INFLUENCE OF WORKPLACE GREEN PRACTICES ON ENVIRONMENTAL SUSTAINABLE PRODUCT SERVICE SYSTEM: MEDIATING ROLE OF GREEN INNOVATIONS

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ABSTRACT: This research empirically examines the influence of green operations on the sustainability of product-service systems, focusing on the mediating role of green innovations within Saudi Arabian manufacturing companies. Using Structural Equation Modelling (SEM) for data analysis, the study gathered data from 361 employees through convenience sampling. The results demonstrated that pollution prevention practices, top management commitment, sustainable human resource management, and product stewardship significantly enhance the sustainability of product-service systems. This study contributes to the literature by revealing a novel connection between green operations and the development of sustainable product-service systems in the Saudi manufacturing sector. It also offers a unique insight into the mediating role of green innovations, emphasizing the transformative potential of these strategies in promoting sustainability in emerging economies. Practically, the study provides valuable recommendations for manufacturing companies seeking to integrate green practices into their operations, aiming to improve both environmental stewardship and business competitiveness.

Keywords: Green Operational, Environmental Sustainability, Product Service System, Saudi Arabia.

1. Introduction

In today's dynamic environment, the manufacturing sector plays a pivotal role in advancing countries towards sustainable development goals. Despite its significant contributions, this sector faces various sustainability challenges, including environmental, economic, and social issues. Among these, environmental sustainability is particularly critical due to climate change, depletion of natural resources, environmental pollution, and various industrial management challenges (Principato et al., 2021). Achieving environmental sustainability in manufacturing necessitates profound changes (Kuo, Wu, & Liu, 2022). Scholars have argued that environmental performance is crucial for supporting sustainable manufacturing development (Ruben et al., 2023). This achievement requires commitment and awareness from all stakeholders (Hariadi, Moengin, & Maulidya, 2023), prompting organizations to adopt clean production and open innovation to foster sustainable product-service systems (Haleem et al., 2023; Hao, Helo, & Shamsuzzoha, 2018).

In the realm of environmental sustainability, an integral component is the product-service system, which focuses on reducing resource use, promoting reuse and recycling, and minimizing the ecological impact throughout the product's lifecycle (Hao et al., 2018). Several factors influence sustainable product-service systems, and assessing the sustainability of green practices in manufacturing remains a challenge (Liu et al., 2023). Organizations that integrate green practices into sustainable product-service systems promote sustainable production and consumption patterns (Zehoul, 2021), thereby enhancing customer satisfaction with environmentally friendly products (Gaiardelli et al., 2021). This approach not only contributes to business performance but also enhances the overall performance of sustainable product-service systems. Previous research highlights that green practices are designed to minimize environmental impact while optimizing production efficiency (Hariadi et al., 2023). Encouraging the adoption of green practice initiatives is crucial for advancing sustainable product-service systems in manufacturing (Sarfraz et al., 2023; Wu et al., 2021). Green practices contribute to achieving environmentally sustainable product-service systems by addressing social issues, reducing carbon emissions, and enhancing ecological preservation (Laurensia, Kosasih, & Salomon, 2023). Effective implementation of green practices can significantly mitigate carbon emissions and tackle environmental concerns (Xu et al., 2021).

The literature discusses various green practices, including pollution prevention practices, top management commitment, product stewardship practices, and sustainable human resource management. Pollution prevention practices focus on reducing waste emissions, enhancing recycling, improving operational efficiency, and ensuring workplace safety (Malhotra et al., 2024). Product stewardship practices involve managing a product's environmental impact throughout its lifecycle (Martinez-Marquez et al., 2022). Additionally, sustainable human resource management plays a critical role in promoting environmental sustainability through

green training initiatives (Aftab & Veneziani, 2024). Therefore, this study aims to examine the impact of green practices on the development of environmentally sustainable product-service systems. Furthermore, several authors have emphasized the importance of encouraging organizations to adopt green practices in innovating environmentally friendly products (Singh et al., 2023). This adoption enhances competitive advantage by fostering organizational culture, knowledge, and innovation capabilities (Azeem et al., 2021), thereby increasing consumer willingness to pay for eco-friendly products and promoting green consumption (Adhiyogo et al., 2022). Scholars argue that green operations aim to minimize waste and pollution while cultivating an environment conducive to innovation (Omar et al., 2024). Similarly, other researchers advocate that companies should prioritize green operations to meet community expectations and stimulate innovation (Massoudi & Fatah, 2021; Sarstedt, Ringle, & Hair, 2020).

