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Green and Digital Leadership: Impact on Sustainable Performance, Mediating Environmental Knowledge Sharing, Moderating Technological Innovation

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Abstract

This study aims to explore the influence of Green Leadership and Digital Leadership on Sustainable Performance through the mediating role of Environmental Knowledge Sharing and the moderating role of Technological Innovation. Data were collected from 365 employees of District regional secretariat in North Aceh Regency, Bireuen Regency, and Lhokseumawe City, Indonesia, using a quantitative method with Structural Equation Modeling (SEM) employing Smart PLS software. The findings reveal that both Green Leadership and Digital Leadership significantly impact Environmental Knowledge Sharing. While Digital Leadership does not directly influence Sustainable Performance significantly, both Digital Leadership and Environmental Knowledge Sharing exhibit a positive and significant effect on Sustainable Performance. Environmental Knowledge Sharing significantly mediates the influence of Green Leadership and Digital Leadership on Sustainable Performance. Moreover, Technological Innovation moderates the relationship between Environmental Knowledge Sharing and Sustainable Performance, indicating a reduction in impact at higher levels of innovation. Theoretical implications of these findings extend understanding of how Digital Leadership and Green Leadership affect sustainable performance through environmental knowledge dissemination. Practical implications suggest organizations should prioritize developing digital and green leadership competencies to enhance their environmental knowledge and sustainable performance.

Keywords: *Green Leadership, Digital Leadership, Environmental Knowledge Sharing, Sustainable Performance, Technological Innovation.*

Introduction

In today's business landscape, green leadership, digital leadership, and sustainable performance have gained significant attention. Green leadership focuses on environmental responsibility, while digital leadership leverages technology for strategic advantage. Sustainable performance balances long-term success with environmental and social impacts. Research highlights that transformational leadership, a core aspect of green leadership, enhances employee sustainable performance (Jiang, Zhao and Ni, 2017), and digital leadership fosters inventive talents, improving sustainability via AI integration (Munir et al., 2023). Digital leadership's impact on sustainable performance is also emphasized in various studies (Khaw et al., 2022; Shin et al., 2023; Retnowati, 2023). Environmental knowledge sharing mediates the relationship between green leadership and sustainable practices (Rasyid and Stepanus, 2024), while technological innovation moderates collaboration networks and sustainability (Muchtar, Muchtar and Putra, 2024). Studies underscore digital leadership's role in driving sustainability through digital transformation and innovation (Al-Hadrawi and Reniati, 2023; Mahmood et al., 2024; Lin, 2023). Further exploration of the interplay between leadership styles, environmental knowledge sharing, and technological innovation is crucial for developing effective sustainability strategies.

Hypothesis Development

Green Leadership and Environmental Knowledge Sharing

Green leadership is an essential approach that emphasizes the importance of environmental values in organizations. Leaders adopting this style inspire employees to engage in eco-friendly behaviors and foster

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a culture that supports sustainability initiatives. Through their commitment, green leaders facilitate environmental knowledge sharing, which enhances collective understanding of environmental issues and potential solutions (Robertson & Barling, 2013; Boiral, 2002; Boiral, Cayer & Baron, 2009). Studies have shown a positive link between green leadership and environmental knowledge sharing. For instance, Masri & Jaaron (2017) and Singh et al. (2020) demonstrated how green leadership promotes such knowledge exchange. Based on this, the following hypothesis is proposed:

Hypothesis 1: Green leadership positively influences environmental knowledge sharing.

Digital Leadership and Environmental Knowledge Sharing

Digital leadership has become crucial in guiding organizations through technological advancements while promoting environmental sustainability. Digital leaders leverage technology to reduce environmental footprints and foster green innovation, thereby supporting environmental knowledge sharing. Studies by Akhtar et al. (2018) and Anthony Jr. (2019) show how digital leadership promotes environmental knowledge sharing by creating collaborative platforms and facilitating the flow of information. Therefore, the following hypothesis is proposed:

Hypothesis 2: Digital leadership positively influences environmental knowledge sharing.

Green Leadership and Sustainable Performance

Green leadership not only promotes environmental values but also drives organizations toward sustainable performance, integrating economic, environmental, and social goals (Robertson & Barling, 2013; Elkington, 1997). By setting clear sustainability goals, leading by example, and investing in green initiatives, green leaders inspire employees and contribute to improved organizational performance. Studies by Graves, Sarkis, and Zhu (2013) support this link between green leadership and sustainable performance. Consequently, the following hypothesis is proposed:

Hypothesis 3: Green leadership positively influences sustainable performance.

Digital Leadership and Sustainable Performance

Digital leadership can drive sustainable performance by utilizing technologies that optimize resources, reduce environmental impact, and foster collaboration (Avolio et al., 2014; Hanelt, Busse & Kolbe, 2017). Digital leaders also promote data-driven decision-making and innovation, which contribute to sustainability outcomes. Studies by Akhtar et al. (2018) and Tran et al. (2023) highlight the positive impact of digital leadership on sustainability. Thus, the following hypothesis is proposed:

Hypothesis 4: Digital leadership positively influences sustainable performance.

