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MODERATING EFFECT OF GREEN TECHNOLOGY ADOPTION ON THE RELATIONSHIP OF SUSTAINABLE OPERATIONS PRACTICES AND SUSTAINABLE OPERATIONAL PERFORMANCE

Musaddag Elrayah[1*], Ooi Chee Keong[2]

[1]Department of Management, School of Business, King Faisal University, Al-Ahsa 31982, Saudi Arabia.
[2]School of Accounting and Finance, Faculty of Business and Law, Taylor's University Malaysia.

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Research Paper

***Abstract**: This research endeavours to examine the influence of sustainable operational practices on sustainable operational performance, incorporating the moderating influence of green technology adoption within the Saudi Arabian textile industry. Through the utilization of a self-administered questionnaire, data were acquired from a sample of 250 employees affiliated with textile companies in Saudi Arabia. Employing a cross-sectional study design and quantitative methodology, this investigation employed Partial Least Square (PLS)-Structural Equation Modelling (SEM) for statistical analysis. The outcomes of this analysis revealed that internal lean practices, quality management, customer and supplier integration, and internal business processes exerted positive and statistically significant effects on operational performance. Furthermore, the study disclosed that green technology adoption functioned as a substantive moderator, amplifying the impact of sustainable practices on operational performance. The theoretical contributions of this study lie in its emphasis on the pivotal role of technology in advancing sustainability practices within the Saudi Arabian textile industry. Moreover, the practical implications extend to managerial and stakeholder considerations, advocating for the strategic utilization of technology to enhance operational efficiency while mitigating environmental impact. The research also underscores essential directions for future investigations, proposing a broader industry inclusion for comparative analyses and endorsing a mixed-method approach to deepen insights into technology adoption and sustainability practices across diverse business landscapes.*

***Keywords**: Sustainable Operations Practices, Green Technology Adoption, Sustainable Operational Performance, Saudi Arabia.*

*Corresponding author: melrayah@kfu.edu.sa (M. Elrayah)
cheekeong.ooi@taylors.edu.my (O. Keong)

1. Introduction

Given the urgency of contemporary environmental challenges, the importance of sustainable operational performance has markedly heightened (Ambec et al., 2013). In response to the pressing need to address environmental concerns, there is a growing recognition among businesses regarding the imperative to adopt sustainable practices to mitigate their ecological footprint. Consequently, sustainable operational performance has emerged as a central focus for both scholarly inquiry and professional endeavours in recent years. Departing from conventional operational methodologies, businesses are increasingly transitioning towards sustainable operations management with the objective of augmenting their sustainable operational performance. In this context, sustainable operational practices, which encompass judicious resource utilization, waste minimization, and emissions reduction, are deemed indispensable not only for compliance with regulatory standards but also for aligning with evolving consumer expectations (Bocken et al., 2013). Furthermore, these initiatives contribute to the future-proofing of businesses against volatile market conditions, yielding reductions in operational costs, fostering innovation, and ensuring long-term viability within an ever-evolving landscape (Alhaddi, 2015). Implementing these measures minimizes environmental impact, enhances operational efficiency, and boosts resilience, resulting in cost savings, improved brand reputation, and a competitive market edge. Prioritizing sustainability enables companies to adapt to regulations, meet consumer demands for eco-friendly offerings, foster innovation, and contribute positively to the global environment, ensuring long-term success (Foo, Kanapathy, Zailani, & Shaharudin, 2019). In pursuit of this significance, numerous studies consistently emphasize the direct correlation between sustainable operational practices and sustainable operational performance (Tan et al., 2019). The incorporation of green technology and innovation is pivotal in augmenting sustainable operations, thereby promoting sustainable operational performance through the integration of environmentally friendly technologies (Alraja et al., 2022). These innovations serve as facilitators for sustainable practices, enabling the optimization of processes, conservation of resources, and reduction of waste (Alraja et al., 2022).

Previous research has predominantly concentrated on evaluating the scope of sustainable operational practices and their interplay with sustainable operational performance. Sustainable operational practices constitute a set of planning, manufacturing, purchasing, and logistical procedures that integrate sustainability into operational frameworks (D'Agostini et al., 2017). In spite of the diverse research endeavors in the realm of sustainability and the proliferation of publications, a definitive consensus regarding the influence of sustainable operations on organizational performance remains elusive (Bocken, Boons, & Baldassarre, 2019; Corbett & Kleindorfer, 2001). Certain authors incorporated sustainable operational practices in their meta-analysis study (Tondolo et al., 2020; Tondolo et al., 2021). Others employed the following sustainable operational practices, categorized into six dimensions: financial projections, competitive advantage, regulations, stakeholder requirements, technology, and support from the leadership team (Bansal & Roth, 2000). Alternative studies explored the impact of green operational practices on operational performance (Jabbour et al., 2016) while there has been limited attention on the impact of green lean practices, quality management, customer integration, supplier integration, and internal business processes on sustainable operational practices, the primary focus has been on sustainable business performance (Raut et

al., 2019). Furthermore, several authors have contended that there is a timely necessity to conduct research on the impact of sustainable operational practices on sustainable operational performance (Pazirandeh & Jafari, 2013). Moreover, empirical studies have failed to establish a definitive positive correlation (Bravi et al., 2020). This underscores the necessity for additional research to elucidate the framework that describes the relationship between sustainable operations and sustainable performance (D'Agostini et al., 2017). A meta-analysis study has also indicated that the relationship between sustainable operations practices and operational performance remains largely unexplored (Tondolo et al., 2020; Tondolo et al., 2021). The heterogeneous nature of these results signifies the imperative for additional temporal research in alternative contexts.

