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[The Moderating Role of Big Data Analytics in The Relationship Between Green Human Resource Management Practices, Green Knowledge Management and Green Operational Performance]

Maryam Tanveer
MS Scholar, University Institute of Management Sciences, PMAS Arid Agriculture University Rawalpindi, Pakistan. tanveermaryam273@gmail.com
Dr. Zia ur Rehman
Assistant Professor, University Institute of Management Sciences, PMAS Arid Agriculture University Rawalpindi, Pakistan. zia.rehman@uaar.edu.pk
Humaira Arzoo
PhD Scholar, University Institute of Management Sciences, PMAS Arid Agriculture University Rawalpindi, Pakistan humairaarzoo022@gmail.com
Tooba Ehtisham
MS Scholar, University Institute of Management Sciences, PMAS Arid Agriculture University Rawalpindi, Pakistan. toobapeerzada789@gmail.com
Muhammad Rafiq
MS Scholar, University Institute of Management Sciences, PMAS Arid Agriculture University Rawalpindi, Pakistan. rafiqniazi637@gmail.com

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ABSTRACT

This research examine into how green human resource management practices and green knowledge management can improve green operational performance in Pakistani manufacturing companies. It also examines whether big data analytics changes or strengthens the impact of these green practices. For this purpose, data was collected through online surveys from 370 professionals in various manufacturing sectors. The study investigation employed a positivist research methodology to examine the relationships. The study is cross-sectional. The study used Smart-PLS 4 software to test the proposed relationships. Results showed that both GHRM and GKM have a strong and positive effect on GOP. This supports the resource-based view theory, which says that valuable internal resources like employee skills and knowledge lead to better performance. However, the study found that BDA does not significantly change the relationship between green practices and performance, possibly due to limited digital readiness and lack of advanced analytics in Pakistan. These findings help organizations understand the value of green HR and knowledge strategies, while also pointing out the need to improve technology use for better environmental outcomes.

Keywords: Green Human Resource Management Practices (GHRM), Green Knowledge Management (GKM), Green Operational Performance (GOP), Big Data Analytics (BDA).

Introduction

In recent years, growing global concerns over climate change, environmental pollution, and resource scarcity have pushed organizations especially in developing countries like Pakistan to rethink their operational strategies (Ali et al., 2023). Industries have been major contributors to environmental degradation through excessive energy use, fossil fuel dependency, and inefficient waste management.

In response to these environmental challenges, organizations are increasingly adopting green and sustainable practices to mitigate their environmental impact and improve their operational efficiency. One such approach is Green Human Resource Management (GHRM), which integrates environmental objectives into human resource policies and practices. GHRM includes green recruitment, green training, performance management, and employee participation in environmental initiatives (Renwick et al., 2013; Jabbour & Santos, 2008). It plays a critical role in shaping employees' environmental behavior and aligning organizational goals with sustainability. It has significant implications for environmental concerns, which have driven organizations to accept ecological practices. Green Human Resource Management has emerged as one of the strategic approaches for incorporating sustainability into the workplace. Such practices are designed to raise employee environmental awareness, promote sustainable behavior, and improve organizational performance by reducing environmental effect (Renwick et al., 2013).

Similarly, Green Knowledge Management plays an important role in enabling firms to tap into environmental knowledge and skills in an appropriate manner in order to avoid the vice. Cultural innovation may be fostered within businesses by proper management and dissemination of green knowledge, resource waste can be avoided,

and overall green operational performance of organizations can be enhanced (Jabbour et al., 2008). In addition, Green Knowledge Management (GKM) has emerged as a strategic capability that involves the creation, dissemination, and application of environmental knowledge across organizational levels (Massaro et al., 2015). GKM helps firms in building knowledge-based competencies to enhance their green innovation and sustainability performance.

Green Operational Performance, provides insight into an organization's achievement in terms of environmental targets such as energy, waste, and sustainability (Yong et al., 2020). Nonetheless, while GHRM and GKM play an important role in improving GOP, the most recent study emphasizes that optimizing interactions between these variables necessitates the addition of other technical patterns, like BDA. Big Data Analytics offers creative methodologies and strategies for analyzing vast amounts of data and gaining a better vision for improving company decisions, hence increasing operational performance. As a result of BDA integration, environmental performance may be monitored in real time while resources are used efficiently and effectively to identify performance improvement possibilities, hence increasing the effectiveness of green practices (Ghobakhloo and Fathi, 2021). The purpose of this study is to look at another aspect of technology growth, Big Data Analytics, and how it affects and modifies the interaction between GHRM, GKM, and GOP in order to help organizations foster sustainability.

Environmental pollution is a burning issue world around. Pakistan is no exception in this regard. Green Operational Performance deals the said issue. This study investigates how GHRM practices and GKM contributes towards improving green operational performance. Moderating role of big data analytics is could not be studied in the extant literature. Furthermore, the study is new for manufacturing sectors of Pakistan.

Literature Review

Green Operational Performance

Green operations refer to the initiatives by organizations to incorporate environmental concerns to their operation management. This entails a package of skills and ideas that help companies to organize and regulate their practices in running a business hence guarantee that they take into consideration the effects of their operations on individuals and the natural world (Liu et al., 2017). In this study, the performance of three green areas of operation is checked on the basis of Liu et al. (2017).

Green design considers the environmental, health, and other concerns during the design works. To safety and in general the viability of goals. Handfield et al., (2002) outlines the process and product life cycles which are also outlined by Liu et al., (2017). The second one is the green purchasing whereby there is the selection of suppliers in case of Delivery of green items. Green, and collaborating with suppliers in order to enhance the ecologic performance (Blome et al., 2014; Liu et al., 2017). The Third, the green production process is concentrated on the reducing negative consequences of production on the environment (Liu et al., 2017; Orlando et al., 2022). It constitutes the overall performance of operations. Proposed that the other important objective is green operational performance (Hanna and Rocky Newman, 1995).