Environmental Knowledge Sharing and Sustainable Performance

Environmental knowledge sharing enhances sustainable performance by enabling organizations to address environmental challenges through collective learning and innovation (Boiral, 2002). Studies by Kim & Park (2017), Nova & Bitencourt (2020), and Ali et al. (2021) emphasize the importance of knowledge sharing in improving sustainability outcomes. Based on these findings, the following hypothesis is proposed:

Hypothesis 5: Environmental knowledge sharing positively influences sustainable performance.

Technological Innovation and Sustainable Performance

Technological innovation is a significant driver of sustainable performance. Innovations in green technology and processes allow organizations to reduce environmental impacts and improve efficiency (Zhang et al., 2019; Cancino et al., 2018). Studies by Chen et al. (2022), Lee et al. (2019), and Awawdeh et

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al. (2021) further highlight the role of technological innovation in achieving sustainability. Therefore, the following hypothesis is proposed:

Hypothesis 6: Technological innovation positively influences sustainable performance.

The Mediating Role of Environmental Knowledge Sharing Between Green Leadership and Sustainable Performance

Environmental knowledge sharing mediates the relationship between green leadership and sustainable performance by translating green leaders' initiatives into actionable practices that enhance sustainability (Su et al., 2020; Riva et al., 2021). This mediation allows organizations to leverage shared knowledge to drive innovation and improve environmental outcomes. Based on these insights, the following hypothesis is proposed:

Hypothesis 7: Environmental knowledge sharing mediates the relationship between green leadership and sustainable performance.

The Mediating Role of Environmental Knowledge Sharing Between Digital Leadership and Sustainable Performance

Environmental knowledge sharing also mediates the relationship between digital leadership and sustainable performance, as digital leaders create platforms for sharing environmental insights and drive organizational innovation (Feroz et al., 2021; Shahzad et al., 2022). By fostering a collaborative environment, digital leadership enhances sustainability outcomes. Thus, the following hypothesis is proposed:

Hypothesis 8: Environmental knowledge sharing mediates the relationship between digital leadership and sustainable performance.

The Moderating Role of Technological Innovation on Effect of Environmental Knowledge Sharing on Sustainable Performance

The moderating role of technological innovation on the effect of environmental knowledge sharing on sustainable performance is well-documented. Studies highlight that technological innovation enhances the impact of environmental knowledge sharing on sustainability outcomes (Qiao, Wang, & Guo, 2021). Wang (2019) found innovation mediates the relationship between environmental regulation and business performance. Behl et al. (2023) noted innovation capabilities positively impact sustainability. Kong et al. (2023) emphasized its moderating effect on ESG performance, enhancing firm value. These findings show that fostering technological innovation and knowledge sharing can significantly improve sustainable performance.

Hypothesis 9: Technological innovation moderates environmental knowledge sharing and sustainable performance.

Conceptual Framework

This conceptual framework (Fig.1) illustrates that Green Leadership (GL) and Digital Leadership (DL) play crucial roles in facilitating Environmental Knowledge Sharing (EKS) within an organization. EKS directly contributes to Sustainable Performance (SP), which encompasses economic, environmental, and social aspects. Additionally, Technological Innovation (TI) has a direct impact on SP. Thus, leadership focused on environmental and technological aspects, as well as technological innovation, all contribute to enhancing the organization's sustainable performance.

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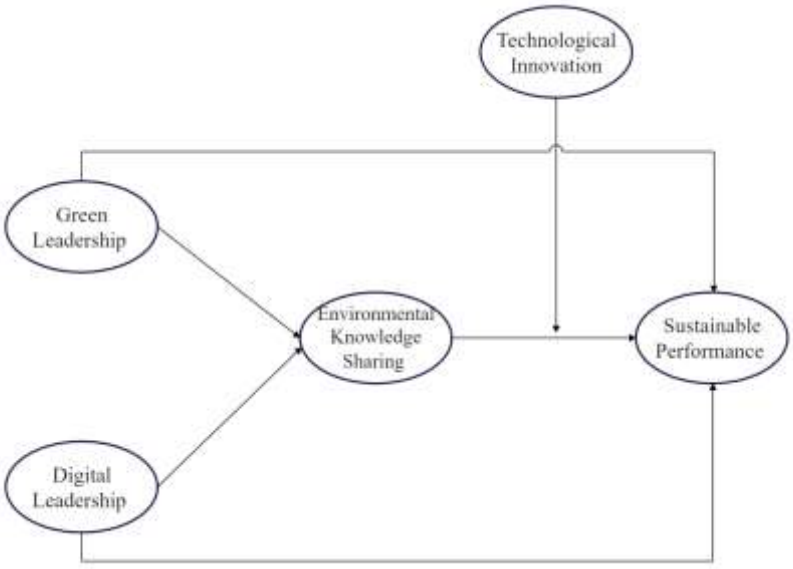

