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Relationship between Green Innovation and Environmental Sustainability the Mediating Role of Environmental Design Product: A Study in a Number of Industries

Mohammed Ibrahim Mohammed Hussein
Iraq - University of Kirkuk - College of Administration and Economics, Assistant Prof Dr. Production Operations and Quality Management

Abstract: In light of the environmental deterioration occurring in Iraq as a result of mismanagement and limited attention by the government to the environmental aspect on the one hand, and as a result of industrial processes that do not take into account the environmental aspects in their activities on the other hand, this has led to an increase in the rate of pollution in the country In light of this, the aim of the study is to prove the relationship between green innovation and environmental sustainability through the environmental design of the product To achieve the aim of the study, address its problem and test its hypotheses, 280 questionnaires were distributed to various workers in different industrial sectors in Iraq After collecting the data, they were analyzed using SPSS, 28 in addition to using Bootstrap technology to determine the relationship between the variables Based on the results of the statistical analysis, it was found that there is a statistically significant relationship between green innovation and environmental sustainability through the environmental design of the product.

Key words: Green innovation, environmental design of the product, environmental sustainability.

1 Introduction

Green innovation is an inevitable response to stringent environmental regulations as well as sustainability trends in production and consumption How to transform green ideas into concrete practices while enhancing competitive advantage is an urgent problem for enterprises Therefore, implementing green innovation strategies and integrating them into the entire product life cycle can help enterprises reduce environmental damage and meet stringent environmental regulations This will enable enterprises to achieve “win-win” outcomes in terms of profit, social benefit, and competitive advantage (Tu & Wu, 2021).

Environmental product design is a fundamental means of reducing environmental pollution and improving corporate performance and competitive advantage, as green design practice reduces resource waste from the beginning and environmental product pollution throughout the entire life

cycle process, so environmental design is a fundamental process for companies to implement green growth models (Chen, et. al, 2018).

Environmental sustainability is one of the important pillars for keeping the earth in good condition for future generations without wasting natural resources or depleting and tampering with the natural environment, and this is achieved by protecting it, such as reducing waste and using renewable natural resources free of fuel and eliminating toxic materials and protecting human health and nature, while at the same time creating innovations that do not affect the lifestyle in our environment and living, as sustainability is a state of interaction between the components of the environment and humans in a way that ensures its sustainability, with the aim of protecting the components of the environment and preserving resources (Majid and Ismail, 2019, 384).

Therefore, environmental sustainability is one of the most important strategies to promote green innovation that meets the needs of consumers by making green products through the use of environmentally friendly technologies that indicate the practical use of resources while developing environmental practices and efficiency (Shahzad, etal, 2020) The concept of green or environmental design has also emerged, which established a solid theoretical foundation and an innovative practical approach to further improve the relationship between humans and the natural environment, based on the theory of sustainable development, and in the field of major economic and social mapping, in order to apply the theory of sustainable development in human production activities to the sustainable use of ecological resources, leading to sustainable development (Li & Sun, 2019) Thus, this study reviews the literature and develops hypotheses related to the relationship between green innovation, environmental design of the product, and environmental sustainability, as well as discussing the results and their implications for the Iraqi environment.

2 Literature review and hypotheses development

2-1- Green innovation

We define green innovation as “innovation in hardware or software related to green products or processes, including innovation in technologies that contribute to energy saving, pollution prevention, waste recycling, green product design, or corporate environmental management” (Hassiba and Ba’ilish, 2022, 110) The success of green innovation depends on the application of its three dimensions, which are (Mahmoud, 2024, 200) (Al-Samak, et. al, 2021, 266): 1- Innovation of green products: This refers to products that use fewer materials in their production process, have a low impact and risk to the environment, and produce less waste throughout their life cycle 2- Green process innovation: It represents the modification procedures in manufacturing processes and systems for producing environmentally friendly goods and products in line with environmental goals, meaning adaptation and harmony in manufacturing while reducing the negative impact on the environment, 3- Organizational innovation: It means implementing a new organizational method in the organization's business location, such as arranging the work place and external relations, meaning that this innovation is concerned with interactive relationships to complete tasks within the work, meaning that it can be focused on the organizational structure or business design and control methods, and it is defined as the organizational ability to renew ideas and knowledge, not to produce new products, services or processes continuously for the benefit of stakeholders.