Big Data Analytics

The capacity to give business insights combining talent (i.e., individuals) and data management infrastructure (i.e., technology) to transform business into a competitive force is known as big data analytics. Modern big data analytics are thought to be more reliable, essential, and safe than previous analytical methods since they can manage large amounts of data (Sivarajah et al., 2017). Big data helps organizations by optimizing resource efficiency and consumption (Shuja et al., 2017). Moreover, big data can be defined as information that is too large to handle efficiently (Scott et al., 2016). Big data can also help executives make timely decisions by enhancing understanding (Duan & Xiong, 2015). Huge data analytics and approaches can be used to analyze the huge data of enterprises (Wuet al., 2016). These days, practically all businesses deal with problems arising from the massive volumes of data produced by both internal (like employees) and external (like suppliers, customers, etc.) stakeholders. Moreover, cloud computing, the Internet of Things (IoT), artificial intelligence, and social media platforms all produce big data (Bibri, 2018).

Green Knowledge Management

The issue of environmental debate has attracted much concern in the recent years. The author of this paper owe ecologists thanks to their constant efforts in making people aware of how natural resources will soon be depleted (Kumar & Barua, 2022) and how the environment will be damaged because of the frenzied use of resources committed by the global business community (Lehmann et al., 2022). Due to better environmental information, the stakeholders have become stricter to the business community to take care of non-human nature and incorporate environmental issues into their businesses and human communities (Abbas, 2022). The scope of green knowledge is broad, and most of the ideas center on our response to natural world and the way we consider to take a more sustainable path towards social, economic, and environmental development. It is not mere data concerning the environmental conditions. Green knowledge is not a resource that can be handled as the other ones because it is something immaterial. The failure by a business to systematically explore the cultural and technological aspects of GKM becomes a problem instead of an advantage (Zbuchea et al., 2019).

Green Human Resource Management Practices

1. Green Recruitment and Selection

The recruiting process is considered as the entry point in the organization. It gives an organization opportunity to attract a pool of applicants to ensure that the best ones are selected to join. Kiruthigaa and Viswanathan (2014) say that, green recruitment is a low impact on the environment, paperless recruitment process. Applications are solicited online through such methods as email, online application forms, and also through the Global Talent Pool. The interviews are conducted by phone or video when possible to reduce any environmental implication made by the travel process.

The activity of applying green or environmentally friendly methods, materials, and technology to attract (and select) skilled job candidates who have the desire and capacity to take up open jobs within a particular firm is referred to as green recruitment and selection. While a number of factors are usually taken into account when choosing job prospects, the willingness and aptitude of the Environmental conservation

candidates undergo testing. Green initiatives should be thoroughly integrated at this point since hiring decisions are largely based on recruiting and selection. This will guarantee that hiring decisions are made based on the willingness and ability of candidates to pursue green initiatives. Also, this will make it simpler for employers to teach newly hired staff members green behavior and culture.

2. Green Job Analysis And Design

Job descriptions are one of the results of job analysis and design. A job description serves as an official framework for describing a position. It may include details about the duties, responsibilities, capabilities, general objectives, competencies, and knowledge that the organization is looking for (Barbouletos, 2011). The process of gathering data for a specific job with the goal of creating a job description and job specification that will ultimately lead to the selection of workers who can carry out their tasks and responsibilities in an environmentally responsible manner is known as "green job analysis and design." Green job analysis and design aim to make sure that an organization determines the tasks, responsibilities, abilities, and competencies for a specific position in order to make a job holder accountable and environmentally friendly while carrying out his or her duties.

3. Green Training And Development

Green training and development require an environmental friendly approach besides equipping the management and staff with information and skills on issues that relate to environmental sustainability. Training and development are aimed at giving staff with knowledge and skills on how to avoid or minimize contamination of the environment and how to conserve the environment in the workplace. It also involves the use of environmental friendly measures and technology in training and development programs. There are two significant objectives of training on environmental issues. In the first place, the environmental regulations of the company must be explained in an appropriate manner to the employees. Second, training should be used to alter activities of the employees to create a steadier and deliberate connection between the employee and the surrounding (Sammalisto & Brorson, 2008 in Jabbar & Abid, 2014). Green training and development initiatives raise staff members' awareness of the importance of environmental management.

4. Green Performance Management

Green job analysis and design can help to make green performance management easy because the employees are provided with green job description. And on his certain job, performance of each employee can be gauged through green duties and responsibilities. Deshwal (2015) recommends the inclusion of the green targets in the key performance areas in performance management systems. This can be translated into green indication of behavior and green level of performance, which should be employed as a measuring rod to assess the performance of workers on any level.

5. Green Reward Management

As we all know, a well-structured compensation plan has been able to motivate employees to perform within the levels of acceptable performance which encompasses environmental performance. The sphere of environmental sustainability management in an organization may be measured fairly well via its reward system (Bratton & Bratton,

2015). Green reward management is also significant towards the motivation of managers and non-managerial personnel to volunteer towards corporate environmental management programs. In return, employees, who are good in the environmental department, can get rewarded by their employers financially in form of endowments, bonuses, or cash rewards. Other companies can give non-financial rewards to employees who are considered good in the environment to use awards, special recognition, honors, and prizes (Arulrajah, Opatha & Nawaratne, 2015).