Figure 1. Conceptual Framework

Measurement

To measure green leadership, indicators developed by Chen & Chang, (2013) are used, which adapt the concept of transformational leadership to an environmental context, including idealized influence (green charisma), inspirational motivation (green inspiration), intellectual stimulation (green stimulation), and individualized consideration (green consideration). To measure digital leadership, indicators developed by Larjovuori et al., (2018) are employed, which include understanding digital technology, strategic capability in the digital era, ability to lead digital change, and fostering a culture of digital innovation. To measure environmental knowledge sharing, we use indicators from N. Wang et al., (2022). These indicators include a workplace atmosphere that supports environmental knowledge exchange, employees' willingness to share knowledge, the frequency and quality of new environmental knowledge generated, employee cohesion and collaboration, increased environmental awareness, the quality of shared knowledge, the impact on environmentally friendly behaviors, and organizational support for knowledge sharing. To gauge technological innovation, indicators recommended by Rosenberg, (2006) are used, such as investment in new technology, number of R&D personnel, scientific and technical publications, and the rate of technology diffusion within the organization. Lastly, for measuring sustainable performance, indicators emphasized by Dumont et al., (2017) are employed, which include eco-helping by promoting environmentally friendly practices among colleagues, participation in organizational environmental initiatives (eco-civic engagement), and initiating eco-friendly projects (eco-initiatives) to enhance overall sustainability efforts.

Material and Method

This research is a quantitative study aimed at discovering the relationships between variables through statistical analysis. The study population includes all employees of the Regency Regional Secretariat in North Aceh Regency, Bireuen Regency, and Lhokseumawe City-Indonesia, totaling 365 employees. The research variables include green leadership and digital leadership as independent variables, employee performance as the dependent variable, environmental knowledge sharing as a mediating variable, and technological innovation as an interaction variable. The research instrument consists of a questionnaire with a Likert scale of 1-5, which has been tested for validity and reliability. Validity was tested using confirmatory factor analysis, while reliability was tested using Cronbach's Alpha coefficient and Composite Reliability. Primary data was collected through questionnaires, while secondary data was obtained from books, journals, and organizational reports. Data analysis was performed using descriptive and inferential statistical analysis.

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Inferential analysis employed PLS-SEM with SmartPLS software, covering the testing of the measurement model and structural model.

Characteristic Respondent

The survey conducted across Bireuen Regency, North Aceh Regency, and Lhokseumawe City included a total of 365 respondents. The majority were male (58.90%) and aged between 20-30 years (39.73%). Education levels varied, with most respondents holding a Bachelor's degree (43.84%), followed by those with a Diploma (28.77%). The data highlights a relatively balanced distribution across the regions and provides insights into the demographic and educational backgrounds of the participants.

Table 1. Characteristic Respondent

Criteria	Bireuen Regency	North Aceh Regency	Lhokseumawe City	Total	Percentage
Gender					
Male	60	85	70	215	58.90%
Female	46	50	54	150	41.10%
Age					
20-30 years	40	55	50	145	39.73%
31-40 years	30	40	35	105	28.77%
41-50 years	26	30	30	86	23.56%
51 years and above	10	10	9	29	7.95%
Education					
High School	15	20	18	53	14.52%
Diploma (D3)	30	40	35	105	28.77%
Bachelor's (S1)	45	60	55	160	43.84%
Master's (S2)	16	15	16	47	12.87%

Statistic Descriptive

Based on the data in Table 2, it can be explained that the average scores for items Green Leadership (GL), Digital Leadership (DL), Environment Knowledge Sharing (EKS), Technological Innovation (TI), and Suitable Performance (SP) are quite high, ranging from 3.510 to 4.454. The relatively low standard deviations, ranging from 0.666 to 1.019, indicate consistent responses from participants. This suggests that the data is of good quality, with the measured items demonstrating high reliability and positive evaluations from respondents for each aspect assessed.

Table 2. Statistic Descriptive

Item	Min	Max	Mean	Std. Deviation	Item	Min	Max	Mean	Std. Deviation
GL1	1	5	4,337	0,877	EKS4	1	5	4,304	0,753
GL2	1	5	4,242	0,880	EKS5	1	5	4,134	0,864
GL3	1	5	4,046	0,856	EKS6	1	5	4,340	0,786
GL4	1	5	3,745	0,931	EKS7	1	5	4,176	0,819
GL5	1	5	3,748	0,940	EKS8	1	5	4,409	0,769
GL6	1	5	3,997	0,828	TI1	1	5	4,209	0,799
GL7	1	5	4,059	0,847	TI2	1	5	4,186	0,794
GL8	1	5	4,127	0,927	TI3	1	5	4,075	0,824
DL1	1	5	4,121	0,693	TI4	1	5	4,167	0,869
DL2	1	5	3,905	0,846	TI5	1	5	4,095	0,880

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Item	Min	Max	Mean	Std. Deviation	Item	Min	Max	Mean	Std. Deviation
DL3	1	5	4,193	0,780	TI6	1	5	3,817	0,988
DL4	1	5	4,160	0,758	TI7	1	5	3,739	0,960
DL5	1	5	4,020	0,833	TI8	1	5	3,892	0,926
DL6	1	5	4,003	0,713	SP1	1	5	4,095	0,790
DL7	1	5	3,925	0,800	SP2	1	5	4,092	0,813
DL8	1	5	3,510	1,019	SP3	1	5	4,229	0,692
EKS1	1	5	4,386	0,790	SP4	1	5	4,248	0,666
EKS2	1	5	4,454	0,793	SP5	1	5	4,248	0,731
EKS3	1	5	4,369	0,816	SP6	1	5	4,376	0,691

Result

Measurement Model (Outer Model)

