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PRODUCTION ENGINEERING ARCHIVES 2024, 30(2), 166-181

PRODUCTION ENGINEERING ARCHIVES

ISSN 2353-5156 (print)
ISSN 2353-7779 (online)

Exist since 4th quarter 2013
Available online at https://pea-journal.eu

The impact of cleaner production strategy on Sustainable supply chain performance

Sadiq Kamel Obaid Al-Humairi[1*], Mahmood Fahad Abd Ali[1], Ali Abdulhassan Abbas[2]

[1] University of Kerbala/ College of Administration and Economics/ Department of Business Administration, Iraq; sadeq.k@s.uokerbala.edu.iq; Kamlsadq86@gmail.com (SKOA); mahmod.fahad@uokerbala.edu.iq (MFAA)
[2] University of Kerbala/ College of Administration and Economics/ Department of Accounting, Iraq; Fuhrer313@gmail.com, ali.abd.alhassan@uokerbala.edu.iq
*Correspondence: Fuhrer313@gmail.com

Article history
Received 24.01.2024
Accepted 08.04.2024
Available online 31.05.2024

Keywords
Cleaner Production Strategy,
Sustainable Supply Chain.

Abstract
There is a paradigm shift occurring in organizations towards sustainable production through cleaner production strategies. This cleaner production concept has been proven to be cost-effective, result-oriented, environment-savvy and provides the organizations a cutting edge over their counterparts. However, there is a lack of awareness about cleaner production practices in Iraq while the current study analyzed one of the most important factories in Iraq for sugar production to understand the factors required for successful application of cleaner production strategy and the challenges to be expected. In this study, the researchers followed an exploratory research approach. For this study, a questionnaire was designed, validated and distributed randomly among 700 potential respondents working in various departments of the organization under study. Out of the total responses, 482 responses were considered and SEM-PLS analysis was conducted. The cleaner production strategies were applied through nine dimensions and the relationship between the performance of the factory and sustainable supply chain was found to be prominent. With a few limitations such as the choice of a single factory, weak relationship between the variables identified from hypothesis testing, the study is a first-of-its-kind in this domain, especially in dealing with sugar refineries. Based on the outcomes, policy recommendations were made to the decision makers and the government. It can be concluded that the application of modern technologies and effective resource management can help in achieving the goal of the study.

DOI: 10.30657/pea.2024.30.16

1. Introduction

Recently, business organizations have started realizing that the current production and consumption patterns are unsustainable and the resources are bound to deplete sooner (Chungyalpa, 2021). So, it has become the duty of every organization to strategize for the integration of cleaner production strategies into their operations and pay attention to achieving a sustainable supply chain. The core components of this strategy include focusing on environmental considerations, development of long-term strategic plans for the implementation of cleaner production and sustainable supply chain and the integration of environmental considerations into the organization's core operations (Gamage et al., 2023). Perhaps, the most important tool to achieve this integration is the acquisition of green technologies that can improve environmental performance following the policies and frameworks. Such technologies have been developed by various industrial organizations and are extensively applied without legislative pressures. This method of dealing the environmental issues is relatively new and has resorted to highly industrialized countries so far. The studies conducted in such countries proved that cleaner production is an effective and efficient method in terms of benefits reaped from protecting the environment (Chen et al., 2023; Gamage, Arachchige and Godakanda, 2023; Kumar et al., 2024), Abd Ali et al., 2020). Despite this, the extent of negligence in applying cleaner production strategies in the Iraqi environment heavily destructed the environment and it has been ranked as fifth most vulnerable country to climate change (Al-Shammari, 2016; USAID, 2023), as a result of primitive production methods. The environmental standards have not been complied with by numerous Iraqi projects. This is aggravated by the absence of a clear vision among the decision-makers in productive organizations regarding the importance of preserving the environment (Moyel et al., 2023).

The problem undertaken in the current study is to develop cleaner production strategies in light of the financial capabilities available to the organization and identify the most important requirements to achieve a sustainable supply chain. The lack of environmental culture in Iraqi society and the lack of awareness about the harm caused by environmental pollution made the majority assume that the application of cleaner production and sustainable supply chain strategies are too expensive and reduce the organization's net profits, though cleaner production practices mitigate the expenses of the company (Prigozhin et al., 2023; Soror and Ahmed, 2023). This assumption led the decision-makers to avert the execution of environment-friendly production methods. Hence, there is a need to create awareness about the process, and develop strategies and intellectual frameworks for organizations to achieve a sustainable supply chain. Through the problem statement of the study, the authors attempt to answer several questions, namely: Can a cleaner production strategy be applied successfully? What are the most important areas of support or preference for a cleaner production strategy? What are the limits of the contribution of a cleaner production strategy in supporting the performance requirements of a sustainable supply chain? And are there any specific preferences for cleaner production strategies and for some dimensions of the performance of the sustainable supply chain. The current study is a first-of-its-kind in this domain in Iraq, though a few studies have been conducted earlier in Iraq that suggested the incorporation of cleaner production process to achieve sustainability (Kinani and Najjar, 2019; AL-Munim and Hameed, 2021). Further, to the best of the authors' knowledge, no study has been conducted so far focusing sugar mills in Iraq or the study company. Thus, the current research work is a valuable contribution to the research community, policy-makers in the government and decision-makers at the organizations to revive their production strategies towards achieving sustainability.

2. Literature review

2.1. Cleaner production strategy

Cleaner production strategy calls for the adoption of consumer and production practices that focus on integrated preventive strategies such as the evaluation of environmental impact, product life cycle, alterations in priorities from waste treatment strategy to prevention of waste generation and environment-friendly production processes that are compatible with consumer requirements. This strategy is continuously evolving in industrial processes that deal with products and services intending to reduce the consumption of natural resources and save the environment (Dehshiri et al., 2023; Hariga et al., 2023). It is an integrated strategy to avoid the negative effects of industrial processes in terms of human health and the environment. Cleaner production strategies include a set of procedures and initiatives in industrial organizations such as employee training on cleaner production concepts, strategic plan development, self-monitoring and environmental auditing operations, product life assessment studies, implementing the suggestions derived from the study outcomes, disseminating the information inside and outside the organization, and periodical follow-up (David et al., 2023; (Al-Tami and Al-Zaidi, 2012; Handhal, 2017).

Some of the possible goals of cleaner production practices include 1) obtaining the financial returns and environmental benefits at a relatively low cost, 2) developing novel production methods and making appropriate modifications to the life cycle of products including the extraction, classification, storage, application and safe disposal of raw materials, 3) integration of health and environmental considerations in all the production processes 4) protection of human health and the environment, 5) alleviating the pressure from compliance to environmental laws, and 6) efficient production by reducing the waste at the source (Majeed and Shaker, 2016). One of the most important goals of cleaner production is to coherently work with others to achieve broader economic development that meets the basic needs of society and also links it with both development plans as well as the principles of environmental conservation. This sort of application reduces the depletion of natural resources, and environmental protection costs and increases the economic returns from recycling and reuse of raw materials, production, energy savings (Hasiany et al., 2023; Morero et al., 2024), and product quality. (Handhal, 2013; AL-Sammk and AL-Rahawi, 2018).