Theoretical Framework

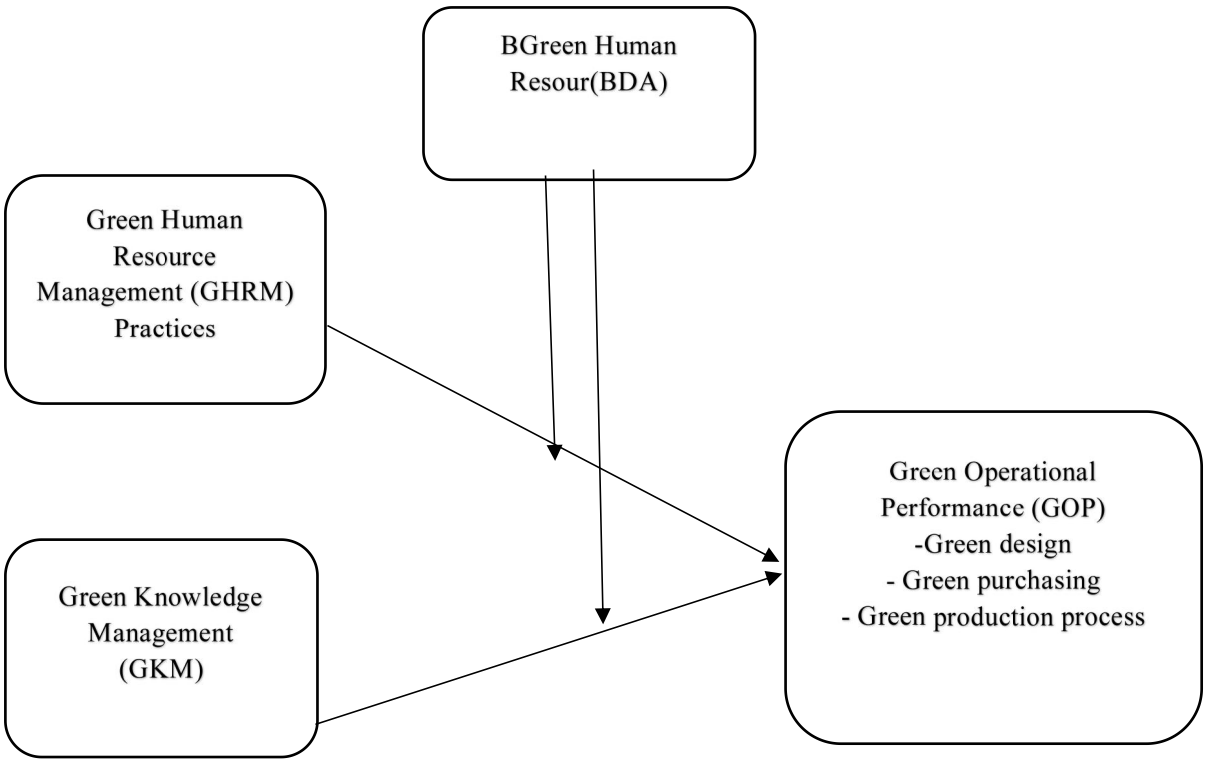

Figure 1 Theoretical Framework

Development Of Hypothesis

Green Human Resource Management practices function significantly to advance environmental sustainability strategies through green design initiatives. GHRM includes ecological human resources programs like green recruitment alongside training and performance management that help develop environmental expertise among staff members. Organization-wide sustainable behavior initiatives support employees in developing environmentally friendly products and processes as well as sustainable practices (Jabbour & Santos, 2008). Training programs classified as green teach personnel essential information about designing products sustainably while maximizing factory resource usage. GHRM influences organizational performance by incorporating environmental targets into employee positions and performance measurement systems and ultimately leads to better adoption of green design practices according to Renwick et al. (2013). Research by Tang et al. (2018) and Yong et al. (2020) found empirical evidence which backs up the direct connection between GHRM and green innovation

capabilities that include sustainable design approaches. GHRM practices enable organizations to strategically embed green design throughout their operational processes. Based on the above discussion, the following hypothesis has been formulated.

H1: Green Human Resource Management practices has a positive impact on Green design.

Employing green human resource management practices positively impacts green purchasing through their activation of staff understanding and responsibility toward sustainable purchasing practices. Organizations develop a sustainable buying behavior culture through green training alongside performance evaluations and reward structures which guide supply chain programs. The integration of environmental criteria into purchasing decisions occurs through GHRM because it builds sustainable competency and motivational levels in employees according to Bag et al. (2020). According to Renwick et al. (2013) GHRM creates indirect enhancements to green purchasing when it establishes employee performance alignment with organizational sustainability outcomes. Procurement departments and relevant staff increase their choice of suppliers with green credentials alongside their preference for eco-friendly materials through these practices. Firms with robust GHRM practices demonstrate higher green supply chain engagement specifically in green purchasing activities according to Ahmad (2015). GHRM establishes itself as a strategic tool that embeds environmental factors throughout procurement operations. Based on the above discussion, the following hypothesis has been formulated.

H2: Green Human Resource Management practices has a positive impact on Green purchasing.

The integration of environmental sustainability throughout organizational culture skills and operational routines forms a positive impact on green production processes through green human resource management practices. GHRM guides employees to develop eco-conscious behaviors through its implementation of green recruitment and employee training and its evaluation and reward techniques. Company practices provide staff members both understanding and drive to use sustainable technologies with energy-efficient production procedures. GHRM supports companies to achieve their commitment to environmental enhancement by developing staff members who consistently work towards process optimization according to Jabbour et al. (2008). The research by Daily et al. (2012) established that training about environmental issues produces better results when performance metrics are simultaneously targeted in production settings. Through GHRM green values are integrated into the production cycle starting from sourcing to ending with final output while lowering waste generation and maximizing resource efficiency and maintaining environmental compliance. Organizations need GHRM to bridge the gap from conventional to sustainable manufacturing operations. Based on the above discussion, the following hypothesis has been formulated.