Regarding innovation factors, both green service innovation and green product innovation are crucial for advancing environmentally sustainable products (Hariadi et al., 2023). Green operations foster a culture of innovative practices such as eco-design, waste reduction, adoption of renewable energy, and collaboration across supply chains, all of which collectively enhance the development of more environmentally sustainable product-service systems (Hariadi et al., 2023). Therefore, this study focuses on examining the impact of green operations on environmentally sustainable product-service systems, with a particular emphasis on the mediating effects of green service innovation and green product innovation. Empirically, there are still various gaps in the research on green operations, green innovations, and environmentally sustainable product systems. Firstly, previous studies have primarily focused on the direct effects of green operations on environmental sustainability and innovations on environmental sustainability, while limited attention has been given to exploring the indirect effects mediated by green service innovation and green product innovation within the context of environmentally sustainable product systems (Aydin et al., 2023; Khan, Yu, & Farooq, 2023; Li et al., 2023). Additionally, existing literature has often treated environmental sustainability as a broad concept, frequently overlooking the specific nuances of environmentally sustainable product systems. Moreover, much of the research has been conducted in contexts outside of Saudi Arabia, focusing on green operations practices such as green marketing, green manufacturing, and green eco-design (Wungkana, Siagian, & Tarigan, 2023). This has led to a neglect of critical aspects such as pollution prevention practices, top management commitment, and product stewardship practices (Hariadi et al., 2023). Furthermore, sustainable human resource management has received little attention in conjunction with other green operations practices, particularly within the Saudi Arabian context (Aftab & Veneziani, 2024; Yasin, Huseynova, & Atif, 2023). Furthermore, while previous studies have examined green operations in Saudi Arabia, there has been limited focus specifically on manufacturing companies. Given significant gaps in the existing literature, this study aims to empirically investigate the impact of green operations on environmentally sustainable product-service systems, with a particular focus on the mediating role of green innovations within Saudi Arabian manufacturing companies.

This study offers significant theoretical and practical implications. Theoretically, it highlights the effectiveness of green operations—such as pollution prevention, top management practices, sustainable human resource management, and product stewardship—in enhancing environmentally sustainable product-service systems. These findings contribute to the literature by validating the role of green operations in reducing environmental impact while improving economic and social outcomes, particularly through the mediating effects of green innovations. Practically, the study provides actionable insights for manufacturing organizations in Saudi Arabia and globally, suggesting that adopting green operations can enhance operational efficiency, reduce resource consumption, and improve environmental stewardship. The study is structured into four sections: literature review, research methodology, data analysis, and discussion and implications.

2. Literature Review

2.1. Theoretical Framework

Environmental sustainability in products is imperative for reducing carbon footprints and conserving natural resources. These products promote responsible production and consumption practices, creating a healthier foundation for future generations. Moreover, their acceptance drives product innovation towards more sustainable and balanced economies. Authors have identified various factors that enhance environmental sustainability in products, with top management commitment emerging as crucial. This commitment fosters a culture of sustainability by implementing supportive practices (Padma, Ganesh, & Rajendran, 2008). According to leadership theory, proactive initiatives by top management can significantly enhance organizational sustainability, inspiring alignment and commitment across the organization (Ytterstad & Olaisen, 2023). Such commitment influences strategic decision-making, resource allocation, and the integration of sustainability into core business practices, thus facilitating the development of sustainable product-service systems (SPSS) (Roman et al., 2023). Additionally, pollution prevention practices (PPP) play a pivotal role in minimizing adverse environmental impacts and promoting product sustainability (Ali, Kausar, & Amir, 2023). According to the Resource-Based View (RBV), PPP are regarded as unique organizational resources that can enhance SPSS by achieving cost savings and improving reputation (Malhotra et al., 2024). Organizations that effectively implement PPP demonstrate their commitment to environmental responsibility by minimizing pollutants, conserving resources, and optimizing production processes. Furthermore, these practices directly contribute to the development of SPSS by mitigating environmental risks throughout product lifecycles (Roman et al., 2023).

On the other hand, product stewardship practices (PSP) embody the concept of extended producer responsibility (EPR), where manufacturers assume responsibility for their products to enhance environmental sustainability (Meyer, 2023). PSP encompasses eco-design, recycling initiatives, and responsible end-of-life management strategies. By adhering to EPR principles, organizations align with regulatory requirements and consumer expectations for sustainable products, thereby contributing to SPSS (Sarancic et al., 2023). From another perspective, sustainable human resource management (SHRM) also plays a crucial role in integrating SPSS into products by implementing appropriate HR policies and practices (Aftab & Veneziani, 2024). Supported by Stakeholder Theory, sustainable human resource management (SHRM) acknowledges employees as critical stakeholders in sustainability initiatives (Piwowar-Sulej et al., 2024). Organizations that adopt SHRM practices engage employees through training, performance incentives, and integrating sustainability criteria into job roles. These practices foster an innovative culture among employees, thereby supporting the development of SPSS (Roman et al., 2023). Based on the preceding discussion, a theoretical research framework has been formulated in Figure 1. This framework includes Top Management Commitment (TMC), PPP, PSP, and SHRM as independent variables, with SPSS as the dependent variable. Green innovations are included as independent variables, and Green Transformational Leadership is considered a moderating variable.