A Measurement Model (or Outer Model) in PLS-SEM is crucial for assessing the relationships between latent variables (constructs) and their observed indicators. It ensures reliability and validity of constructs before analyzing structural relationships. Key aspects include Indicator Reliability, Internal Consistency, Convergent Validity, and Discriminant Validity. (Sarstedt, Ringle and Hair, 2021) emphasize that only when the measurement model meets all criteria can researchers proceed to evaluate the structural model and confirm hypothesized relationships. (Fig.2)

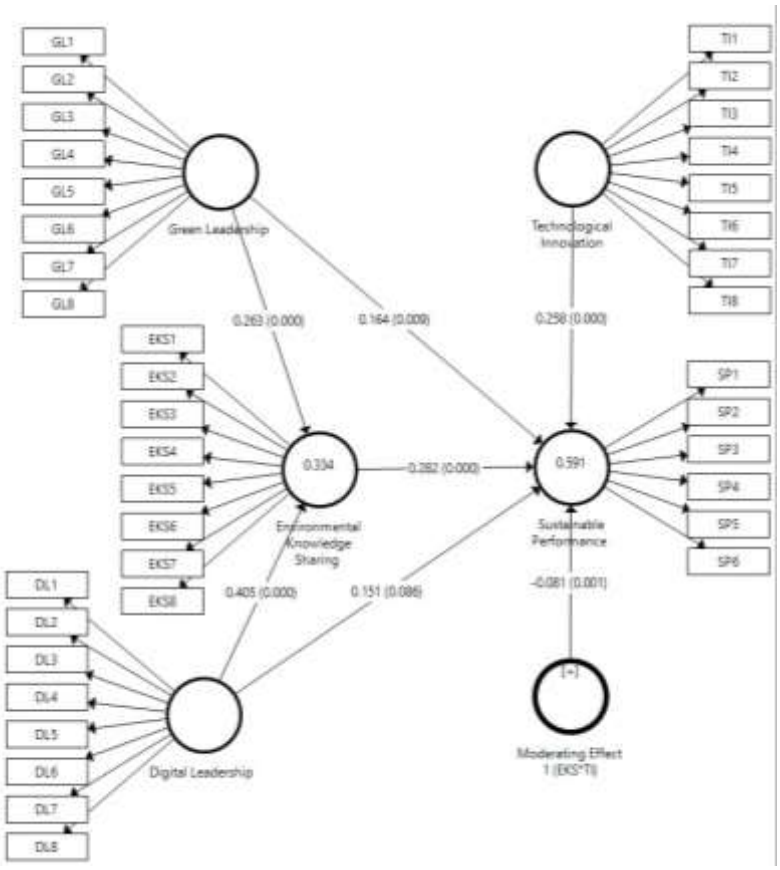

Figure 2. Estimation Results of the Outer Model

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Indicator Reliability

Indicator Reliability assesses the consistency of each indicator in representing its construct. It is evaluated through outer loadings, with a recommended threshold of ≥ 0.70. This value indicates that the indicator accurately reflects its measured construct. Indicators with loadings below 0.70 may need to be considered for removal or revision, depending on their impact on content validity and composite reliability. (Sarstedt, Ringle and Hair, 2021)

Based on Figure 2, it can be concluded that all items have outer loading values greater than 0.70. This means that each indicator used in this model demonstrates good convergent validity. In the context of PLS-SEM (Partial Least Squares Structural Equation Modeling) analysis, an outer loading value greater than 0.70 indicates that the indicators significantly measure the constructs or latent variables they represent. In other words, these indicators have a strong and consistent contribution to the measurement of their respective constructs, making the resulting model reliable and valid.

Convergent Validity

Based on the results presented in Table 3 for Construct Reliability and Validity, all constructs demonstrate high reliability and validity. Each construct has a Cronbach's Alpha and Composite Reliability above 0.90, indicating excellent internal consistency. Digital Leadership has a Cronbach's Alpha of 0.938, Composite Reliability of 0.949, and an AVE of 0.700. Environmental Knowledge Sharing has a Cronbach's Alpha of 0.965, Composite Reliability of 0.970, and an AVE of 0.804. Green Leadership has a Cronbach's Alpha of 0.949, Composite Reliability of 0.958, and an AVE of 0.740. Sustainable Performance has a Cronbach's Alpha of 0.939, Composite Reliability of 0.952, and an AVE of 0.767. Technological Innovation has a Cronbach's Alpha of 0.950, Composite Reliability of 0.958, and an AVE of 0.741. These values indicate that the constructs are reliable and valid for use in the research model.

Table 3. Construct Reliability and Validity

Construct	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Digital Leadership	0,938	0,944	0,949	0,700
Environmental Knowledge Sharing	0,965	0,966	0,970	0,804
Green Leadership	0,949	0,957	0,958	0,740
Sustainable Performance	0,939	0,945	0,952	0,767
Technological Innovation	0,950	0,956	0,958	0,741

Discriminant Validity

Based on the results of the discriminant validity analysis presented in Table 4, all constructs demonstrate good discriminant validity. This is evidenced by the square root of the Average Variance Extracted (AVE) for each construct being greater than the correlations between constructs. Digital Leadership has a square root of AVE of 0.837, Environmental Knowledge Sharing 0.897, Green Leadership 0.860, Sustainable Performance 0.876, and Technological Innovation 0.861. These values are higher than the inter-construct correlations, indicating that each construct has adequate discriminant validity and can be clearly distinguished from other constructs within the research