Subsequent research underscores the importance of exploring moderating variables when initial findings yield diverse conclusions. In this context, the incorporation of green technology adoption assumes significance as a substantial moderating factor. A resilient technology adoption framework within organizations can significantly optimize their operational management. The prevalent shift towards technology underscores the significance of technology adoption in the integration of technological advancements at the firm level (Arpaci et al., 2012) facilitating organizations in enhancing sustainable performance (Yavuz et al., 2023). Aboelmaged and Hashem (2019) and Yavuz et al. (2023) further highlight the direct influence of green technology adoption on sustainable performance Alraja et al. (2022). Alraja et al. (2022)emphasized that variables influencing technology adoption constitute essential components within sustainable operational practices, leading to the enhancement of sustainable operational performance Umar et al. (2022). the study also demonstrated that smart city environments incorporating technology-based smart logistics exerted an indirect influence on both financial and social performance. These relationships indicate that the adoption of green technology becomes an integral element in augmenting sustainable operational performance and refining sustainable operational practices Dadhich and Hiran (2022). Therefore, this study underscores the significance of green technology adoption as a pivotal factor in augmenting sustainable operations to enhance sustainable operational performance.

The influence of sustainable operational practices on sustainable operational performance has been comprehensively examined across diverse countries (Jabbour et al., 2016; Raut et al., 2019; Tondolo et al., 2021), however, there has been comparatively limited attention directed towards the textile manufacturing sector in Saudi Arabia. Authors have also posited that companies in this sector should prioritize sustainable practices to attain a competitive advantage (Yusuf & Lytras, 2023). The authors further argued that companies in Saudi Arabia should prioritize the adoption of green technology to enhance their overall performance (Wasiq, Kamal, & Ali, 2023a). Hence, it is crucial to investigate the impact of sustainable operational practices on sustainable performance, with the moderating effect of green technology adoption in the Saudi textile manufacturing sector. This inquiry is imperative, considering the country's commitment to diversify its economy and transition towards sustainability (Alfantookh, Osman, & Ellaythey, 2023). Conducting comprehensive studies within this specific context will not merely elucidate the challenges and opportunities associated with sustainable practices in the region, but will also furnish valuable insights for companies to formulate bespoke strategies for achieving sustainable operational excellence (Annarelli & Nonino, 2016).

The study specifically examines how green technology adoption moderates the relationship between sustainable practices and operational performance, presenting an innovative framework for improving sustainable operational performance in the Saudi textile industry. It offers practical insights for decision-making on technology investments and establishes a theoretical direction for future research, fostering a deeper understanding of the role of technology in enhancing sustainable operations across diverse industries. It elucidates the potential of harnessing advanced eco-friendly technologies in conjunction with established sustainable practices, unveiling new opportunities for optimizing operational efficiencies, diminishing environmental footprints, and enhancing competitiveness within the Saudi Arabian textile sector. The research is structured into four chapters, encompassing literature review, research methodology, data analysis and interpretation, as well as discussion, implications, and conclusions.

2. Literature Review

2.1 Sustainable Performance

Sustainable operational performance, which includes environmentally conscious practices and efficient resource management, is fundamental for businesses confronting contemporary environmental challenges (Gupta, Kumar, & Wasan, 2021). Organisations incorporating sustainability into their operations not only mitigate environmental impact but also achieve enhanced operational efficiency and cost-effectiveness Habidin et al. (2020). This emphasis on sustainable practices leads to diminished resource consumption, waste generation, and emissions, providing a competitive advantage by aligning with consumer preferences for eco-friendly products and adhering to rigorous environmental regulations Lebas and Euske (2002). Moreover, it cultivates innovation, resilience, and long-term viability in a dynamic market environment, contributing to the pursuit of economic growth while mitigating environmental degradation (Abid et al., 2022). The significance of sustainable operational performance is rooted not solely in ethical and environmental considerations but also in its tangible benefits for organisational success and longevity (Habidin et al., 2020; Siems & Seuring, 2021).

2.2 Sustainable Operations Practices

The integration of environmental, social, and economic considerations into business operations constitutes the central focus of sustainable operations practices. Various studies (Pagell & Wu, 2017a, 2017b; Sarkis & Zhu, 2018) emphasize the significance of sustainability in operations management, exploring tactics like waste reduction, energy conservation, sustainable sourcing, and the implementation of cleaner technologies. These approaches result in cost savings, environmental advantages, and enhanced brand reputation. Sustainable operations encompass various dimensions. Among those dimensions Raut et al. (2019), conceptualized the dimensions of sustainable practices to include green lean practices, customer integration, supplier integration, quality management, and internal business processes, all deemed crucial for sustainable operational performance.

Within these dimensions, green Lean practices amalgamate the principles of Lean Management and environmental sustainability Singh et al. (2022).(Singh et al., 2022) underscores the amalgamation of waste reduction with eco-friendly initiatives, entailing the minimization of waste, optimization of processes, and reduction of

environmental impact through a focus on resource efficiency and emission reduction. Additionally, there has been a recent surge in attention towards customer engagement in sustainable practices. Studies (Bansal, 2005; Heikkurinen, Young, & Morgan, 2019) (Bansal, 2005; Heikkurinen et al., 2019)underscores the importance of involving customers in sustainability endeavours through eco-friendly product design, green marketing, and feedback mechanisms. Such engagement frequently results in heightened customer loyalty and a positive brand image. Conversely, forming collaborations with suppliers for sustainable initiatives is deemed crucial. Research (Harms, 2011) emphasizes the significance of cultivating robust relationships with suppliers to ensure ethical sourcing, diminish environmental impact across the supply chain, and stimulate innovation for sustainability. Conversely, customer integration involves engaging customers in the product life cycle, as demonstrated in studies by Cambra-Fierro, Melero-Polo, and Sese (2018) Cambra-Fierro et al. (2018)and Alexander and Jaakkola (2015), signifies a transition towards co-creation and the engagement of customers in value creation processes. This strategy promotes sustainability by aligning product development with customer needs, preferences, and environmental considerations. Lastly, the internal business process demonstrates that effective internal business processes play a pivotal role in sustainability Mohammad Ebrahimi and Koh (2021). Ebrahimi and Koh (2021)examine the importance of enhancing internal operations through the implementation of sustainable practices, the streamlining of processes, and the utilization of eco-friendly technologies to mitigate waste and energy consumption. The subsequent section delves into the empirical study exploring the relationship among sustainable operational practices, the adoption of green technology, and sustainable operational performance.

