

The Impact Of Green Technology Adoption And Green HRM On Operational Efficiency: Evidence From Pakistan's Textile Manufacturing Sector

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Abstract

The Pakistani textile industry is facing challenges in achieving operational efficiency (OE hereafter). This is due to increased resource wastage and environmental concerns. This study examined the adoption of green technology (GTA hereafter) and its impact on a firm's OE. This study also accounted for the role of green human resource management practices (GHRM hereafter) and gender diversity (GD hereafter). Using a quantitative method, 380 structured survey questionnaires were distributed among managers of textile companies in Lahore, Pakistan. We employed a structural equation modeling approach to investigate the relationship between variables. The results of this study suggest that adopting green technologies can enhance the OE of the Pakistani textile industry. Moreover, Green HRM practices successfully mediate this relationship positively. Furthermore, recent literature indicates that GD does not influence the OE of the firm, nor does it moderate the relationship between the GTA and OE. The study suggests that textile firms should prioritize and adopt green technologies, as well as implement GHRM practices, to enhance their OE. These practices not only improve performance but also help companies contribute to environmental betterment.

Keywords: Operational efficiency, green technology adoption, green human resource practices, gender, diversity, textile industry, environment

1. INTRODUCTION

1.1 Background of study

Companies continually invest time and effort in improving OE, as it has become a critical factor in their success (Cai, 2023). There is consistent pressure to maintain profits and remain relevant to the industry. The manufacturing sector must continually transform its operations to stay competitive, productive, and efficient while also addressing environmental concerns (Kamar & Harms, 2004; Wijethilake et al., 2023). For this purpose, many organizations aim to re-examine their processes in light of recent environmental concerns. Organizations are striving to adopt techniques that optimize the use of their resources. The manufacturing sector aims to cut waste and make the business more sustainable. As Allen and Rai (1996) and Uddin and Akhtar (2025) have found in their studies, OE is the combination of both the inputs and outcomes of collaborative activities. Since the Industrial Revolution of 1760, Efficiency Is defined as how correctly activities are planned and performed effectively (Klečina et al., 2024). The primary goal of the industry transformation was to shift organizational operations toward greater mechanization and the adoption of new technologies (Juhász et al., 2024). The goal was to minimize resource waste by organizing all key activities, aiming to make industries more efficient and productive (Clark, 2014; Zafari et al., 2025). Following this significant shift in narrative, OE emerged as the cornerstone of the organizational framework (Marelli & Dello Sbarba, 2025). This transformation paved the way for a new stream of knowledge, and significant efforts have been devoted to it ever since. One of the major theories that also showcased the importance of efficiency was the Taylor time-motion study in 1856 (Jakhongir, 2025). This theory posits that time is a valuable resource and should be utilized effectively. The firm is deemed efficient when evaluated by the number of resources it has utilized to complete a specific operation (Badiru, 2010; Hingorani & Swami, 2025). Organizations often encounter uncertainties, financial constraints, and fierce competition, making it difficult to operate in an ideal and efficient manner. According to E. Soares (2024), in a competitive business environment, companies must execute all activities efficiently.

Businesses are eager to adopt principles that will help them conserve valuable resources, such as time, money, and materials, while maintaining high-quality productivity (Fallahi et al., 2023). The integration of technology allows companies to achieve automation, thereby gaining a competitive edge in a hypercompetitive environment. Recent literature has increasingly emphasized OE (Ghobakhloo et al., 2023). Industries are collectively driving this concept, particularly the Pakistani textile industry (Naeem & Siddique, 2024). The textile industry in Pakistan plays a vital role in the country's economy by contributing to manufacturing output, employment generation, and export earnings (Akhund & Abbas, 2023). The recent literature suggests that the textile industry contributes 8.5% to the country's GDP, accounts for 54% of total exports, and employs 38% of the workforce (Nabi & Hamid, 2016). Despite the significant contribution of the textile industry, recent literature claims that the Pakistani textile industry is struggling for OE (Jianguo & Solangi, 2023; Aslam et al., 2024). The purpose of this study is to address the challenges and needs of the textile industry in achieving organizational efficiency. There are many dimensions to look at in OE. An organization's competitive position is closely tied to the adoption of environmentally friendly practices and procedures that enhance OE (Zhang et al., 2023). This study focuses on the textile industry because it is regarded as one of the world's most polluting sectors. The process of manufacturing any apparel starts with making fabric; however, pressing and finishing this cycle are not executed effectively. There are three major types of waste: gaseous emissions, liquid waste, and solid waste. Noman et al. (2013) state that approximately 7% of Pakistan's total textile sector workforce is employed in Faisalabad-based textile industries. The textile units in Faisalabad, operating under traditional mechanisms, mishandle or mismanage waste, including the emission of gases and solid waste (Awan et al., 2024, April). Effectively and efficiently managing waste significantly enhances an organization's OE, enabling it to achieve sustainable performance (Azad et al., 2018). Earlier literature from Pakistan indicates that textile organizations often waste valuable resources due to inefficiencies, such as failing to adopt environmentally friendly practices in their daily operations, which undermines their sense of responsibility. Furthermore, recent literature suggests that the Pakistani textile industry lacks sufficient technology and equipment to address environmental challenges and manage waste effectively. By addressing these challenges and issues, the current study aims to contribute to the existing literature by utilizing the foundational resource-based view (RBV hereafter) theory and outlining the practical implications for the dominant textile sector in Pakistan's economy. These implications will enable mechanized processes, leading to mass and lean production while minimizing waste. Focusing on these inefficiencies is crucial for maintaining competitiveness and reducing costs.