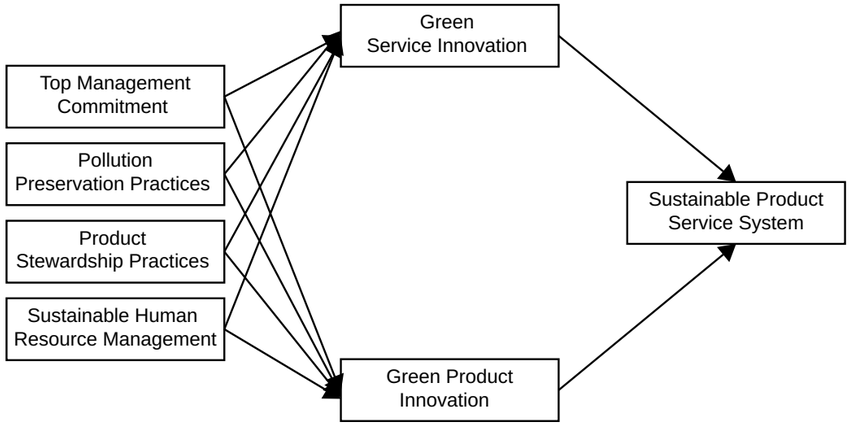

Figure 1: Theoretical Framework.

2.2. Hypothesis Development

Several empirical studies have examined the impact of TMC on SPSS, yet these studies have often overlooked the mediating role of green innovation systems. For instance, Lutfi et al. (2023) found that robust TMC in environmental initiatives positively influences innovation, thereby fostering the development of green services. Similarly, Soomro et al. (2024) underscored that firms with stronger TMC can enhance product innovation systems, thereby promoting sustainable product systems within organizations. Furthermore, Shabbir et al. (2024) investigated the moderating role of TMC and observed

a significant impact on SPSS, suggesting potential for future research to explore TMC with other mediating variables. Based on these insights, researchers have formulated the following research hypotheses,

H1: Top management commitment has significant effect on sustainable product service system with mediating effect of green service innovation.

Several empirical studies have explored the relationship between PPP, SPSS, and Green Service Innovation (GSI). For instance, Cheng, Lin and Yang (2024) provide empirical evidence that organizations implementing effective pollution prevention strategies not only reduce environmental impacts but also stimulate innovation in green services. Their findings indicate that companies integrating PPP into their operations tend to develop innovative service solutions that cater to environmentally conscious consumer preferences, thereby enhancing their SPSS. Similarly, Singh et al. (2023) highlighted that PPP contribute to organizational capabilities in eco-innovation, which subsequently drives the development of sustainable service systems. Conversely, Ali et al. (2023) underscored the positive and significant impact of PPP on SPSS products. They further suggested that an increase in green innovation culture within organizations correlates with enhanced SPSS. Based on these insights, the study has formulated the following research hypotheses,

H2: Pollution prevention practices have significant effect on sustainable product service system with mediating effect of green service innovation.

Furthermore, studies have examined the relationship between PSP, Green Innovation Systems (GIS), and SPSS. For example, Chhillar et al. (2023) found that companies adhering to extended producer responsibility (EPR) principles, a key component of PSP, are more inclined to innovate in eco-friendly product-service solutions. Their research highlights that PSP not only enhances SPSS but also strengthens organizational capabilities in delivering sustainable services. Similarly, research by Hariadi et al. (2023) demonstrated that PSP positively influences the adoption of green service innovations aimed at reducing environmental impacts throughout product lifecycles. On the other hand, Nabi, Liu and Hasan (2023) tested the impact of PSP on green innovations and identified a positive and significant relationship. They argued that promoting green innovation contributes to reducing electronic waste and improving recycling rates, emphasizing the pivotal role of innovative approaches in achieving sustainability goals. Additionally, Conlon (2024) conducted a study exploring consumer preferences for environmentally sustainable products and noted that companies investing in green innovation tend to attract eco-conscious consumers, thereby enhancing SPSS. Based on these findings, the study has formulated the following research hypotheses,

H3: Product stewardship practices have significant influence on sustainable product service system with mediating effect of green service innovation.

Rana and Arya (2024) conducted a study on the impact of SHRM practices on environmental sustainability, finding a positive and significant effect of SHRM on environmentally sustainable products. Their research also identified the partial mediation of green innovation between SHRM and environmental sustainability, suggesting that this mediating relationship could be further explored in other developing countries. Similarly, Aftab and Veneziani (2024) investigated the impact of SHRM on environmental sustainability, confirming a positive and significant influence and proposing the examination of mediating effects between SHRM and environmental sustainability. Furthermore, Aftab and Veneziani (2024) highlighted that organizations implementing SHRM practices, such as environmental training and employee involvement in sustainability, cultivate a culture of innovation that fosters the development of green services. Their study underscored that SHRM enhances organizational capabilities in delivering environmentally friendly products and services, thereby improving SPSS. Similarly, Rana and Arya (2024) suggested that SHRM practices positively influence organizational commitment to sustainability, which stimulates innovations in green services. Based on these studies, the following research hypotheses have been formulated,

H4: Sustainable human resource management has significant impact on product service system performance with mediating effect of green service innovation.