This is consistent with the study (Wang, et al, 2021) which aims to investigate the impact of stakeholders' opinions on green innovation practices (GI), and the impact on environmental and organizational performance (OP), and a sample of 515 responses was used, and data was collected from manufacturing and service companies through a field survey using a questionnaire in Pakistan, our results proved the existence of a significant positive link between stakeholders' opinions on green innovation practices, and a significant link was also found between green innovation practices, the environment and organizational performance.

2-2- Green innovation and environmental sustainability

(Muhammad and Nasser, 2023, 44) and (Al-Shammari and Al-Sudani, 2020, 366) agree that environmental sustainability is the good handling of natural resources and their use for the benefit of humans, without disrupting other components of the environment, in addition to preserving the quality of the natural environment and preserving ecological systems in order to provide basic goods and services for human life, such as clean water and food, as well as preserving biodiversity and regulating the climate Environmental sustainability can be achieved through specific dimensions or requirements according to what some writers and researchers consider, such as (Salman, 2016, 155) (Dawoud, 2017, 83): 1- Reducing pollution: It has become necessary to monitor environmental pollution, know the sources of pollution, and work to put an end to them in order to preserve human health and the natural environment 2- Rationalization of resource consumption: The necessity of having a scientific management of natural resources that is linked to environmental management to reduce pressure on them, through how to deal with available resources and exploit them in a way that ensures meeting the needs of current individuals and future generations without causing harm to them 3- Use of renewable energy: Renewable energy is that which we can obtain through its repeated presence in nature in an automatic and periodic form, such as electrical energy generated from the sun, wind, geothermal and hydrothermal heat, biomass, and bio-hydrogen fuel extracted from the earth's interior, all of which are renewable sources, and this achieves environmental sustainability.

A study (Qawasmi, 2021) focused on the topic of "The reality of applying green innovation and its role in enhancing environmental sustainability in industrial establishments in Hebron Governorate from the point of view of senior management" The study aimed to know the reality of applying green innovation and its role in enhancing environmental sustainability in industrial establishments in Hebron Governorate from the point of view of senior management To achieve the objectives of the study, the study used the descriptive analytical approach, and designed a questionnaire that included (44) paragraphs distributed over two axes The first axis included the reality of applying green innovation in industrial establishments, while the second axis was related to enhancing environmental sustainability in industrial establishments The study community consisted of (207) employees on whom this study was conducted The most prominent results were the existence of a significant impact relationship of green innovation on environmental sustainability This result helped us formulate the following hypothesis:

H1: The dimensions of green innovation (green product innovation H1a - green process innovation H1b - green organizational innovation H1c) have a positive impact on environmental sustainability.

2-3- Green Innovation and Environmental Design Product

In 1998, the concept of environmental design of the product was used by (John Button) in its initial stages, which focused on the details of the environmental design practice for the industry as a whole (Al-Alwan and Beck, 2017, 4) There are several definitions to determine the environmental design of products, as it was defined as an integrated system whose primary goal is to preserve the environment and work to reduce the environmental impacts of the product throughout its life cycle, through the use of materials that are not harmful to the environment, as the environmental aspects of the product are determined and then integrated into the product design process in the early stage of the product development process (Bidyar and Bouasha, 2022, 26) The environmental performance of the life cycle can be improved by applying three main types of environmental design strategies for the product: (Al-Abbadi and Al-Tawil, 2022, 26) (Fiksel, 2009, 52): 1- Product life extension strategy: Specialists in the field of green marketing are greatly interested in the product life cycle, as they focus on extending the product life cycle as much as possible by always seeking to distinguish the product in a way that gives it priority over other products Other 2- End-of-life strategy: This strategy aims to recover materials at the end of

the product's life, close the material cycle and partially recover other resources used in its manufacture such as reusing systems and components, and recycling materials in the primary production cycle 3- Resource reduction strategy: The previous strategy has a clear impact only after the product is manufactured, therefore, a third important type of environmental strategy is operated before the production stage, known as the resource reduction strategy, which is again related to the material dimension of the product, and aims to reduce the resources used in its manufacture The study (Chen, et. al, 2018) focused on "the relationship between environmental product design and green innovation" indicates that environmental design is one of the main factors that promote green innovation in companies According to academic literature, the environmental design of products contributes to reducing the environmental impact of products during their life cycle, which leads to improving the environmental performance of the organization and increasing its sustainable competitive advantages, as some studies have confirmed that green innovation is positively affected by integrating environmental design principles into the initial stages of product development, and the study found statistically significant differences between environmental design of the product and green innovation, in light of which the following hypothesis was formulated:

H2: The dimensions of green innovation (green product innovation H2a - green process innovation H2b - green organizational innovation H2c) have a positive impact on the environmental design of the product.