1.3 Significance of the study

This study makes a significant contribution to empirical knowledge, both as a theoretical framework and as practical guidance for management. This study aims to contribute to facilitating organizations in gaining a competitive advantage in the hyper-competitive market. The terms "GTA" and "GHRM" are part of the broader United Nations Sustainable Development Goals (SDGs hereafter). The findings of this study aim to contribute to policymakers and regulatory authorities. These two factors collectively enable an organization to work more efficiently by minimizing waste in processes and maximizing the utilization of resources. This research contributes to literature by providing a strong foundation for further studies to gain a more detailed understanding of how green initiatives and diversity can impact OE within an organization. The findings of this research are intended to facilitate the business manager currently working in the textile sector. The results of this study help companies determine whether to implement these initiatives. This study empowers companies to make informed decisions about investing in machines, adopting green initiatives, and utilizing resources efficiently. Embracing GHRM impacts organizational policies and procedures. The findings of the present study facilitate companies in introducing environmentally friendly policies and may also encourage the implementation of similar training programs and sustainable work initiatives. Furthermore, it enables managers to effectively engage with employees, helping them reach their full potential. The positive effect of GD brings a more varied talent pool to operational roles, resulting in enhanced decision-making. By effectively applying these practices, organizations or managers can achieve efficiency while contributing to an environmentally responsible experience that aligns with stakeholder expectations.

2. Literature Review

2.1 GTA and OE

Adopting and integrating green technology is a challenging task, as it slightly affects the technology in practice but yields a long-term return for the firm (Zhang et al., 2019). Adopting technologies that promote green practices is evident in many diverse sectors. Integrating green practices into daily operations yields greater and long-term benefits, including cost savings and resource conservation. Sarkis (2018) emphasized the importance of sustainability in operations, proposing strategies such as waste reduction, energy conservation, and the adoption of cleaner and safer environmental technologies. Wasiq et al. (2023) claim that by using the GTA, companies gain access to tools and methods that result in improved operational efficiencies and open new opportunities to continue working on and improving existing practices. Additionally, previous studies have demonstrated that GTA has enhanced the operational performance of the firm, and it is universally commended and acknowledged (Qiu et al., 2020). According to Hottenrott et al. (2016), firms can mitigate productivity shortcomings and losses through GTA, which in turn positively impacts their OE. Green sustainable practices have a positive and significant impact on operational performance (Elrayah & Keong, 2023). Therefore, this study aims to test the hypothesis.

H1: *GTA positively impacts the OE of the firm.*

2.2 Mediating role of GHRM practices between GTA and OE

GHRM is defined as "the set of discrete behaviors, occupations, and procedures intended for capturing, increasing, and keeping the organization's HR resource" (Lado & Wilson, 1994). Previously, we discussed how GTA positively impacts the operational performance of businesses. Firms that adopt GHRM are likely to improve OE and save costs associated with paying environmental fines (Afum et al., 2020). Additionally, previous studies have shown that another factor related to OE is GHRM. It aligns HRM practices, such as hiring and training, with the organization's objectives and goals. The GHRM informs individuals whether natural resources are renewable or not. Additionally, GHRM raises awareness about the importance and abundance of natural resources, which supports the notion that green HRM practices have a positive impact on a firm's sustainability performance (Sriram & Suba, 2017; Zaid et al., 2018). According to El-Khalil and Mezher (2020), sustainability has a positive and significant impact on operational performance, suggesting that GHRM has a pragmatic relationship with OE as other studies have reached similar conclusions. The HR department plays a crucial role in green management by hiring suitable employees, training them, and rewarding them based on their performance, as well as enhancing their understanding of green practices within the organization (Paillé et al., 2013). Therefore, this study proposes the following hypothesis.