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Table 4. Discriminant Validity

Construct	Digital Leadership	Environmental Knowledge Sharing	Green Leadership	Sustainable Performance	Technological Innovation
Digital Leadership	**0,837**				
Environmental Knowledge Sharing	0,530	**0,897**			
Green Leadership	0,479	0,456	**0,860**		
Sustainable Performance	0,588	0,636	0,533	**0,876**	
Technological Innovation	0,541	0,459	0,388	0,583	**0,861**

Heterotrait-Monotrait Ratio (HTMT)

Based on the results of the Heterotrait-Monotrait Ratio (HTMT) analysis presented in Table 5, all HTMT values are below the threshold of 0.90, indicating good discriminant validity for each construct. Digital Leadership has HTMT values of 0.550 with Environmental Knowledge Sharing, 0.511 with Green Leadership, 0.622 with Sustainable Performance, and 0.573 with Technological Innovation. Environmental Knowledge Sharing has HTMT values of 0.468 with Green Leadership, 0.660 with Sustainable Performance, and 0.472 with Technological Innovation. Green Leadership has an HTMT value of 0.561 with Sustainable Performance and 0.407 with Technological Innovation. Sustainable Performance has an HTMT value of 0.608 with Technological Innovation. These results indicate that each construct is well distinguished from the other constructs within the research model.

Table 5. Heterotrait-Monotrait Ratio (HTMT)

	Digital Leadership	Environmental Knowledge Sharing	Green Leadership	Sustainable Performance
Environmental Knowledge Sharing	0,550			
Green Leadership	0,511	0,468		
Sustainable Performance	0,622	0,660	0,561	
Technological Innovation	0,573	0,472	0,407	0,608

Structural Model (Inner Model)

Sarstedt et al., (2021) explains that "The structural model (also called the inner model in PLS-SEM) describes the relationships between latent constructs based on substantive theory." In the inner model, several aspects that are discussed or assessed include: Path Coefficients, R-square (R^2) Values, Effect Size (f^2), Predictive Relevance (Q^2) and Goodness of Fit (GoF). (Fig.3)

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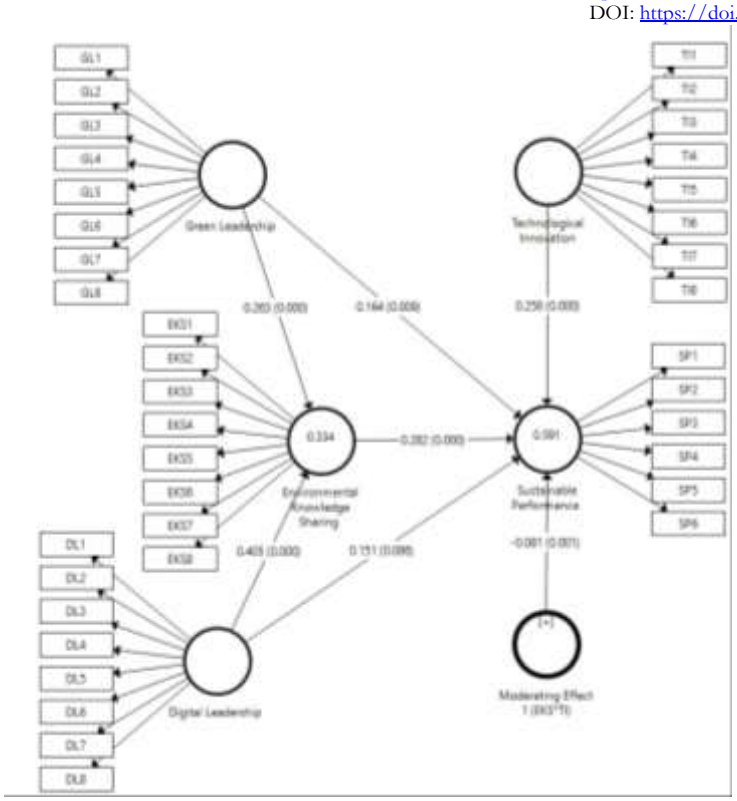

Figure 3. Structural Model (Inner Model)

Path Coefficients (Table 6)

Direct Effects

The path coefficient analysis (Table 6) reveals several significant direct relationships. Digital Leadership significantly impacts Environmental Knowledge Sharing (O = 0.405, T = 6.343, P = 0.000) but has a marginally non-significant effect on Sustainable Performance (O = 0.151, T = 1.714, P = 0.087). Environmental Knowledge Sharing significantly influences Sustainable Performance (O = 0.282, T = 5.146, P = 0.000). Green Leadership shows a significant positive effect on both Environmental Knowledge Sharing (O = 0.263, T = 4.551, P = 0.000) and Sustainable Performance (O = 0.164, T = 2.537, P = 0.011). The moderating effect of Environmental Knowledge Sharing combined with Technological Innovation (EKS*TI) on Sustainable Performance is negative and significant (O = -0.081, T = 3.612, P = 0.000). Lastly, Technological Innovation has a significant positive effect on Sustainable Performance (O = 0.258, T = 3.767, P = 0.000).

