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GREEN OPERATION STRATEGIES AND SUSTAINABLE OPERATION PERFORMANCE: EXAMINING ROLE OF INFORMATION TECHNOLOGY AS MODERATOR

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Research Paper

***Abstract**: The research aimed to assess the moderating effect of information technology strategies on the relationship between green operations strategies and sustainable operational performance within pharmaceutical companies in Saudi Arabia. Data were gathered from 282 pharmaceutical companies in Saudi Arabia, utilizing a quantitative deductive approach, and a questionnaire was distributed following a cross-sectional research design. Results obtained through Partial Least Square (PLS)-Structural Equation Modelling (SEM) revealed that all green operations strategies exerted a positive and significant influence on sustainable operational performance. Additionally, moderating effect results indicated that information technology strategy positively and significantly moderates the relationship between green operational strategies and sustainable operational performance. These findings not only empirically validate existing literature but also extend theoretical implications by underscoring the importance of integrating information technology strategies to optimize the impact of green operational strategies within the pharmaceutical industry context. The practical implications are substantial, urging pharmaceutical firms to prioritize effective integration of information technology strategies, thereby fostering data management, process automation, and enhanced supply chain transparency. Furthermore, the research contributes significantly to the field by highlighting the moderating role of information technology strategies. It calls for further exploration into the intricate interactions between information technology strategies and specific green strategies, such as green purchases, green warehouses, and green design within the pharmaceutical industry. This offers a valuable direction for future research and practical implementations.*

***Keywords**: Green Operations Strategies, Sustainable Operational Performance, Information Technology Strategy, Saudi Arabia.*

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1. Introduction

Sustainable operational performance is realized within an organization through the persistent adherence to its mission and values throughout temporal fluctuations in the business landscape, coupled with a proactive and agile response to dynamic changes (Caiado et al., 2019). Hence, sustainable operational performance emerges as an indispensable facet within the contemporary competitive milieu, serving to ameliorate the environment and contribute to heightened resource efficiency (D'Agostini et al., 2017). To perpetuate this endeavour, the importance of adopting green operational strategies becomes a pivotal element contributing significantly to the sustainability of operational performance (Jabbour et al., 2016). The objective of these strategies is to diminish carbon footprints, manage waste effectively, and embrace production processes that are environmentally friendly (Jabbour et al., 2016). The importance of green operational strategies resides in their capacity to augment the sustainability of operational performance. Through the incorporation of environmentally conscientious practices, companies can mitigate environmental risks, adhere to rigorous regulations, bolster their corporate image, and optimize operational efficiency (Santos, Lannelongue, & Gonzalez-Benito, 2019). Tactics encompassing diminished paper consumption, curtailed electrical power usage, hazard reduction, minimized direct greenhouse gas emissions, decreased non-hazardous waste generation, green procurement, eco-conscious design, and environmentally aligned warehousing not only attenuate environmental ramifications but also yield cost reductions and heightened competitiveness in the market (Migdadi & Omari, 2019). Furthermore, the pivotal role of information technology strategies in optimizing green operational approaches cannot be overstated. Information technology assumes a fundamental role in facilitating the implementation and efficacy of environmentally conscious practices (Umar et al., 2022). Technological advancements facilitate the real-time monitoring of energy consumption, waste management, and supply chain efficiency, thereby enabling informed decision-making in the pursuit of enhanced sustainability in operational practices (Singh & El-Kassar, 2019).

In theoretical terms, the RBV posits that an organization's competitive advantage is derived from the uniqueness and value of its resources and capabilities (Manzoor et al., 2022). In this context, green operational strategies encapsulate ecologically sustainable practices directed towards the diminution of waste, energy consumption, and overall environmental footprint (Manzoor et al., 2022). Upon integration into operational frameworks, these strategies contribute to the advancement of sustainable operational performance through cost reduction, elevation of brand reputation, and fulfilment of regulatory mandates (Cherrafi et al., 2018). Moreover, information technology has the potential to amplify these advantages by enabling the deployment and surveillance of green capabilities or strategies. IT systems play a crucial role in data collection, analysis, and decision-making, thereby augmenting the influence of green operational strategies on sustainable operational performance (Singh & El-Kassar, 2019) that could contribute to the augmentation of influence on sustainable operational performance (Khan, Yu, & Farooq, 2023; Prajogo et al., 2018).

Addressing empirical voids, within extant empirical investigations, divergent findings have been observed concerning the association between green operational practices and sustainable operational performance. Primarily, certain studies

underscore a positive correlation (Khan, Yu, & Farooq, 2023), conversely, others have presented outcomes that are mixed or inconclusive in nature (Khan, Yu, & Farooq, 2023; Zhu & Sarkis, 2004). Likewise, the correlation between information technology strategies and sustainable performance has demonstrated variability in its effects (Gayialis, Kechagias, & Konstantakopoulos, 2022). Prior research has posited that the relationship between green operational strategies and sustainable performance could be examined in alternative contexts (Yavuz, Uner, Okumus, & Karatepe, 2023). Given these disparities, there is an assertion that exploring the moderating influence of information technology strategies in the nexus between green operational strategies and sustainable operational performance is imperative. Prior research has also indicated that the incorporation of information technology has the potential to enhance the influence of green operational strategies on sustainable performance (Umar et al., 2022). Hence, the suggested moderating function of information technology aims to facilitate the optimization and execution of green initiatives, thereby augmenting their efficacy and ultimately contributing to enhanced sustainable operations. Secondly, current literature has primarily concentrated on six dimensions of green operational strategies, namely, reducing paper consumption, minimizing electrical power usage, mitigating hazards, diminishing direct greenhouse gas emissions, lowering non-hazardous waste generation, and green purchasing practices (Migdadi & Omari, 2019), alternatively, some studies have focused on three dimensions, specifically, green purchasing, green design, and green manufacturing in their examination (Umar et al., 2022). While prior studies have not concurrently incorporated all these dimensions in a single investigation, this study addresses this gap by integrating the aforementioned dimensions into the current research. Thirdly, antecedent research has investigated the association between green operations and sustainable performance across diverse industries and international contexts (Bandoophanit, Breen, & Barber, 2018; Migdadi & Omari, 2019). Limited scholarly inquiry has specifically delved into the Saudi Arabian pharmaceutical sector. The distinctive socio-economic and regulatory framework of Saudi Arabia presents unique challenges and opportunities for the adoption of green operational strategies. Consequently, this study endeavours to formulate a comprehensive framework elucidating the interplay of these elements within the specific context of the pharmaceutical industry in Saudi Arabia.