H2: *GHRM positively mediates the relationship between GTA and a firm's OE.*

2.3 GD and OE

GD has become a key area of focus in organizational research, primarily due to its role in enhancing organizational efficiency (Zhang, 2020). The relationship between GD and OE is complex and determined by multiple factors, as earlier literature has documented on GD and performance, despite the results being inconsistent (Stajkovic & Luthans, 1998; Ullah et al., 2020; Khatib et al., 2021; Ferrary & Déo, 2023; Laskar et al., 2024), as some researchers support this relationship, and some oppose it. Studies from both developing and developed economies have contrasting opinions about the impact of GD on operational performance (Moreno-Gómez et al., 2018). The argument of Ajmi et al. (2014) is that the growth and performance of an enterprise depend on its diverse workforce, and enthusiastic firms take steps in this direction. GD may lead to potential conflicts and a slower decision-making process, which is not conducive to an environment where speedy decisions are crucial (Gallego-Álvarez et al., 2010). In the context of OE, gender-diverse workplaces vary by region and country, depending on the particular industry; the more GD is accepted and normalized, the more positively it impacts performance (Zhang, 2020). GD, as accepted by norms, is more important than the institutional rules in which it is being implemented (Laique et al., 2023). Studies have not found a strong relationship between GD and

performance in export-oriented firms (Solakoglu & Demir, 2016). Most of Pakistan's textile industry is export-based, and its share of exports has been growing recently (Amin et al., 2024). Moreover, based on the above discussion, the present study proposes the following hypothesis.

H3: GD has no significant effect on OE in textile manufacturing.

2.4 Moderating effect of GD between GTA and OE

The earlier literature affirms that integrating green practices into daily operations yields greater and long-term benefits, including cost savings and resource conservation. Earlier literature demonstrated that GTA has enhanced the operational performance of the firm, and it is universally commended and acknowledged (Qiu et al., 2020). Green sustainable practices have a positive and significant impact on operational performance (Elrayah & Keong, 2023). Furthermore, the literature confirms that the presence of a diverse workforce at the management level significantly enhances the adoption of green technologies, thereby improving operational efficiency (Martinez-Jimenez et al., 2020).

The moderating role of GD in the relationship between GTA and OE has not been researched by previous researchers, providing an opportunity for this relationship to be studied. GD enhances creativity and problem-solving within an organization, as more diverse teams can generate more refined ideas (Welbourne et al., 2007). GTA enables companies to utilize hands-on tools and methods that improve operational efficiencies and open new opportunities for continuing to work on and refine existing practices (Wasiq et al., 2023). It suggests that GD may strengthen the positive effects of GTA on OE.

H4: GD moderates the relationship between GTA and OE, such that the positive impact of GTA on OE is more substantial in organizations with higher GD.

2.5 Underpinning Theory

The concepts and variables discussed in this study have been addressed in prior research. The primary theory under examination is the RBV theory, initially formulated by Wernerfelt (1984) and later refined by Barney (1991). This theory suggests that an organization's resources are valuable and contribute to achieving a competitive advantage; thus, the RBV theory supports the role of GTA and GHRM in attaining OE. It posits that an organization's resources are the primary source of its revenue (Barney, 1991). RBV suggests that leveraging unique resources within an organization can yield competitive advantages, increase efficiency, and enhance profitability.

The triple bottom line (TBL hereafter) theory also supports this framework. It laid the groundwork for the modern business world and aligns with the concept of corporate social responsibility. It enabled businesses to maximize profits while being mindful of the environment and its impact on people, as TBL formulated the 3Ps: "people, planet, and profit" (Elkington & Dickinson, 2025). By maximizing these 3Ps, organizations can achieve positive environmental and financial impacts to achieve the OE. Developing this comprehensive framework at this time is challenging for businesses, but it is critical and needs to be addressed.