Previous discussions have explored the relationship between TMC and SPSS. Various authors have also studied the impact of TMC on green product innovation. Huang and Huang (2024) found a positive and significant impact of TMC on GPI, suggesting potential connections with SPSS. Similarly, Nugroho, Tarigan and Siagian (2024) identified a positive and significant impact of TMC on green purchasing behaviour and recommended further exploration into green product innovation. Additionally, Nugroho et al. (2024) found that firms with strong TMC for sustainability initiatives are more likely to invest in green product development and innovation. This commitment fosters strategic decisions prioritizing eco-friendly product designs and lifecycle management, thereby enhancing SPSS. Similarly, Hariadi et al. (2023) emphasized that proactive TMC cultivates an innovative climate driving green product innovations aligned with environmental sustainability goals. These studies underscore the pivotal role of TMC in improving green product innovation to enhance SPSS. Based on these insights, the study proposes the following research hypotheses,

H5: Top management commitment has significant effect on sustainable product service system with mediating effect of green product innovation.

As discussed earlier, PPP are linked to SPSS. Various authors have studied this relationship. Islam, Muthaiyah and Fie (2020) concluded from their study that PPP is crucial for fostering innovations and suggested exploring green product innovation further. Similarly, Ali et al. (2023) emphasized that PPP enhances a culture of innovation and recommended testing this relationship across different countries to understand variations in results. Moreover, Hui et al. (2024) demonstrated that organizations implementing effective PPP are more likely to innovate in eco-friendly product designs and technologies, thereby contributing to SPSS development through reduced environmental impacts and meeting consumer demand for sustainability. Additionally, Zhu and Tan (2022) indicated that PPP enhances organizational capabilities in eco-innovation, facilitating the adoption of green product innovations that support SPSS. Based on these discussions, the study formulates the following research hypotheses,

H6: Pollution prevention practices have significant effect on sustainable product service system with mediating effect of green product innovation.

Further studies have explored the relationship between PSP, SPSS, and GPI. Martinez-Marquez et al. (2022) investigated PSP and concluded it as a significant factor in increasing GPI. Similarly, Waheed et al. (2020) found a positive and significant impact of PSP on innovation, suggesting GPI could serve as a mediating variable in future research. Aligning with these findings, Meyer (2023) highlighted that organizations adhering to EPR principles, a key aspect of PSP, are more likely to innovate in sustainable product designs and technologies. This innovation contributes to SPSS by enhancing environmental performance and meeting regulatory requirements. Likewise, Singh, Singh and Deepak (2024) explored how PSP enhances organizational capabilities in eco-innovation, driving the adoption of green product innovations that support sustainability goals. These studies underscore that PSP plays a critical role in fostering a culture of GPI, thereby contributing to SPSS. Based on these insights, the study proposes the following research hypotheses,

H7: Product stewardship practices have significant influence on sustainable product service system with mediating effect of green product innovation.

SHRM practices contribute to enhancing SPSS. Afsar, Bibi and Umrani (2023) found that SHRM practices, including environmental training and employee involvement in sustainability, foster a culture of innovation leading to the development of green products. This highlights SHRM's role in enhancing organizational capabilities to deliver environmentally friendly products and increase SPSS. Ahmad (2024) similarly argued that SHRM practices positively influence organizational commitment to sustainability, driving innovations in green products. Moreover, studies by Aftab and Veneziani (2024) and Yasin et al. (2023) confirmed the positive and significant impact of SHRM on environmental sustainability, recommending further exploration of SHRM's role in enhancing product innovation with mediating effects in future research. Based on these findings, the study formulates the following hypotheses,

H8: Sustainable human resource management has significant impact on product service system performance with mediating effect of green product innovation.

2.3. Research Design and Sampling

The researcher utilized a cross-sectional research design, collecting data once through a self-administered questionnaire. This approach offers efficient data collection, rapid insights into prevalence and relationships, and is suitable for hypothesis generation in the social sciences (Robinson, Schmidt, & Teti, 2005). Consequently, the study opted for a cross-sectional design over longitudinal research. Quantitative data were gathered using a survey instrument adapted from previous studies. TMC was assessed using 10 items adapted from Padma et al. (2008). PPP were measured with four adapted items from Bhupendra and Sangle (2015). Product Stewardship was evaluated using three items adapted from Islam et al. (2020). SHRM was assessed with seven items adopted from Yu et al. (2021). GPI was measured using three items adapted from Xie, Huo and Zou (2019). GSI was assessed with nine items adapted from Chen et al. (2015)green dynamic capacities and green service innovation to

improve firm performance: An analysis of structural equation modeling (SEM. Finally, SPS were measured using four items adopted from Tseng et al. (2018). The questionnaire utilized a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was administered to 450 employees across diverse manufacturing companies in Saudi Arabia. The choice of the manufacturing sector in Saudi Arabia was intentional, given its substantial impact on the national economy and employment landscape, providing a diverse demographic of employees with varying job roles and experiences. Convenient sampling was preferred over probability sampling methods due to practical considerations such as accessibility and time constraints. This approach facilitated broader participation within the sector, ensuring a representative sample of employees, thereby enhancing the study's capacity to gather insights pertinent to the research objectives (Sedgwick, 2013). Out of the 450 questionnaires distributed, 361 were returned, yielding a response rate of approximately 80%, which is considered robust in survey research and bolsters the reliability of the study's findings (Israel, 1992).