2.3 Green Lean Practices and Sustainable Operations Performance

The integration of green lean practices in operations management is a focal point for achieving sustainable performance. It prioritizes waste reduction and minimizing environmental impact while preserving operational efficiency. Empirical evidence, as highlighted in studies of Jabbour et al. (2016), and Vazquez-Brust and Campos (2019a); Vazquez-Brust and Campos (2019b), demonstrates a positive correlation between green lean methods and sustainable operational performance. Findings indicate that the application of green lean principles enhances operational efficiency, reduces waste production, and utilizes fewer resources, positively impacting the performance of sustainable operations. Moreover Cherrafi et al. (2018), Cherrafi et al. (2018)emphasized how incorporating green lean practices nurtures a culture of sustainability within an organization, reinforcing the favourable effects on operations. Consequently, the study posits the following research hypotheses;

H1: *Green lean practices have significant and positive effect on sustainable operations performance.*

2.4 Quality Management and Sustainable Operations Performance

Extensive investigation in empirical literature has delved into the pivotal role of quality management in ensuring both operational excellence and sustainability Akanmu, Hassan, and Bahaudin (2020). Akanmu et al. (2020)and Maletič (2018) Maletič (2018)indicated the positive impact of incorporating quality management practices on the performance of sustainable operations. They indicate that embracing quality management practices improves process efficiency, lowers defects, and fosters a culture of continuous improvement within the organization. Consequently, this contributes to sustainable operations by reducing resource wastage and enhancing the quality of products or

services. Furthermore, the work of Sutrisno (2019), Kaynak (2003), Sutrisno (2019)and Wu et al. (2022) Wu et al. (2022)indicates that incorporating quality management practices throughout operational processes positively impacts sustainable operational performance by enhancing productivity and reducing environmental impact. As a result, the study formulates the following research hypotheses;

H2: *Quality management has significant and positive effect on sustainable operations performance.*

2.5 Customer Integration and Sustainable Operations Performance

The inclusion of customers in operational strategies has emerged as a pivotal factor in augmenting sustainable operations Hassan, Abindin, and Nordin (2018). Hassan et al. (2018)emphasizing the involvement of customers in innovation and design processes contributes to the development of environmentally sustainable products or services. Their participation enables the identification of eco-friendly preferences, resulting in the creation of products aligned with sustainability goals. Additionally, studies by Ruzo-Sanmartín et al. (2023) underscored the importance of customer integration by accentuating its influence on waste reduction and efficiency enhancement within supply chains, thereby ultimately promoting sustainable operations. These empirical findings collectively signify that the involvement of customers in the operational process exerts a positive influence on sustainable performance, aligning products or services with eco-friendly demands and diminishing waste generation. Consequently, the study formulates the following research hypothesis.

H3: *Customer integration has significant and positive effect on sustainable operations performance.*

2.6 Supplier Integration and Sustainable Operations Performance

The relationship between supplier integration and sustainable operations performance has been extensively investigated in empirical studies Mani, Gunasekaran, and Delgado (2018). Mani et al. (2018)further illustrates that a robust relationship between companies and their suppliers correlates with enhanced environmental and social performance. Collaborative initiatives with suppliers, involving the adoption of sustainable practices like emissions reduction and improved resource efficiency, positively impact sustainable operations. Furthermore, studies by He et al. (2017) demonstrating that incorporating suppliers into an organization's sustainability initiatives positively affects long-term sustainable performance through resource optimization and environmental impact reduction. Empirical investigations collectively support the hypothesis that supplier integration significantly contributes to sustainable operations performance.

H4: *Supplier integration has significant and positive effect on sustainable operations performance.*

2.7 Internal Business Processes and Sustainable Operations Performance:

Extensive empirical research has delved into the significance of internal business processes in shaping sustainable operations. Studies by Raut et al. (2019) and Magon et al. (2018) Magon et al. (2018)highlighting the pivotal role of internal business processes in shaping sustainable operations, the findings indicate that well-structured and efficient internal processes contribute to decreased waste generation, improved resource efficiency, and overall operational effectiveness, positively influencing

sustainable performance. Additionally Corbett and Kleindorfer (2001), underscores the link between streamlined internal processes and reduced environmental impact, enhancing sustainability in organizational operations. These empirical studies collectively indicate that optimizing and managing internal business processes crucially contribute to reinforcing sustainable operations, positively influencing environmental and social aspects.

Furthermore, other studies by Dumas et al. (2018) and Rozman, Draghici, and Riel (2015) reaffirms the importance of internal business process management for attaining sustainable operations. Empirical investigations show that prioritizing lean and efficient internal processes not only improves operational performance but also reduces energy consumption and waste production, aligning with sustainable objectives. The incorporation of green practices within internal business processes has been demonstrated to yield significant environmental advantages, as outlined by Leonidou et al. (2017a); Leonidou et al. (2017b), suggesting that prioritizing process efficiency and waste reduction has a notable impact on sustainable operations. These collective findings support the hypothesis that optimizing and proficiently managing internal business processes positively affects sustainable operations performance, thereby contributing to an organization's environmental and social responsibility.