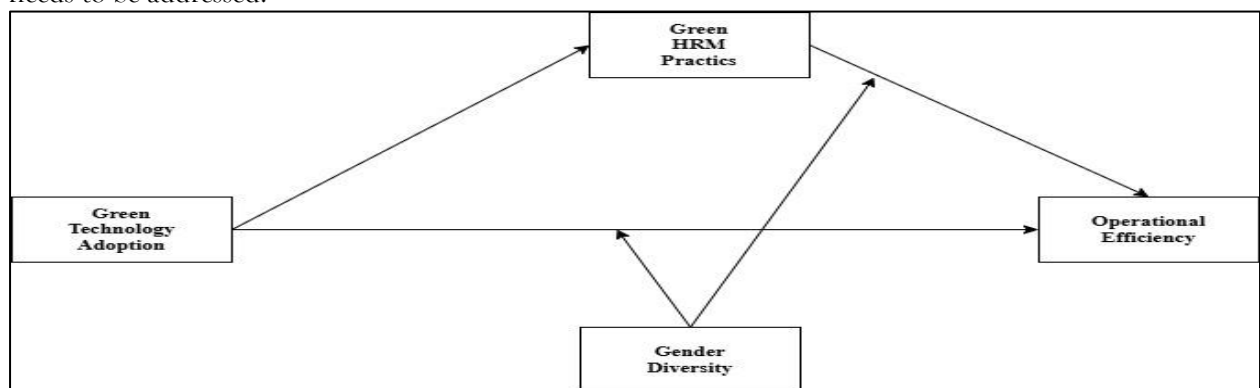


Figure 2.1: Theoretical Framework

3. METHODOLOGY

The present study collects quantitative data using primary sources by adapting a previously tested questionnaire that has been proven to measure the variables involved in the study. The present study measured each variable separately using a 5-point Likert scale (from "Strongly Disagree" to "Strongly Agree"). This approach allowed us to analyze each factor independently before examining its relationships (Joshi et al., 2015). GTA facilitates organizations in acquiring or adopting technology to deal with environmental concerns in hyper-competitive global markets. The present study used the 7-item questionnaire to measure GTA, adapted from earlier literature (Wasiq et al., 2023). GHRM facilitates companies to incorporate relevant environmental duties and obligations into the job descriptions of new employees during the hiring process. The present study adapted the 7-item survey questionnaire to measure GHRM from existing literature (Masri & Jaaron, 2017). Earlier literature has affirmed that diversity of gender at the top management level in organizations offers opportunities to facilitate environmentally friendly decision-making through creativity. Earlier literature has failed to evaluate the role of GD in Pakistan's textile industry. The present study adapted the 5-item survey questionnaire from existing literature to measure the GD (Charlotte, 2012). Operational performance remains a challenge for the textile industry in Pakistan. The present study intends to measure OE using a 7-item survey questionnaire adapted from existing literature (McDermott & Stock, 1999). The present study employed the partial least squares structural equation modeling (PLS-SEM hereafter) approach. The present study proposes a reflective and formative approach, and PLS-SEM is helpful for these kinds of frameworks (Jarvis et al., 2003). The present study employed SmartPLS software, as it is known to be suitable for handling smaller datasets and non-normal data distributions (Fauzi, 2022). The present study employ convenience and non-probability sampling techniques, we gathered responses from the managerial staff of textile companies operating in Faisalabad and Lahore, Pakistan. The total sample was 398 managers with response rate of 58% from the major textile industries currently operating in Faisalabad and Lahore two major cities of Pakistan.

3.1 Measurement Model

3.1.1 Reliability and Validity

As table 1 reports construct reliability and validity of key latent constructs. According to Cherryholmes (1988), construct validity is necessary to determine how well a concept is measured in a study. The threshold values for Cronbach's Alpha, CR, and AVE are 0.70, 0.70, and 0.50. The findings are well above the threshold values, and no validity or reliability problem has been encountered (Mehralian et al., 2020).