The study, focusing on the impact of green operational strategies on sustainable operational performance with the moderating effect of information technology strategy in the Saudi Arabian pharmaceutical sector, holds paramount significance for its sustainable development. Positive impacts of green operational strategies indicate their crucial role in substantial improvements in sustainable operational performance within the industry. Additionally, the study underscores the vital moderating effect of information technology strategies in augmenting these green initiatives for enhanced sustainability. It not only validates the effectiveness of specific green strategies in the Saudi pharmaceutical context but also emphasizes the pivotal role of information technology in driving and amplifying sustainability efforts. The study advocates for the comprehensive adoption and integration of

green operational strategies supported by information technology to propel the pharmaceutical industry in Saudi Arabia towards a more sustainable and environmentally conscious future. The study is organized into four chapters: literature review, research methodology, data analysis and interpretation, and results and limitations.

2. Literature Review

2.1 Green operation strategies and Sustainable Operational Performance

Sustainable operational performance has become a focal point of research in the contemporary dynamic business environment (D'Agostini et al., 2017). Several scholarly discussions underscore the significance of aligning operational practices with operational performance to attain a competitive advantage while simultaneously mitigating environmental impacts (Migdadi & Omari, 2019). The scholarly literature underscores the pivotal strategies for achieving sustainability in operations, emphasizing the adoption of cleaner production methods, waste reduction, and responsible supply chain management (Seuring & Müller, 2008). In numerous prior investigations, it has been discerned that the implementation of green operational strategies plays a crucial role in augmenting the sustainable operational performance of organizations. These operations have contributed diversely to the enhancement of various initiatives, thereby fostering environmental protection and subsequently elevating overall performance.

Through the reduction of resource consumption, minimization of waste generation, and mitigation of emissions, green operational strategies actively contribute to the conservation of natural resources and ecosystems (Zhu, Shah, & Sarkis, 2020). Furthermore, these strategies align with societal expectations regarding corporate social responsibility, thereby exerting a positive influence on a company's reputation and brand image (Umar et al., 2022). Thus, the implementation of these strategies has the potential to foster innovations and technological advancements, ultimately contributing to the enhancement of sustainable operational performance (Umar et al., 2022). Ultimately, the incorporation of green operational strategies into organizational frameworks not only fosters environmental sustainability but also augments long-term competitiveness and resilience in a dynamic business environment (Khan, Yu, Umar, & Tanveer, 2022). Given their significance for sustainable operational practices, green operational strategies encompass a variety of approaches, including the reduction of paper consumption, minimizing electrical power usage, hazard reduction, diminished direct greenhouse gas emissions, reduced non-hazardous waste, as well as practices related to green purchasing, green design, and green warehousing (Migdadi & Omari, 2019).

In empirical terms, a dimension of sustainable operational strategy involves the reduction of paper consumption within operations, entailing the adoption of digital documentation, electronic communication, and process optimization to minimize the usage of paper (Migdadi & Omari, 2019). Kitsis and Chen (2023) discovered that the reduction of paper consumption resulted in decreased costs, heightened efficiency, and diminished environmental impact. Chen et al. (2022) revealed that the reduction of paper consumption had a positive impact on organizational environmental performance and increased efficiency. Similarly, endeavours to decrease electrical

power consumption encompass the implementation of energy-efficient technologies, optimization of equipment usage, and the adoption of renewable energy sources (Carter & Rogers, 2008). This not only mitigates the environmental impact associated with carbon emissions (Zhu, Shah, & Sarkis, 2020). Williams, Sovacool, and Foxon (2022) revealed that prioritizing energy-saving technologies could lead to the reduction of energy consumption, thereby enhancing the sustainability of operational performance. Li et al. (2023) Furthermore, it was underscored that reductions in electrical power consumption could enhance operational efficiency by diminishing resource utilization. Additionally, strategies concentrating on the reduction of hazards and non-hazardous waste in operations play a substantial role in promoting sustainability. The implementation of safer processes, materials, and disposal methods not only minimizes risks to employee health and the environment but also ensures compliance with regulations (Qian et al., 2021). Shabani, Jerie, and Shabani (2023) delved into the correlation between hazard reduction and sustainable operational performance. Their findings unveiled that organizations prioritizing hazard reduction strategies witnessed advancements in employee well-being, heightened productivity, and bolstered operational safety. Gadekar, Sarkar, and Gadekar (2022) observed that hazard reduction also exerts a positive and significant impact on operational sustainability through the reduction of operational risks.