2-4- Environmental design of the product and environmental sustainability

The relationship between environmental design of the product and environmental sustainability was consistent with the study (Delaney, et. al, 2022) This study was entitled (Investigating environmental sustainability and product design: A critical review) This study aims to identify and review the basic factors through which product design has the ability to influence and improve the overall environmental sustainability of the product A comprehensive review of the literature was conducted to identify trends over the past four decades Factors with great potential, such as 6Rs, waste and energy, were identified and discussed, which help designers implement environmental sustainability during the product design process Through this analysis, a new conceptual framework was envisioned that facilitates designers to implement environmental sustainability during product development In addition, future research opportunities were identified, which helped us formulate the third hypothesis and its branches:

H3: The dimensions of environmental design of the product (extending the life of the product H3a - end of the life of the product H3b - and reducing resources H3c) have a statistically significant effect on environmental sustainability.

2-5- Green innovation, environmental design of the product and environmental sustainability

Green innovation contributes significantly to supporting environmental sustainability as an effective tool to address environmental challenges such as emissions and waste, polluted water, climate change, loss of biodiversity, and overuse of resources These challenges require the development of a comprehensive model for green innovation to eradicate environmental problems from their roots, which leads to saving resources, creating more sustainable operations, and achieving a competitive advantage and higher revenues for business institutions This is positively reflected on companies seeking to adopt the green innovation approach, by improving and creating an environmentally friendly product, process and service In addition, studies, research and inventions that will be completed in the context of applying green innovation in the institution, and attracting human minds to carry out these tasks will add competitive value to the institution (Al-Qawasmi, 2021).

In the field of product design, integrating environmental sustainability into product development is called environmental design Ecological design was developed in the 1990s with the aim of improving the environmental performance of the product In this way, ecological design expands the product design model, adding to the existing aesthetic and performance considerations, enabling designers to make design decisions that affect the greenhouse gas emissions of the product through their choice of materials and/or the amount of materials used This will achieve the management of sustainability goals in product design (Wei, et. al, 2023, 815) In light of this, we will be able to formulate the fourth hypothesis, which is:

H4: The dimensions of green innovation (green product innovation H1a - green process innovation H1b - green organizational innovation H1c) have a positive impact on environmental sustainability through the ecological design of the product.