H3: Green Human Resource Management practices has a positive impact on Green production process.

The process of green knowledge management functions as a essential component for enhanced green design efforts because it helps organizations preserve and communicate environment-friendly information across product development activities. GKM promotes

organizations to integrate eco-friendly methods and principles from design conception and planning stages resulting in innovative sustainable product results. Organizations achieve products with reduced environmental footprint throughout their life cycle when they embed ecological knowledge into their design process according to Chen and Chang (2013). The eco-design abilities of organizations are enhanced through GKM practices of knowledge acquisition and sharing and storage which provide relevant sustainability information to cross-functional teams (Sarkis et al., 2010). Improved materials become available because of GKM and firms can implement energy-efficient manufacturing techniques alongside products which are recyclable or biodegradable. Through GKM organizations gain an organized framework to integrate sustainability into design methodology resulting in dual environmental and organizational target achievement. Based on the above discussion, the following hypothesis has been formulated.

H4: Green Knowledge Management has a positive impact on Green design.

An organization's implementation of effective green purchasing practices receives significant enhancement through green knowledge management because it integrates environmental factors into procurement decisions. Organizations become more capable at supplier environmental performance assessment while picking eco-friendly materials and services through their implementation of green knowledge acquisition sharing and application activities. Systematic green knowledge management by organizations makes them more successful at adopting environmentally responsible sourcing approaches which decreases supply chain environmental impacts per Chuang et al. (2013). Using green knowledge enables procurement teams to understand environmental regulations so they can conduct strategic sourcing while evaluating product life cycles (Sarkis & Zhu, 2018). Through the use of GKM organizations make purchasing choices which adhere to environmental standards while sustaining operational sustainability over the long term. Based on the above discussion, the following hypothesis has been formulated.

H5: Green Knowledge Management has a positive impact on Green purchasing.

Firms need green knowledge management to drive green production processes because it enables their implementation of environmentally sustainable manufacturing practices. Organizations achieve production innovations through effective management of green knowledge which leads to waste reduction and energy conservation and emission minimization. Bernardo et al. (2010) explain that employee understanding of environmental matters leads to the adoption of cleaner production techniques along with better regulatory compliance. GKM enhances green innovation capabilities so they directly work to achieve greater production process sustainability according to Sahoo et al. (2023). Organizations become capable of implementing resource-saving technologies and sustainable operations by developing continuous environmental learning cultures through GKM. Based on the above discussion, the following hypothesis has been formulated.

H6: Green Knowledge Management has a positive impact on Green production process.

Big Data Analytics functions as an essential linking mechanism to enhance the connection between Green Human Resource Management practices and green design programs. GHRM promotes eco-conscious behavior changes through employee training while BDA brings integration of varied environmental dataset into real-time organization design

choices. The research of Dubey et al. (2019) demonstrates how BDA allows organizations to analyze environmental and operational data in order to construct sustainable products with eco-friendly designs. Wamba et al. (2017) state that BDA strengthens corporate dynamic capabilities through predictive modeling and trend analysis which meets green design requirements. GHRM initiatives that have access to analytical insights act as better guides for environmental sustainability through green innovation and design decisions.

The application of big data analytics functions as an essential moderator to improve the effectiveness of green human resource management practices in green purchasing decisions. The commitment of employees to environmental sustainability created through GHRM practices remains inefficient when analytical insights are not available for green purchasing. BDA system allows organizations to evaluate massive supplier and production and customer information for sustainable sourcing prioritization. BDA provides firms with improved supply chain visibility for supplier sustainability performance assessment and environmental risk mitigation according to Queiroz and Telles (2018). The implementation of BDA allows Dubey et al. (2021) to demonstrate that evidence-based decision-making supports organizations' sustainability values because it leads to procurement strategies with environmental consciousness. Application of BDA enhances the decision-making capabilities of GHRM to direct eco-friendly purchasing decisions.

Through real-time data analytics big data analytics improves the influence of green human resource management practices on green production operations through data-informed decision support systems for operational control. GHRM creates environmentally responsible worker behaviors and BDA creates measurable and optimized green outcomes from these employee behaviors during production. BDA tools observe resource usage and release levels and production efficiency metrics so organizations can instantly modify their operational processes to achieve lower environmental impact as Wang et al. (2016) describe. GHRM initiatives integrated with BDA systems provide organizations with improved capabilities to implement sustainable manufacturing processes. The combined approach of GHRM and BDA provides firms with innovative capabilities to optimize green technologies during their production process which results in enhanced operational performance according to Dubey et al. (2019). Based on the above discussion, the following hypothesis has been formulated.

H7: Big data analytics moderates the positive relationship between Green human resource management practices and Green operational performance.

Organizations transform environmental knowledge into eco-innovative insights through big data analytics which controls the relationship between green knowledge management and green design. Environmental sustainability knowledge creation happens through GKM and the system shares this knowledge for application in green product design through BDA analysis of big data sources which handles structured and unstructured content. BDA integration in knowledge management systems enables firms to detect environmental trends and customer preferences in an early phase which enhances the development of sustainable product designs according to Wamba et al. (2017). Organizations whose knowledge management systems integrate with BDA

capabilities tend to develop novel green products that fulfill regulatory demands and customer needs according to Nguyen et al. (2018). BDA creates stronger results from GKM applications in green design by improving the processing of environmental data and decision systems and the organization's response to ecological challenges.