On the contrary, the mitigation of direct greenhouse gas emissions exhibits a noteworthy and positive influence on operational performance. Companies, through the adoption of emission reduction strategies in their operations, not only contribute to environmental conservation but also realize enhanced operational efficiency and cost savings (Gadekar, Sarkar, & Gadekar, 2022). On the other hand, Gadekar, Sarkar, and Gadekar (2022) identified that greenhouse gas reduction also aids in diminishing emissions, thereby exerting a positive influence on operational sustainability through the enhancement of resource efficiency. In other words, Jiang and Bansal (2018) further examination delved into the impacts of reducing non-hazardous waste on organizational performance. The research revealed that organizations implementing initiatives to minimize waste witnessed a reduction in operational costs, improved resource efficiency, and heightened environmental sustainability. Rosli et al. (2023) determined that the reduction of non-hazardous waste positively contributed to operational efficiency through streamlined processes and a diminished environmental impact. Simultaneously, green purchasing practices entail the sourcing of products and materials from environmentally responsible suppliers, fostering a closed-loop system that prioritizes sustainability throughout the supply chain (Qian et al., 2021). In addition, the integration of green design principles into product development and manufacturing endeavours to produce environmentally friendly and resource-efficient products, thereby diminishing environmental impact across their lifecycle (Ye, Lau, & Teo, 2023). Furthermore, the adoption of green warehousing strategies, encompassing optimization of storage layouts for energy efficiency and the implementation of sustainable packaging solutions, serves to diminish operational carbon footprints and reduce resource consumption (Kitsis & Chen, 2023). In a general sense, these specifically targeted green operational strategies collectively contribute to sustainable performance by mitigating environmental impact and aligning operational practices with broader sustainability objectives (Kitsis & Chen, 2023). Prior studies have demonstrated that each dimension plays a crucial role in enhancing sustainable operational performance. In this context, the present study formulates the

following research hypotheses.

H1: *Reduce paper consumption effect significantly to sustainable operational performance.*
H2: *reducing electrical power effect significantly to sustainable operational performance.*
H3: *reducing hazards effect significantly to sustainable operational performance.*
H4: *reduced direct greenhouse effect significantly to sustainable operational performance.*
H5: *reduced non hazards waste effect significantly to sustainable operational performance.*
H6: *green purchasing effect significantly to sustainable operational performance.*
H7: *Green warehousing effect significantly to sustainable operational performance.*
H8: *Green Design effect significantly to sustainable operational performance.*

3. Moderating Effect

The existing relationship between green operational strategies and operational performance remains inconclusive, indicating a need for a moderating variable. In this regard, information technology emerges as a significant factor that has the potential to augment operational strategies, thereby enhancing operational performance (Umar et al., 2022). Das, Tao, Liu, and Cheng (2022) underscore that the integration of information technology for purposes of digitalization, document management systems, and workflow automation markedly enhances the effectiveness of efforts aimed at reducing paper consumption (Abdullah & Lim, 2023). On the other hand, (Yang et al., 2017) aligning information technology strategies with energy-saving initiatives, such as smart grids and real-time monitoring, enhances the impact of reducing electrical power on sustainable operational performance. IT facilitates energy management, supports data-driven decision-making, optimizes energy usage, and integrates renewable sources, leading to improved resource conservation and operational sustainability. Furthermore, information technology plays a pivotal role in mitigating operational hazards through real-time monitoring, predictive analytics, and risk management systems. These IT-based tools strengthen hazard reduction efforts, ensuring safer work environments, minimizing risks, and ultimately enhancing sustainable operational performance (Dwivedi et al., 2022).

de Camargo Fiorini and Jabbour (2017) further investigation revealed the significance of information technology in the realm of green warehousing. Employing information technology solutions for warehouse optimization and energy-efficient logistics enhances resource utilization and environmental sustainability, thereby positively impacting sustainable operational performance. In addition, Dwivedi et al., (2022) further emphasized is the role of information technology in enhancing the impact of green design on sustainable operational performance, utilizing simulation, modelling, and innovation in design processes. Information technology facilitates data-driven decision-making and innovation, leading to resource optimization and improved sustainable operational performance (Wong & Zhou, 2015). In light of the preceding discourse, the following research hypotheses have been formulated.

H9: *Reduce paper consumption has significant impact on sustainable operational performance in interaction of information technology strategy.*

H10: *reducing electrical power has significant impact on sustainable operational performance in interaction of information technology strategy.*
H11: *reducing hazards has significant impact on sustainable operational performance in interaction of information technology strategy.*
H12: *reduced direct greenhouse has significant impact on sustainable operational performance in interaction of information technology strategy.*
H13: *reduced non hazards waste has significant impact on sustainable operational performance in interaction of information technology strategy.*
H14: *green purchasing has significant impact on sustainable operational performance in interaction of information technology strategy.*
H15: *Green warehousing has significant impact on sustainable operational performance in interaction of information technology strategy.*
H16: *Green Design has significant impact on sustainable operational performance in interaction of information technology strategy.*

4. Data and Methods

The research aimed to examine the moderating effect of information technology strategies within the context of green operational strategies and sustainable operational performance among pharmaceutical companies in Saudi Arabia. A quantitative research approach was employed, facilitating numerical data collection, statistical analysis, and the quantification of relationships between variables. This approach adhered to a fixed timeframe (cross-sectional) as opposed to qualitative research, which prioritizes subjective interpretation and depth. The researchers opted for an explanatory research approach to comprehend causal relationships. This choice contrasts with exploratory research, which seeks to explore new areas without rigidly testing hypotheses. The explanatory approach, focused on testing specific relationships between variables, was deemed most suitable for the study. The researchers also utilized a cross-sectional research design, collecting data at a single point in time, which is ideal for examining relationships between variables at a specific moment. This approach differed from a longitudinal design, which tracks changes over time and is not conducive to capturing instantaneous relationships between variables, making it unsuitable for this cross-sectional study.

