong as green purchasing. This implies that working closely with suppliers and partners is important, but it might need more investment to show some bigger and productive trends in the green innovations for the sample firm. Additionally, the sustainable transportation and storage do not have much impact on green innovation. Besides, the results show that sustainable manufacturing showed a moderate positive effect towards the green innovation, provided that improving production processes can also contribute to boosting green innovation. Overall, green purchasing, sustainable collaboration, and sustainable manufacturing are the most significant factors for encouraging green innovation. The study provides several suggestions which are as follows:

The first suggestion is that the Central Oil Company should strengthen its green purchasing policies by sourcing more eco-friendly products from a diversified supplier. By doing so, the company can help promote the development of sustainable technologies and practices, which will, in turn, drive green innovation. Next thing is that, the company should work more closely with its suppliers and other partners to share knowledge and resources with mutual agreement in order to create an environment of strategic alliance. In this way, with such a collaboration, new green technologies and practices can be developed, which will encourage innovation across the whole supply chain management practices specifically on sustainable grounds. Another key suggestion is linked to the manufacturing linked with the concept of sustainability.

Since sustainable manufacturing has a positive impact on green innovation; therefore, the current research suggests the selected company invest in upgrading its production processes. Additionally, another suggestion for the selected company is to focus on sustainable transportation and storage. While these areas had weaker results, they shouldn't be overlooked. By improving transportation methods and storage practices, the company can still make a significant impact in reducing its environmental footprint and promoting innovation. Additionally, the study suggests that the company should integrate sustainability throughout the supply chain. All departments and operations need to align with the goal of promoting green innovation, ensuring sustainability becomes a core part of the company's operations. Finally, the company should make green innovation a central part of its overall strategy.

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