The application of big data analytics functions as a key moderation force to enhance the impact of green knowledge management on green purchasing. The concept of GKM describes organizational procedures for creating storing sharing and utilizing environment-friendly operational practices in procurement functions. Firms supported by BDA gain better capabilities to analyze supplier performance and environmental data as well as sustainability credentials to support better purchasing decisions. BDA provides companies with a system to match green purchasing approaches directly to current environmental performance indicators and supplier sustainability assessments (Dubey et al. 2019). Organization success in managing green purchasing through BDA platform implementation enables them to find environmental and cost-efficient suppliers thus cutting environmental impacts through their supply chains according to Yadav et al. (2020). GKM's effectiveness increases through the implementation of BDA because this technology strengthens analytical ability thus producing better sustainable procurement choices. Based on the above discussion, the following hypothesis has been formulated.

H8: Big data analytics moderates the positive relationship between Green knowledge management and Green operational performance.

Underpinning Theory RBV also emphasizes the importance of human capital and knowledge within an organization for maintaining a competitive advantage (Barney, 1991). In this study, both GHRM and GKM are viewed as valuable assets that improve an organization's ability to achieve sustainable operational performance. GHRM influences employees' green behavior, whereas GKM promotes the development and distribution of green knowledge. For environmental performance, RBV carefully observes that organizations that can effectively manage their people resources and knowledge have a better chance of attaining the green operational breakthrough, which is why GHRM and GKM are critical for organizational green operational performance.

Methodology

This study examine a quantitative research approach and positivism research philosophy. This approach facilitates objective measurement and hypothesis testing through empirical data (Hair et al., 2014).The target population comprised professionals from Pakistan’s manufacturing and energy/utilities sectors**,** specifically HR managers, operational specialist and data analysts engaged in sustainability and digital transformation practices. In this research, nonprobability and purposive sampling method of data collection was applied. Data were collected using a structured questionnaire based on previously validated measurement instruments. GHRM 6 items adapted from Dumont et al. (2016).GKM 5 items adopted from Sahoo et al. (2022). GOP 14 items adopted from Liu et al. (2017). BDA 12 items adopted from Ahmed, Philbin, and Cheema (2020). An electronically administered questionnaire for data collecting utilizing the online survey method. Data was obtained by means of a structured questionnaire filled-in electronically, on the online sources, such as Google Forms. Out of 370 distributed questionnaires, 201 valid responses were received. Although the

recommended sample size based on Hair et al. (2014) 37*10 = 370 (i.e., 370 for 37 items), the 201 responses obtained were sufficient for robust analysis using structural equation modeling via SmartPLS4.

Results And Discussion

Demographic Analysis

In Table 1 Demographic characteristic of the 201 respondents shows that 70.1% of the respondents were male and 29.9% of them were female. On an age basis, 29.4% were below 25, 22.9%were under 25-34, 21.4% had 35-44, 18.9% had 45-54 and 7.5% were aged 55 or above. Educational-wise, 60.2% of them have their master degrees, 36.3% have their bachelor degrees, and 3.5% have their doctorate degrees. Occupations were managers (32.3%), operational specialists (27.4%), data/IT (21.4%) and HR professionals (18.9%). Eighty eight and one percent of the respondents belonged in the manufacturing sector with 11.9% in energy and utilities. Less than 5 years was experienced by 42.3% between 5-15 years by 28.2% and above 15 years by 14.4%. In terms of organizational size, 42.8% of them were working in large firms, 29.4% in the medium sized, and 27.9% in the small organizations.

Table 1 Respondent of Demographic

Demographic	Features	Frequency	Percentage
Gender	Male	141	70.1
	Female	60	29.9
Age	Below 25	59	29.4
	25-34	46	22.9
	35-44	43	21.4
	45-54	38	18.9
	55 & above	15	7.5
Education	Bachelors	73	36.3
	Masters	121	60.2
	Doctorate	7	3.5
Job Title	Manager	65	32.3
	HR Professional	38	18.9
	Data analyst/ IT specialist	43	21.4
	Operational Specialist	55	27.4
Industry Type	Manufacturing	177	88.1
	Energy \ Utilities	24	11.9
Work Experience	less than 5 years	85	42.3
	5-10 years	52	25.9
	11-15 years	35	17.4
	more than 15 years	29	14.4
Organization Size	Small (1-50 employees)	56	27.9

	Medium (51-250 employees)	59	29.4
	Large (251 and above)	86	42.8

Descriptive Statistics

Table 2 displays the main variable of the study in terms of its normality and 210 descriptiveness along with their respective Skewness and Kurtosis values. The GHRM value carried mean and standard deviation value of (M=3.7222, STD=0.71265) while GKM (M=3.7781, STD=0.67314) big data analytics (M=3.7890, STD=0.55609) and green operational performance (M= 3.7210, STD= 0.60287). According to George (2011), the data considered normally distributed for the Skewness and Kurtosis values fall within the +/-2 range.

Table 2 Descriptive Statistics

	Mean	Std. Deviation	Skewness	Kurtosis
	Statistic	Statistic	Statistic	Statistic
GHRM	3.7222	0.71265	-0.868	1.372
GKM	3.7781	0.67314	-1.222	2.546
BDA	3.7890	0.55609	-1.203	4.279
GOP	3.7210	0.60287	-1.176	3.061

Measurement Model Assessment

For testing of measurement model in SmartPLS 4 PLS algorithm was performed for examination of the reliability of the constructs; convergent validity and discriminant validity, and factor loading of the indicators of respective constructs (Urbach and Ahlemann, 2010). Figure 1 explains the initial measurement model. It shows respective factor loading of each indicator of the respective constructs.