Cleaner production is approached from two aspects such as a narrow aspect that focuses on inputs (energy sources). Accordingly, cleaner production is defined as the optimal utilization of resources to reduce both waste and emissions. The second aspect is a broader one that emphasizes sustainability in the whole production system i.e., inputs, processes and outputs. The latter provides a comprehensive, integrated and preventive approach to protect the environment, leverage the inputs, processes, and outputs, reduce the emission of pollutants, reach zero pollution, ensure the product's quality, reduce the cost and ensure cleaner production. This process has four stages such as the inputs, processes, products and services as briefed below. Inputs: It denotes the raw materials used in the organizations that are renewable and recyclable. This aspect includes the energy required for the transformational processes, the possibility of minimally using non-renewable and non-recyclable materials and energy, and excluding the toxic and polluting materials that harm the environment. Processes: This component involves the storage of inputs, production line tasks and reduction of hazardous emissions during the operation process. Products (goods): This stage has a minimum negative impact along the product's life cycle from the extraction of raw materials to its safe disposal and its reuse. Services: It includes environmental concerns in both design and provision of the services (Ismael, 2014; Al-Shawi, 2017; (Qasim, 2019; Rosak-Szyrocka and Abbase, 2020). The researchers (Ismael, 2014; Handhel, 2013) identified a set of practices that an organization should adopt while implementing a cleaner production strategy and it is briefed below.

Good Operating Practices: These are the procedural and administrative measures to be implemented in every department of an organization to reduce costs, emissions and pollution and improve efficiency.

1. Management and employee practices: Training programs must be developed for employees related to cleaner production practices and their implementation. Further, incentive programs should be developed to reduce emissions and pollutants.
2. Storage and handling practices for materials: This part includes the development of personnel and practices for dealing with raw materials and appropriate storage conditions to reduce material damage, leakage, and their negative effects on the environment. This committee monitors the warehouses periodically, reviews and incorporates the modern storage methods as per the global competitors or identifies suitable alternatives to reduce pollution during the storage period.
3. Deployment of policies and personnel regarding the reduction of pollutants and emissions from ageing machines and equipment through periodic evaluation and methods to either repair or replace them.
4. Waste separation/sorting practices: This component reduces the volume of hazardous waste by preventing the hazardous waste from mixing with non-hazardous waste.
5. Cost accounting practices: This component involves the calculations of costs allocated to waste treatment and disposal.

Change in raw materials: Air and water are the most commonly affected natural elements. So, the production materials that cause harm to the environment must be replaced in the pursuit of health reasons. For instance, the replacement of certain cancer-causing solvents and compounds like lead-containing paints with non-carcinogenic materials such as water-based cleaners instead of organic solvent-based cleaners, application of alternative compounds that do not harm the ozone layer, avoiding the usage of asbestos fibres (glass fibres) due to non-renewable nature of the source.

Technology Change: This component involves the modifications made in machines and equipment, removal of polluting machines, (either partial or at times, the complete revamp of the machinery), and identifying cost-effective machines to ensure the sustainable production capability of the organization, high efficiency and the discharge of less environmental pollutants. This includes the removal of processes that cause harmful substances. A well-known example lies in the manufacture of chlorine products and caustic soda in which the discharge of mercury into the environment can be avoided by factories by following the membrane cell method.

These changes may include changes brought in production technology as well

1. Changes in the production process
2. Modification of equipment and internal design of the equipment and machines
3. Automation of the processes
4. Changes in the processes such as flow rates, temperatures and working environment.

Product Design Change: It includes the changes brought in the product to reduce the emissions during its use and after disposal. These changes can lead to redesigning the product and its technical composition. These changes are made through quality specifications, product formulation, reliability and replacement of the product.

Reducing, Reusing & Recycling

It refers to the prevention of waste generation at its source that starts from reducing the usage of raw materials and energy, reusing the waste generated and recycling it as useful materials through a set of treatments. To be precise, the processes correspond to repetitive usage of the product by changing its original use. The recycling process means returning the product or materials that can be treated by adding some chemicals or biological materials or through physical treatment methods. Recycling supports the usage of raw materials in the production process using the once-useless waste. However, such waste gains high value once it is recycled. Further, the waste generated in some industries can be sold to other companies either after recycling or as a raw material.

2.2. Sustainable supply chain performance

Sustainable supply chain performance is relatively a new terminology that closely associates sustainability with supply chain performance. This amalgamation started with a special focus on integrating the 'green' considerations in supply chain management practices. Further, it also expanded by encompassing social considerations within the concept of supply chain management. A sustainable supply chain is considered to be an extension of green supply chain performance. Many studies (Tundys, 2020; Pereira et al., 2023; Sarfraz, Khawaja, et al., 2023) infer the effectiveness of sustainable supply chain performance as an important business strategy to improve the environmental and social sustainability of the organization. The literature emphasizes that a sustainable supply chain helps in achieving the profit goals, expanding the market share, and reducing the negative environmental and social impacts. It further represents an evolution of the traditional supply chain management combined with the overall goals of sustainability. It has been defined as the management of the flow of materials, information, and funds, as well as cooperation between the organizations along the supply chain, to achieve economic, environmental, and social objectives that stem from the requirements of customers and stakeholders. In addition to this, it also represents "a strategic and transparent integration within which the organization's social, environmental and economic goals are achieved, through comprehensive coordination of the main operations between the organizations to improve the long-term economic performance of the focal institution and its supply chains." According to (Mahmahi and Mazhouda, 2021), sustainable processing is a supply chain management process that is aimed at preserving environmental, economic and social stability to achieve sustainable growth. Organizations that adopt sustainable practices can generate economic returns and new revenue sources. In addition to customer and employee satisfaction, the integration of sustainability into business has become a strategic choice. The strategic choices that seek sustainability can be a decisive factor in giving organizations a competitive edge in terms of product image, sales, and market share. For this outcome, a sustainability strategy should be implemented in the supply chain process to accomplish economic, environmental and social well-being (Hassan and Al-Nima, 2020). The goal of supply chain management practices is to deliver the required products or services at the right time to customers by managing all the supply chain activities and increasing the profitability of the organizations. However, today's organizations cannot focus only on profitability or financial performance, but also on social and environmental performance. Unlike the traditional concept, the modern concept encompasses economic, environmental and social considerations in evaluating the organization's performance (Sehgal et al., 2022; Coelho et al., 2023; Sarfraz, Ozturk, et al., 2023). As briefed earlier, supply chain management is an integrated process that manages the flow of materials, information and capital and ensures cooperation between the companies in the supply chain to achieve customer and stakeholder requirements sustainably. It acts as a comprehensive key business process between the organizations to improve their long-term economic performance (Al-juboury and Al-Nima, 2021). It creates a crucial link between the inputs and outputs. Traditional challenges involved in the supply chain include high costs, timely delivery, and reduced sustainable product design according to business needs. However, the increasing environmental, social and economic costs of these networks and the increasing consumer pressure for eco-friendly products led numerous organizations to view 'sustainable supply chain' as a new metric for profitable logistics management (Li, 2023; Sadeghi and Qaisari Hasan Abadi, 2024). This paradigm shift translates that sustainable supply chains mean profitable supply chains. The idea of integrating the concepts of environmental sustainability and supply chain practices motivated major companies to adopt the approach for achieving sustainable supply chains. This integration enables the companies to preserve the environment, as well as safeguard their employees. This, in turn, gets reflected in a culture between the consumer and the company, since the purchasing decisions of consumers are decided by the potential negative effects of the products (Sadeli et al., 2023). According to Al-Shamroukh, 2022, the reason behind the shift of the companies to manufacture in an eco-friendly manner is yet to be explored. However, the consumers already started preferring products from eco-friendly production practices (Shahrukh et al., 2023; Lopes, Gomes and Trancoso, 2024). The benefits reaped by a customer in the supply chain include less inventory and its optimal distribution, high-quality products, low transportation cost, increased sales, rapid marketing time, heightened customer service and loyalty, supply of highly-efficient raw materials and finished goods, improved employee productivity waste reduction, cost mitigation and highly efficient supply chain operations (Bedawd and Hussein, 2022). According to (Onu and Mbohwa, 2019), a critical role will be played by robots in developing cleaner production technology and supporting sustainable supply chains. Adopting cleaner production technology within industry 4.0 technologies has a significant and positive impact on the performance of sustainable supply chains. In the literature, the authors went further by adopting industry 4.0 technologies in developing precise and focused cleaner production strategies (Karmaker et al., 2023).

