Digital Transformation empowers ESG Performance based on the Mediating Effect of Green Innovation

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Introduction:

ESG (Environmental, Social and Governance) considerations has gained significant attention in business globally due to increased awareness of environmental issues, social inequalities, and Corporate Governance failures (1). In Indian context also, a similar awakening is taking place amongst the corporates. Companies operating in India are increasingly recognizing the imperative nature of aligning their strategies and operations with ESG principles (2). Around the globe most of the developing countries have pledged to carbon neutrality and improving their ESG Performance for sustainability. Upholding the shared vision of a sustainable future for mankind, the Indian government is also dedicated to global climate governance through concrete actions, and has announced enhanced climate commitments including 50 percent of installed electric capacity from non-fossil fuel sources to reach 500 GW by 2030, reducing carbon intensity of the economy by 45 per cent by 2030 and to achieve the target of net zero emissions by 2070 (3). While there is a widespread discussions and research going on Digitalization and how it affects the ESG at the Global level but there is a limited understanding of how Indian companies are following this transformative journey. The present research aimed to highlight the impact of Digital Transformation on ESG Performance through the mediating effect of Green Innovation with special focus on green processes and green products in manufacturing companies in India.

Literature Review and Framework:

The manufacturing industry in India has emerged as a fast-growing sector owing to the rapidly increasing population in the country. Investments in the sector have been on the rise and initiatives like 'Make in India' aim to the South Asian country into a global manufacturing hub. The annual production growth rate in the manufacturing industry was 4.7 percent during fiscal year 2023 (Rathore Manya, Statista). According to the latest government data (2023), manufacturing sector's share in India's GDP is estimated at around 17 per cent currently (Virmani Arvind). The industry consumes a lot of energy and natural resources while producing waste that is detrimental to the environment. The shift towards sustainable manufacturing has already started, and Indian manufacturers are increasingly becoming conscious of how they can optimize resource and material usage, reduce emissions, and improve machine efficiency to minimize waste (Mallya Supriya, 2023).

Sun, H et.al (2023) commented that ESG performance has significant promotion and continuation effects on corporate reputation and the three dimensions of ESG performance (environmental, social and corporate governance) have synergistic effects in the promotion process. The research further indicates that Corporate transparency has a mediating effect on the relationship between ESG performance and corporate reputation and it gradually increases under the role of corporate transparency and there is a significant double threshold effect. Companies around the world started using digital technologies to modifying existing business processes, culture, and customer experiences to meet the ever-changing business and market expectations and requirements. The impact of enterprises' digital transformation strategy on their ESG performance is evident in the following aspects: First, enterprises with good performance in environmental responsibility are committed to capturing and solving public environmental problems, thus increasing the capital investment in undertaking environmental responsibility (Wang, L.; Chen et.al, 2021), Secondly, enterprises that perform well in ESG have a strong sense of social responsibility, which is reflected in the

organization's willingness to make strategic decisions on social responsibility (Yang, Q et.al 2020). Yang, P., Hao, X et.al (2024) in their research also analyses the impact of digital transformation on corporate environmental, social and governance (ESG) performance .

With the rapid development of the global digital economy, digital transformation has become a strategic choice that firms must use to respond to the above issues in changing times. According to the theory of innovation value chain (Hansen, M.T), digital transformation is a comprehensive digital innovation activity for the entire ecological network, including all stages of enterprise business activities. Therefore, business digitalization can be seen as the process from creative generation to commercial application carried out by enterprises in collaboration with green supply chain partners through digital technology. [Liu, Y.2020]. Based on the analysis of above aspects it is observed that, enterprise digital transformation has a positive impact on enterprise ESG performance. Hence, the following hypothesis is formed:

H_1: Digital Transformation has a positive impact on ESG Performance.