Table 1: Construct validity and reliability

	Loadings	Cronbach's Alpha	CR	AVE
GD_1	0.885	0.893	0.902	0.650
GD_2	0.676			
GD_3	0.779			
GD_4	0.800			
GD_5	0.873			
GHRM_1	0.685	0.853	0.889	0.533
GHRM_2	0.723			
GHRM_3	0.682			
GHRM_4	0.751			
GHRM_5	0.796			
GHRM_6	0.735			
GHRM_7	0.733			
GTA_1	0.726	0.882	0.907	0.584
GTA_2	0.730			
GTA_3	0.674			
GTA_4	0.806			

GTA_5	0.808			
GTA_6	0.798			
GTA_7	0.797			
OE_1	0.817	0.92	0.936	0.675
OE_2	0.854			
OE_3	0.825			
OE_4	0.801			
OE_5	0.798			
OE_6	0.823			

3.1.2 Discriminant validity

The other important component of the measurement model is discriminant validity. To evaluate the discriminant validity and reliability, we first employ the Heterotrait-Monotrait (HTMT) technique (Al-Marouf & Al-Emran, 2018). According to Gold et al. (2001), the strict cutoff is 0.85, while Kline (2011) suggests a more lenient threshold of 0.90. Table 2 reports the results of discriminant validity.

Table 2: Discriminant validity

		1	2	3	4
1	Gender Diversity				
2	Green HRM	0.205			
3	Green Technology Adoption	0.099	0.515		
4	Operational Efficiency	0.084	0.468	0.458	

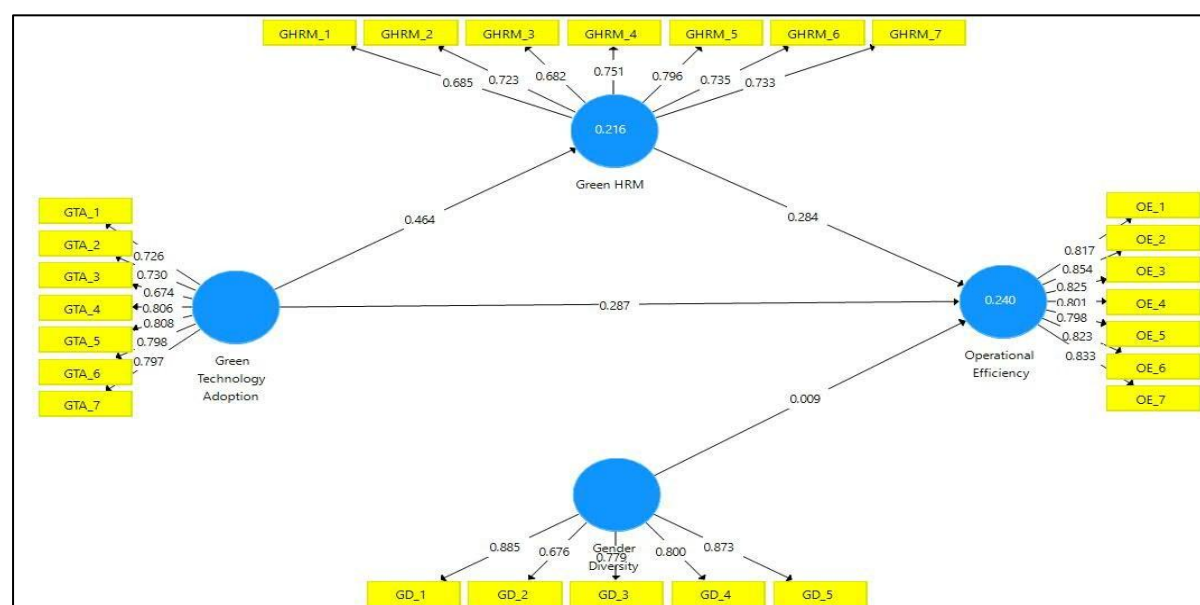


Figure 3.2: Assessment Measurement Model

4. RESULTS AND DISCUSSION

This study offers insight into green initiatives and their impact on a company's overall operational efficiency (OE). To achieve this objective, the present study investigated the relationship between the GTA and OE within the firm. In addition, the present study proposes that GHRM mediates the relationship between the GTA and OE. Furthermore, the present study proposed that GD plays a moderating role between the GTA, GHRM, and OE. The empirical findings of the present study were reported in Table 3. The empirical findings indicate that GTA has a significant and positive influence on OE ($\beta = 0.287$, $t = 5.541$, $p < 0.05$). The results of the current study indicate that the GTA implemented by an organization will positively impact on overall effectiveness of the firm, implying that it leads to