H5: *Internal business process has significant and positive effect on sustainable operations performance*

2.8 Moderating effect of Green Technology adoption and Research Framework

The New Resource-Based View (NRBV) theory can substantively underpin the framework that investigates the moderating influence of green technology adoption on the correlation between sustainable operations practices and sustainable operational performance. NRBV theory underscores the strategic importance of resources and capabilities in fostering a competitive advantage for a firm Hart and Milstein (2003). Furthermore Hashem and Aboelmaged (2023b), Hashem and Aboelmaged (2023a)proposed that theoretically, the integration of environmental factors into its foundation can be supported by the NRBV. According to the NRBV, organizations embracing sustainable operational practices possess distinctive resources and capabilities that propel them towards heightened competitiveness (McDougall, Wagner, & MacBryde, 2022). Ahmadi-Gh and Bello-Pintado (2022) Ahmadi-Gh and Bello-Pintado (2022)concluded that the adoption of sustainable practices enhances sustainability outcomes in meeting stakeholder demands and expectations. To cultivate expertise that can foster innovative competitiveness among marketers and facilitate organizational transformations, managerial support is indispensable. Hence, within the realm of sustainable operations, the theory posits that a company's resources, specifically the amalgamation of sustainable practices and technology, can serve as a continual source of competitive advantage. The incorporation of green technology functions as an additional resource, augmenting the value and influence of sustainable operational practices (Ahmadi-Gh & Bello-Pintado, 2022).

Through the adoption of green technology, companies acquire innovative tools and methodologies that enhance operational efficiencies, diminish environmental footprints, and potentially provide new capabilities to augment existing sustainable practices (Wasiq et al., 2023a). According to the NRBV theory, resources that are unique, rare, and challenging to imitate contribute to a firm's competitive advantage. Thus, integrating green technology with sustainable operational practices not only enriches the company's overall resource base but also enhances the value derived from these resources in terms of operational performance. This alignment with the

NRBV theory underscores the strategic importance of resource management in the pursuit of sustainable operational excellence. The combination of sustainable practices and innovative technology establishes a distinctive and challenging-to-replicate competitive advantage, fostering superior operational performance in the long term (Wasiq et al., 2023a).

H6*: Green technology adoption has significant moderating effect between green lean practices and sustainable operational performance.*
H7*: Green technology adoption has significant moderating effect between quality management and sustainable operational performance.*
H8*: Green technology adoption has significant moderating effect between customer integration and sustainable operational performance.*
H9*: Green technology adoption has significant moderating effect between Supplier integration and sustainable operational performance.*
H10*: Green technology adoption has significant moderating effect between internal business process and sustainable operational performance.*
Based on the preceding discussion, the following research hypotheses are formulated below, and the research framework is depicted in Figure 1.

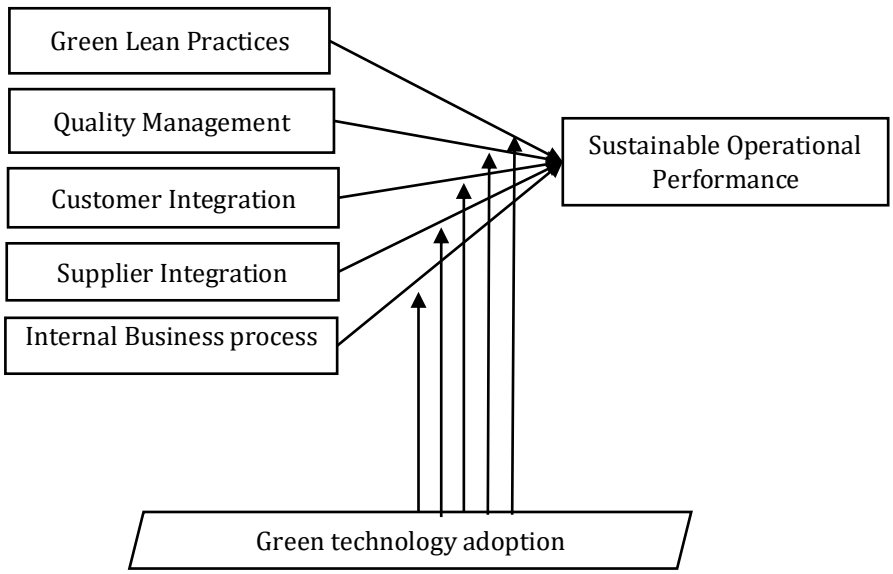

Figure.1: Research Framework

3. Research Methodology

The selected research approach for this study involved a quantitative approach, deemed more favourable than a qualitative approach (Creswell, 1999a; Creswell, 1999b; Lazaraton, 2005). The study adopted a cross-sectional research design, acquiring data at a specific moment, in contrast to a longitudinal design, which involves collecting data across different time frames (Menard, 2007). Particularly, in the case of survey-based data collection, a cross-sectional approach is considered the most suitable (Olsen, 2004). The study concentrated on employees within the operations department of textile companies in Saudi Arabia. The research instrument was borrowed from prior studies where it had already undergone testing. The

measurement of sustainable operations practices included five practices: internal lean practices, quality management, customer integration, supplier integration, and internal business processes. Internal lean practices were assessed through five items adapted from the research conducted by (Dubey et al., 2016b; Raut et al., 2019), quality management was gauged using five items adapted from previous research (Raut et al., 2019), customer integration consisted of five items adapted from the research of (Dubey et al., 2016b; Raut et al., 2019), supplier integration comprised four items adapted from the study of (Dubey et al., 2016a; Dubey et al., 2016b; Raut et al., 2019), and i internal business processes consisted of three items adapted from the research of (Raut et al., 2019). Green technology adoption was measured using three items adopted from the research of (Wasiq et al., 2023a). Finally, sustainable operational performance was assessed using six items adopted from the study of (Flynn, Huo, & Zhao, 2010). All these factors were evaluated on a five-point Likert scale, with a ranking of 1 for strongly disagree and 5 for strongly agree. The adapted research instrument has been included in Appendix A below.

The data collection questionnaire comprised two sections. The first section investigated the demographics of textile firms, exploring elements such as firm age, initial investment cost, average annual turnover, number of employees, and primary operational areas. The second part delved into sustainable operational practices, green technology adoption, and sustainable operational performance, utilizing a closed-ended 5-point Likert scale. The survey was disseminated among 500 employees, yielding 250 valid responses. The collected data underwent descriptive and multiple linear regression analyses, constituting the basis of the research design. Various assessments, including Cronbach's alpha and different validity tests, were employed to ensure the reliability and validity of the survey instrument.