The researcher employed a research questionnaire derived from prior studies with established reliability. Green operational strategies were assessed across eight dimensions: reducing paper consumption, measured by three items; reducing fuel consumption, measured by 10 items; reducing electrical power, measured by five items; reducing hazardous waste, measured by seven items; reducing non-hazardous waste, measured by five items; and reducing direct greenhouse gas emissions, measured by 10 items. All items were adapted from the study of Migdadi and Omari (2019). Other green operational strategies, specifically green design (measured by four items), green purchasing (measured by five items), and green manufacturing (measured by five items), were assessed. These items were adapted from the study conducted by Liu, Zhu, and Seuring (2017). The measurement of information technology support was conducted using three items, as derived from the study conducted by Liu, Zhu, and Seuring (2017). Finally, the measurement of sustainable operational performance involved five items, adapted from the study conducted by

(Flynn, Huo, & Zhao, 2010). These items were assessed using a five-point Likert Scale, where 1 represents "strongly disagree" and 5 represents "strongly agree." The adapted questionnaire was distributed among 350 employees of pharmaceutical companies using a convenient sampling technique, and 282 questionnaires were returned, indicating an approximate 81 percent response rate. The variables discussed above are illustrated in the predictive model shown in Figure 1.

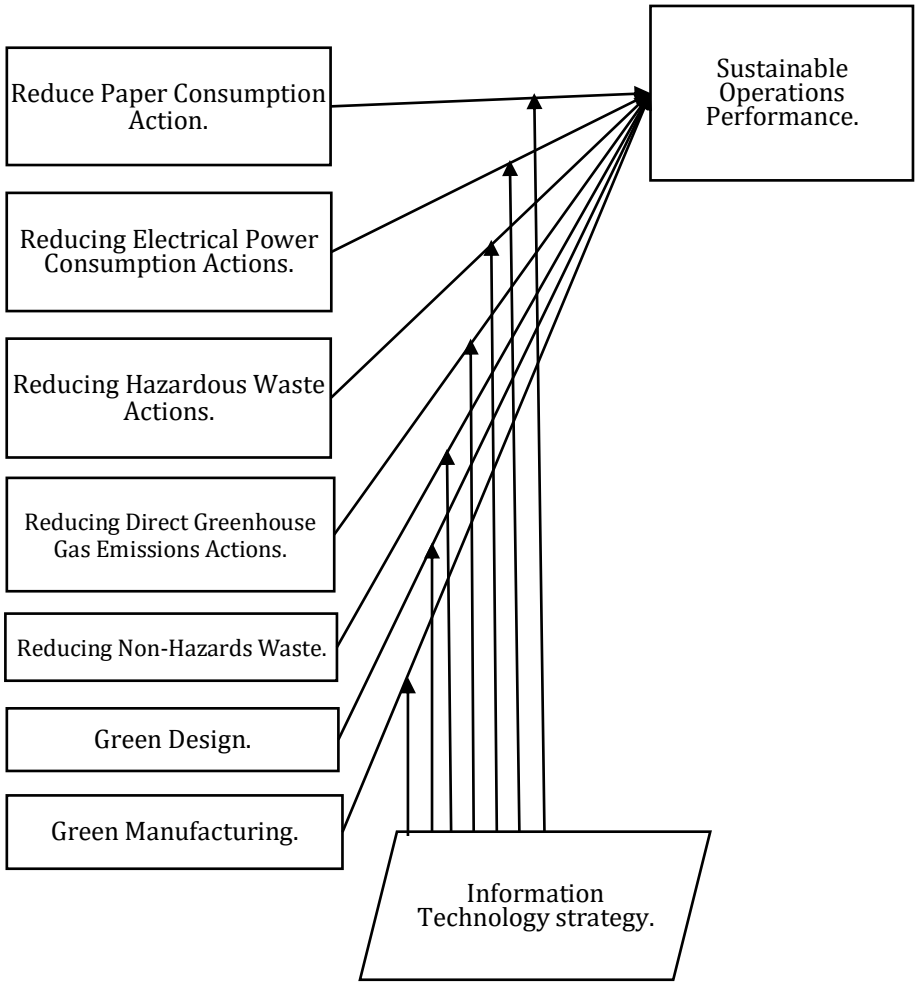


Figure.1: Conceptual Framework.

5. Descriptive Statistics

In the specific context of the pharmaceutical industry in Saudi Arabia, the descriptive statistics offer insights into sector perceptions. Mean scores across dimensions indicate a generally positive sentiment towards sustainable operational performance, with a notable emphasis on reducing fuel consumption (mean = 4.23), suggesting heightened awareness or effort in this domain. Other factors, such as reducing paper consumption (mean = 3.81), green design (mean = 3.81), and green

manufacturing (mean = 3.81), also reveal a relatively favourable outlook, indicating a concerted effort towards sustainable operational performance. However, dimensions like reducing hazardous waste (mean = 3.51) and information technology support (mean = 3.45) exhibit comparatively lower mean scores, pointing to potential areas for improvement or increased focus. The standard deviations highlight varying levels of dispersion or consensus within the industry, reflecting differing degrees of emphasis or implementation of sustainable measures among pharmaceutical entities in Saudi Arabia. These variables are outlined in Table 1.

Table.1: Results of Descriptive.