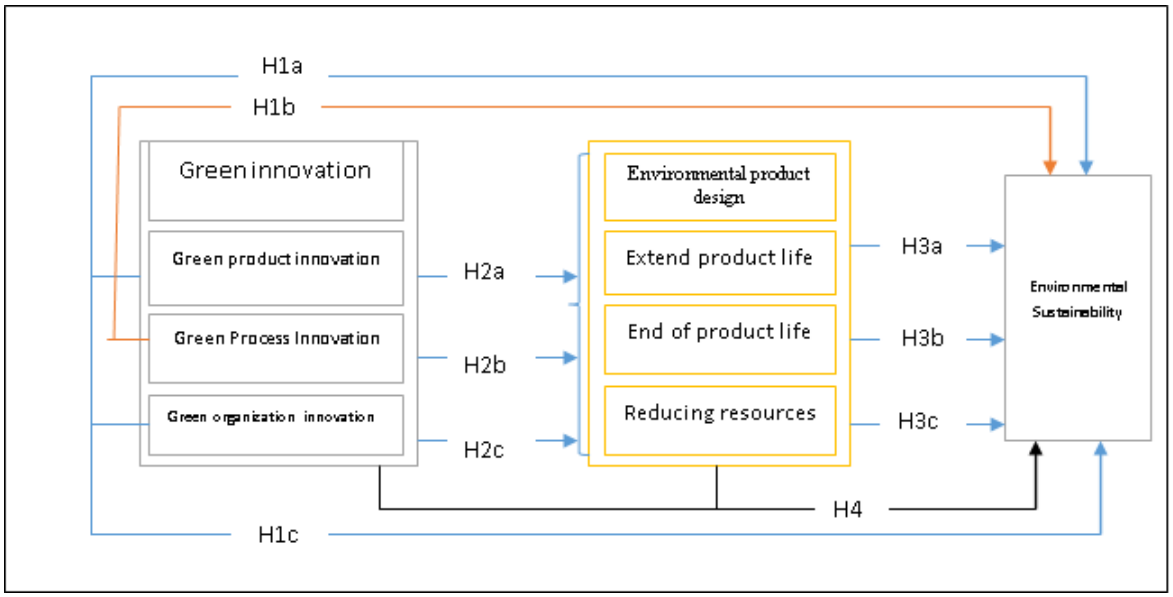

Figure 1 Conceptual Model

3- Study Methodology

The Iraqi environment faces many problems and challenges, including environmental pollution resulting from the production processes carried out by Iraqi industrial companies This pollution negatively affects human health and the natural environment alike, which undermines the government's efforts to achieve sustainable development To solve this problem, green products must be created and designed in a way that is friendly to the environment and society and generates revenues for the state on the one hand, and helps achieve environmental sustainability on the other hand The following question can be raised: How does green innovation contribute to achieving environmental sustainability through the environmental design of the product?

The main objective of the study is to find the relationship between green innovation and environmental sustainability through the environmental design of the product This objective will enable us to identify the most important obstacles facing green innovation, environmental design and environmental sustainability and address them based on the theoretical and practical aspects of the study.

The study adopted the descriptive analytical approach, and data were collected using the questionnaire form, Table (2) The study sample consisted of 20 Iraqi companies operating in various fields, such as electrical and electronic industries, medical industries, building materials and equipment, food products, and others The total number of individuals in the study sample from the total industries was 280 individuals, as shown in Table (1).

Table (1) Types of industries and number of individuals in the study sample in each industry

Industry type	Number of people	percentage
Electrical industries	50	018
Electronic industries	45	016
Food industry	80	029
Medical industries	30	011
Equipment manufacturing	35	012
Building materials industry	40	014
the total	280	%100

3-1- Procedures:

The study adopted the questionnaire as a tool for collecting data, and the questionnaire was designed according to the five-point Likert scale (strongly agree 5, agree 4, neutral 3, disagree 2, strongly disagree 1), and this questionnaire was divided into three sections:

a- Green innovation: We adopted three dimensions (green product innovation, green process innovation, green organizational innovation) and each dimension was divided into five items as shown in Table (2) according to (Mahmoud, 2024) (Qawasmi, 2021) (Chen & Chang, 2013) (Dangelico & Pujari, 2013).

b- Environmental design of the product: We used three dimensions in environmental design, which are (extending the life of the product, the end of the life of the product, reducing resources), and each dimension included five items according to the sources (Khan, et al, 2018) (Gehin, 2008) Chen & Shen, 2017).

c- Environmental sustainability: Environmental sustainability is based on three paragraphs (reducing environmental pollution, rationalizing the use of resources, using renewable energy), and each of these dimensions includes five items in sustainability, which is consistent with (Ren, et al, 2013, Del Río, et al, 2021, Irena, 2018) (WBCSD, 2018) (Ottman, 2017).

3-2- Questionnaire design and data collection

The case study used three steps to design the questionnaire, with the aim of ensuring the accuracy of the scales and verifying the validity of the study content, we interviewed 20 executives in the first step, who must have a comprehensive understanding of the internal and external operations of their companies, experts helped create a preliminary questionnaire by reviewing the literature in the second step.

The third step involved interviewing a number of other executives to collect feedback for the final questionnaire, as shown in Table 2 We divided the questionnaire into two parts to mitigate bias, inviting different respondents from each company to complete one part each Part A included only the types of industries and the number of individuals in each industry, while Part B included green innovation, product eco-design, and environmental sustainability.

Table 2 shows the questionnaire scales taken from the literature relevant to this study We evaluated all responses using a five-point Likert scale, ranging from 1 to 5 The Likert scale is widely used by researchers as a quantitative measure to measure views and attitudes on various topics (Huang et al, 2023) We collected a total of 255 valid questionnaires for analysis, achieving a statistically acceptable response rate of 91%.