The driving forces for adopting sustainability practices in the supply chain are as follows (Gajanayake et al., 2024) (Mahmahi et al., 2022; Saadi, 2020):

1. Scientific progress was achieved in the observation, assessment and determination of the environmental damage caused by the industries.
2. Rapid communication and dissemination of information through the internet to both consumers as well as stakeholders about the impact caused by the organizational activities. Being the most influential, the organizations constantly communicate with their consumers to dispel environmental concerns.
3. Predicted long-term occurrence of environmental problems due to rapid technological changes.
4. The increase in population increases the costs incurred from environmental damage.
5. The spread of some negative practices due to the lack of implementation and respect for regulatory and legal rules to protect the workers.
6. Pressure from stakeholders; two stakeholders play a major role in creating interest towards sustainability such as the customers and the organization's employees who have an important role in the organization's initiative to include sustainability in operations.
7. Resource depletion: Resource consumption cannot be considered a proactive driver of sustainability. The main goal of any organization is to increase profitability within a short period. However, it is a fact that resources are non-renewable and tend to deplete. Therefore , organizations must focus on recycling or reducing their raw materials' usage. Though it reduces the financial performance, the environmental performance of the firm increases. In other terms, the profitability in both medium- and long-term increases despite a short-term low in profits.
8. Low-carbon economy. When the rate of carbon emissions per capita reduces, it results in a low-carbon economy. The main reasons for the increased volume of carbon in nature are industrial organizations, unsustainable supply chain processes, and human activities and efforts should be taken to reduce carbon emissions.
9. Environmental standards: The Standardization Company (ISO) has provided 14001 certification to organizations starting in 1996 to reduce the environmental risks due to their operations. This standard focuses on strategic management, legal compliance, and working with business partners to standardize the operations in an eco-friendly manner.
10. Social responsibility: Equal importance should be given to social responsibility standards to ensure good working conditions, fair business practices and a sense of well-being in the community.

From the review of the literature, it can be understood that the application of cleaner production strategies in Iraqi firms is yet to be complied though a few studies highlighted the importance of incorporating cleaner production practices (Hh et al., 2020; Soror and Ahmed, 2023; Sulaiman, 2023). No study has so far focused on the sugar refining industries in Iraq while the current study is a first-of-its-kind attempt towards the same. The rationale behind the selection of the sugar refining industry in Iraq is that the industry also contributes to pollution in addition to petroleum refineries from known times (Ahmad and Mahmoud, 1982; Al-Rawi, 2005) while globally the researchers (Sahu, 2018; Ibrahim and Workneh, 2023) emphasized the contribution of pollution by sugar industries. In this scenario, it is crucial to investigate the supportive and destructive factors that help in the implementation of a cleaner production strategy in Iraqi industries.

3. Methodology

3.1. Building hypotheses

As discussed in the literature, various studies have indicated the presence of a relationship between cleaner production technology and sustainable supply chains (Arshed, Hameed and Saher, 2022; Yu et al., 2022). It has been pointed out that cleaner production technology creates an impact on sustainable supply chains and green supply chains (Ahmad et al., 2022). Cleaner production technology affects three dimensions of sustainability simultaneously such as environmental, social, and economic. In the literature, it was found that there is a state of integration between the supply chain and sustainability while cleaner production technology is an independent variable (Govindan et al., 2014). Cleaner production technology and sustainable innovation re-engineering affect the sustainable supply chain outcomes and they are integrated as a result of the current environmental revolution. In this background, the current study follows the exploratory approach to analyze cleaner production technology initiatives, according to the sustainable supply chain management. Through the review of literature, the current study focuses on the most important aspects discussed earlier based on which the hypotheses have been developed.

First main hypothesis: *There is a significant influence relationship between cleaner production strategies and the performance of the sustainable supply chain:*

Sub-hypotheses

From this hypothesis, several sub-hypotheses branch out. In today's business environments, sustainability has become a factor that provides competitive edge to many companies from their competitors. Therefore, organizations started devising strategic plans to integrate sustainability and supply chain to improve their performance. According to (Sun et al., 2022), the most important strategies required for this integration are the selection of appropriate processes and correct eco-friendly technologies as it affects the performance of the sustainable supply chain (Sachin and Rajesh, 2022).

One of the basic principles of sustainable supply chain is to reduce emissions and waste generation. This results in energy savings, cost savings, increased production and improved environmental performance. Sustainable supply chain, which combines the concept of sustainability and supply chain, helps the industries in reducing the waste and carbon emissions by using advanced technologies (Yadav et al., 2021; Agility Logistics, 2021; Surgere, 2023) for which the hypothesis is as follows:

Second sub-hypothesis: *There is a significant influence relationship between waste and the performance of the sustainable supply chain.*

A sustainable supply chain process can develop multiple scenarios for waste disposal and recycling without affecting the environment using modern technologies. These technologies can digitally identify and isolate the materials (Czekała, Drozdowski and Łabiak, 2023). Waste recycling is one of the important strategies to reduce the negative impact on the environment (Zheng et al., 2022) for which the hypothesis is as follows:

Third sub-hypothesis: *There is a significant influence relationship between recycling and the performance of the sustainable supply chain*

The adoption of Industry 4.0 technologies positively affects the performance of a sustainable supply chain including a product's life cycle. In Industry 4.0, sustainable supply chain processes help organizations to design products with extended life cycles, generating low waste (Kmar et al ., 2023). It is essential to evaluate the organization's sustainable supply chain as a part of product life cycle management. This evaluation remains useful in developing appropriate strategies for risk mitigation (Sayles, 2023). Based on this notion, the following hypothesis is drafted.