Indirect Effects

The analysis of indirect effects shows that Digital Leadership significantly influences Sustainable Performance through Environmental Knowledge Sharing (O = 0.114, T = 3.456, P = 0.001). Similarly, Green Leadership also has a significant indirect effect on Sustainable Performance through Environmental Knowledge Sharing (O = 0.074, T = 3.300, P = 0.001). These results suggest that Environmental Knowledge Sharing mediates the relationships between Digital Leadership, Green Leadership, and Sustainable Performance.

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Table 6. Path Coefficients

Direct Effect	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
Green Leadership -> Environmental Knowledge Sharing	0,263	4,551	0,000
Digital Leadership -> Environmental Knowledge Sharing	0,405	6,343	0,000
Green Leadership -> Sustainable Performance	0,164	2,537	0,011
Digital Leadership -> Sustainable Performance	0,151	1,714	0,087
Environmental Knowledge Sharing -> Sustainable Performance	0,282	5,146	0,000
Technological Innovation -> Sustainable Performance	0,258	3,767	0,000
Moderating Effect 1 (EKS*TI) -> Sustainable Performance	-0,081	3,612	0,000
Indirect Effect	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
Digital Leadership -> Environmental Knowledge Sharing -> Sustainable Performance	0,114	3,456	0,001
Green Leadership -> Environmental Knowledge Sharing -> Sustainable Performance	0,074	3,300	0,001

R-square (R^2) and R Square Adjusted

Based on the results presented in Table 7, the R^2 values indicate that the model explains 33.4% of the variance in Environmental Knowledge Sharing and 59.1% of the variance in Sustainable Performance. The adjusted R^2 values, which account for the number of predictors in the model, are slightly lower but still significant, with 33.0% for Environmental Knowledge Sharing and 58.5% for Sustainable Performance. The high T-statistics and significant P-values (P = 0.000) for both R^2 and adjusted R^2 values suggest that the model's explanatory power for these constructs is strong and reliable.

Table 7. R-square (R^2) and R Square Adjusted

R Square	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
Environmental Knowledge Sharing	0,334	4,377	0,000
Sustainable Performance	0,591	9,162	0,000
R Square Adjusted			
Environmental Knowledge Sharing	0,330	4,291	0,000
Sustainable Performance	0,585	8,908	0,000

Values, Effect Size (f^2)

Based on the effect size (f^2) results in Table 8, Digital Leadership has a medium effect on Environmental Knowledge Sharing (f^2 = 0.189, P = 0.011) but a negligible and non-significant effect on Sustainable Performance (f^2 = 0.031, P = 0.434). Environmental Knowledge Sharing has a small but significant effect on Sustainable Performance (f^2 = 0.114, P = 0.013). Green Leadership shows a small effect on Environmental Knowledge Sharing (f^2 = 0.080, P = 0.047) and an insignificant effect on Sustainable Performance (f^2 = 0.045, P = 0.241). The moderating effect of Environmental Knowledge Sharing combined with Technological Innovation (EKS*TI) on Sustainable Performance is small but significant (f^2 = 0.049, P = 0.042). Technological Innovation has a small and non-significant effect on Sustainable

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Performance (f^2 = 0.107, P = 0.105). These findings highlight the varying degrees of impact that each construct has within the model.

Table 8. Effect Size (f^2)

Relationship of Construct	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
Digital Leadership -> Environmental Knowledge Sharing	0,189	2,538	0,011
Digital Leadership -> Sustainable Performance	0,031	0,783	0,434
Environmental Knowledge Sharing -> Sustainable Performance	0,114	2,507	0,013
Green Leadership -> Environmental Knowledge Sharing	0,080	1,987	0,047
Green Leadership -> Sustainable Performance	0,045	1,173	0,241
Moderating Effect 1 (EKS*TI) -> Sustainable Performance	0,049	2,044	0,042
Technological Innovation -> Sustainable Performance	0,107	1,625	0,105

Predictive Relevance (Q^2)

Based on the Predictive Relevance (Q^2) results in Table 9, Sustainable Performance shows a substantial predictive relevance (Q^2 = 0.442), indicating that the model has good predictive power for this construct. Environmental Knowledge Sharing also exhibits moderate predictive relevance (Q^2 = 0.263), suggesting adequate predictive capability. The other constructs—Digital Leadership, Green Leadership, Moderating Effect 1 (EKS*TI), and Technological Innovation—show Q^2 values of 0, indicating that their predictive relevance is not supported by the model. These findings suggest that while Sustainable Performance and to some extent Environmental Knowledge Sharing are well-predicted by the model, other constructs may require further investigation or refinement in predictive modeling.

