

Technological Innovation and Green Process Innovation: A Serial Mediation Model of Information Quality and Green Work Engagement

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Abstract

Growing environmental concerns and increasing sustainability expectations have encouraged manufacturing organizations to adopt technological innovations that support environmentally responsible production processes. However, the mechanisms through which technological innovation enhances green process innovation remain insufficiently understood. This study investigates the direct effect of technological innovation on green process innovation and examines the serial mediating roles of information quality and green work engagement in Malaysian manufacturing organizations. Drawing upon the Resource-Based View (RBV) and the Ability–Motivation–Opportunity (AMO) framework, a conceptual model was developed and empirically tested. A quantitative cross-sectional survey was conducted among employees of manufacturing organizations in Malaysia, and 391 responses were collected using a convenience sampling technique. The collected data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. The findings indicate that technological innovation positively influences information quality and green process innovation. Information quality significantly enhances both green work engagement and green process innovation, while green work engagement positively contributes to green process innovation. Furthermore, the results support the mediating role of information quality and the serial mediating effects of information quality and green work engagement in the relationship between technological innovation and green process innovation. These findings highlight the importance of integrating technological capabilities with high-quality organizational information and employees' environmental engagement to achieve sustainable manufacturing practices.

Keywords: technological innovation; information quality; green work engagement; green process innovation; sustainability; Malaysia

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1. Introduction

Growing environmental concerns, stricter regulatory requirements, and increasing stakeholder expectations have encouraged manufacturing organizations to adopt sustainable production practices (Baah et al., 2021). Green process innovation, which focuses on reducing environmental impacts through cleaner production processes, efficient resource utilization, recycling initiatives, and environmentally friendly manufacturing technologies, has become an important strategic capability for firms seeking long-term competitiveness and environmental sustainability (Chiou et al., 2011). Despite growing interest in green innovation, many manufacturing organizations still face challenges in identifying the organizational mechanisms through which technological innovation contributes to green process innovation (Zhang et al., 2020).

Technological innovation is recognized as a primary driver of organizational competitiveness and sustainable development (Hamdouna & Khmelyarchuk, 2025). By investing in research and development, adopting

advanced production technologies, implementing innovative manufacturing methods, and utilizing digital marketing technologies, organizations can improve operational efficiency while reducing environmental impacts (Chege & Wang, 2020). In the manufacturing sector, technological innovation enables firms to optimize production processes, minimize resource consumption, reduce waste generation, and improve environmental performance (Li et al., 2023). However, technological innovation alone may not automatically translate into successful green process innovation. According to Martínez-Peláez et al. (2023), understanding the organizational mechanisms that transform technological capabilities into environmentally sustainable processes remains an important research challenge.

Information quality has emerged as an important organizational resource that enhances managerial decision-making and operational performance (Biswas et al., 2024). High-quality information is characterized by accuracy, relevance, completeness, and timeliness, enabling managers and employees to make informed decisions regarding production planning, environmental management, and resource utilization (Zia & Alzahrani, 2022). In manufacturing organizations, quality information generated through technological systems supports monitoring production activities, identifying environmental inefficiencies, and implementing sustainable manufacturing practices (Cioffi et al., 2020). Consequently, organizations with stronger technological capabilities are likely to generate higher-quality information, which subsequently supports green process innovation initiatives.

Beyond technological and informational capabilities, employee engagement in environmental activities represents another important determinant of organizational sustainability (Alshukri et al., 2024). Employee participation and engagement in working for the environment. Green work engagement refers to a positive, fulfilling, work-related psychological state characterized by enthusiasm, dedication, and vigor toward environmentally responsible work activities (Aboramadan, 2022). Employees who are highly engaged in environmental initiatives are more likely to participate actively in sustainability programs, support green manufacturing practices, and contribute innovative ideas for environmentally friendly production processes (Begum et al., 2022). Therefore, technological innovation may enhance employees' environmental engagement through improved access to reliable information, digital systems, and effective communication, ultimately facilitating green process innovation.

Although previous studies have separately examined the relationships between technological innovation and sustainability, information quality and organizational performance, and green work engagement and employee green behavior, limited empirical research has simultaneously investigated the sequential mechanisms through which technological innovation influences green process innovation. In particular, little evidence exists regarding whether information quality enhances employees' green work engagement, thereby creating a serial mediation pathway that strengthens green process innovation within manufacturing organizations (Jnaneswar, 2024). Addressing this gap contributes to a better understanding of how technological resources translate into sustainable manufacturing outcomes.

The present study develops and tests a serial mediation model in which technological innovation influences green process innovation directly and indirectly through information quality and green work engagement. Specifically, the study proposes that technological innovation improves organizational information quality, which in turn enhances employees' green work engagement and ultimately promotes green process innovation. The proposed framework integrates technological capability, information management, employee engagement, and environmental innovation into a comprehensive model that extends current sustainability literature.