2.4. Data Analysis and Explanation

The analysis was conducted using two software packages, namely SPSS and AMOS. Demographic and descriptive analyses were performed using SPSS, while regression analysis was conducted using AMOS.

2.5. Demographic Profile

Table 1 presents the demographic profile of the respondents. The majority of respondents, approximately 71.4%, were male, which mirrors the gender distribution commonly observed across various industries in Saudi Arabia. In terms of educational qualifications, a significant proportion of respondents (48.6%) held master's degrees, indicating a high level of educational attainment among the workforce. This aligns with the emphasis on higher education for professional roles and career advancement in the region. Regarding age distribution, the respondents were evenly distributed across different age brackets: 25-30 years (28.6%), 31-35 years (25.7%), 36-40 years (20%), and above 40 years (25.7%). This diverse age demographic is crucial for understanding generational perspectives within organizational contexts in Saudi Arabia.

Table 1: Demographic Profile.

Demographic Category	Number of Employees	Percentage (%)
Total Employees	350	100
Gender		
Male	250	71.4
Female	100	28.6
Education		
Graduation	100	28.6
Masters	170	48.6
Others	80	22.9
Age		
25-30 years	100	28.6
31-35 years	90	25.7
36-40 years	70	20
Above 40 years	90	25.7

2.6. Measurement Model

The SEM conducted in AMOS confirms the construct validity and reliability of the measurement model (Sarstedt, Ringle, & Hair, 2021). Internal consistency and reliability were evaluated using Cronbach's alpha and composite reliability, with all coefficients exceeding 0.70, indicating satisfactory reliability (Hair et al., 2017). Table 2 displays Cronbach's alpha coefficients and composite reliability scores, all of which are above 0.7, confirming the internal consistency of the constructs. Factor loadings, indicating the strength of relationships between observed variables and latent constructs, were also examined and found to exceed 0.50, meeting robustness criteria (Sarstedt et al., 2021). Convergent validity, assessed through average variance extracted (AVE) values, shows all values surpassing 0.5 as recommended (Hair et al., 2017), as depicted in Table 2. Discriminant validity, evaluated using the Fornell–Larcker Criterion, demonstrates that the square root of AVE values exceeds the correlations between constructs in Table 3, confirming discriminant validity (Hair et al., 2017; Henseler, Ringle, & Sarstedt, 2015). Additionally, multicollinearity was assessed using Variance Inflation Factors (VIFs), all of which were below 3, well below the threshold of concern (Sarstedt et al., 2021), indicating no issues with multicollinearity in the dataset. Detailed results for convergent and discriminant validity are presented in Tables 2 and 3, respectively.

Table 2: Convergent Validity.

Variable	Factor Loadings	Cronbach's Alpha	Composite Reliability	AVE	VIF
Top Management Commitment		0.871	0.89	0.72	1.23
TMC1	0.853				1.18
TMC 2	0.816				1.15
TMC 3	0.797				1.22
TMC 4	0.767				1.19
TMC 5	0.828				1.21
TMC6	0.672				1.56
TMC7	0.892				1.67
TMC8	0.866				1.89
TMC9	0.782				1.56
Pollution Prevention Practices		0.832	0.86	0.68	1.15
PPP1	0.782				1.17
PPP 2	0.754				1.21
PPP 3	0.736				1.18
PPP 4	0.797				1.28
Product Stewardship Practices		0.853	0.88	0.7	1.23
PSP 1	0.823				1.19
PSP 2	0.763				1.16
PSP3	0.825				1.21
Sustainable HRM		0.881	0.912	0.75	1.28
SHRM1	0.771				1.17
SHRM 2	0.794				1.19
SHRM 3	0.815				1.22
SHRM 4	0.832				1.18
SHRM 5	0.855				1.18
SHRM6	0.832				2.33
SHRM7	0.731				2.91
SHRM8	0.782				1.78
Green Service Innovation		0.833	0.867	0.721	
GSI1	0.842				1.16
GSI2	0.821				1.18
GSI3	0.781				1.26
GSI 4	0.822				1.17
GSI5	0.865				1.19
GSI5	0.790				1.88
GSI6	0.561				1.56
GSI7	0.783				1.90
GSI8	0.902				1.79
Green Product Innovation		0.823	0.883	0.673	
GPI1	0.831				1.18
GPI2	0.794				1.15
GPI3	0.813				1.21
Sustainable Product Service System					
SPSS1	0.710	0.821	0.835		1.56
SPPS2	0.932				1.67
SPSS3	0.856				1.19
SPSS4	0.873				1.22

Table 3: Discriminant Validity.