Dimension	Mean	Standard Deviation	Minimum	Maximum
Reduce Paper Consumption.	3.81	0.62	1	5
Reduce Fuel Consumption.	4.23	0.76	1	5
Reduce Electrical Power.	3.92	0.88	1	5
Reduce Hazardous Waste.	3.51	0.77	1	5
Reduce Non-Hazardous Waste.	3.91	0.90	1	5
Reduce Direct GHG Emissions.	3.71	0.87	1	5
Green Design.	3.81	0.81	1	5
Green Purchasing.	3.50	0.90	1	5
Green Manufacturing.	3.81	0.89	1	5
Information Technology Support.	3.45	0.94	1	5
Sustainable Operational Performance.	3.72	0.93	1	5

6. Measurement Model

The researchers utilized Smart PLS for the inferential analysis, employing the PLS-SEM technique for both the measurement and structural model. The evaluation of the measurement model involves assessing both convergent and discriminant validity (Hair, Howard, & Nitzl, 2020). Convergent validity centres on the consistency of indicators measuring the same construct, assessed through the examination of factor loadings. Ideally, these loadings should exceed 0.70, indicating a robust relationship between the indicator and its corresponding construct (Hair, Howard, & Nitzl, 2020). Moreover, internal consistency can be assessed using Cronbach's alpha, with the objective of achieving a value surpassing 0.70, indicative of the reliability of the construct (Hair, Howard, & Nitzl, 2020). Convergent validity is evaluated through the CR, with a threshold of 0.70 or higher, affirming the reliability of the construct (Hair, Hollingsworth, Randolph, & Chong, 2017). Furthermore, the AVE, preferably exceeding 0.50, illustrates the extent of variance captured by the indicators of the construct in comparison to measurement error (Hair et al., 2017). Table 2 presents values indicating that all values surpass the recommended thresholds, affirming the convergent validity of the construct.

Table.2: Convergent Validity.

Dimensions	Items	Loadings	Cronbach's Alpha	Composite Reliability	AVE
Reduce Paper Consumption	RPC1	0.783	0.85	0.88	0.75
	RPC2	0.872			
	RPC3	0.834			

Reduce Electrical Power	REP1	0.783	0.75	0.79	0.65
	REP2	0.672			
	REP3	0.893			
	REP4	0.731			
	REP5	0.781			
Reduce Hazardous Waste	REH1	0.772	0.80	0.84	0.72
	REH2	0.903			
	REH3	0.731			
	REH4	0.881			
	REH5	0.772			
	REH6	0.912			
	REH7	0.840			
Reduce Non-Hazardous Waste	RNHW1	0.941	0.82	0.86	0.73
	RNHW2	0.731			
	RNHW3	0.794			
	RNHW4	0.784			
	RNHW5	0.913			
Reduce Direct Warehouse	RDW1	0.721	0.77	0.81	0.69
	RDW2	0.830			
	RDW3	0.789			
	RDW4	0.682			
	RDW5	0.906			
	RDW6	0.783			
	RDW7	0.689			
	RDW8	0.782			
	RDW9	0.753			
	RDW10	0.563			
Green Design	GRD1	0.783	0.83	0.87	0.74
	GRD2	0.891			
	GRD3	0.784			
	GRD4	0.795			
Green Purchasing	GRP1	0.794	0.79	0.83	0.71
	GRP2	0.794			
	GRP3	0.745			
	GRP4	0.796			
	GRP5	0.896			
Green Manufacturing	GRM1	0.851	0.76	0.80	0.67
	GRM2	0.853			
	GRM3	0.858			
	GRM4	0.873			
	GRM5	0.867			
Information Technology Support	ITS1	0.780	0.85	0.88	0.75
	ITS2	0.687			
	ITS3	0.932			
Sustainable Operational Performance	SOP1	0.795	0.81	0.85	
	SOP2	0.893			
	SOP3	0.892			
	SOP4	0.882			
	SOP5	0.745			

Note: RPC-reduce paper consumption, REP-reduce electrical power, REH-reduce hazards, RDG-reduce direct warehouse, RNHW-reduce non hazards waste, GRP-green purchasing, GWH-green warehouse, GRD-green design, ITS-information technology strategies, SOP-sustainable operations performance.

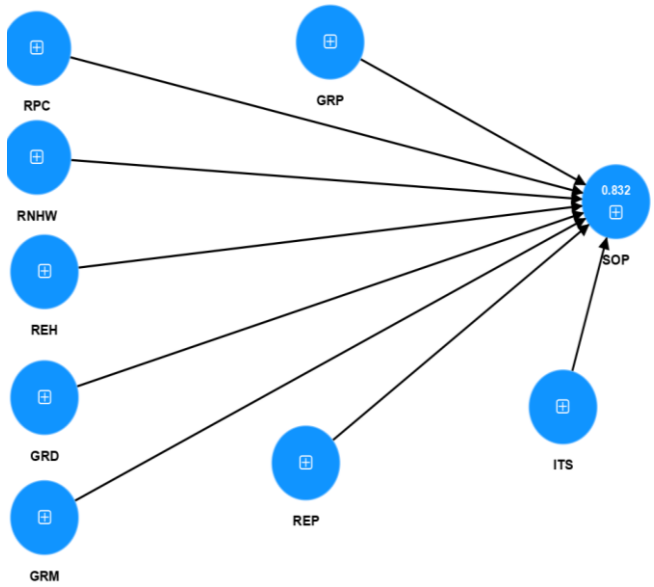


Figure.2: R Square.