Green Innovation, which combines environmental protection and technological innovation, is a bridge between ecosystem construction and economic development (Sun et al., 2022). Green innovation is an important measure by which enterprises can achieve sustainable development goals, and has been widely recognized by all sectors of society. Actively carrying out green innovation can help enterprises build their green image and enhance their competitive advantages (Xie, X.M.et.al 2021). Green innovation is often related to product, process, or organizational changes that may create environmental burdens in the course of business operations aimed at designing the products that use less energy, require fewer raw materials to manufacture, have less adverse impact on the environment, and are easy to recycle. In order to improve ESG performance, enterprises can strengthen resource exchanges with suppliers on green materials and environmental protection technologies via platform digitalization to promote green process innovation and green product innovation (Khanra, S. 2022). A study conducted by Jun Dai et.al, 2023 reveals that in the era of the digital economy, companies strive to promote green innovation by enhancing their ESG performance, aiming to create new advantages for high-quality corporate development. The study reveals that good ESG performance significantly fosters green innovation. Additionally, digital transformation plays a positive moderating role in the relationship between ESG performance and green innovation. Sustainable and responsible companies factor in ESG goals when they digitally transform themselves. Researchers found that the higher the degree of implementation of digital transformation strategy, the better the enterprise ESG performance and the promotional role of enterprise green innovation is also crucial (Zhao Q et.al, 2023). Hence through implementing digital transformation, companies adopt technologies that support sustainable practices and reduces a business' impact on the environment, society and governance. (Wang, J et,al 2023), (Bist Sunit 2022). On the basis of analysis of above aspects following hypotheses is framed:

H_2: Green Innovation has a mediating effect on the relationship between Digital Transformation and ESG Performance

H_{2a}: Green Process Innovation has a mediating effect on the relationship between Digital Transformation and ESG Performance

H_{2b}: Green Product Innovation has a mediating effect on the relationship between Digital Transformation and ESG Performance

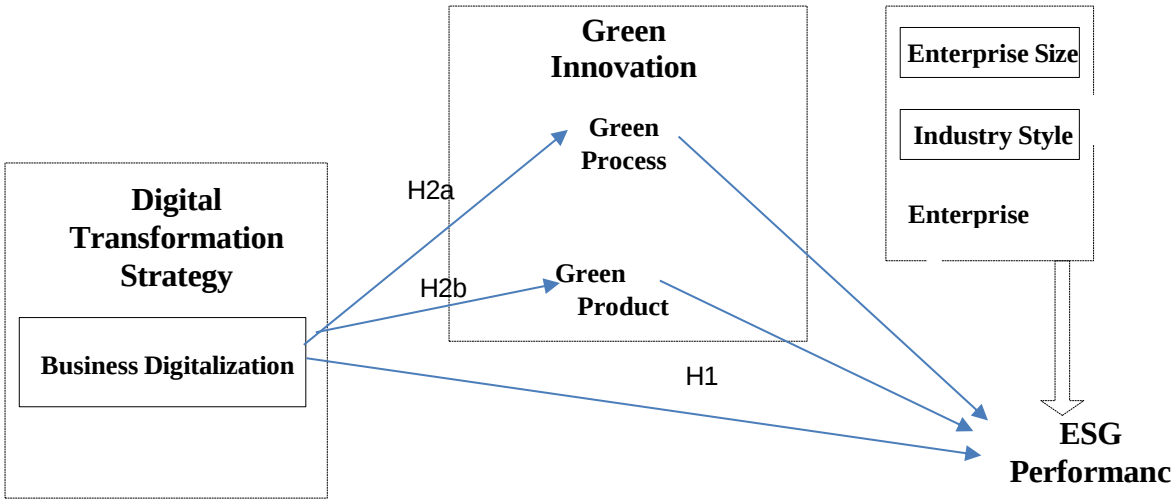

Figure 1: Research Framework

Methodology:

This study adopts a structured approach to data collection, focusing on large manufacturing enterprises through snowball sampling. While this method controls alumni and entrepreneur associations for access, it may introduce selection bias, limiting sample diversity. The use of online surveys ensures efficient distribution but may exclude firms less active in digital platforms. The study's three-stage data collection approach helps reduce common method bias by separating variables into distinct phases; however, reliance on self-reported data poses a risk of response bias. A total of 200 questionnaires were issued, with 124 valid responses, yielding an effective recovery rate of 62%. This sample size is sufficient for analysis, but non-response bias remains a concern. Secondary data sources such as corporate reports and regulatory databases enhance the study's credibility by supplementing primary data.