increased profitability and the effective use of resources, particularly in the adoption of green technology. The findings of the present study align well with prior literature. GTA significantly addresses the challenges related to environmental sustainability and enhances the operational efficiency of the manufacturing industry (Tian et al., 2023). Additionally, literature also affirms that GTA significantly enhances organizational dynamic capabilities by balancing environmental concerns and improving overall efficiency (Wang et al., 2024). Furthermore, the empirical findings indicate that GHRM has a significant and positive association with OE at the 5% level of significance ($\beta = 0.284$, $t = 5.004$, $p < 0.05$). In the case of a direct relationship, the empirical findings indicate that GTA and GHRM significantly and positively influence OE. Moreover, in the case of an indirect relationship, the results suggest that GTA significantly and positively predicts the GHRM ($\beta = 0.464$, $t = 9.252$, $p < 0.05$). The study demonstrates that integrating GHRM with the GTA can further enhance the overall operational efficiency (OE) of companies within the textile industry. Prior literature indicates that the GHRM has a significant influence on the operational efficiency of the manufacturing sector (Zaid & Jaaron, 2021, November). Furthermore, the empirical findings indicate that GHRM, along with GTA, significantly enhances the operational efficiency of Pakistan's textile sector. The present study proposes that green human resource management (GHRM) mediates the relationship between green technology adoption (GTA) and operational efficiency (OE). The empirical findings indicate that GHRM significantly and positively mediates the relationship between GTA and OE at the 5% level of significance ($\beta = 0.132$, $t = 3.921$, $p < 0.05$). The results of the present study show that GTA significantly improves the OE through GHRM between the GTA and OE. Recent literature affirms that the GHRM significantly and positively mediates the relationship between technology adoption and operational efficiency (Azhar et al., 2025; Hossain et al., 2025). Furthermore, the direct effect of gender diversity (GD) indicates a positive yet insignificant association with operational efficiency (OE) at the 5% level of significance ($\beta = 0.009$, $t = 0.201$, $p > 0.05$). The GD in this study suggests that GD in the textile sector does not significantly impact a company's operational efficiency. In addition, the present study proposes that GD moderates the relationship between the GTA, GHRM, and OE. The empirical findings indicate that GD has a positive yet insignificant moderating effect on the relationship between GTA and OE at the 5% level of significance ($\beta = 0.109$, $t = 1.313$, $p > 0.05$). Moreover, GD has a partially significant and positive moderating effect on the relationship between GHRM and OE at the 5% level of significance ($\beta = 0.182$, $t = 1.808$, $p > 0.05$). However, the empirical findings are significant at the 10% level of significance. The study emphasized that GD in the textile industry neither slows down nor speeds up OE when adopting green technology. This study suggests that involvement in greener and more sustainable initiatives has a positive impact on the company's operational performance. This study serves as a valuable resource for companies in Pakistan's textile sector. They can leverage their operational performance and efficiency under the findings of this study. This study further fosters a culture of adopting safer and greener technologies, leading to increased profits and reduced environmental impact.

Table 3: Empirical Results

	Coeff.	S. D	T-values	P-values
Green Technology Adoption -> Operational Efficiency	0.287	0.052	5.541	0.000
Green Technology Adoption -> Green HRM	0.464	0.050	9.252	0.000
Green HRM -> Operational Efficiency	0.284	0.057	5.004	0.000
Green Technology Adoption -> Green HRM -> Operational Efficiency	0.132	0.034	3.921	0.000
Gender Diversity -> Operational Efficiency	0.009	0.093	0.201	0.844
Gender Diversity * Green Technology Adoption -> Operational Efficiency	0.109	0.083	1.313	0.213
Gender Diversity * Green HRM -> Operational Efficiency	0.182	0.101	1.808	0.095