Moreover, discriminant validity ensures the differentiation of distinct constructs. Traditionally, the Fornell-Larcker criterion evaluates whether the square root of the AVE of a construct surpasses its correlations with other constructs (Hair et al., 2017; Hair, Howard, & Nitzl, 2020). Cross-loadings, which involve scrutinizing an indicator's loading on its designated construct as opposed to other constructs, also contribute to the assessment (Hair, Howard, & Nitzl, 2020). Nevertheless, the Heterotrait-Monotrait correlations (HTMT) ratio has garnered attention for its heightened efficiency in discerning discriminant validity. HTMT values below 0.90 or 0.85 are widely considered acceptable, establishing a robust criterion to ensure that constructs measure distinct underlying concepts in PLS-SEM (Henseler, Ringle, & Sarstedt, 2015). Table 3 displays values indicating that all constructs have HTMT correlation values below 0.85, affirming the discriminant validity of the construct.

Table.3: Discriminant Validity.

Constructs	RPC	REP	REH	RNHW	RDW	GRD	GRP	GRM	ITS	SOP
RPC										
REP	0.65									
REH	0.68	0.70								
RNHW	0.55	0.59	0.61							
RDW	0.60	0.64	0.66	0.50	NA					
GRD	0.62	0.67	0.69	0.53	0.58					
GRP	0.70	0.75	0.78	0.58	0.63	0.65				
GRM	0.58	0.62	0.64	0.52	0.55	0.60	0.68			
ITS	0.61	0.66	0.68	0.55	0.58	0.63	0.71	0.58		
SOP	0.63	0.68	0.70	0.57	0.60	0.65	0.73	0.60	0.62	

7. Path Analysis

The study employed path analysis to assess the hypotheses, utilizing a bootstrap

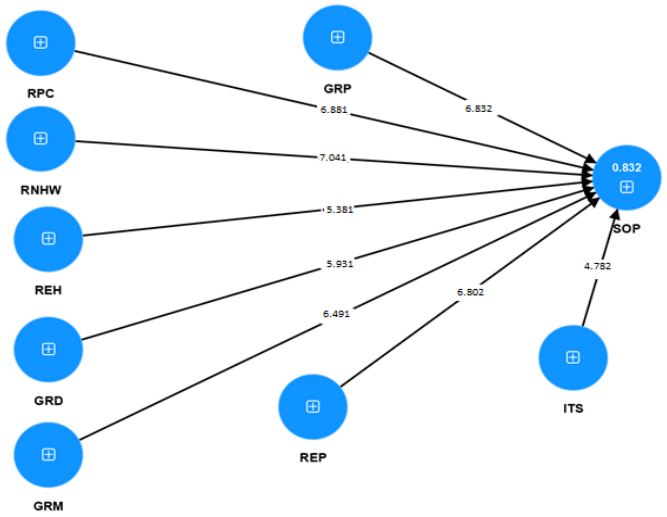
resampling technique with 5000 iterations in PLS-SEM. The PLS-SEM path coefficients indicate a positive and significant impact of reducing paper consumption (RPC), reducing electronic power (REP), reducing hazards, and reducing direct greenhouse gas emissions (RDG) on sustainable operational performance (SOP). These results imply that as pharmaceutical companies in Saudi Arabia adopt strategies to reduce paper usage, minimize power consumption, and mitigate hazards, there are tangible improvements in their SOP. Such positive impacts may include reduced waste generation, diminished environmental footprints, and potentially streamlined operational efficiencies, aligning with global sustainability objectives and enhancing their competitive position in the industry.

Furthermore, other green operational practices, specifically green purchasing (GP), green warehousing (GWH), and green design (GRD), also exhibit a positive and significant effect on the SOP of Saudi Arabian pharmaceutical firms. The beta values, ranging from 0.33 to 0.52, indicate a substantial positive impact of these strategies on enhancing sustainable operations. These findings suggest that investments in eco-friendly procurement, environmentally conscious warehouse management, and green design approaches significantly contribute to increasing sustainability performance.

Moreover, the findings reveal a positive and significant relationship between green operational strategies (RPC, REP, REH, RDG, RNHW, GRP, GWH, GRD) and sustainable operational performance (SOP) within pharmaceutical companies in Saudi Arabia, with the moderating effect of information technology strategies (ITS). This implies that when ITS is strategically integrated with initiatives related to RPC, REP, REH, RDG, RNHW, GRP, GWH, GRD, these pharmaceutical companies witness a notably enhanced SOP. This synergy underscores the importance of adopting a comprehensive approach that combines technological advancements with diverse sustainability initiatives, yielding positive and impactful outcomes in the realm of sustainability efforts for Saudi Arabian pharmaceutical firms. The detailed results are presented in Table 5.

Table.5: Path Analysis.

Hypothesis	Beta Value	Standard Error	T Value	P Value	Result
RPC->SOP	0.551	0.081	6.881	***	Accepted
REP->SOP	0.422	0.062	6.802	***	Accepted
REH->SOP	0.381	0.071	5.381	***	Accepted
RDG->SOP	0.612	0.091	6.752	***	Accepted
RNHW->SOP	0.571	0.081	7.041	***	Accepted
GRP->SOP	0.492	0.072	6.832	***	Accepted
GWH->SOP	0.331	0.051	6.491	***	Accepted
GRD->SOP	0.481	0.081	5.931	***	Accepted
ITS*RPC->SOP	0.632	0.101	6.302	***	Accepted
ITS*REP->SOP	0.513	0.092	5.573	***	Accepted
ITS*REH->SOP	0.453	0.093	5.831	***	Accepted
ITS*RDG->SOP	0.532	0.096	6.583	***	Accepted
ITS*RNHW->SOP	0.552	0.082	6.731	***	Accepted
ITS*GRP->SOP	0.471	0.071	6.632	***	Accepted
ITS*GWH->SOP	0.391	0.061	6.451	***	Accepted
ITS*GRD->SOP	0.517	0.092	5.612	***	Accepted



8. Discussion

The primary objective of this research was to examine the moderating effect of information technology strategies on the relationship between green operational strategies and sustainable operational performance among pharmaceutical companies in Saudi Arabia. The results indicate that reducing paper consumption (RPC) has a positive and significant impact on sustainable operational practices (SOP). These findings suggest that pharmaceutical companies in Saudi Arabia are not only emphasizing sustainable goals but are also actively contributing to the reduction of paper usage, thereby minimizing waste and operational costs. This aligns with the findings of Migdadi and Omari (2019) who similarly demonstrated the positive influence of reduced paper usage on operational efficiencies and environmental sustainability in pharmaceutical companies.