Table 2 Measurement items

Main	Dimensions	code	Paragraphs	Source
Green innovation	Green Product Innovation	GPI1	The company's management emphasizes the production of green, environmentally friendly products	Mahmoud, 2024
		GPI2	The company focuses on ensuring safe and sound use for its customers by adopting green production	
		GPI3	The company considers the environment as one of the important elements in achieving competitive superiority	
		GPI4	The company seeks to develop its products in a manner that suits the desires and needs of customers and does not harm the environment	
		GPI5	The product must be recyclable	
	Green Process Innovation	GPI6	The facility follows technologies in its production processes that reduce the emission of hazardous substances	Qawasmi, 2021
		GPI7	The facility replaces old machines with new, environmentally friendly machines	
		GPI8	The facility designs and develops machinery systems that take into account the flow of operations without causing environmental damage	
		GPI9	The facility uses clean technology that prevents pollution	
		GPI10	The facility follows techniques that reduce waste in its production processes	
	Green organizational innovation	GOI11	There is clarity in the implementation of the organization's policies related to environmental conservation	Chen & Chang, 2013 Dangelico & Pujari, 2013
		GOI12	The organization's management is interested in innovations that reduce environmental impact	
		GOI13	The organization encourages employees to suggest new environmental ideas and initiatives	
		GOI14	The organization provides training courses for employees on green innovation	
		GOI15	The organization relies on cross-departmental collaboration to foster sustainable innovation	
Environmental product design	Extend product life	EPL16	Design for Durability The ability of a product to perform a function for an extended period of time without	Khan, et al, 2018 Gehin, 2008
		EPL17	Design for reliability that the product will operate for a specified period without failure	
		EPL18	Design for Product Connection The love and trust that users feel towards the product	
		EPL19	Designed for ease of maintenance and repair to maintain the functional capability of the product	
		EPL20	Designed for easy disassembly and reassembly by separating and reassembling products and parts	
	End of life	EPL21	Striving to reduce the use of hazardous materials when designing and manufacturing products	
		EPL22	Reusing products after their expiry date, provided they are repaired	
		EPL23	Recycling expired products	
		EPL24	Increase the use of recycled materials in product manufacturing	
		EPL25	Ensuring that the ingredients of products that are put on the market do not contain environmentally friendly ingredients	
	Reducing resources RRU	RRU 26	Our company works to educate workers on the rational use of resources	Chen & Shen, 2017
		RRU 27	Our company wants to use renewable energy to preserve natural environment resources	

		RRU 28	Our company uses technologies or equipment aimed at improving energy efficiency (such as high-efficiency (appliances, thermal insulation	
		RRU 29	Our company periodically analyzes resource consumption (such as energy, water) to identify opportunities for efficiency improvement	
		RRU 30	The company relies on recycling materials and products to enhance resource efficiency	
Environmental Sustainability	reduce pollution	RP31	The company is committed to recycling waste on a daily basis	Ottman, 2017
		RP32	Our company uses environmentally friendly products (such as biodegradable materials and bags)	
		RP33	Our company takes appropriate measures to reduce energy consumption	
		RP34	Our company participates in campaigns aimed at reducing pollution to raise community awareness of environmental sustainability issues	
		RP35	The company's management constantly evaluates the role of innovation in developing sustainable solutions to environmental challenges	
	Rationalization of resource consumption	RRC36	The company adopts a clear policy to rationalize the consumption of resources (such as water and energy)	WBCSD, 2018
		RRC37	The company's management measures and monitors resource consumption in all activities it carries out	
		RRC38	The company uses intelligent control systems to improve resource efficiency	
		RRC39	Our company encourages employees to suggest ideas to improve resource efficiency	
		RRC40	green supply chain to ensure that it complies with sustainability standards	
	Use of renewable energy	RE41	Our company uses relatively renewable energy sources (solar, wind, hydropower)	Ren, et al, 2013, Del Río, et al, 2021, IRENA, 2018
		RE 42	Corporate social responsibility is one of the reasons that motivate the company to use renewable energy	
		RE 43	Your company faces challenges in adopting renewable energy such as high initial investment costs	
		RE 44	The company integrates environmental sustainability goals into its strategic plans for the use of renewable energy	
		RE 45	Our company continually evaluates the impact of renewable energy use on your company's environmental performance	

3-3- Reliability and Validity

The partial least squares method was used to measure the reliability and validity of the respective constructs, and the internal reliability of the constructs was assessed by “Cronbach’s alpha (CA) and composite reliability”. According to (Weher, et. al, 2013), CA should be greater than 0.7. Moreover, Hinton (2014) classified four ranges of CA. First, if the value falls within the range of 0.9, it falls in the region of excellent reliability. Second, if it falls between 0.7 and 0.9, it has high reliability. Third, if it falls within the range of 0.5 to 0.7, it falls in the region of moderate. Fourth, if it falls below 0.5, it is classified as low. Table 3 shows that all Cronbach's alpha (CA) values are between (0.752 and 0.772) which are in the range of high reliability. To assess convergent validity, the average variance extracted (AVE) was used. Wang et.al, 2021) suggests that the AVE value should be greater than 0.5. According to the results in the table, the AVE values are between (0.558, 0.694) which are greater than 0.5. All the values of the constructs meet the general rule. (Chin, 1998) recommended that the loading value should be greater than 0.5 because it indicates the reliability of the constructs. All the loading values were found in the range of 0.734 to 0.92.