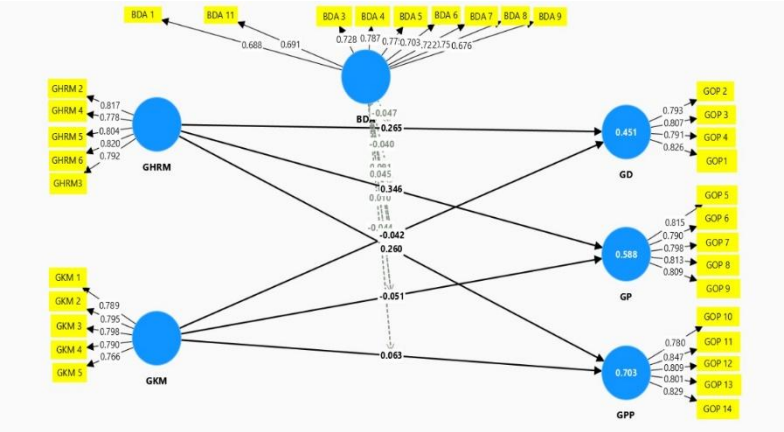

Figure 2 Measurement Model

Table 3 Reliability analysis of the measurement model, all constructs fit the suggested thresholds of internal consistency. Cronbach Alpha value is between 0.818 and 0.887 which is more than the acceptable level of 0.70 according to Ramayah (2011). In turn,

there is a relation between the Composite Reliability and the requirement of CR >0.70, suggested by Hair et al. (2011), and the results are between 0.822 and 0.890. These findings verify the validity of the scales such as those of GHRM practices, dimensions of GOP (GD, GP, and GPP), BDA and GKM.

Table 3 Reliability Analysis Measurement Model

Constructs	Cronbach Alpha > 0.70, Ramayah (2011)	Composite Reliability > 0.70, (Hair et al. 2019)
GHRM Practices	0.861	0.863
GOP		
GD	0.818	0.822
GP	0.864	0.866
GPP	0.872	0.874
BDA	0.887	0.89
GKM	0.848	0.852

In Table 4 shows the convergent validity of the measurement model reveal that all the constructs have a recommended AVE of ≥ 0.50 as recommended by Hair et al. (2011). All the values of AVE between 0.527 and 0.662 which is a good percentage of the variance accounted by the indicators of each construct. Particularly, GHRM Practices had an AVE of 0.643, BDA 0.527 and GKM 0.621.GOP dimensions; GD, GP and GPP had sufficient AVE values 0.647, 0.648 and 0.662 respectively and accepted a sufficient convergent validity of all variables.

Table 4 Convergent Validity Measurement Model

Constructs	Average Variance Extracted ≥ 0.50 (Hair et al., 2019)
GHRM Practices	0.643
GOP	
GD	0.647
GP	0.648
GPP	0.662
GKM	0.621
BDA	0.527

Table 5 shows the results of Fornell-Larcker criteria for establishing discriminant validity. Results showed that diagonal values of the square root of average variance extracted are higher than the other values in their respective rows. Table 5 shows that the square root of AVE, which is, for big data analytics was reported 0.726, GD was reported 0.804, GHRM practices was reported 0.802, GKM was reported 0.788, GP was reported 0.805,

GPP was reported 0.814. The above values show that all diagonal values of the square root of AVE was higher than inter-construct correlations of their respective rows. Therefore, it shows that as far as measurement model is concerned, there is no issue of discriminant validity in the final measurement model.

Table 5 Discriminant Validity (Fornell - Larcker Criterion)

Constructs	BDA	GD	GHRM Practices	GKM	GP	GPP
BDA	0.726					
GD	0.633	0.804				
GHRM Practices	0.579	0.523	0.802			
GKM	0.741	0.504	0.684	0.788		
GP	0.717	0.693	0.633	0.597	0.805	
GPP	0.803	0.713	0.656	0.695	0.738	0.814

Structural Equation Model

According to Duarte and Raposo (2010) in SEM, the structural model is the representation of the hypothesized relationship. After assessing goodness of measurement model in the first stage, the second stage provide the evidence supporting relationships hypothesized in the model for the current study (Chin, 2017). According to Henseler et al. (2012). In order to double the original data, Smart PLS utilizes a bootstrap methodology (Preacher and Hayes, 2008).

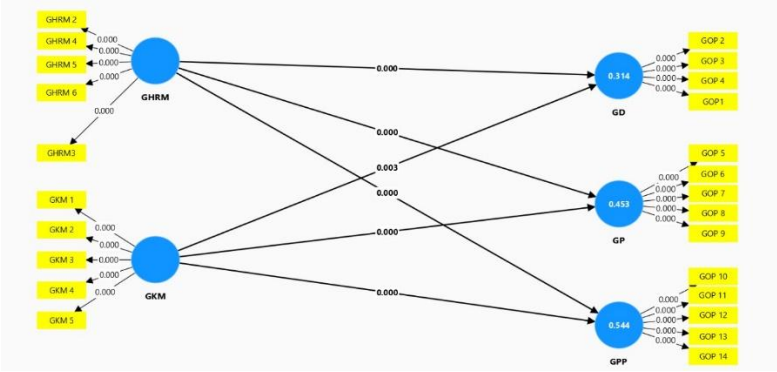

Figure 4 Structural Equation Model

The results of hypothesis testing derived from the structural model using Smart PLS 4. The model examined the direct relationships between green human resource management, green knowledge management, and green operational performance, including green design, green purchasing, and green production process. The significance of the hypothesis paths were evaluated based on path coefficients (β), t-statistics, and p-values obtained through bootstrapping. The results indicate the extent to which the proposed hypotheses were supported by the data.