Table 9. Predictive Relevance (Q2)

Construct	SSO	SSE	Q^2 (=1-SSE/SSO)
Digital Leadership	2448,000	2448,000	
Environmental Knowledge Sharing	2448,000	1804,024	0,263
Green Leadership	2448,000	2448,000	
Moderating Effect 1 (EKS*TI)	306,000	306,000	
Sustainable Performance	1836,000	1025,287	0,442
Technological Innovation	2448,000	2448,000	

Goodness of Fit (GoF)

Based on the Goodness of Fit (GoF) results in Table 10, the estimated model shows a satisfactory fit with a Standardized Root Mean Residual (SRMR) of 0.064, indicating a reasonable fit to the data. The discrepancy in the ULS (Unweighted Least Squares) and G (Geodesic) indices suggests some minor deviations from the saturated model but generally acceptable fit (d_ULS = 3.048, d_G = 1.909). The Chi-Square value is high but typical for large sample sizes, and the NFI (Normed Fit Index) indicates a moderately good fit (NFI = 0.783). Overall, while the model shows some discrepancies compared to the saturated model, it generally fits the data adequately

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Table 10. Goodness of Fit (GoF)

Criteria	Saturated Model	Estimated Model
SRMR	0,056	0,064
d_ULS	2,329	3,048
d_G	1,885	1,909
Chi-Square	3024,802	3027,906
NFI	0,784	0,783

Discussion

Impact of Green Leadership on Environmental Knowledge Sharing

Green Leadership positively and significantly influences Environmental Knowledge Sharing ($\beta = 0.263$, $t = 4.551$, $p < 0.001$). This result is supported by several studies. Singh & El-Kassar, (2019) found that green leadership promotes pro-environmental behaviors among employees. Mittal & Dhar, (2016) demonstrated its role in fostering green creativity. Han et al., (2011) showed that green leadership enhances environmental knowledge sharing in the hospitality industry, while Iqbal et al., (2020) highlighted its importance in creating an eco-friendly organizational culture. Theoretical implication: Expands understanding of Green Leadership's role in facilitating environmental knowledge sharing. Practical implication: Organizations should train leaders in green leadership aspects to increase environmental awareness and knowledge sharing.

Impact of Digital Leadership on Environmental Knowledge Sharing

Digital Leadership has a positive and significant effect on Environmental Knowledge Sharing ($\beta = 0.405$, $t = 6.343$, $p < 0.001$). This finding aligns with several recent studies. Li et al., (2016) demonstrated that digital leadership fosters a knowledge-sharing culture in organizations. Similarly, Cortellazzo et al., (2019) found that digital leaders facilitate information exchange through technology. Schiuma et al., (2022) highlighted the role of digital leadership in promoting environmental awareness, while Bresciani et al., (2018) showed its positive impact on sustainability-oriented knowledge sharing. Theoretical implication: Strengthens digital leadership theory in the context of environmental management. Practical implication: Organizations need to develop digital competencies of leaders to enhance environmental knowledge sharing.

Impact of Green Leadership on Sustainable Performance

Green Leadership has a positive and significant effect on Sustainable Performance ($\beta = 0.164$, $t = 2.537$, $p = 0.011$). This result is consistent with several studies. Singh et al., (2020) found that green leadership contributes to better environmental performance. Mi et al., (2019) demonstrated its positive impact on green innovation performance. Iqbal et al., (2020) showed that green leadership enhances organizational sustainability, while Mittal & Dhar, (2016) highlighted its role in fostering green creativity and performance. Theoretical implication: Strengthens green leadership theory in the context of sustainable performance. Practical implication: Organizations should prioritize developing green leadership to enhance sustainable performance.

Impact of Digital Leadership on Sustainable Performance

Digital Leadership has a positive but non-significant effect on Sustainable Performance ($\beta = 0.151$, $t = 1.714$, $p = 0.087$). This finding contrasts with some existing literature. Bresciani et al., (2018) found a positive relationship between digital leadership and sustainable performance. Eller et al. (2020) demonstrated that digital leadership enhances organizational performance. However, Schiuma et al., (2022) suggested that the relationship might be more complex and mediated by other factors. Mergel et al., (2019) also highlighted the challenges in translating digital leadership directly into sustainable outcomes. Theoretical implication: Indicates that the relationship between Digital Leadership and Sustainable

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Performance may be more complex and requires further research. Practical implication: Organizations need to consider factors beyond digital leadership in efforts to improve sustainable performance.

Impact of Environmental Knowledge Sharing on Sustainable Performance

Environmental Knowledge Sharing positively and significantly influences Sustainable Performance ($\beta = 0.282$, $t = 5.146$, $p < 0.001$). This finding is supported by various studies. Liang et al., (2019) found that environmental knowledge sharing enhances green innovation performance. Singh & El-Kassar, (2019) demonstrated its positive impact on environmental performance. Agyabeng-Mensah et al., (2020) showed its role in improving sustainable performance in supply chains, while Yu et al., (2016) highlighted its importance in achieving eco-innovation. Theoretical implication: Strengthens knowledge management theory in the context of sustainability. Practical implication: Organizations need to create systems and culture that support environmental knowledge sharing to improve sustainable performance.

Impact of Technological Innovation on Sustainable Performance

Technological Innovation positively and significantly influences Sustainable Performance ($\beta = 0.258$, $t = 3.767$, $p < 0.001$). This finding is supported by several recent studies. Saunila et al., (2018) found that technological innovation drives sustainable performance in SMEs. Similarly, Ardito et al., (2018) demonstrated the positive impact of green technology innovation on firm performance. García-Sánchez et al., (2020) highlighted the role of technological innovation in enhancing corporate sustainability, while Lopes et al., (2017) showed its importance in achieving eco-innovation and sustainability. Theoretical implication: Strengthens innovation theory in the context of sustainability. Practical implication: Organizations need to invest in technological innovation to enhance their sustainable performance.