3.1 Statistical Analysis

Data analysis was undertaken from both descriptive and inferential statistics perspectives, as discussed in the next two sections.

3.2 Demographic Profile

The results in Table 1 provide insights into the demographic profile characteristics of the participants in the Saudi Arabian textile industry. Regarding gender distribution, the majority are male, constituting 60%, compared to 40% female respondents, aligning with the global trend of a higher male presence in textile-related industries in Saudi Arabia. In terms of age groups, a significant proportion falls within the 25-34 years bracket (30%), followed by 18-24 years (16%), indicating a relatively young workforce. Educationally, the majority hold either a Bachelor's degree (40%) or have pursued Vocational/Technical education (30%), demonstrating a balance between theoretically and practically trained individuals, which is valuable in an industry like textiles that often requires technical skills. Concerning company size and years in operation, a significant 30% are within the 5-10 years bracket, indicating a dynamic sector with numerous medium-scale and burgeoning textile businesses. This breakdown implies that the Saudi Arabian textile industry tends to attract a younger workforce with a well-balanced mix of educational backgrounds, suggesting a vibrant and evolving industry seeking both technical expertise and academic knowledge for its growth and sustainability. The aforementioned findings are presented in Table 1.

3.3 Measurement Model

Smart PLS was utilized for the analysis due to its capability to handle intricate models that encompass both moderation and mediating variables (Hair & Sarstedt, 2021). The study employed the Partial Least Square (PLS)-Structural Equation Modelling (SEM) approach for analysis. The measurement and structural models were conducted separately. Convergent and discriminant validity tests were applied to the measurement model. Convergent validity was evaluated using various metrics: composite reliability (recommended value of 0.7), factor loadings (recommended value of 0.5), average variance extracted (recommended value of 0.5), and Cronbach alpha (recommended value of 0.7). The suggested values were by the (Hair & Sarstedt, 2021; Hair Jr et al., 2021a, 2021b; Memon et al., 2021a; Memon et al., 2021b; Sarstedt et al., 2022). Discriminant validity is the next step in measuring the measurement model. Three commonly used methods include cross loadings, Fornell and Larcker, and heterotrait-monotrait correlation. In Fornell and Larcker, all AVE diagonal square roots should be larger than the corresponding values below (Fornell & Larcker, 1981a; Fornell & Larcker, 1981b). Moreover, when assessing the instrument's adequacy, the cross-loading method is utilized. It is essential for cross-loading values to align with factor loadings (Hair Jr et al., 2017). Thirdly, the HTMT correlated values must be below 0.85 and 0.90 (Henseler, Ringle, & Sarstedt, 2015). The researchers exclusively reported HTMT as it represents the overall discriminant validity of the construct (Farrell & Rudd, 2009). The HTMT value is presented in Table.3.

Table.2: Convergent Validity

Factor	Sub factor	Loadings	Alpha	Composite Reliability	AVE
Green Technology adoption	GTA1	0.787	0.812	0.856	0.782
	GTA2	0.783			
	GTA3	0.789			
Green Lean Practices (GLP)	GLP1	0.689	0.893	0.897	0.734
	GLP2	0.893			
	GLP3	0.831			
	GLP4	0.901			
	GLP5	0.789			
Quality Management (QM)	QM1	0.890	0.810	0.887	0.724
	QM2	0.934			
	QM3	0.678			
	QM4	0.743			
	QM5	0.836			
Customer Integration (CI)	CI1	0.834	0.804	0.884	0.717
	CI2	0.878			
	CI3	0.856			
	CI4	0.845			
Supplier Integration (SI)	SI1	0.843	0.935	0.951	0.830
	SI2	0.781			
	SI3	0.772			
	SI4	0.920			
	SI5	0.934			
Internal Business Process (IBP)	IBP1	0.923	0.848	0.902	0.774
	IBP2	0.876			
	IBP3	0.845			
Sustainable operation Performance (SOP)	SOP1	0.831	0.843	0.896	0.685
	SOP2	0.849			
	SOP3	0.852			
	SOP4	0.845			
	SOP5	0.841			
	SOP6	0.848			

Table.3: Discriminant Validity

	PMS	ME	PR	CC
GTA				
GLP	0.398			
QM	0.293	0.452		
CI	0.504	0.269	0.238	
SI	0.185	0.872		
IBP	0.196	0.358	0.349	
SOP	0.642	0.143	0.412	0.490

3.4 Empirical Analysis Results

Following the measurement model, the researchers utilized a bootstrap resampling approach with 5000 iterations to evaluate the study hypotheses. The outcomes from the PLS-SEM approach indicate a positive and significant influence of all green operational practices on sustainable operations performance. Notably, the specific sustainable practice of green lean practices exhibits a substantial positive impact ($\beta = 0.543$, $p = 0.003$), emphasizing that incorporating eco-friendly and lean methodologies significantly contributes to improved sustainable operations performance. Additionally, quality management shows a significant positive impact ($\beta = 0.465$, $p = 0.005$) on sustainable operational performance, underscoring the crucial role of effective quality practices in promoting sustainability within operational contexts. Moreover, customer integration reveals a noteworthy positive influence ($\beta = 0.621$, $p = 0.001$) on sustainable operational performance, highlighting the substantial impact of engaging customers in promoting sustainable performance. Similarly, supplier integration exhibits a significant and positive impact on sustainable operational performance ($\beta = 0.389$, $p = 0.012$). Finally, internal business processes exhibit a notably strong, positive, and significant impact ($\beta = 0.578$, $p = 0.002$) on sustainable operations performance, underscoring the crucial role of optimized and efficient internal processes in enhancing sustainability within operations. These findings collectively emphasize the integral significance of green lean practices, quality management, customer and supplier integration, and efficient internal processes in positively influencing and driving sustainable operations performance among textile companies in Saudi Arabia.