Constructs	TMC	PPP	PSP	SHRM	GSI	GPI	SPSS
TMC	0.853						
PPP	0.312	0.820					
PSP	0.353	0.253	0.841				
SHRM	0.423	0.342	0.353	0.891			
GSI	0.454	0.253	0.323	0.353	0.842		
GPI	0.534	0.342	0.353	0.442	0.453	0.803	
SPSS	0.342	0.783	0.683	0.453	0.453	0.374	0.783

3. Empirical Findings

This section presents the findings of the hypotheses tested. The results indicate a positive and significant influence of TMC on SPSS, mediated by GSI, thus supporting the proposed hypotheses. Similarly, PPP show a positive and significant impact on SPSS, mediated by GSI. Additionally, both PSP and SHRM practices demonstrate a positive and significant impact on SPSS, with mediation through GSI. Furthermore, TMC, PPP, PSP, and SHRM also exhibit positive and significant impacts on SPSS, mediated by GPI. These results underscore the pivotal role of GPI and GSI as mediators in Saudi Arabian manufacturing firms. They facilitate the transformation of green operational practices into sustainable product-service systems, enhancing efficiency, reducing environmental impact, and fostering innovation. These findings not only align businesses with global sustainability standards but also bolster competitiveness in environmentally conscious markets. Detailed results are presented in Table 4.

Table 4: Regression Results.

Variable Path	β	Standard Error	T Statistic	Decision
TMC -> GSI -> SPSS	0.451	0.081	5.561***	Accepted
PPP -> GSI -> SPSS	0.320	0.062	5.162***	Accepted
PSP -> GSI -> SPSS	0.383	0.071	5.471`***	Accepted
SHRM -> GSI -> SPSS	0.512	0.092	5.622***	Accepted
TMC -> GPI -> SPSS	0.371	0.071	5.221***	Accepted
PPP -> GPI -> SPSS	0.282	0.051	5.521`***	Accepted
PSP -> GPI -> SPSS	0.341	0.062	5.510`***	Accepted
SHRM -> GPI -> SPSS	0.422	0.081	5.221***	Accepted

Acronyms: TMC-Top Management Commitment, GSI-Green Service Innovation, SPSS-Sustainable Product Service System, PPP-Pollution Prevention Practices, SHRM-Sustainable Human Resource Management, GPI-Green Product Innovation, PSP-Product Stewardship Practices.

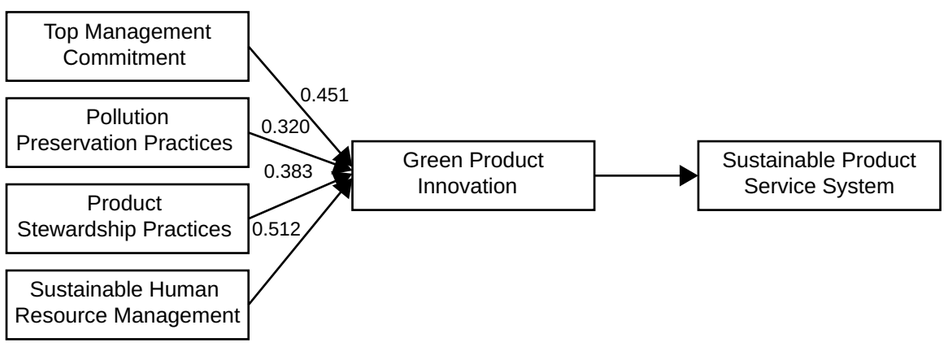

Figure 2: Green Service Innovation Mediating Effect Beta Values.

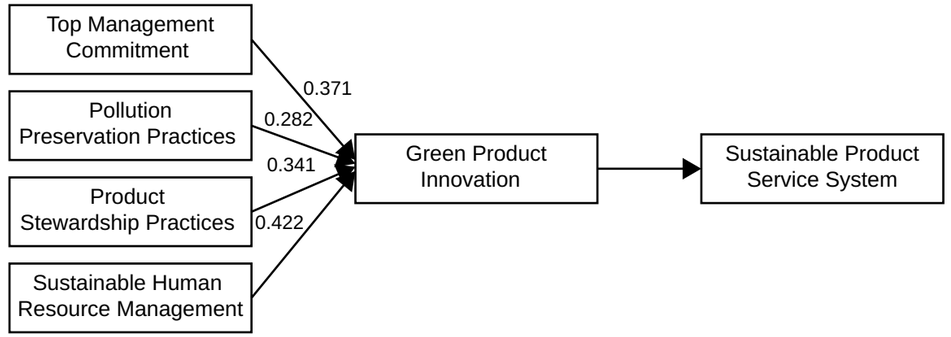

Figure 3: Green Production Innovation Mediating Effect Beta Values.

4. Discussion

The study reveals that TMC positively and significantly influences environmental SPSS through the mediating effect of GSI in Saudi Arabian manufacturing companies. This underscores how TMC fosters a culture where sustainability goals are prioritized and integrated into strategic decisions, driving innovation in green services and products (Shabbir et al., 2024). These findings align with prior research (Dubey et al., 2018; Huang & Huang, 2024), which highlights that TMC facilitates innovation in sustainable practices, thus bolstering SPSS. Chulkov (2024) also supports this argument, suggesting that TMC enhances organizational innovation capacities, thereby enhancing SPSS. Furthermore, the study finds that PPP positively impact SPSS, mediated by GSI. Effective PPP in Saudi Arabian manufacturing companies plays a critical role in reducing environmental footprints and enhancing operational sustainability, consistent with prior research (Hariadi et al., 2023). In a context where environmental concerns pose challenges to economic growth, robust PPP enhances corporate sustainability credentials and ensures compliance with local and international environmental standards. Therefore, it is argued that Saudi Arabian manufacturing companies should integrate PPP into their operations. This strategic approach can lead to significant cost savings through improvements in resource efficiency and waste reduction initiatives, thereby making a positive contribution to the development of SPSS (Ali et al., 2023). Further results indicate that PSP have a positive and significant effect on SPSS with the mediating effect of GSI in Saudi Arabian manufacturing companies. These findings suggest that companies in Saudi Arabia prioritizing PSP not only minimize environmental impacts throughout the product lifecycle but also drive innovation in green services and products (Bustinza, Vendrell-Herrero, & Jabbour, 2024). This is consistent with the study by Ries, Beckmann and Wehnert (2023), which found that organizations focusing on PSP can enhance the development of sustainable products.