Table 6 Direct Hypothesis

Hypothesis	Path	Original sample (O) β	T statistics (|O/STDEV|)	P values	Results
H1	GHRM -> GD	0.336	3.723	0	Accepted
H2	GHRM -> GP	0.423	5.598	0	Accepted
H3	GHRM -> GPP	0.342	4.242	0	Accepted
H4	GKM -> GD	0.275	3.009	0.003	Accepted
H5	GKM -> GP	0.309	3.707	0	Accepted
H6	GKM -> GPP	0.46	5.703	0	Accepted

In Table 6 H1 GHRM has a positive and significant impact on GD with $\beta =$ 0.336, T= 3.723, P< 0.001. H2 GHRM has a significant and positive impact on GP with $\beta =$ 0.423, T= 5.598, P< 0.001. H3 GHRM has a positive impact on GPP. $\beta =$ 0.342, T= 4.242, P< 0.001. H4 GKM has a positive impact on GD with $\beta =$ 0.275, T= 3.009, P< 0.003. H5 GHRM has a positive impact on GP with $\beta =$ 0.309, T= 3.707, P< 0.001. H6 GHRM has a positive impact on GPP with $\beta =$ 0.46, T= 5.703, P< 0.001.

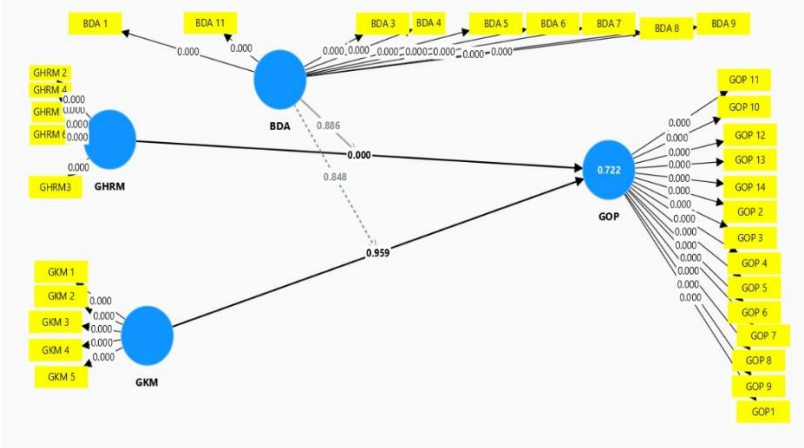

Figure 4 Moderation Anlalysis (SEM)

Table 7 Moderation Analysis

Hypothesis	Path	Original sample (β)	T statistics (|O/STDEV|)	P values	Results
H7	BDA x GKM -> GOP	0.009	0.191	0.848	Rejected
H8	BDA x GHRM -> GOP	-0.008	0.143	0.886	Rejected

Table 4.9 H7 BDA moderates the relation between GKM and GOP was not significant with $\beta =$ 0.009, T= 0.191, P= 0.848. H8 BDA moderates the relation between GHRM and GOP

was not significant with β =-0.008, T= 0.143, P= 0.886.

Discussion On Reserch Findings

For the current study, research objectives have been formulated based on the research questions and problem statement. 1 To understand the way that Green Human Resource Management practice affect Green Operational Performance. Research Question 1 How GHRM Practices affects GOP? H1, H2, H3. These hypotheses aim to explore the impact of GHRM on the different dimensions of green operational outcomes. The results of the current study showed a significant relationship. This revealed that there is no impact of GHRM on GOP with other dimensions, contradicting with previous studies which showed that this specific relationship is positive and significant. These results align with other research, such as that of Renwick et al. (2013) and Yong et al. (2020), by concluding that green HR practices can enhance sustainability performance.

2. To understand the way that Green Knowledge Management affects Green Operational Performance. Research Question 2 How GKM affects GOP? H4, H5, H6. These hypotheses aim to explore the impact of GKM on the different dimensions of green operational outcomes. The results of the current study showed a significant relationship. This revealed that there is no impact of GKM on GOP with other dimensions, contradicting with previous studies which showed that this specific relationship is positive and significant. These results align with other research, such as that of (Jabbour et al., 2008) and Massaro et al. (2015) which highlight that organizations with strong green knowledge frameworks are better equipped to implement eco-friendly design choices, adopt sustainable sourcing practices, and optimize resource usage in production.

3. To analyze the moderation effect of Big Data Analytics in the relationship between GHRM practices and Green Operational Performance. Research Question 3. How BDA moderates the relationship between GHRM Practices on GOP? This study aimed to check whether Big Data Analytics (BDA) strengthens the relationship between Green Human Resource Management (GHRM) practices and Green Operational Performance (GOP). Two hypotheses were tested to examine this effect. However, the results showed that both hypotheses were not statistically significant. This means that BDA did not increase the positive effect of GHRM on GOP in the companies surveyed in Pakistan. These findings are different from international studies like Ghobakhloo and Fathi (2021) and Dubey et al. (2021), where BDA helped improve green operational performance, especially in companies that had strong digital systems and a data-driven culture. In contrast, the current results match the findings of Hussain et al. (2023), who also found that BDA did not play a significant role in Pakistani firms. This suggests that even though BDA is a useful tool in theory, its practical impact may be limited in developing countries like Pakistan. Reasons may include poor technical infrastructure, lack of data skills among employees, and low commitment from management toward adopting digital tools. These barriers prevent companies from using BDA as an effective tool to support green strategies.