Fourth sub-hypothesis: *There is a significant influence relationship between the life cycle and the performance of the sustainable supply chain.*

The application of cleaner production strategies helps in leveraging resources and reducing pollution effectively and efficiently. When a cleaner production strategy is applied on an ongoing basis, it results in an integrated preventive environmental strategy towards the production processes and the final product. This in turn reduces the risks posed upon human beings. Further, the raw materials and energy can be preserved and the removal of toxic materials and toxic emissions can be achieved. In addition to this, enhanced production processes, environmental performance and productivity can be attained (Shekarian et al., 2023; Prigozhin et al., 2023) Therefore, the hypothesis is as follows:

Fifth sub-hypothesis: *There is a significant influence relationship between resources and the performance of the sustainable supply chain.*

Adopting energy-efficient practices within supply chains not only brings environmental benefits but economic benefits too (Ahi et al., 2016). The application of a cleaner production strategy in effective energy management is an essential foundation for a sustainable supply chain. It involves the application of renewable energy throughout the sustainable supply chain to reduce costs, mitigate risks, generate new revenues, and enhance the brand value (Beheshtinia and Fathi, 2023). On this basis, the following hypothesis is drafted.

Sixth sub-hypothesis: *There is a significant influence relationship between energy and the performance of the sustainable supply chain.*

Applying a cleaner production strategy increases the efficiency of the production process. Further, it provides control of the inventory, energy consumption, integrated production system, production planning, and resource management and also provides a positive impact on the organization's performance including environmental performance and increased productivity (Govindan et al., 2020; Shekarian et al., 2022). So, the hypothesis is as follows:

Seventh sub-hypothesis: *There is a significant influence relationship between production and the performance of the sustainable supply chain.*

Using a cleaner production strategy means enhanced work safety, teamwork, exchange of knowledge among the teams and planning and implementation to improve the working conditions. These factors enhance the performance of a sustainable supply chain (Subramanian and Gunasekaran, 2015). When cleaner production strategies are applied at work, it increases employee efficiency and competitiveness and reduces the workplace that gets reflected in increased sustainable supply chain performance (Roy et al., 2020) for which the hypothesis is as follows:

Eighth sub-hypothesis: *There is a significant influence relationship between work and the performance of the sustainable supply chain*

Various studies conducted earlier recorded that there exists a positive impact of a sustainable supply chain on the environmental performance of the factors (Jum'a et al., 2021). The use of a cleaner production strategy also contributes to improved organizational performance and efficient environmental management. This gets reflected in the increased performance of sustainable supply chains (Wang and Dai, 2018). On this basis, the following hypothesis is framed.

Ninth sub-hypothesis: *There is a significant influence relationship between the performance environment and the performance of the sustainable supply chain.*

By reviewing the literature that was used to build the hypotheses, the following model has been developed:

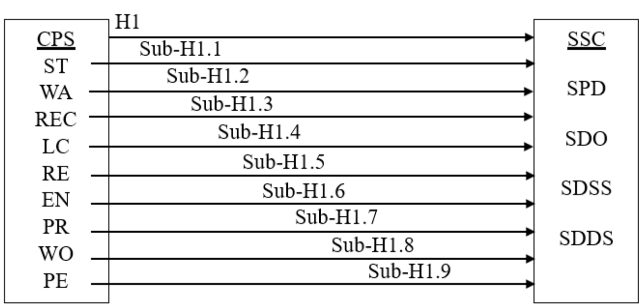

Fig. 1. Hypothetical diagram of the study

3.2. Sample and data collection

Al-Ittihad Food Industries Company, Babylon was selected for the study as it is one of the leading companies in the region. The company was established in 2012 at the Al-Madhatiya area, Babil governorate. In the beginning, it was established as a sugar refining factory whereas the production of refined white sugar was started in 2015. At present, the company has a production capacity of 3,600 tons of refined white sugar per day. The company established a vegetable oil refining factory in 2016, adjacent to its sugar refining factory. In early 2017, the production of refined vegetable oil began with an initial production capacity of 2,000 tons per day. The production capacity has doubled in recent years and employs over 2,000 employees (with 700 in sugar production and 400 in oil plant). Al-Ittihad Transport Company owns 200 trucks to transport raw sugar and 100 tankers to transport crude oil from the port of Umm Qasr in Basra. The trucks also transport the company's products to the local market. The rationale behind the choice i.e., Al-Ittihad Company is its suitability to the current research aim, as the company obtained ISCC-EU certificate and GMP+ certificate for secondary products, after meeting all the international conditions and requirements. This norm qualifies the company to export its food products to Europe and all global countries. Therefore, the current study sought to investigate the extent of applying cleaner production strategies and determine the performance of a sustainable supply chain.

The company is also committed to environmental standards and monthly visits are paid to the factory by the Environmental Department, Babylon Governorate. Therefore, the aim of the current study is compatible with the sample factory chosen. The current study attempts to find the weak points to be addressed since the factory management is keen on environmental issues and is trying to enter the field of global exports. For conducting the study, the required approvals were obtained from the factory through the letter numbered: D6 2607 on 11/15/2023. The study period was two months and the data was collected in November 2023 from a group of randomly selected employees from different departments such as administrative, technical and human resources. The data was collected through an electronic questionnaire (Google Forms). A total of 482 complete questionnaires, suitable for statistical analysis, was obtained, representing (68.85%) of the total sugar factory population of (700) employees. The questionnaires that were invalid, incomplete, or not filled out correctly were not considered. Employees were given 25 days to complete the survey. Many field visits were made to the Al-Ittihad Company's sugar factory site, the production lines were viewed and many interviews were conducted with the factory's workers and employees in all the departments. Refer to Table (1) for the demographic distribution of the sample.

Table 1. Shows the demographic distribution of the sample

Demographic	Categories	Frequency (n)
Age	20 years and less	**150**
	21-30	**300**
	31-40	**200**
	41-50	**50**
Gender	male	**700**
	Female	**0**
marital status	Single	**250**
	married	**450**
Education	Intermediate education and above	**200**
	Preparatory school	**50**
	diploma	**20**
	Bachelor's	**410**
	Higher Diploma	**10**
	Master's	**10**
Work Year	5 years and less	**300**
	6-10	**250**
	11-15	**100**
	16-20	**50**
job position	Head of the Department	**20**
	Division official	**50**
	Unit official	**100**
	employee	**530**

3.3. Study scales

By reviewing the literature, the following best-approved standards were obtained.

Cleaner production strategy: For this independent variable, the scale was adopted from literature (Satyro et al., 2023) with nine dimensions: Strategy (2) paragraphs, Waste (3) paragraphs, Recycling (3) paragraphs, and Life cycle (2) Paragraph, Resources (2) Paragraph, Energy (2) Paragraph, Production (8) Paragraph, Work (4) Paragraph, Performance Environment (2) Paragraph.

Sustainable supply chain performance: For this dependent variable, the scale was adopted from literature (Paulraj et al., 2017) with four dimensions Sustainable product design (7) Paragraph, Sustainable process design (5) Paragraph, and Sustainable design in one aspect. Supply-side sustainability collaboration (6) paragraph, Demand-side sustainability collaboration (5) paragraph.

A five-point Likert scale was used in all the measures with terms such as Strongly Disagree being valued at (1) to Strongly Agree valued at (5).

4. Statistical Data Analysis

The Structural Equation Modelling (SEM) technique was used in this investigation while Partial Least Squares was employed as an analytical tool (PLS). PLS was used to investigate the psychometric characteristics and provide evidence for the existence or lack of relationships. The data in this research was analysed in two stages using SmartPLS 3.2.9 and SPSS 29. The first step was the measurement model that analysed the content, convergent validity, and discriminant validity. The structural model and hypotheses were tested in the second stage (Structural Model). Harman's single-factor test was used to investigate the Common Method Bias (CMB) (Aguirre-Urreta and Hu, 2019); the proportion of the factor's explained variation for the common factor (15.7%) was less than 50%, suggesting the absence of this issue (MacKenzie and Podsakoff, 2012;).