Furthermore, the research reveals that REP also has a positive and significant impact on SOP. These findings suggest that Saudi Arabian pharmaceutical companies are making substantial efforts to reduce electrical power consumption, and these endeavours have been well-documented for their positive effects on sustainability within industries. The results are similar with the study of Migdadi and Omari (2019) where emphasize how reducing electrical power usage not only contributes to cost savings but also fosters sustainable development and environmental conservation. These decreases in energy consumption contribute positively to the company's environmental impact and financial performance. Moreover, additional findings demonstrate a positive and significant impact of reducing hazards (REH) on the sustainable operational performance (SOP) of pharmaceutical companies in Saudi Arabia. These results underscore the critical importance of hazard mitigation within pharmaceutical operations in Saudi Arabia, addressing both worker safety and environmental sustainability. These outcomes align with the findings of previous studies of Migdadi and Omari (2019) and Karsh, Holden, Alper, and Or (2006). Reducing RDG also exhibits a positive and significant impact on SOP in pharmaceutical companies in Saudi Arabia. These findings indicate that the active involvement of pharmaceutical

companies in Saudi Arabia in minimizing direct greenhouse gas emissions from warehouse activities is associated with enhanced sustainability metrics in supply chain operations. These results find support in the study conducted by Sahdev, Kumar, and Dhingra (2016) which elucidated how optimizing warehouse operations positively contributes to sustainability by diminishing waste, lowering energy consumption, and reducing emissions. This optimization leads to an overall improvement in operational efficiency and sustainability performance. In a different context, the reduction of non-hazardous waste significantly and positively influences SOP. These findings underscore the significance of efficiently managing non-hazardous waste for sustainable operations, aligning with the study by Qian et al. (2021). The mentioned study emphasizes how the reduction of non-hazardous waste positively impacts operational performance in industries such as pharmaceuticals, thereby aligning with the sustainability goals of pharmaceutical companies in Saudi Arabia.

Additional research has indicated that green purchasing (GRP) also yields a positive and significant impact on sustainability. These findings reveal that the adoption of green purchasing practices in the pharmaceutical industries of Saudi Arabia has demonstrated a positive influence on sustainability across diverse sectors. This aligns with the findings of a prior study by Basana, Siagian, Ubud, and Tarigan (2022) which also established a positive correlation between green purchasing and sustainability performance. This applicability is relevant to pharmaceutical companies in Saudi Arabia as it involves the promotion of environmentally responsible sourcing and operations. Similar findings were reported by Abdul Rahman et al. (2023), emphasizing the positive contribution of green warehouse initiatives to sustainability through the reduction of energy consumption, waste, and emissions, thereby elevating overall operational sustainability. Furthermore, the direct effect analysis reveals that GRD also exerts a positive and significant impact on sustainable operational performance. Consistent results are identified in the study conducted by Khan, Yu, and Farooq (2023) where the discussion centres on how green design principles enhance sustainability performance by mitigating environmental impact and improving operational efficiency. This insight can be extrapolated to the context of Saudi Arabian pharmaceutical companies in their facility design and operations.

On the contrary, additional findings indicate that information technology strategies (ITS) positively and significantly moderate the relationship between all green operational strategies and sustainable operational performance in the pharmaceutical sector of Saudi Arabia. Notably, the positive correlation among RPC & SOP aligns precisely with studies such as Kaur, Sharma, and Mehta (2024), which alignment is consistent with their research, which established that firms embracing digital documentation systems experienced a significant reduction in paper waste—a pivotal measure for fostering environmentally responsible practices in pharmaceutical operations. Furthermore, the identified correlation between REP & SOP aligns with the findings of Umar et al. (2022). Their study illustrated how energy-efficient information technology (IT) systems positively impact operational sustainability in the Saudi pharmaceutical sector, aligning with broader national goals of energy conservation and environmental responsibility. This relationship underscores the potential influence of enhancing IT strategies tailored to specific sustainability concerns, thereby significantly improving operational sustainability within Saudi Arabia's pharmaceutical industry. Additionally, the associations between REH, RDG,

RNHW, GRP, GWH, & GRD with SOP are also significantly and positively moderated by TS. While direct studies linking each ITS to SOP in the Saudi pharmaceutical context may be limited, existing literature underscores the importance of these strategies. Previous research has argued that ITS plays a pivotal role in advancing green operational strategies by facilitating efficient data management, process automation, and transparency within supply chains (Umar et al., 2022). These innovations driven by information technology enable real-time monitoring, analysis, and optimization of resource utilization, thereby enhancing the incorporation of environmentally friendly practices into operational processes (Xia et al., 2022). Hence, these collective findings imply that the robust adoption of varied information technology-driven sustainability strategies can strengthen and propel the sustainable operations of pharmaceutical companies in Saudi Arabia.