Conversely, the results of the moderating effect indicate that green technology adoption exhibits a statistically significant moderation between green lean practices and sustainable operations performance ($\beta = 0.378$, $p = 0.007$), highlighting its role in enhancing the impact of eco-friendly and lean methodologies on sustainable operations. In a similar vein, it demonstrated a noteworthy moderating effect between quality management and sustainable operations performance ($\beta = 0.421$, $p = 0.004$), underscoring its role in reinforcing the connection between effective quality practices and sustainability. Furthermore, it exhibited a robust moderating effect between customer integration and sustainable operations performance ($\beta = 0.556$, $p = 0.013$), accentuating its significant impact in fortifying the association between customer involvement and sustainability. However, for supplier integration and internal business processes, the moderating effect of green technology adoption was observed, albeit with comparatively lower significance ($\beta = 0.314$, $p = 0.034$ and $\beta = 0.489$, $p = 0.023$, respectively), indicating a less pronounced yet still noteworthy influence in strengthening their relationship with sustainable operations performance. These

findings underscore the substantial contribution of green technology adoption in enhancing and reinforcing the connection between diverse operational aspects and sustainable operational performance within organizational frameworks. The aforementioned results are outlined in Table 4.

Table.4: Hypothesis Results

Hypothesis	Beta Value	T Value	P Value	Effect Size	Decision
Green Lean Practices → Sustainable Operations Performance	0.543	3.212	0.003	0.25	Accepted
Quality Management → Sustainable Operations Performance	0.465	2.981	0.005	0.21	Accepted
Customer Integration → Sustainable Operations Performance	0.621	4.126	0.001	0.31	Accepted
Supplier Integration → Sustainable Operations Performance	0.389	2.534	0.012	0.18	Accepted
Internal Business Process → Sustainable Operations Performance	0.578	3.769	0.002	0.28	Accepted
Green Technology Adoption*Green Lean Practices → Sustainable Operations Performance	0.378	2.754	0.007	0.20	Accepted
Green Technology Adoption*Quality Management → Sustainable Operations Performance	0.421	3.102	0.004	0.23	Accepted
Green Technology Adoption *Customer Integration → Sustainable Operations Performance	0.556	3.987	0.013	0.29	Accepted
Green Technology Adoption*Supplier Integration → Sustainable Operations Performance	0.314	2.123	0.034	0.16	Accepted
Green Technology Adoption*Internal Business Process → Sustainable Operations Performance	0.489	3.442	0.023	0.25	Accepted