4.1. Measurement Model

The measurement model was examined for reflective and latent variables to determine the reliability and validity of the model's constructs, see Figure (2). To examine the reliability and construct validity, factor loadings, composite reliability (CR), and discriminant validity were utilized (Hair and Lukas, 2014). Hair et al. (2017) suggested that the indicators with loadings less than 0.4 should be removed to improve Composite Reliability (CR) while above 0.6 should be maintained (Fornell and Larcker, 1981). As demonstrated in Table (2) and Figure (2), some items were removed from the model since it had factor loading values below 0.4. Furthermore, Average Variance Extracted (AVE) values should be greater than 0.5 (Hair et al., 2017); however, the values greater than 0.4 are also acceptable, provided if the values of CR are greater than 0.6 (Fornell and Larcker, 1981). These findings in Table (2) show that the study met the criteria for convergent validity and internal consistency of the measures.

Table 2. Convergent validity and internal reliability consistency

Construct	Item	CR	AVE	Loading
Strategy	STR1	0.726	0.583	0.565
	STR2			0.92
Waste	WAS1	0.745	0.593	0.771
	WAS2			0.77
	WAS3			Deleted
Recycling	REC1	0.854	0.746	0.863
	REC2			0.864
	REC3			Deleted

Life cycle	LIF1	0.732	0.583	0.641
	LIF2			0.868
Resources	RES1	0.705	0.556	0.563
	RES2			0.892
Energy	ENE1	0.7	0.54	0.791
	ENE2			0.675
Production	PRO1	0.802	0.412	0.67
	PRO2			0.774
	PRO3			0.474
	PRO4			0.658
	PRO5			0.743
	PRO6			Deleted
	PRO7			0.465
	PRO8			Deleted
Work	WOR1	0.843	0.574	0.659
	WOR2			0.81
	WOR3			0.832
	WOR4			0.717
Performance Environment	PER1	0.704	0.551	0.864
	PER2			0.597
Sustainable product design	SPD1	0.776	0.412	0.573
	SPD2			0.758
	SPD3			0.664
	SPD5			0.606
	SPD6			0.592
	SPD7			Deleted
Sustainable design of operations	SDO2	0.743	0.433	0.657
	SDO3			0.428
	SDO4			0.852
	SDO5			0.625
Sustainable design on the supply side	SDSS1	0.795	0.40	0.553
	SDSS2			0.733
	SDSS3			0.597
	SDSS4			0.726
	SDSS5			0.549
	SDSS6			0.588
Sustainable design on the demand side	SDDS2	0.784	0.478	0.603
	SDDS3			0.781
	SDDS4			0.641
	SDDS5			0.726
Remark: ***Reliability and convergent validity are attained***				

After establishing the convergent validity, the discriminant validity was examined. This aspect examined how much a construct differs from the rest of the constructs. Discriminant validity is usually established by examining the Fornell-Larcker criterion that ensures that the indicator loads heavily only on the construct to which it is associated. When using the Fornell-Larcker criterion, the square root of the construct's AVE should be higher than any of the construct's correlations with other constructs (Ab Hamid, Sami and Mohmad Sidek, 2017). As per this guideline, the discriminant validity was constructed since the square root values of the construct's AVE were found to be higher than any of the construct's correlations with other constructs as in Table (3).

4.2. Descriptive statistics and multiple correlations

In this section, some of the descriptive statistics and multiple correlations between the selected constructs are shown. These include mean (M) and Standard Deviation (SD) as shown in Table (4). The descriptive statistics for 'Cleaner Production Strategy' was ($M = 4.159, SD = 0.359$), and for "Sustainable Supply Chain Performance", it was ($M = 4.145, SD = 0.376$). Between the dimensions of the independent variable, 'Performance Environment' had the highest mean ($M = 4.319, SD = 0.575$) whereas 'Resources' had the least mean ($M = 3.962, SD = 0.687$). Between the dimensions of the dependent variable, 'Sustainable design of operations' had the highest mean ($M = 4.295, SD = 0.458$) and 'Sustainable design on the demand side' had the lowest mean ($M = 4.022, SD = 0.562$).

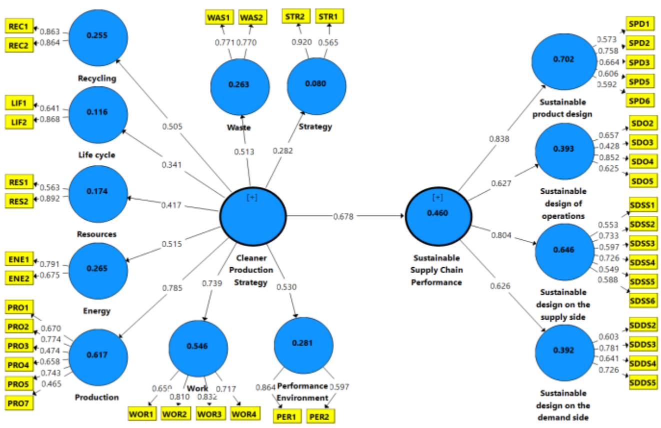

Fig. 2. Measurement model

Table 3. Discriminant validity (Fornell-Larcker criterion)

Construct	Energy	Life cycle	Performance Environment	Production	Recycling	Resources	Strategy	Sustainable design of operations	Sustainable design on the demand side	Sustainable design on the supply side	Sustainable product design	Waste	Work
Energy	**0.735**												
Life cycle	0.208	**0.763**											
Performance Environment	0.34	0.024	**0.742**										
Production	0.312	0.082	0.439	**0.642**									
Recycling	0.209	0.23	0.276	0.186	**0.864**								
Resources	0.226	-0.013	0.149	0.195	0.201	**0.746**							
Strategy	0.028	0.062	0.229	0.097	0.22	0.057	**0.763**						
Sustainable design of operations	0.501	0.127	0.5	0.273	0.273	0.15	0.246	**0.658**					
Sustainable design on the demand side	0.137	0.234	0.191	0.165	0.395	0.114	0.061	0.245	**0.691**				
Sustainable design on the supply side	0.424	0.175	0.255	0.405	0.266	0.302	-0.02	0.302	0.34	**0.629**			
Sustainable product design	0.386	0.336	0.234	0.307	0.217	0.154	0.005	0.424	0.386	0.547	**0.642**		
Waste	0.195	0.119	0.232	0.274	0.196	0.233	0.344	0.417	0.077	0.267	0.152	**0.77**	
Work	0.212	0.307	0.101	0.482	0.228	0.263	0.067	0.277	0.197	0.545	0.521	0.259	**0.758**

Remark: ***Discriminant validity are attained***

Table 4. Descriptive statistic

Construct		N	Mean	SD	Skewness	Kurtosis
Strategy	x1	482	4.2199	0.689	-0.926	0.959
Waste	x2	482	4.1639	0.676	-1.211	2.272
Recycling	x3	482	4.1888	0.790	-1.758	4.419
Life cycle	x4	482	3.9865	0.826	-0.749	-0.192
Resources	x5	482	3.9616	0.687	-0.692	0.675