Similarly, SHRM also has a positive and significant impact on SPSS with the mediating effect of GSI in Saudi Arabian manufacturing companies. This indicates that investments in SHRM practices, such as environmental training and employee engagement in sustainability initiatives, foster a workforce capable of innovating in green services and products (Awwad Al-Shammari et al., 2022). In Saudi Arabia, where human development is a key focus of Vision 2030, SHRM practices not only boost employee morale and retention but also cultivate a culture of sustainability within organizations. Therefore, Saudi Arabian companies should prioritize the development of SHRM initiatives to align their operations with evolving market demands for sustainable solutions and position themselves as leaders in environmental stewardship. Other findings indicate a positive and significant indirect effect of TMC on SPSS with the mediating effect of GPI in Saudi Arabian manufacturing companies. These results underscore the critical role of TMC in fostering GPI within Saudi manufacturing firms. This finding is consistent with Al-Humaiqani and Al-Ghamdi (2023), who argue that leadership-driven initiatives prioritizing innovation in product development can lead to the creation of eco-friendly products that meet market demands and regulatory requirements, thus enhancing product sustainability. By focusing on TMC to promote GPI, Saudi companies can strengthen their market position and contribute positively to SPSS development. This approach not only supports corporate sustainability goals but also aligns with global trends towards sustainable consumption and production, positioning Saudi manufacturers as leaders in responsible business practices.

Similarly, PPP also show a positive and significant impact on SPSS with the mediating role of GPI. These findings underscore the importance of effective PPP in driving GPI within Saudi Arabia's manufacturing sector, thereby enhancing SPSS. These findings are consistent with studies such as Cheng et al. (2024), which suggest that companies integrating robust PPP are better positioned to innovate in sustainable product designs and technologies. Such innovations not only mitigate environmental impacts but also meet consumer preferences for eco-friendly products. Therefore, based on these findings, it is recommended that Saudi Arabian manufacturing companies adopt PPP to enhance their capabilities in green product development, thereby positively contributing to SPSS aligned with national sustainability goals and global environmental standards. Further findings indicate that GPI positively and significantly mediates the relationship between PSP and SPSS in Saudi Arabian manufacturing companies. This significant result underscores the role of PSP in fostering GPI among Saudi manufacturers, thereby enhancing SPSS. This argument is supported by Vezzoli and Macrì (2024), who highlight that responsible product lifecycle management and extended producer responsibility contribute to SPSS development when coupled with a culture of innovation. Similarly, Al-Swidi et al. (2024) recommend that investing in green product offerings not only reduces environmental impacts but also boosts market competitiveness and brand reputation for firms. These studies collectively demonstrate that PSP significantly enhances SPSS, especially when GPI serves as a mediating factor. Therefore, Saudi manufacturing companies can enhance their environmental impact positively by prioritizing eco-friendly design and innovative technologies. Emphasizing continuous improvement and transparency in these practices can strengthen their position both nationally and internationally.

Furthermore, SHRM practices also significantly influence SPSS with the mediating effect of GPI in Saudi Arabian manufacturing companies. These findings underscore the significant role of SHRM practices in driving green product innovation within the manufacturing sector of Saudi Arabia, thereby enhancing SPSS. These results align with Rana and Arya (2024), who observed that companies investing in SHRM initiatives, such as training programs and employee engagement in sustainability, cultivate a culture of innovation in product development leading to sustainable product designs. Therefore, by prioritizing SHRM in their operations, Saudi manufacturing companies can strengthen their capabilities in developing eco-friendly products that meet evolving consumer demands and regulatory standards. This strategic focus not only supports corporate sustainability goals but also contributes positively to the development of SPSS.

4.1. Theoretical Implications

The study has made significant theoretical contributions by expanding the research focus on green innovation and green product development within Saudi Arabia's manufacturing sector. While existing literature predominantly focuses on developed nations, this research fills a gap by emphasizing the roles of top management commitment, pollution prevention practices, product stewardship practices, and sustainable human resource management in driving SPSS through green innovations. By enriching the theoretical understanding of sustainable practices in a unique regional context, the study underscores the importance of integrating a robust framework of green operational practices, spanning from top-level commitment to operational strategies, to foster innovation. This integrated approach aligns with theories of sustainable development and innovation management, emphasizing the interplay between organizational leadership, environmental stewardship, and technological advancements. Furthermore, the research model offers insights that could guide future studies on how green practices influence SPSS in other developing economies facing similar environmental challenges.