4. To analyze the moderation effect of Big Data Analytics in the relationship between Green Knowledge Management and Green Operational Performance. Research Question 4 How BDA moderates the relationship between GKM on GOP? In the present study, a hypothesis was placed forward with the anticipation that BDA would tie this relationship

even further. But unfortunately the hypothesis was not supported by the statistical result because the moderating impact of the BDA was considered as insignificant. Such a conclusion differs with the previous ones like Dubey et al. (2021) and Ghobakhloo and Fathi (2021), who indicated that the benefits of BDA have significant positive effects on the outcomes of green practices, especially in cases where organizations are well endowed with powerful data infrastructures and analytics abilities. They surmised that BDA may enhance the capabilities of environmental performance through enhanced knowledge exchange, predictability and decision-making. It can be however, aligned with the findings of Hussain et al. (2023) who also found that the BDA is not significantly moderated in Pakistani firms, and therefore, there is a possibility that, the upshot of integration of BDA and green knowledge practice in Pakistan is not yet at a mature stage to produce a more meaningful effect. Low digital adoption, poor technical skills, and marginal investment in the data infrastructure can be the reasons why BDA did not moderate the relationship between GKM and GOP.

Theoretical And Practical Implications

This study contributes to evolving disclosure of sustainable management in providing the environment of green human resource management, green knowledge management, and big data analytics to the understanding of the resource-based view theory. Positive and significant correlation rate between variables has been ascertained between GHRM and green operational performance and GKM and GOP, which confirms the RBV theory statement that scarce, rare, and inimitable resources which are green skills and environment-related knowledge maintenance have positive inputs to the organizational performance. These results justify human and knowledge capital as a strategic resource in terms of sustainability.

However, insignificant moderating role of big data analytics calls the generalization of the RBV to situations with an incomplete level of technology readiness. This means that the strategic resources like BDA might not be effective under all circumstances, such as digital infrastructure, managerial capacity, and organizational preparedness and specifically in the developing economies like Pakistan. The impacts of green human resource management influences different aspects of green operational performance such as green design, green purchasing, and green production. It is vital for practitioners to adopt green recruitment policies, green training, and green appraisal systems that foster sustainable behaviors. These approaches will increase employees' environmental consciousness and help institutionalize sustainability into the corporate culture which can improve the organization's operational performance (Renwick et al., 2013; Jabbour & Santos, 2008).

The positive link between GKM and GOP illustrates the need for environmental knowledge creation, sharing, and application throughout the organization. Mangers need to put in place green knowledge repositories, collaborative systems for learning, and multifunctional teams that deal with green innovations and manage the green knowledge databases. Companies can build a culture of continuous improvement and innovation powered by sustainability by facilitating the sharing and learning of green knowledge (Massaro et al., 2015). The findings suggest GHRM and GKM can both be used strategically to improve sustainability performance. Within the Pakistani industrial setting,

the study indicated BDA played little to no role in moderating the impact of GHRM/GKM on GOP. This indicates that BDA is not matched in practice because of challenges such as lack of infrastructure, inadequate specialized workforce, and mind low levels of digital preparedness. Because of this, firms need to think twice before pouring resources into BDA strategies, taking into account the existing technological frameworks within the company. There should be a focus on systems for digital and sustainability training, as well as gradual implementation of analytics into sustainability frameworks as opposed to rule-based systems (Hussain et al., 2024).

Future Recommendations

Finding of this present research, various recommendations can be given to organizations, practitioners, and policymakers in developing countries such as Pakistan. The first experience is that an organization needs to take time to develop technological readiness before big data analytics can play a valid role in sustainable performances. This study revealed no marked moderating role of BDA implying that a large number of companies might not possess the necessary infrastructure, data proficiency, or management assistance to make the most out of the offering of big data in relation to green activities. Firms, therefore, need to focus more on digital transformation activities by creating awareness, capacity building, and integrating data to get the best out of the BDA.

Second, since green human resource management and the green knowledge management were proved to have particularly significant influence on the green operational performance the role of these areas should becoming stronger in organizations. This entails introduction of green recruitment policies, undertake environmental awareness training, engagement of employees in green initiatives and facilitation of knowledge sharing relative to sustainability. The practices are affordable and practical to enhance efficiency of operation and less impact to the environment.

Finally, there is a possibility to develop a longitudinal study or qualitative research in the future that should study this topic to understand the transformation of BDA in an organization in the future. The sector-specific part of the challenge should also require further research, and the barriers of digital and environmental transformation may vary across industries. Future research with such areas addressed will enable discovering more specific measures regarding improving sustainability in developing economies.

Conclusion

The purpose of the study was to test the relationship between green human resource management and green knowledge management practice and green operational performance, and also moderating effect of big data analytics in these associations. The findings validate that both GHRM and GKM significantly influence GOP, the propositions support the Resource-Based View theory, which states that competitive internal resources, which are rare, valuable, and possess the factor of inimitability, are of green skills and green knowledge, which enable firms to increase their performance (Barney, 1991; Renwick et al., 2013). However, it was discovered that the moderating effect by BDA was not significant, which implies that merely the availability of big data will not make companies efficient in its usage but should be technologically prepared and culturally oriented to work with it (Hussain et al., 2023). Such an observation is different from research results produced in developed environments (e.g., Ghobakhloo & Fathi,

2021), which means that there is an information gap in the digital preparedness of Pakistani companies. Finally, the research has a theoretical and practical contribution as it proves the relevance of green human and knowledge resources in reaching sustainable operational performance, as well as identifies the difficulties of digitalization in the economies with low levels of development, such as Pakistan.

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