Energy	x6	482	4.1680	0.620	-0.639	-0.109
Production	x7	482	4.1667	0.615	-1.415	2.413
Work	x8	482	4.2552	0.648	-1.559	3.183
Performance Environment	x9	482	4.3185	0.575	-0.693	0.146
Sustainable product design	y1	482	4.1292	0.534	-0.602	-0.264
Sustainable design of operations	y2	482	4.2946	0.458	-0.849	0.748
Sustainable design on the supply side	y3	482	4.1324	0.588	-1.259	3.157
Sustainable design on the demand side	y4	482	4.0216	0.562	-0.471	-0.562
Cleaner Production Strategy	X	482	4.1588	0.359	-0.818	0.952
Sustainable Supply Chain Performance	Y	482	4.1445	0.376	-0.793	0.820

The values for Skewness between -2 to +2 and kurtosis between -7 and +7 are considered to be acceptable for establishing normal distribution (Hair et al. 2014; Byrne 2016). The results in Table (4) show that the Skewness and kurtosis values for the constructs were within the specified range. The Pearson product-moment correlation coefficient was calculated to determine the strength and direction of the relationship between the selected constructs. Correlation coefficients marked with two stars (**) are significant at 0.01, coefficients marked with one star (*) are significant at 0.05, and finally, the coefficients that are NOT marked remain insignificant at 0.05, i.e., the P-values are greater than 0.05. Figure (3) shows the scatterplots of each pair of numeric variables on the left part of the figure.

Pearson correlation is displayed on the right. Variable distribution is available on the diagonal. The results indicate the presence of a positive relationship between the independent variable (and its dimensions) and the dependent variable (and its dimensions). It is also observed that there exists a significant positive relationship between *Cleaner Production Strategy* and *Sustainable Supply Chain Performance* since $(r(482) = 0.613, P < 0.01)$.

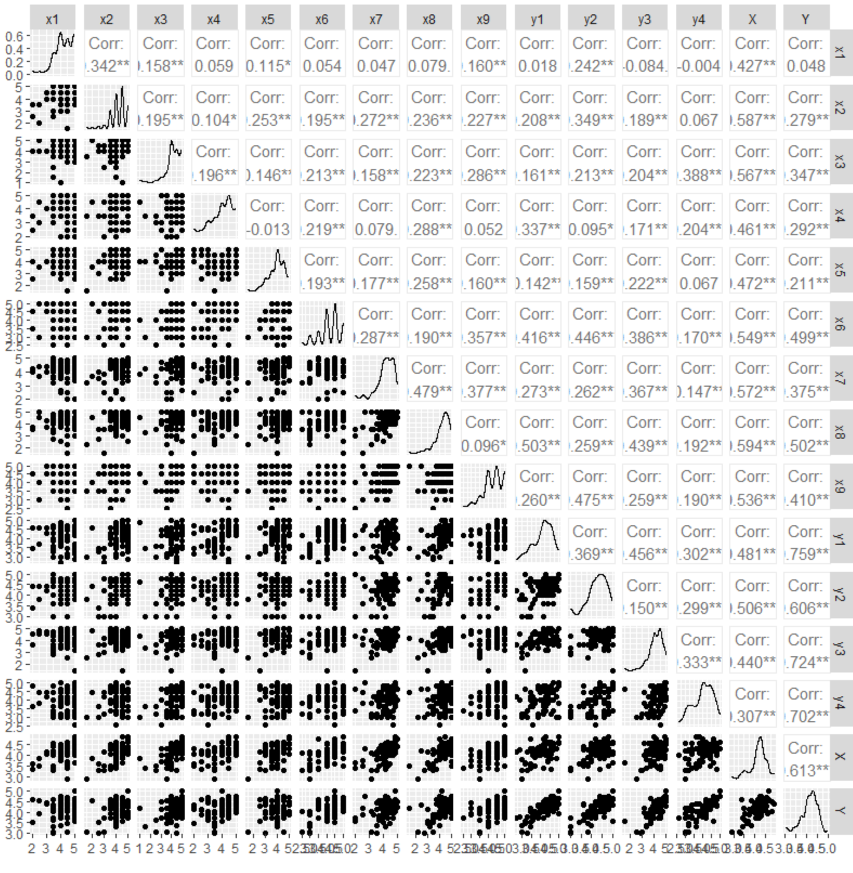

Fig. 3. Visualization of scatter plots, distributions and correlations

4.3. Structural model assessment

Path coefficients, collinearity diagnostics, coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and global goodness of fit criteria were used to examine the structural model in this study. Before analysing the structural model, the collinearity across the constructs was investigated.

In Table (5), using variance inflation factors (VIF), all the values were determined to be less than the threshold of 5 (Hair et al., 2017). The formula for the variance inflation factor is as follows (Murray et al., 2012).

$$VIF_i = r^{ii} = \frac{1}{1-R_i^2}, i = 1, \dots 9 \qquad (1)$$

Table 5. Structural model assessment

H	Path	B	t-value	P-value	95% Bias-Corrected CI		f-Square	VIF	Remark
					LB	UB	>0.02	<5	
H1	*Cleaner Production Strategy -> Sustainable Supply Chain Performance*	0.678	18.16	0	0.59	0.739	0.851	1	Supported
H1.1	*Strategy -> Sustainable Supply Chain Performance*	-0.062	1.434	0.152	-0.149	-0.001	0.009	1.185	Not Supported
H1.2	*Waste -> Sustainable Supply Chain Performance*	0.12	2.858	0.004	0.039	0.195	0.032	1.259	Supported
H1.3	*Recycling -> Sustainable Supply Chain Performance*	0.111	3.57	0	0.055	0.176	0.028	1.259	Supported
H1.4	*Life cycle -> Sustainable Supply Chain Performance*	0.036	1.026	0.305	-0.042	0.097	0.003	1.222	Not Supported
H1.5	*Resources -> Sustainable Supply Chain Performance*	0.007	0.159	0.874	-0.085	0.083	0	1.231	Not Supported
H1.6	*Energy -> Sustainable Supply Chain Performance*	0.301	9.161	0	0.241	0.369	0.188	1.346	Supported
H1.7	*Production -> Sustainable Supply Chain Performance*	-0.007	0.21	0.834	-0.077	0.051	0	1.529	Not Supported
H1.8	*Work -> Sustainable Supply Chain Performance*	0.45	11.125	0	0.372	0.535	0.354	1.602	Supported
H1.9	*Performance Environment -> Sustainable Supply Chain Performance*	0.258	8.46	0	0.205	0.324	0.141	1.321	Supported
R-Squared (>0.19): Main Hypothesis =0.46; Sub-Hypotheses = 0.643									
Q-Squared (>0): Main Hypothesis =0.101; Sub-Hypotheses = 0.134									
GGoF (>0.36): Main Hypothesis = 0.493; Sub-Hypotheses = 0.582									
CI=Confidence Interval; LB=Lower Bound; UB=Upper Bound. Cut-off values: Chin (1998), Cohen (1988), Hair et al. (2017),									

The results of the hypotheses analyses are shown in Table (5) while Figure (4) shows that a cleaner production strategy yielded a significant positive effect on sustainable supply chain performance, since $(\beta = 0.678, t = 18.16, P < 0.001, 95\% CI for \beta = [0.59, 0.739])$, with large Cohen's effect size as $(f^2 = 0.851)$. Cohen's effect size is determined by $D = \frac{M_1 - M_2}{S_p}$ where M1 and M2 represent the sample means for the two groups being compared and Sp denotes the pooled estimated population standard deviation (National University, 2024). As a consequence, the main hypothesis is confirmed. The results of hypothesis testing, shown in Table (5) and Figure (5), confirmed that *Waste* yielded a significant positive effect on *Sustainable Supply Chain Performance* since $(\beta = 0.12, P < 0.01)$, with a small Cohen's effect size as $(f^2 = 0.032)$ and consequently, the second sub-hypothesis is confirmed.