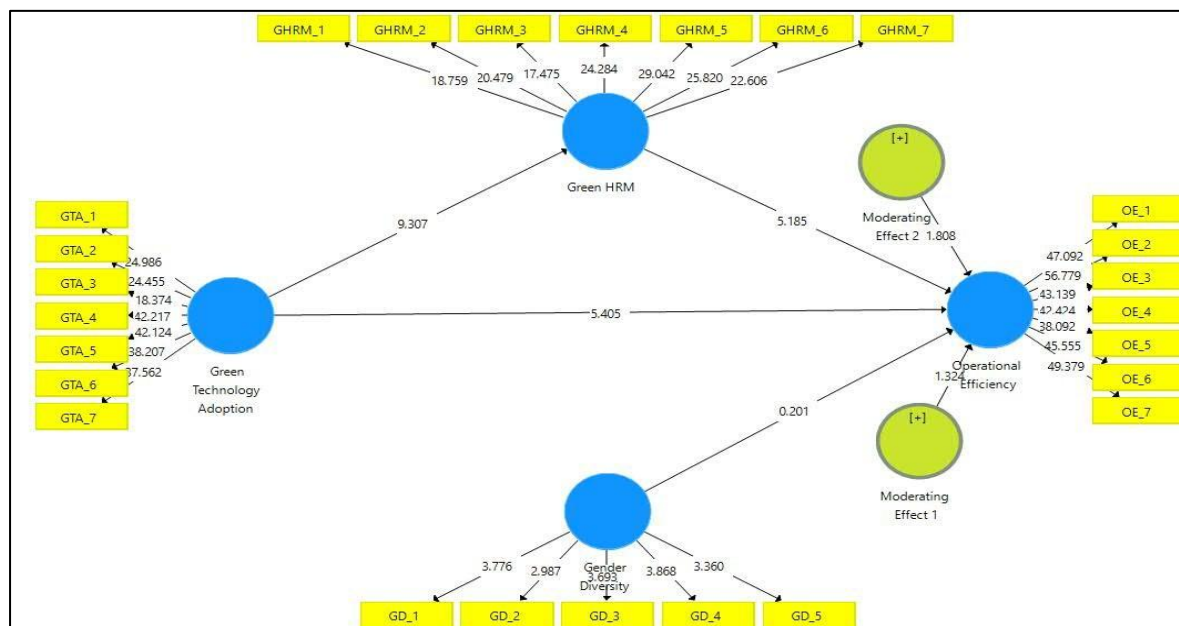


Figure 3.3: Assessment of Structural Model

5. CONCLUSION, IMPLICATIONS, AND LIMITATION

The objective of this study was to determine whether adopting and implementing green technology would improve and enhance the OE of the textile sector in Pakistan. This study finds that adopting green technologies in the process will undoubtedly improve operational efficiencies. This is due to the reduction of waste and the effective utilization of all available resources. Green technologies significantly reduce energy consumption, shifting priorities towards more sustainable and recyclable sources of energy. Another reason for this outcome is the automation that comes with technology adoption, which results in reduced errors and mistakes and brings increased speed to production. These are the possible constructs underlying the outcome of this research, which suggests that green technology has a positive impact on the OE of companies in the textile industry. Furthermore, it is evident that in organizations, GHRM has proven to be the mediator between green technology adoption and the overall OE of the firm. If companies in the textile industry implement GHRM within their organizations and provide employees with environmental training, it will increase the OE of the company. The study also highlighted that GD does not significantly impact OE in the textile industry. It may be because in the textile manufacturing sector, GD does not bring value to overall operations, nor is it considered vital from the production and operational perspective of the company. Henceforth, it does not impact or moderate the relationship between the GTA and OE. On the other hand, it does not slow or hinder the process either. This study concluded that green and environmentally friendly technologies are beneficial for the company and overall efficiency. Optimization of production is necessary for Pakistan's textile industry.

5.1 Implications

This study presents key findings that are both theoretically and practically beneficial. The results of this research contribute to underpinning theories. It supports the RBV theory that unique and essential resources, such as green technology and GHRM, when utilized effectively, will be the source of competitive advantage. The outcomes can be implemented as a policy framework for organizations, enabling them to adopt and implement green practices that enhance OE and sustainability. These practices can be promoted in organizations by providing incentives and making subsequent regulations. This study also provides a strong foundation for further research in this field.

5.2 limitations

Few are lacking in this study that can open the path for further potential studies. This study focused on the Pakistani textile industry. Further studies can utilize this concept to examine the textile industries of

other countries and validate the findings of this study. Additionally, future studies can focus on other industries to validate the empirical findings of present study. This study concluded that GD does not influence the OE of the firm. Other benefits and perspectives were not discussed in this research. Future researchers may discover additional benefits that result from a gender-diverse workforce. Future studies can also focus on different variables that influence OE. Furthermore, this study was conducted in a cross-sectional time frame. Longitudinal studies can also be conducted to examine the long-term effects of adopting green technology and implementing GHRM on organizational performance and efficiency.

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