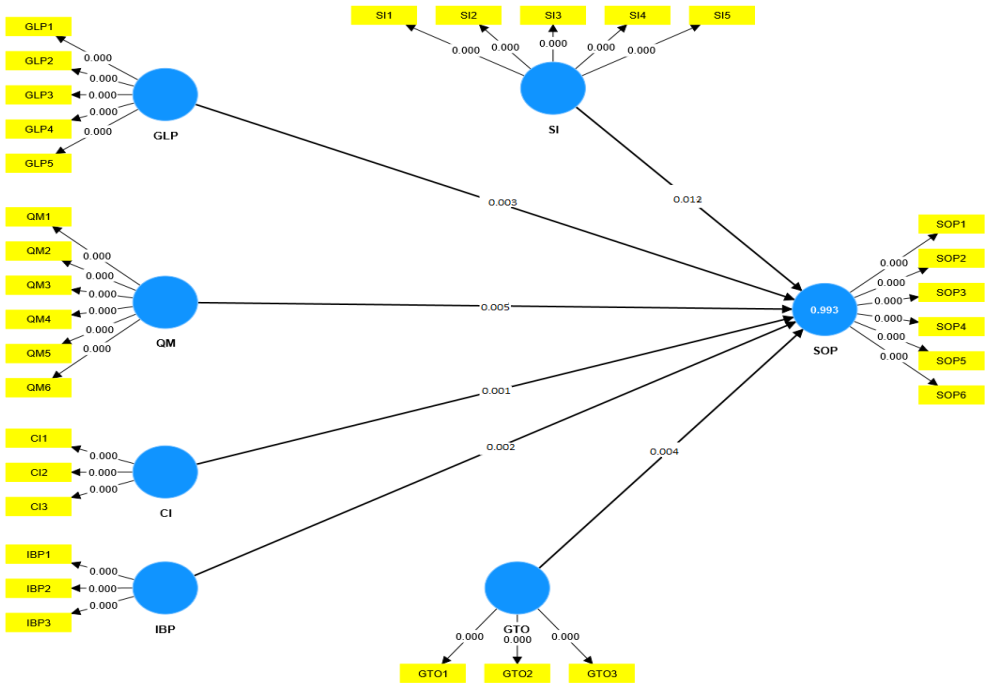

Figure.2: Direct Effect Model

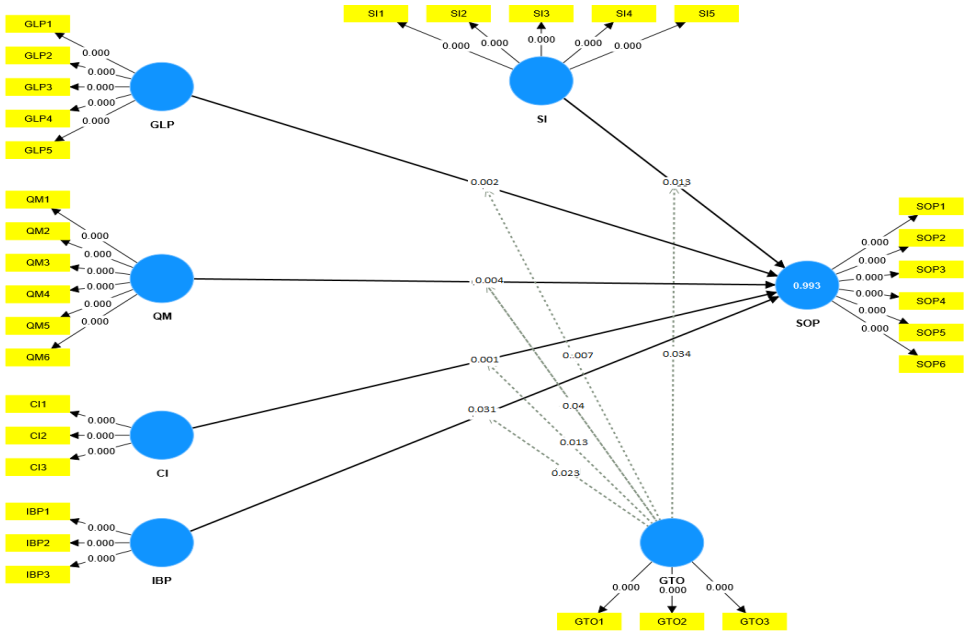

Figure.3: Moderating Effect Model

4. Discussion

To examine the influence of sustainable operations practices on sustainable operational performance with the moderating effect of green technology adoption, the research formulated direct and moderating effect hypotheses. Initially, the findings of the direct effect analysis reveal a positive and statistically significant impact of green lean practices on sustainable operational practices within Saudi Arabian textile companies. This outcome implies that the implementation of environmentally friendly and efficient processes (GLP) exerts a positive influence on the overall sustainability of operations. Saudi Arabian textile companies have commenced the integration of lean principles into their operations, emphasizing waste reduction and resource optimization Chavez et al. (2013a). Chavez et al. (2013b)emphasizing the implementation of green lean practices in the Saudi textile industry resulted in reduced production costs and improved operational efficiency, supporting the observed relationship. Quality management in Saudi textile companies exhibits a positive and significant impact on sustainable operations performance, underscoring its pivotal role. Prioritizing quality management contributes to improved production processes, reduced defects, and heightened overall sustainability in these firms Shaheen (2022). further corroborates this, illustrating that QM practices positively influence operations. Similarly, customer integration also exhibits a positive and significant impact on sustainable operations performance in Saudi Arabian textile companies. Companies actively incorporating customer needs and feedback into their operational strategies tend to experience enhanced operational sustainability. Saudi textile firms gain from aligning their operations with customer demands, ultimately improving their overall sustainability (Chavez et al., 2015). (Chavez et al., 2015; Hemstrom, 2022) indicate that customer integration strategies significantly influence

operational performance. Supplier integration also has a positive and significant impact on sustainable operations performance in Saudi textile companies. Effective collaboration with suppliers influences the sustainability of operations, albeit to a lesser extent compared to other factors. Saudi textile firms engaging in robust supplier integration experience improvements in material sourcing, inventory management, and ultimately operational sustainability Duhaylongsod and De Giovanni (2019). Duhaylongsod and De Giovanni (2019)and Amoako-Gyampah et al. (2020) supports the positive influence of supplier integration on operational performance. The last direct effect of internal business processes also indicates a positive and significant impact on sustainable operational performance. Effective and efficient internal processes significantly contribute to operational sustainability. Textile firms in Saudi Arabia, focusing on streamlining internal operations, witness enhanced sustainability in their production and delivery processes Prajogo et al. (2018b).Prajogo et al. (2018a) and Wong, Sinnandavar, and Soh (2021) supports the findings that effective internal business processes positively influence operational performance.

Secondly, it was observed that all sustainable practices have a positive and significant impact on sustainable operational performance in the presence of the moderating variable, green technology adoption. Within the elements examined, green lean practices exhibit a positive and substantial impact on sustainable operational performance, further enhanced by the moderating influence of green technology adoption in Saudi Arabian textile enterprises. This underscores that the integration of environmentally friendly technology amplifies the favourable effects of green lean practices on operational sustainability, fostering heightened efficiency and diminished environmental impact (Fernando, Chiappetta Jabbour, & Wah, 2019). confirm that integrating green technologies with sustainable practices can lead to improved operational performance. The second set of results also shows that green technology adoption positively and significantly moderates the relationship between quality management and sustainable operational performance. This implies that the adoption of technology enhances the effectiveness of quality management practices in promoting operational sustainability. When Saudi textile enterprises integrate green technology with quality management strategies, they attain heightened product quality and operational efficiency, thereby making a substantial contribution to overall sustainability Dean Jr and Bowen (1994). Dean Jr and Bowen (1994)confirms this by demonstrating that the incorporation of green technology in quality management positively impacts operational performance in the Saudi textile industry.

The third moderating effect reveals that green technology adoption positively and significantly moderates the relationship between customer integration and sustainable operational performance. These findings suggest that incorporating green technology to align customer needs with operational strategies improves the overall sustainability of operations. Saudi textile firms utilizing technology to integrate customer demands experience heightened market responsiveness and operational efficiency, contributing to improved sustainability. The fourth practice similarly exhibits a positive and noteworthy influence on sustainable operational performance when coupled with green technology adoption. The results imply that integrating green technology into supplier relationships positively affects operational sustainability, although the extent of this impact may be somewhat diminished. Saudi textile enterprises that embrace green technology in supplier integration experience enhanced supply chain efficiency and diminished environmental footprint Jermsittiparsert, Sriyakul, and Sangperm (2019). underscoring that companies with

proficient technology adoption witness an augmentation in supplier engagement. Furthermore, the incorporation of green technology demonstrates a constructive and noteworthy moderating influence on the relationship between internal business processes and sustainable operational performance within Saudi textile enterprises. The adoption of green technology in internal business processes positively influences operational sustainability. Saudi Arabian textile enterprises, upon integrating advanced technology into their internal processes, observe heightened operational efficiency and diminished resource wastage, thereby enhancing overall sustainability Ball (2016). demonstrating that the positive impact of green technology adoption extends to the augmentation of internal processes within the Saudi textile industry.