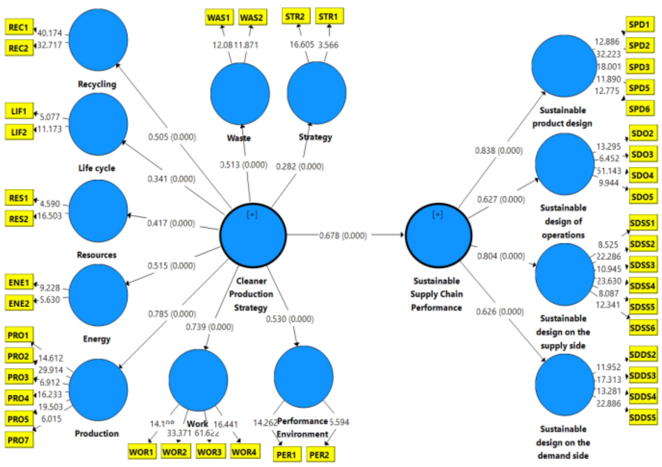

Fig. 4. Structural model (Main Hypothesis)

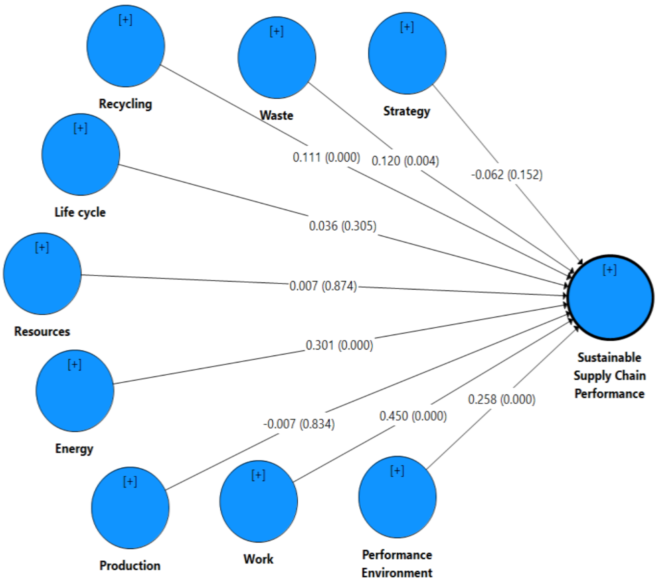

Fig. 5. Structural model (Sub-Hypothesis)

Also, *Recycling* yielded a significant positive effect on *Sustainable Supply Chain Performance* since ($\beta = 0.111, P < 0.001$), with a small Cohen's effect size ($f^2 = 0.028$), consequently, the third sub-hypothesis is confirmed. Further, *Energy* yielded a significant positive effect on *Sustainable Supply Chain Performance* since ($\beta = 0.301, P < 0.001$), with moderate Cohen's effect size as ($f^2 = 0.188$), consequently, the sixth sub-hypothesis is confirmed. Moreover, *Work* yielded a significant positive effect on *Sustainable Supply Chain Performance* since ($\beta = 0.45, P < 0.001$), with a large Cohen's effect size ($f^2 = 0.354$), consequently, the eighth sub-hypothesis is confirmed. Finally, *the Performance Environment* yielded a significant positive effect on *Sustainable Supply Chain Performance* since ($\beta = 0.258, P < 0.001$), with almost moderate Cohen's effect size ($f^2 = 0.141$), consequently, the ninth sub-hypothesis is confirmed. The other sub-hypotheses were not supported as the P-values for each factor were below the threshold of 0.05.

Furthermore, 46% of the variations in sustainable supply chain performance were explained by the variations in cleaner production strategy. On the other hand, 64% of the variations in sustainable supply chain performance were explained by the variations in the dimensions of cleaner production strategy. All the values of the Variance Inflation Factor (VIF) in Table (5) were below 5, thus indicating the absence of a collinearity problem. Then, the predictive relevance was determined by assessing Stone-Geisser's Q^2 sourced from (Ratzmann, Gudergan and Bouncken, 2016).

Blindfolding is a sample reuse technique that is used to calculate the Q^2 values for latent variables. The current study executed the blindfolding procedure and calculated the Q^2 values for the endogenous variables. All the values were higher than zero for the Main Hypothesis ($Q^2 = 0.101$) and Sub-Hypotheses ($Q^2 = 0.134$). Thus, the results indicate predictive relevance for endogenous latent variables in the PLS path model of the study (Hair et al. 2017). The Global Goodness of Fit (GGoF) was introduced by Tenenhaus et al. (2005)

$$\sum_k \frac{(O-E)^2}{E} \qquad (2)$$

Here, O denotes the observed values E denotes the expected values and k corresponds to the number of different data cells or categories. This measure is used as a global fit metric to determine if the GGoF values are too little, too moderate, or too high to be considered a globally adequate PLS model. The GGOF value of (0.493) for the main hypothesis and (0.582) for the sub-hypothesis were greater than 0.36, thus indicating a high fit. So, it can be safely concluded that the GGoF model is large enough to be considered as a sufficiently valid global PLS model.

4.4. Importance of Performance Map Analysis

Importance Performance Map Analysis (IPMA) is generally conducted to provide additional insights by combining the importance (I) and performance (P) dimensions analysis (Ringle and Sarstedt, 2016).

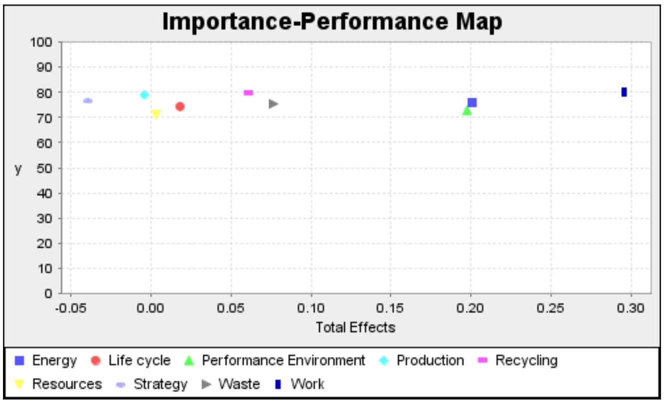

Fig. 6. Importance performance map

IPMA enables the identification of places where action is necessary. Specifically, one may identify elements of the process that are relatively important yet perform poorly to deploy management methods that lead to changes. Figure (6) depicts the dimensions of the constructs that influence the dependent variable *Sustainable Supply Chain Performance* (Y). The IPMA findings are displayed as a two-dimensional graph, with the horizontal axis describing the "importance" (total effect) of influential factors on a scale of 0 to 1, and the vertical axis describing their performance on a range of 0 to 100. Figure (6) shows that Work was the most important construct (0.295), followed by Energy (0.201), Performance Environment (0.198), Waste (0.076), and Recycling (0.061). Moreover, Work performed the best (80.346), followed by Recycling (79.734), Production (78.943), Strategy (76.494), Energy (76.194), Waste (75.455), Life cycle (74.432), Performance Environment (72.959) and Resources (71.097).