The research measures key constructs using a five-point Likert scale, ensuring consistency and comparability. The explanatory variable, Digital Transformation Strategy, is assessed through business digitalization dimensions, following validated scales. The explained variable, ESG Performance, incorporates environmental, social, and governance factors based on India's ESG rating system. The intermediary variable, Green Innovation, captures both green process and product innovation, reflecting sustainable manufacturing practices. Control variables include Enterprise Size, Industry Type, and Enterprise Age, which account for structural differences but may overlook market competition or regulatory influences. Future research could refine this model by integrating mixed methods or longitudinal data to analyze digital transformation's evolving impact on ESG performance. This study employs Confirmatory Factor Analysis (CFA) to ensure construct validity, with a Kaiser-Meyer-Olkin (KMO) value of 0.923 ($p < 0.001$). Since KMO > 0.9, this confirms the data's suitability for factor analysis and indicates strong correlations among variables. Additionally, the cumulative variance explained by the first factor is 20.924%, well below the 40% threshold, suggesting that common method bias is not a significant concern. To assess reliability, Cronbach's Alpha values were calculated for each variable, with all exceeding 0.6, meeting the general reliability threshold. The Enterprise ESG Performance (ESGP) scale exhibited the highest internal consistency ($\alpha = 0.946$), followed by Business Digitalization (BDG) at 0.921, Green Process Innovation (GPCI) at 0.936, and Green Product Innovation (GPDI) at 0.936. These high reliability scores confirm that the measurement instruments used are consistent and appropriate for further statistical analysis.

Results & Findings:

Table -1

Variables	Mean	Std. Deviation	BDG	GPCI	GPDI	ESGP
BDG	4.2894	0.72240	—			
GPCI	4.3025	0.75968	0.752 ***	—		
GPDI	4.2533	0.78290	0.756 ***	0.835 ***	—	
ESGP	4.3386	0.70184	0.785 ***	0.833 ***	0.724 ***	—

Table1 presents the mean, standard deviation, and Pearson correlation coefficients for the four key variables: Business Digitalization (BDG), Green Process Innovation (GPCI), Green Product Innovation (GPDI), and Enterprise ESG Performance (ESGP). The correlation analysis reveals that all variable pairs exhibit significant positive correlations ($p < 0.001$), indicating strong interrelationships between digital transformation, green innovation, and ESG outcomes. The highest correlation is observed between GPCI and ESGP ($r = 0.833$, $p < 0.001$), suggesting that green process innovation plays a crucial role in enhancing ESG performance.

Hypothesis Testing and Regression Analysis:

The results of regression analysis are shown in Table 2. Model 1, Model 2, were used to verify H_1 (direct effect). Model 3 and Model 4 were used to test H_2 (mediation effect).

Model 1: Direct Regression

Model 1 examined the direct impact of control variables treated them as independent variables such as enterprise size, industry type, and enterprise age on enterprise ESG performance. The regression analysis revealed that the R^2 values were too small, indicating that these factors alone were insufficient to explain variations in ESG performance.

Model 2: Impact of Business Digitalization on ESG Performance

Building on Model 1, business digitalization (BDG) was introduced as an independent variable in Model 2. The regression results showed that BDG had a significant positive effect on ESG performance ($\beta = 0.743$, $p < 0.001$). This confirms that business digitalization significantly enhances enterprise ESGP, thereby supporting Hypothesis 1.

Model 3: Mediating Role of Green Process Innovation (GPCI)

Model 3 explored the mediating effect of green process innovation (GPCI) on the relationship between digitalization and ESG performance. The results indicated that GPCI had a significant positive effect on ESG performance ($\beta = 0.487$, $p < 0.001$). Comparing the regression results of Model 2 and Model 3, the significance levels and coefficients of BDG decreased when GPCI was introduced. This suggests that GPCI partially mediates the impact of BDG on ESGP, thereby providing preliminary support for Hypotheses 2a.