9. Practical and Theoretical Implications

From both a practical and theoretical standpoint, this study contributes extensive findings that underscore the pivotal role of ITS as a moderating variable in influencing the impact of various green operational strategies on SOP within the pharmaceutical sector of Saudi Arabia. In practical terms, this underscores the imperative for pharmaceutical companies in the region to adeptly integrate ITS. This integration facilitates efficient data management, process automation, and heightened transparency within the supply chain. The study also offers valuable insights for policymakers and managers, advocating for a technology-driven approach where a robust ITS emerges as a key enabler supporting and optimizing the implementation of green operational strategies. This, in turn, can substantially enhance sustainable operational performance. Therefore, the study's findings emphasize that prioritizing the IT environment alongside these green strategies could significantly augment sustainable operational performance in Saudi Arabian pharmaceutical companies.

Theoretically, the findings affirm existing literature by empirically validating positive relationships between specific green strategies and sustainable operational performance. Consequently, delving into how these integrated strategies align with broader sustainability frameworks and regulations could enrich the theoretical understanding of sustainable operations management within this industry context. Moreover, the study extends theoretical frameworks by shedding light on the moderating role of ITS in reinforcing the relationship between ITS and sustainable operational performance. The study's findings underscore the importance of integrating ITS to play a crucial role in enhancing green operational practices and optimizing their impact on sustainable operational performance within the context of Saudi Arabia's pharmaceutical companies. Therefore, this study, with its findings, contributes to the understanding that ITS as a moderating variable constitutes a significant contribution, emphasizing the need for future research to delve deeper into the mechanisms through which ITS interacts with and amplifies the effects of GRP, GWH, and GRD within the pharmaceutical sector of Saudi Arabia.

10. Conclusion and Future Directions

The study aimed to examine the moderating impact of ITS on the relationship between green operational strategies and sustainable operational performance in Saudi Arabian

pharmaceutical companies. Data collected from 282 employees were analysed using PLS-SEM. Results revealed that all green operational strategies significantly influenced sustainable operational performance. Additionally, ITS exhibited a positive and significant moderating effect on the relationship between green operational strategies and sustainable operational performance. These findings not only validate existing literature but also extend theoretical frameworks by emphasizing the crucial role of integrating ITS to optimize the impact of green operational strategies in the pharmaceutical industry. The study contributes by highlighting the moderating role of ITS and suggests further exploration into interactions between ITS and specific green strategies (e.g., green purchases, green warehouses, and green design), providing direction for future research and practical implementations.

The study has limitations that could be addressed for increased research validity. It is confined to one sector, limiting generalizability. Future research could explore other sectors for comparative analysis. Additionally, the study focuses on mediation effects, neglecting potential moderating variables (e.g., age, culture), which could enhance generalizability. The quantitative approach and cross-sectional design, collecting data at one time, present limitations, and future research could benefit from a longitudinal design for increased generalizability.

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Appendix A

Survey Instrument

Category	Question	1	2	3	4	5
Information Technology	Integration with SCM process for timely, reliable support					
	Compatibility with supply chain partners for information sharing					
	Enhancing collaborations for knowledge sharing and problem-solving					
Green Design	Reduced material/energy consumption in product design					
	Design for reuse, recycle, and recovery of materials					
	Avoidance/reduction of hazardous materials in products/manufacturing					
	Design for longevity and durability					
Green Purchasing	Environmental requirements in design specifications for suppliers					
	Cooperation with suppliers for environmental objectives					
	Environmental audits for suppliers' management					
	Suppliers' ISO14000 series certification evaluation					
Green Manufacturing	Cross-functional cooperation for environmental improvements"					
	Total quality environmental management					
	Environmental compliance and auditing programs					
	ISO14000 series certification					
	Existence of environmental management systems					
Reducing Paper Consumption	Go green campaigns/increasing worker awareness					
	Adherence to EMAS/ISO standards or internal policies					
	Reduction of printing in medical documentation					
Reducing Electrical Power Consumption	Use of movement sensors/timers for lighting					
	Transition to LED lighting					
	Installation of efficient washing tunnels, environmentally friendly technologies					
	Use of compressed air pumps, good practice manuals for staff					
	AC temperature setting adjustments and scheduling					
	Adhere to ISO standard					
	Adjusting AC temperature setting and schedule					
	Use technologies which are friendly in environmentally.					
Reducing Hazardous Waste	Onsite solar plant construction					
	Awareness increase and monitoring of waste segregation					
	Auditing top waste generator units, adherence to EMS-ISO monitoring					

	Closed suction system use, correcting staff practices, controlling laboratory waste discharge
	Adhering to ISO good systematic monitoring.
	Use a proper close section system.
	Have good correctected practices in their staffs
	Control waste discharge through laboratories
	Annual waste statements and monthly unit reports
Reducing Non-Hazardous Waste	Comprehensive hospital waste management policy
	Source sorting, adherence to ISO waste management
	Post-consumer program (return to supplier), employee training
	Internal waste compaction for volume reduction
	Training to the employees in the evaluation and properly provide waste management facility.
	"Compacting ordinary waste internally to reduce for you"
Greenhouse Gas Emissions	Boiler replacement, thermostatic valves, automated heating circuits, energy metering
	Replace boilers with thermally efficient heaters
	Install thermostatic valves in radiators
	Automate heating circuits with programmable valves
	Use energy metering equipment
	Utilize residual energy (cogeneration)
	Adjust schedules and temperature settings
	Manage ignition of pump heating system
	Apply thermal insulation with aluminum joinery
	Provide staff accommodation compounds
	Offer transportation allowance (fewer fleet trips)
Sustainable operation performance	Company has the ability to swiftly introduce new products to the market
	Company displays agility in responding to market demand changes
	Company maintains an exceptional on-time delivery record to major customers
	Company offers a superior level of customer service to major client
	Company has the ability to swiftly introduce new products to the market