4.2. Practical Implications

The study provides practical strategic guidance for Saudi Arabia's manufacturing firms to enhance their sustainable practices. By emphasizing the significant roles of top management commitment, pollution prevention, product stewardship, and sustainable HRM in driving green innovations, companies can develop strategies aligned with Saudi Vision 2030 objectives. Implementation of these strategies not only ensures compliance with regulatory requirements but also positions the firms as leaders in sustainable manufacturing practices. Furthermore, adopting robust pollution prevention and product stewardship practices allows Saudi firms to enhance operational efficiency and reduce environmental footprints across product lifecycles. This supports sustainable business operations while mitigating risks associated with environmental regulations and resource scarcity. The study also underscores the importance of investing in sustainable HRM practices to foster a culture of sustainability and innovation within organizations. By doing so, top management can align their focus with global sustainable development goals, thereby enhancing Saudi Arabia's competitive advantage in the international market.

2.3. Limitations and Future Directions

The study's significant findings also have several limitations that could be addressed in future research. Firstly, the study was confined to a cross-sectional research design, limiting its scope compared to longitudinal research approaches. Future studies could adopt longitudinal methods to expand the research scope and explore variations in findings over time. Secondly, the study focused exclusively on the manufacturing sector in Saudi Arabia, which may restrict the generalizability of its results to other sectors, particularly service industries. Future research could explore the service sector to broaden the study's applicability. Lastly, while the study examined mediating roles, it did not explore moderating effects. Future research could investigate moderating effects to enhance the generalizability and depth of the findings.

5. Conclusion

The research aimed to assess how green operations impact environmental sustainable product systems with the mediating effect of green innovations in Saudi Arabia's manufacturing sector. Data were collected from employees of manufacturing firms in Saudi Arabia. The findings underscored that adopting green practices—such as top management commitment, pollution prevention, product stewardship, and sustainable HRM—positively and significantly enhances sustainable product-service systems. These practices foster a culture of innovation in green products and services, improving operational efficiency and corporate sustainability. By leveraging green innovations, Saudi firms can gain competitive advantage, comply with regulations, and contribute to sustainable economic growth under Saudi Vision 2030. Addressing the study's limitations and exploring future directions could open new research avenues.

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Appendix: Survey Instrument

Item Questions	1	2	3	4	5
Green Product Innovation					
1. Making changes to product designs in order to avoid polluting or toxic compounds within production processes.					
2. Improving and designing environmentally-friendly packaging for existing and new products.					
3. Making product design modifications aimed to improve energy efficiency during usage.					
Green Service Innovation					
1. The firm repackages existing products/services based on its concern for the environment.					
2. The firm frequently extends products/services based on its concern for the environment.					
3. The firm creates and establishes new lines of products/services based on its concern for the environment.					
4. The firm offers new customer service practices based on its concern for the environment.					
5. The firm offers new practices in selling products/services based on its concern for the environment.					
6. The firm offers new practices in after-sales services based on its commitment to the environment.					
7. The firm offers new practices in new product/service development based on its environmental concerns.					
8. The firm proposes new practices in the promotion of new products/services related to environmental reputation.					
9. The firm proposes new practices related to internal administration and operations based on its environmental concerns.					
Production Prevention Practices					
1. In my organization, there is wide spread understanding on pollution prevention policy for green practices.					
2. My organization has implemented best housekeeping practices to reduce in-house Pollution in green practices.					
3. In my organization, production processes are redesigned to match pollution prevention Goals in green practices.					
4. In my organization, production technologies are modified to match pollution prevention goals in green practices.					
Product Stewardship Practices					
1. Our firm has policies for green practice that encourage us to use the energy efficient products.					
2. To install software to make material sourcing and acquisition more environmentally friendly.					
3. To make product distribution and delivery more environmentally friendly.					
Sustainable Human Resource Management					
1. HRM follows a sustainable development orientation.					
2. HRM follows the principle of favourable innovation.					
3. HRM adheres to the people-oriented principle.					
4. HRM adheres to the principles of fairness, neutrality, and openness					
5. HRM follows efficiency orientation.					
6. HRM policy includes a clear statement about sustainable development.					
7. The company promotes employees' innovative capacity through training.					
Environmental Sustainable Product Service System					
1. Use energy-saving technologies production					
2. Establish strict management system					
3. Price change					
4. Safety certified					
Top Management Commitment					
1. To implement green practices, our top management is committed to setting policies and strategies based on green practices.					
2. Communicate green practice-related initiatives to all employees.					
3. Assess green practice policies periodically and consequently.					
4. Emphasizing ongoing review and improvement of green practices Partnership.					
5. Our top management engages suppliers in decision-making about green practices.					
6. Our suppliers are the organization's green partners and have ISO certification.					
7. Collaborate with suppliers and integrate into green practices Resource Allocation.					
8. To implement green practices, our top management allocates sufficient resources.					
9. Allocate sufficient resources to learn and innovate.					
10. Allocate sufficient fencing for green practices.					