Model 4: Mediating Role of Green Product Innovation (GPDI)

Model 4 tested the mediating effect of green product innovation (GPDI). Although the inclusion of GPDI caused a slight decrease in the significance levels of BD, GPDI itself did not exhibit a significant positive effect on ESG performance ($\beta = -0.100$, $p = 0.105$). As a result, Hypotheses 2b remain inconclusive and require further investigation. The regression analysis confirms that business digitalization positively influences enterprise ESG performance, with green process innovation acting as a partial mediator in these relationships. However, the mediating effect of green product innovation was not supported, highlighting the need for further research to explore its potential role in ESG performance.

Table 2: Hierarchical regression analysis

Variables	Model 1	Model 2	Model 3	Model 4
Constant	4.131 ***	1.091 **	0.527 **	0.526 **
Control Variables				
ES	0.065 ***	0.014	0.012	0.011
IS	0.054 *	0.016	0.01	0.009
EA	−0.039 *	−0.008	0.002	0.003
Independent Variables				
BDG	0.743 ***		0.289 ***	0.306 ***
Intermediary Variable				
GPCI	0.487 ***			0.540 ***
GPDI				−0.100
R^2	0.088	0.62	0.759	0.762
ΔR2	0.088	0.532	0.104	0.003
ΔF	7.072	306.795	93.823	2.65

Table-3: The results of bootstrap regression analysis.

DV	IV	Coeff	SE	LLCI	ULCI
GPC	ES	0.0000	0.0130	−0.0255	0.0256
	IS	0.0073	0.0184	−0.0289	0.0435
	EA	−0.189	0.0135	−0.0455	0.0077
	BD	0.7798	0.0489	0.6834	0.8762
GPD	ES	−0.0085	0.0135	−0.0345	0.0182
	IS	0.0028	0.0164	−0.0292	0.0360
	EA	−0.0050	0.0127	−0.0302	0.0195
	BD	0.8245	0.0506	0.7137	0.9126
ESG	ES	0.0141	0.0085	−0.0023	0.0315
	IS	0.0124	0.0129	−0.0135	0.0373
	EA	0.0020	0.0096	−0.0177	0.0199
	BD	0.3393	0.0650	0.2187	0.4747
	GPC	0.5177	0.0603	0.3949	0.6298
	ES	0.0165	0.0115	−0.0061	0.0388
	IS	0.0154	0.0162	−0.0171	0.0476
	EA	−0.0064	0.0118	−0.0300	0.0160
	BD	0.5154	0.0807	0.3586	0.6771
	GPD	0.2761	0.0670	0.1448	0.4090

Table 3 presents the bootstrap regression results examining the relationships among business digitalization (BDG), green process innovation (GPCI), green product innovation (GPDI), and enterprise ESG performance. The regression coefficients, standard errors (SE), and confidence intervals (LLCI, ULCI) provide insight into the statistical significance of these relationships. When GPCI was the dependent variable, BD showed a significant positive effect ($\beta = 0.7798$, SE = 0.0489, 95% CI [0.6834, 0.8762], $p < 0.001$), indicating that increased business digitalization enhances green

process innovation. Similarly, when GPDI was the dependent variable, BDG again exhibited a significant positive impact (β = 0.8245, SE = 0.0506, 95% CI [0.7137, 0.9126], p < 0.001), suggesting that digital transformation also fosters green product innovation. GPCI significantly influenced ESG performance (β = 0.5177, SE = 0.0603, 95% CI [0.3949, 0.6298], p < 0.001), confirming that advancements in green process innovation contribute positively to ESG performance. GPDI also had a positive effect on ESG performance (β = 0.2761, SE = 0.0670, 95% CI [0.1448, 0.4090], p < 0.001), suggesting that green product innovation enhances ESG outcomes, albeit to a lesser extent than green process innovation. BDG had a direct positive impact on ESG performance (β = 0.5154, SE = 0.0807, 95% CI [0.3586, 0.6771], p < 0.001). Additionally, BDG influenced ESG performance through GPCI (β = 0.3393, SE = 0.0650, 95% CI [0.2187, 0.4747], p < 0.001), confirming that GPCI serves as a mediator in this relationship. Enterprise size (ES), industry style (IS), and enterprise age (EA) were included as control variables. However, their regression coefficients were not statistically significant, as their confidence intervals contained zero in most cases. This suggests that these factors had a minimal direct influence on ESG performance compared to digitalization and green innovation variables.