Thus, the results showed that all the composite constructs (CR) showed reliability exceeding 0.7, with item loadings ranging from 0.828 to 0.944. Thus, it was proven that all the values meet the general rule set by scholars, as shown in Table 3.

Table 3. Assessment of measurement

Dimen	code	Factor loading analysis	Cronbach's Alpha	CR	AVE	Dimen	code	Factor loading analysis	Cronbach's Alpha	CR	AVE
Green Product Innovation	GPI1	0.920	0.765	0.885	0.558	Resource Reduction	RRU26	0.844	0.759	0.828	0.694
	GPI2	0.772	0.765				RRU27	0.780	0.755		
	GPI3	0.837	0.760				RRU28	0.767	0.760		
	GPI4	0.761	0.770				RRU29	0.832	0.762		
	GPI5	0.796	0.768				RRU30	0.799	0.753		
Green Process Innovation	GPI6	0.878	0.763	0.901	0.673	Pollution Reduction	RP31	0.839	0.755	0.868	0.664
	GPI7	0.787	0.759				RP32	0.803	0.758		
	GPI8	0.818	0.765				RP33	0.806	0.756		
	GPI9	0.874	0.761				RP34	0.795	0.746		
	GPI10	0.756	0.770				RP35	0.764	0.761		
Green Organizational Innovation	GOI11	0.770	0.764	0.87	0.662	Resource Optimization	RRC36	0.830	0.763	0.90	0.625
	GOI12	0.861	0.770				RRC37	0.808	0.759		
	GOI13	0.853	0.767				RRC38	0.828	0.763		
	GOI14	0.883	0.771				RRC39	0.748	0.762		
	GOI15	0.884	0.772				RRC40	0.742	0.763		
Product Life Extension	EPL16	0.853	0.757	0.89	0.655	Renewable Energy Use	RE41	0.836	0.761	0.944	0.629
	EPL17	0.779	0.767				RE 42	0.734	0.761		
	EPL18	0.816	0.761				RE 43	0.849	0.753		
	EPL19	0.804	0.766				RE 44	0.794	0.769		
	EPL20	0.719	0.760				RE 45	0.782	0.768		
Product End of Life	EPL21	0.850	0.762	0.86	0.655						
	EPL22	0.755	0.760								
	EPL23	0.906	0.758								
	EPL24	0.883	0.764								
	EPL25	0.798	0.762								

3-4- Exploratory factor analysis

Table 4 presents the results of the factor analysis on a set of data, and aims to determine the number of latent factors that can explain the variance in the data. Based on these results, the focus can be on the first fourteen factors (GPI1 to GPI14) because they explain the largest proportion of the variance (more than 81%). The factors that follow explain small proportions of the variance and may not be of great importance in explaining the phenomenon you are studying in the practical analysis. The focus is often on factors with eigenvalues greater than 1 because they are considered more statistically significant according to the Kaiser criterion (1960). Given that the main factors that explain the largest proportion of the variance are related to green innovation and environmental design, this supports the hypothesis that there is a strong relationship between these variables and environmental sustainability. Therefore, the first fourteen factors can be important indicators of the extent to which green innovation and environmental design affect achieving environmental sustainability goals.

Table 4. Total Variance Explained

compoment	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	
GPI1	7.040	15.645	15.645	7.040	15.645	15.645	
GPI2	6.139	13.642	29.287	6.139	13.642	29.287	
GPI3	4.216	9.369	38.656	4.216	9.369	38.656	
GPI4	2.879	6.398	45.054	2.879	6.398	45.054	
GPI5	2.347	5.216	50.270	2.347	5.216	50.270	
GPI6	2.229	4.954	55.224	2.229	4.954	55.224	