Moderating Effect of Technological Innovation on the Relationship between Environmental Knowledge Sharing and Sustainable Performance

Technological Innovation negatively and significantly moderates the relationship between Environmental Knowledge Sharing and Sustainable Performance ($\beta = -0.081$, $t = 3.612$, $p < 0.001$). This interesting finding suggests that at high levels of technological innovation, the impact of environmental knowledge sharing on sustainable performance decreases. While this specific moderation effect is not widely studied, it relates to broader literature on innovation and sustainability. Ghisetti & Rennings, (2014) found that not all types of environmental innovations lead to better economic performance. Hojnik & Ruzzier, (2016) highlighted the complexities in the relationship between eco-innovation and firm performance. Cainelli et al., (2020) discussed the potential trade-offs between different types of innovations in the context of sustainability, while Przychodzen et al., (2020) explored the sometimes-conflicting relationship between eco-innovation and financial performance. Theoretical implication: Reveals the complexity of interactions between knowledge sharing, technological innovation, and sustainable performance. Practical implication: Organizations need to balance their focus on technological innovation and environmental knowledge sharing to optimize sustainable performance.

Indirect Effect of Digital Leadership on Sustainable Performance through Environmental Knowledge Sharing

Digital Leadership has a positive and significant indirect effect on Sustainable Performance through Environmental Knowledge Sharing ($\beta = 0.114$, $t = 3.456$, $p = 0.001$). This finding is supported by various studies exploring the mediating role of knowledge sharing in leadership-performance relationships A. Iqbal et al., (2019) found that knowledge sharing mediates the relationship between transformational leadership and innovative work behavior. Similarly, S. H. Han et al., (2016) demonstrated the mediating role of knowledge sharing between transformational leadership and employee creativity. Masa'deh et al., (2016) showed that knowledge sharing mediates the impact of transformational leadership on job performance, while Le & Lei, (2019) highlighted its mediating role between transformational leadership and innovation performance. Theoretical implication: Expands understanding of the mechanisms through which Digital Leadership affects Sustainable Performance. Practical implication: Organizations should focus on

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enhancing environmental knowledge sharing to maximize the impact of digital leadership on sustainable performance.

Indirect Effect of Green Leadership on Sustainable Performance through Environmental Knowledge Sharing

Green Leadership has a positive and significant indirect effect on Sustainable Performance through Environmental Knowledge Sharing ($\beta = 0.074$, $t = 3.300$, $p = 0.001$). This result is supported by several studies. Singh et al., (2020) found that green transformational leadership indirectly influences green innovation performance through green knowledge sharing. Ansari et al., (2021) demonstrated that green human resource management practices, often driven by green leadership, indirectly affect environmental performance through green employee empowerment. Yin et al., (2021) showed that environmentally specific transformational leadership indirectly influences employees' green behavior through green mindfulness, while Saleem et al., (2020) highlighted the indirect effect of green transformational leadership on employees' green voice behavior through green self-efficacy. Theoretical implication: Enriches understanding of the mechanisms through which Green Leadership influences Sustainable Performance. Practical implication: Organizations need to ensure that their green leadership initiatives promote environmental knowledge sharing to enhance sustainable performance.

Research Implications

Theoretical Implications

Theoretical implications of this study emphasize the crucial roles of digital and green leadership in achieving organizational sustainability. The findings highlight environmental knowledge sharing as a key mechanism through which these leadership styles impact sustainable performance. By focusing on the indirect effects of leadership on sustainability via knowledge dissemination, the study enhances understanding of how leaders can strategically promote environmental awareness and practices. These insights advance leadership theory by integrating environmental considerations into leadership frameworks, contributing to the discourse on sustainable management in modern organizations.

Practical Implications

Practical implications of the study suggest actionable strategies for organizational leaders. Firstly, promoting a culture of environmental knowledge sharing can enhance sustainable performance. Organizations should invest in developing digital and green leadership skills to effectively manage environmental stewardship. Secondly, recognizing the role of technological innovation highlights the need for balanced investments in technology and environmental initiatives. Leaders should prioritize sustainable innovation that supports environmental knowledge sharing. Implementing these strategies can help organizations align leadership practices with sustainable development goals, thereby improving their environmental and social impact.

Limitations of This Study

The study's limitations include reliance on self-reported data, which may introduce response bias, and its focus on specific industries or regions, limiting generalizability. Future research could address these by employing diverse methodologies such as longitudinal studies or mixed-method approaches. Exploring additional moderators or mediators beyond technological innovation, and considering external factors like organizational culture or regulatory environments, could provide deeper insights into how leadership practices interact with broader socio-economic contexts to influence sustainability outcomes effectively.

Conclusion

This study reveals that digital leadership significantly enhances environmental knowledge sharing within organizations, akin to the positive impact of green leadership on the same. Environmental knowledge sharing, in turn, significantly influences sustainable performance. While direct effects of digital leadership on sustainable performance were not significant, an indirect effect through environmental knowledge

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sharing was notable. In contrast, green leadership directly and positively affects sustainable performance. Yet, the moderation by technological innovation suggests that high levels of innovation may weaken the positive relationship between environmental knowledge sharing and sustainable performance. These findings highlight the critical importance of reinforcing digital and green leadership while promoting a culture of environmental knowledge sharing to bolster organizational sustainability.

Credit Authorship Contribution Statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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