Table 4: The results of the mediating effect test.

	Path	**Coeff**	**SE**	**t**	***p***	**LLCI**	**ULCI**	**Result**
H2a	BDG → GPCI → ESGP	0.7430	0.0424	17.5156	0.0000	0.6594	0.8266	Supported
H2b	BDG → GPDI → ESGP	0.5154	0.0601	8.5784	0.0000	0.3970	0.6338	Supported

Table 5 presents the results of the mediating effect test using 5000 bootstrap samples to examine the indirect impact of business digitalization (BDG) on ESG performance through green process innovation (GPCI) and green product innovation (GPDI). The 95% confidence interval for the indirect effect of BDG on ESG performance through GPCI was [0.6594, 0.8266]. Since the confidence interval did not include zero, this confirms that GPCI significantly mediates the relationship between BDG and ESGP (β = 0.7430, p < 0.001). Therefore, Hypothesis 2a and 2b was supported, indicating that business digitalization enhances ESG performance by promoting green process innovation.

Discussion

The study's findings demonstrate how digital transformation has a major influence on ESG performance in the Indian manufacturing sector, with green innovation acting as a key moderator. The current analysis demonstrates a robust positive relationship between ESG performance (ESGP) and business digitalization (BDG). It demonstrates how digital technology have the capacity to revolutionize and promote sustainable business practices. These findings support previous studies (Wang, L.; Chen et al., 2021; Yang, Q et al., 2020) that highlight how digitization can improve governance standards, social duty, and environmental responsibility.

The present study shows that Green Process Innovation significantly mediates the relationship between digital transformation and ESG performance, suggesting that companies that integrate digital technologies into their green processes achieve higher ESG outcomes. This aligns with the innovation value chain theory (Hansen, M.T.) and the research by Liu, Y. (2020), which posit that digitalization drives comprehensive innovation across business activities.

It's interesting to note that although green product innovation (GPDI) also had a positive correlation with ESG performance, this association was less strong than that of GPCI. This might be explained by the fact that green product creation is still in its infancy in Indian manufacturing, where businesses may put process efficiency ahead of product innovations because of financial limitations and regulatory demands.

Enterprise age, industry type, and size all had little direct impact on ESG performance, indicating that green innovation and digital transformation are more important factors. According to this research, implementing sustainable practices and digital technology can significantly improve ESG results.

Conclusion

This study provides empirical evidence on the positive impact of digital transformation on ESG performance in Indian manufacturing companies, with green innovation acting as a mediating factor. The findings validate that digitization promotes sustainable business practices through green process and product innovations in addition to increasing operational efficiencies.

Green process innovation plays a more substantial mediating role than green product innovation, indicating that process-oriented digital strategies are more effective in driving ESG performance. This insight is crucial for policymakers and business leaders aiming to promote sustainable development within the manufacturing sector.

The present study has major limitation, as it is based on primarily collected data and may be possible selection bias through snowball sampling, highlighting area for future research. Deeper understanding of the changing dynamics of digital transformation and ESG performance may be possible through longitudinal research and mixed-method approaches. Furthermore, investigating regulatory influences and industry-specific issues may enhance our comprehension of sustainable practices in various industrial contexts.

In conclusion, the integration of digital technologies with green innovation strategies is imperative for Indian manufacturers striving to enhance their ESG performance and contribute to the global sustainability agenda.

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