5. Implications

The research holds various theoretical and practical implications. Theoretical implications within the Saudi Arabian context are ground-breaking, as the model showcasing Green Technology Adoption as a moderator between sustainable operations practices and operational performance introduces an innovative framework not previously explored in this industry setting. This presents a novel perspective for research, highlighting the crucial role of technology in augmenting the effectiveness of sustainable practices. The results indicate that integrating advanced green technologies with established sustainable practices is a promising approach to significantly enhance operational sustainability in Saudi Arabian textile companies. These insights offer a new direction for further research, encouraging the exploration and development of comprehensive frameworks that blend sustainability practices with technological advancements to achieve optimal operational performance.

From a practical standpoint, these findings provide valuable insights for managers and stakeholders in Saudi Arabian textile companies. Recognizing Green Technology Adoption as a potent moderator underscores the potential of technology in amplifying the impact of sustainable practices. This insight can guide managerial decision-making, emphasizing the significance of investing in and integrating advanced eco-friendly technologies across diverse operational aspects. Implementing such technologies to complement existing sustainable practices can result in improved operational efficiencies, diminished environmental footprints, and heightened competitiveness within the Saudi Arabian textile industry. This presents an opportunity for these companies to strategically harness technology, optimizing positive outcomes from sustainability initiatives and laying the groundwork for more effective operational strategies.

6. Research Limitations and Future Directions

Though the study introduces Green Technology Adoption as a moderator in the realm of sustainable operations in Saudi Arabian textile companies, it acknowledges certain limitations and suggests future directions. These could involve broadening the research scope to encompass a more diverse range of industries in Saudi Arabia, facilitating a comparative analysis to grasp the nuances and variations in technology adoption and sustainability practices across sectors. Mitigating these limitations could augment the generalizability of the findings and foster a more holistic understanding

of technology's role in sustainability across the broader Saudi Arabian business landscape. Moreover, since the study relied on quantitative analysis through a survey questionnaire, future research endeavours might employ a mixed-method approach. Additionally, considering the study's focus on one specific country, where cultural and environmental factors may differ, future research could extend to other developed countries to enhance the generalizability of the findings.

7. Conclusion

The research aimed to examine the moderating effect of green technology adoption on the relationship between green supply chain operations and sustainable operations performance. To fulfil this objective, data were gathered from senior managers in Saudi Arabia. The empirical results underscore the substantial impact of sustainable operational practices in Saudi Arabian textile companies. The direct effects of Green Lean Practices, QM, Customer Integration, Supplier Integration, and Internal Business Processes highlight their distinct contributions to improving operational sustainability. Furthermore, integrating Green Technology Adoption as a moderating variable significantly enhances the positive impact of sustainable practices on operational performance, underscoring the pivotal role of technology in bolstering sustainability initiatives. These findings provide a fresh outlook on incorporating advanced eco-friendly technologies with established sustainable practices, presenting a promising avenue for enhancing operational sustainability in the Saudi Arabian textile industry. Theoretical implications underscore the model's innovative potential, while practical implications emphasize actionable insights for managers and stakeholders, guiding strategic investments in eco-friendly technologies for enhanced efficiency, reduced environmental impact, and heightened competitiveness. While the results show promise, acknowledging the study's limitations emphasizes the necessity for diverse industry representation. Additionally, the potential for future research using mixed methods or expanding to other countries underscores the ongoing pursuit of broader applicability and a more comprehensive understanding of the role of technology in sustainability practices across varied business landscapes.

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Factor	Questions	Adapted from
Green Technology adoption	Green technology potentially brings greater economic benefits with improved environmental performance. Green technology potentially improves company credibility. Green practices can be easily implemented into any organisational framework.	(Wasiq, Kamal, & Ali, 2023b)
Green Lean Practices	The company effectively employs tools and techniques to enhance operational efficiency and minimize waste. The company actively implements and utilizes energy-efficient technologies to reduce energy consumption and environmental impact. The company integrates eco-friendly green practices in its manufacturing processes to reduce its environmental footprint. The company actively engages in the reuse, recycling, and re-manufacturing of materials to minimize waste and support sustainable practices.	(Dubey et al., 2016a; Raut et al., 2019)
Quality Management	The company employs manufacturing systems that are easily reconfigurable to adapt to changing production needs and reduce resource consumption. The company effectively manages costs in relation to the quality of its products. The company consistently implements total quality management practices to ensure high standards and customer satisfaction. The company maintains and enhances the overall effectiveness of its machinery and equipment through total productive maintenance practices. The company ensures high-quality data for decision-making and operational purposes, minimizing errors and inconsistencies. The company consistently delivers high-quality service and an exceptional experience to its customers. The company's efforts to integrate customer feedback into eco-design processes are effective.	(Dubey et al., 2016a; Raut et al., 2019)
Customer Integration	The level of customer cooperation in promoting cleaner production practices is significant. Customers actively support and engage in green purchasing initiatives of the company. The company provides an effective information-sharing structure for customers regarding eco-friendly practices and product details.	(Dubey et al., 2016a; Raut et al., 2019)
Supplier Integration	Our suppliers in supporting our sustainability initiatives. Our sustainability targets shared with our vendors and suppliers. Our suppliers as green partners in our sustainability. Information-sharing structure is effective with our suppliers regarding sustainability practices and goals.	(Dubey et al., 2016a; Raut et al., 2019)
Internal Business Process	The company has clearly defined and documented objectives and policies for sustainability. Sustainability practices are seamlessly integrated into our routine business operations. 'The company effectively shares information about goals among its internal stakeholders.	(Dubey et al., 2016a; Raut et al., 2019)
Sustainable Operational Performance	Our company can quickly modify products to meet our major customer's requirements. Our company can quickly introduce new products into the market. Our company can quickly respond to changes in market demand. Our company has an outstanding on-time delivery record to our major customer. The lead time for fulfilling customers' orders (the time which elapses between the receipt of customers order and the delivery of the goods. Our company provides a high level of customer service to our major customer.	(Flynn et al., 2010)