GPI7	2.000	4.444	59.667	2.000	4.444	59.667	
GPI8	1.865	4.146	63.813	1.865	4.146	63.813	
GPI9	1.657	3.681	67.494	1.657	3.681	67.494	
GPI10	1.542	3.427	70.921	1.542	3.427	70.921	
GOI11	1.389	3.086	74.007	1.389	3.086	74.007	
GOI12	1.157	2.571	76.579	1.157	2.571	76.579	
GOI13	1.091	2.424	79.002	1.091	2.424	79.002	
GOI14	1.043	2.317	81.319	1.043	2.317	81.319	
GOI15	0.948	2.107	83.427				
EPL16	0.835	1.856	85.282				
EPL17	0.784	1.743	87.025				
EPL18	0.684	1.520	88.545				
EPL19	0.663	1.473	90.018				
EPL20	0.520	1.156	91.174				
EPL21	0.459	1.021	92.195				
EPL22	0.449	0.998	93.193				
EPL23	0.408	0.906	94.099				
EPL24	0.352	0.782	94.881				
EPL25	0.309	0.688	95.568				
RRU26	0.278	0.618	96.186				
RRU27	0.249	0.553	96.739				
RRU28	0.202	0.449	97.189				
RRU29	0.194	0.431	97.620				
RRU30	0.180	0.401	98.020				
RP31	0.162	0.360	98.380				
RP32	0.152	0.338	98.718				
RP33	0.118	0.263	98.981				
RP34	0.114	0.254	99.234				
RP35	0.081	0.180	99.414				
RRC36	0.070	0.156	99.570				
RRC37	0.054	0.119	99.689				
RRC38	0.045	0.100	99.789				
RRC39	0.033	0.073	99.862				
RRC40	0.025	0.055	99.917				
RE41	0.018	0.040	99.957				
RE 42	0.009	0.019	99.977				
RE 43	0.007	0.015	99.991				
RE 44	0.003	0.006	99.997				
RE 45	0.001	0.003	100.000				

3-4- Hypothesis Testing:

To ensure the relationship between the variables and test the hypotheses, the ProcessMacro program was used. This program undertakes the analysis of mediation and direct and indirect effects. It is common to determine the relationships between variables. Resampling was used using the Bootstrap method with a random sample of 1000 and a confidence interval of 0.95. The reliability and validity of the results are confirmed. Confidence intervals (BootLLCI and BootULCI): The lower and upper limits of the confidence intervals show the extent of the sample's influence on the outcome, and are necessary to determine whether the effect is

statistically significant. If the confidence interval does not include zero, this means that the effect is statistically significant.

The results in Table 5 showed that there are direct effects and full and partial mediation between the studied variables. This highlights the vital role that mediating variables such as Environmental Product Design (EPD) play in enhancing environmental performance (ES). This means that organizations can significantly improve environmental performance by focusing on specific mediating factors.

Based on the Bootstrap statistical analysis, the hypotheses presented in the study can be accepted because there are direct relationships, full and partial mediation, which confirms the importance of green innovation, environmental product design and related policies in improving environmental sustainability.

Table 5. Bootstrap mediating effect

Relationship	Hypothesis	Total effect	SE	Direct effect	Indirect effect	BootSE	BootLLCI	BootULCI	Result
GPI > ES	H1a	0.0623	0.0598	0.006	0.0823	0.0434	0.0532	0.153	**Direct effect**
GPI > ES	H1b	0.609	0.0388	0.0311	0.546	0.0297	0.361	0.511	**Direct effect**
GOI > ES	H1c	0.411	0,0453	0.0233	0.411	0.0354	0.353	0.473	**Direct effect**
GPI > EPD > ES	H2a	0.421	0.0445	0.0145	0.417	0.0388	0.372	0.523	**Full Mediation**
GPI > EPD > ES	H2b	0.401	0.0400	0.0292	0.382	0.0342	0.349	0.496	**Full mediation**
GOI > EPD > ES	H3c	0.411	0.0410	0.0342	0.0321	0.0400	0.345	0.482	**Partialmediation**
EPL > ES	H3a	0.396	0.0543	0.0322	0.361	0.0467	0.337	0.467	**Direct effect**
EPL > ES	H3b	0.387	0.0434	0.0381	0.352	0.0365	0.335	0.456	**Direct effect**
UUR> ES	H3c	0.501	0.0561	0.009	0.478	0.0488	0.324	0.476	**Direct effect**
GI > EPD > ES	H4	0.421	0.0431	0.0343	0.391	0.0421	0.317	0.461	**Full mediation**

4- Discussions and implications

This study aims to investigate the relationship between green innovation and environmental sustainability through the mediation of the environmental design of the product in Iraqi companies. The study also discussed the direct and indirect impact of green innovation in all its dimensions (green product innovation, green process innovation, green organizational innovation) on environmental sustainability, as well as discussing the indirect impact through the environmental design of the product, while the direct impact is without the intervention of the mediating variable, in addition to examining the relationship of the direct impact of environmental design in all its dimensions (extending the life of the product, the end of the life of the product, reducing resources) on environmental sustainability. To examine this relationship, we designed a questionnaire on companies in Iraq using hypothetical models, which led to the following conclusions:

First: It appears that green innovation has a general positive impact on the environmental design of the product, indicating that most companies have the resources necessary to take the proactive innovative measures required to support the environmental design processes of the product. In contrast, the results show that green innovation has a positive impact on environmental sustainability through environmental design, which justifies companies taking only reactive and remedial measures to deal with environmental issues. This result is somewhat similar to many studies that indicated the positive impact of green innovation On the environmental sustainability of companies, but they differ at the level of sub-dimensions (Al-Qawasmi, 2021, Chen, et. al, 2018). However, these studies only emphasize the interrelationships, while our results show that green innovation requires more details to understand how it affects the environmental issues of

Iraqi companies, which supports decision-makers with a deeper understanding of the requirements for adopting environmental issues.

Second: The results of the mediating variable, environmental design, in all its dimensions (extending product life, end of product life, reducing resources) indicate that it has a strong impact on environmental sustainability. These results are consistent with the conclusions reached by (Delaney, et. al, 2022, Wei, et. al, 2023, 815), that the environmental design of the product helps improve the quality of products and services by exploring and developing new environmental knowledge, technologies and capabilities, and helps create a positive image of green companies, which is difficult to imitate and exceed, to meet the needs of the market and potential customers, and to create a distinctive competitive advantage for the company.

Third: Our results show that (product life extension, end of product life, resource reduction) completely mediate the relationship between green innovation and environmental sustainability, as the results indicate that all dimensions of environmental design have the same direct and indirect effects on the study variables, which explains why Iraqi companies need environmental design indicators for the product to improve their environmental performance, and it also highlights the importance of the environmental design indicator for the product as an intervening variable.

5- Administrative implications

Iraq is one of the countries most affected by environmental degradation, which has led to the loss of a large part of its water resources and a significant increase in desertification rates. Recently, the government has begun to implement strict environmental regulations that include various industrial companies. Many of these companies have begun to integrate environmental issues into their development strategies, through the use of clean energy sources and recycled raw materials, the development of recyclable products, and innovation in environmental fields. In addition, the issue of environmental performance has received great attention from managers inside and outside the organization. External parties have a major role in improving environmental performance by enacting laws to protect the environment and organizations' commitment to implementing them in order to reduce the negative impact of their activities on the environment by adopting sustainable practices, such as reducing harmful emissions and using resources efficiently, with the aim of achieving a balance between economic growth and environmental responsibility (Al-Janabi, 2011, 70). These changes are expected to affect green innovation for institutions in many ways. Therefore, this study aims to provide some practical recommendations for management.

First: Company managers should use green innovation as a tool to improve the overall and environmental performance of organizations. This can be achieved by encouraging companies to integrate green innovation into the design and production process of their products, by integrating environmental issues into their strategic plans.

Second: Companies should pay great attention to the environmental design of products, given its importance in enhancing the environmental sustainability of the company and the country. Environmental design plays a fundamental role in achieving a balance between green innovation and environmental sustainability. Therefore, companies should re-evaluate their traditional concepts and recognize that green innovation represents an opportunity to improve the quality of their products, increase their environmental efficiency, and reduce environmental degradation by adopting environmental design principles and using new resources to develop more sustainable products.

Third: The results of the study indicate that achieving environmental sustainability requires an integrated and balanced system that combines green innovation and environmental sustainability. This integrated system contributes to creating an effective framework for environmental management, in addition to a system of incentives and penalties for environmental protection.

This will enhance the corporate culture that places the environment at the forefront of its priorities, which will lead to increased environmental awareness among employees and partners in the field of green innovation. In addition, adopting green standards will enable companies to choose and develop environmentally friendly product designs.

6- Conclusions and limitations

This study demonstrates the impact of green innovation on environmental sustainability through the mediation of product eco-design. The results reveal that green innovation has a positive impact on environmental sustainability across its three dimensions (green product innovation, green process innovation, green organizational innovation). Our results also indicate that green innovation does not directly affect environmental sustainability, but rather exerts an indirect effect through the mediation of product eco-design, thus validating the role of eco-design as a mediating variable. This study has some limitations because it only collects the same data for the variables at one point in time, ignoring cross-sectional data. Future research should be designed based on longitudinal data tracking to examine causal relationships more closely. Future research should also examine other mediating factors or external factors as moderating variables, such as the integration of sustainable and green innovation.

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