4.5. Discussion

As shown in Table (2), based on the convergent validity values numerous questions were erased while the degree of discriminant validity was found to be good. This finding infers the ability of the scale to distinguish between two or more distinct concepts. Further, it also establishes that the scale measures a specific construct and not another and also the scale tool is accurate. Also, the Composite Reliability (CR) was not less than 0.7 for all the dimensions of the dependent and independent. This is a good indication of the high reliability of the composite and all the items consistently measure the same construct. In other terms, the questions in the questionnaire are correct and have a relationship with the variables.

Table (3) shows about achieving the discriminant validity. The shaded numbers indicate the relationship of each dimension with itself and it was found to be larger than the numbers that indicate the relationship of each dimension with the rest of the dimensions. Figure (3) shows the correlations between the dimensions of each variable and between independent and dependent variables. All the correlations were found to be positive and significant. The forms of the normal distribution were included in the diagonal axis and the distribution was found to be normal for most of the dimensions of the study variables. For the lower triangle on the left side, the drawings were placed to show the shape of the spread between the dimensions of the variables. It can be observed that the points take an ascending shape which indicates that as the independent variable increases, the dependent variable increases directly. As per the importance-performance map analysis outcomes, work was found to be most important construct with good performance while resources remained the least. This infers that the working environment, culture among the employees, and working conditions have been provided much focus while the policymakers should strategize their plans to improve the resources and recycling techniques to achieve a sustainable supply chain.

The current study proves the existence of a significant and influential relationship between a cleaner production strategy and the performance of a sustainable supply chain from Table (5) which aligns with that of the literature (Severo, Guimarães and HENRI DORION, 2017; Hei et al., 2019; Kinani and Najjar, 2019; Gamage, Arachchige and Godakanda, 2023). This confirms the validity of the main hypothesis and its fulfilment. The factory studied in this research work applies several cleaner production strategies and is committed to achieving sustainable supply chain performance. On the whole, the study found that there exists a relationship between waste generation, recycling, energy consumption, work and environmental performance with that of the sustainable supply chain performance. According to the literature (Hernandez et al., 2023), there exists a positive relationship between customers, environment, government, suppliers, and the intention to adopt sustainable supply chain management practices. In addition to this, institutional pressure (Hebaz, Oulfarsi and Sahib Eddine, 2024) also acts as an important driving factor for its implementation. So, it is important for the policymakers in the factory must take the necessary initiatives to drive the operations towards a sustainable supply chain. Some of the limitations of the study are as follows; the impact rate was good 0.678 although it is not very high which is attributed to not meeting some of the dimensions of cleaner production technology. For example, the 4th and 5th sub-hypotheses (life cycle and resources) were not met, because they had a very weak influence relationship. With regards to 1st and 7th sub-hypotheses i.e., strategy and production, the effect relationship was inverse and very small to consider. Further, the study considered only one factory as its study location while future studies should focus on conducting parallel investigations in multiple locations, about sugar production and refineries. In addition to this,future researchers can also focus on oil refineries since it also contribute heavily to the environmental pollution issues in Iraq.

5. Conclusion

To increase environmental awareness among companies and society and to confront the pressure from environmental organizations to reduce pollution, a set of restrictions has been imposed on organizations in recent years in Iraq (Ministry of Environment Iraq, 2009; Shilan Aziz Salih, 2015). These restrictions make the firms take numerous measures to improve their workplace and reduce pollution by applying cleaner production strategies. The application of these strategies largely depends on the development of technology. In addition to this, applying cleaner production strategies increases competitiveness. The presence of an influential relationship between a cleaner production strategy and a sustainable supply chain results in achieving a sustainable competitive advantage. The reason for rejecting the first sub-hypothesis is the lack of strategic plans in the firm under study, to achieve some aspects regarding cleaner production strategy. Therefore, the factory management must develop long-term plans and strategies for the implementation of cleaner production strategies. However, this does not indicate that the factory failed to adhere to environmental standards since the main hypothesis proved the existence of a morally influential relationship and positive correlations at a good level. Since the factory management aspires to enter the global field, it must establish a few mechanisms to implement, achieve and sustain the performance. In addition to this, the policy makers should also focus on product's life cycle since this was not supported. It is important for the sugar products to have a longer shelf life for consumption while it should also be free from chemicals. With this information, the decision makers can draft the future policies. The resources utilized in the factory must be leveraged to the best possibility and achieve zero waste policy so that energy can be generated while the existing resources can be used for better outcomes. The production capacity and novel technology-enabled production practices must be improved so that the company can achieve a sustainable supply chain shortly. The seventh sub-hypothesis also had negative results. This requires planning for efficient production and an integrated production system. The factory has great potential to achieve the aim and has well-trained human cadres with modern devices and equipment. The current study recommends framing the procedures to be followed to implement all cleaner production strategies, because it is one of the important factories in Iraq. In the future, training workshops should be conducted with workers and officials at the factory and strategic plans should be developed to implement cleaner production.

Numerous recommendations are suggested as listed below to implement a cleaner production strategy through different measures.

1. Process modifications: strategic modifications in the production process to reduce resource consumption, improve efficiency, reduce the rate of damage, optimum energy usage, and find the best maintenance methods that do not increase costs on the production process.
2. Waste management: This is done by installing a unit inside the factory to treat waste, and find the best ways to recycle the waste or convert it into other materials that can be used by other parties.
3. Applying health standards: ensuring comprehensive cleaning and sterilization from time to time, and conducting periodic examinations of the workers to ensure that they are not infected with any infectious disease.
4. Sustainable use: Emphasizing the use of resources in a way that ~~it~~ does not harm the environment, using sustainable natural resources and reducing the rate of waste.
5. Identify the sources of waste in all the production stages and address them.
6. Reduce water consumption and install a filtration system before disposing of the water used in production.
7. Consolidating the concepts of sustainability among those working in the sustainable supply chain performance by building cleaner production practices. Healthy environmental education is the key to sustainability. So, seminars and workshops must be held with all the departments in the factory and these concepts must be consolidated in them.

Applying these strategies together will achieve a state of integration in achieving cleaner production strategies.

5.1. Future studies

In future, the researchers must focus on development, implementation and validation of cleaner production strategies for multiple types of sugar refining factories with different processes. Further, the current study suggests to add green intellectual capital as an intermediary variable between cleaner production strategies and sustainable supply chain, or green human resource management practices in future research studies. Iraqi society needs a strong educational campaign in the fields of green production, environmental care and pollution reduction as part of achieving cleaner production. These topics require further in-depth study in the Iraqi environment and in other countries that still lag behind, in this domain.

Thanks and gratitude

We, the researchers, extend our thanks and gratitude to the factory management, which provided us with all the data we needed. They were very cooperative and had the desire to implement the largest number of cleaner production strategies as quickly as possible.

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