2. Literature Review and Hypothesis Development

2.1. Theoretical Foundation

This study is grounded primarily in the Resource-Based View (RBV), which argues that organizations achieve sustainable competitive advantage by developing valuable, rare, inimitable, and non-substitutable resources and capabilities. Technological innovation represents a strategic organizational capability that enables firms

to improve operational efficiency, strengthen information management, and develop environmentally sustainable production processes (Khan et al., 2022). However, RBV also suggests that technological resources alone do not create superior organizational outcomes. Instead, complementary organizational resources, including high-quality information and engaged employees, are required to fully exploit technological capabilities (Ahn et al., 2022).

The proposed research model also draws upon the Ability–Motivation–Opportunity (AMO) framework, which explains how employees' abilities, motivation, and opportunities influence organizational performance. Technological innovation enhances employees' ability by providing advanced technologies and reliable information systems, while information quality improves employees' understanding of environmental objectives (Firasati et al., 2024). Consequently, employees become more engaged in green work activities, ultimately contributing to green process innovation. Together, RBV and AMO provide a comprehensive theoretical explanation for understanding how technological innovation is transformed into sustainable manufacturing practices through organizational information quality and employees' green work engagement (Waseem et al., 2025).

2.2. Technological Innovation and Green Process Innovation

Technological innovation refers to an organization's capability to develop and implement new technologies, production methods, research and development activities, and innovative marketing practices that improve organizational performance (Chege & Wang, 2020). In manufacturing organizations, technological innovation facilitates automation, efficient production planning, resource optimization, and cleaner manufacturing processes (Sahoo & Lo, 2022). These capabilities enable firms to reduce waste generation, improve energy efficiency, minimize pollution, and enhance environmental sustainability. Green process innovation refers to improvements in production processes that reduce environmental impacts through efficient resource utilization, recycling, renewable technologies, and environmentally friendly manufacturing systems (Chiou et al., 2011). Organizations adopting advanced technologies are better positioned to redesign production systems and implement environmentally sustainable manufacturing practices (Hegab et al., 2023). Chege and Wang (2020) demonstrated that technological innovation significantly improves firms' environmental sustainability practices and organizational performance. Similarly, manufacturing firms investing in research and development are more likely to adopt environmentally friendly production technologies that support green process innovation (Bataineh et al., 2024). Thus, the following hypothesis is proposed.

H1: Technological innovation influences green process innovation.

2.3. Technological Innovation and Information Quality

Information quality refers to the accuracy, completeness, relevance, and usefulness of information generated by organizational information systems (Zia & Alzahrani, 2022). High-quality information supports managerial decision-making, operational coordination, and organizational learning. Technological innovation substantially improves organizational information quality through digital technologies, integrated information systems, automation, cloud computing, and real-time data analytics (Al-Qerem et al., 2025). Manufacturing organizations adopting advanced technologies can collect, process, and disseminate more accurate and timely information, thereby improving decision quality across production and environmental management functions (Atieh et al., 2023). Zia and Alzahrani (2022) reported that technology-enabled information systems significantly improve information quality and organizational effectiveness. Thus, this study proposes the following hypothesis.

H2: Technological innovation influences information quality.

2.4. Information Quality and Green Work Engagement

Green work engagement refers to a positive psychological state characterized by employees' vigor, dedication, enthusiasm, and absorption in environmentally related work activities (Aboramadan, 2022). Employees who

receive accurate, timely, and meaningful environmental information are better able to understand organizational sustainability objectives and actively participate in green initiatives (Jamil et al., 2023). High-quality information reduces uncertainty, improves communication, enhances employees' environmental awareness, and strengthens confidence in organizational sustainability programs (Huda, 2024). When employees clearly understand environmental goals and receive reliable information supporting green practices, they become more motivated to engage in environmentally responsible behaviors (Ercantan & Eyupoglu, 2022). Aboramadan (2022) argued that organizational practices supporting environmental sustainability positively influence employees' green work engagement. Likewise, information quality enhances employees' ability to perform environmental tasks effectively by providing the knowledge needed to implement green initiatives successfully (Ahmad et al., 2023). Thus, the following hypothesis is proposed.

H3: Information quality influences green work engagement.

2.5. Green Work Engagement and Green Process Innovation

Green work engagement represents employees' emotional, cognitive, and behavioral commitment toward environmental responsibilities within the workplace (Karatepe et al., 2022). Engaged employees devote greater effort to identifying opportunities for environmental improvement, supporting sustainability initiatives, and implementing environmentally friendly production practices (Umair et al., 2024). Employees with high levels of green work engagement actively contribute ideas to reduce waste, conserve resources, improve production efficiency, and implement cleaner manufacturing technologies (Li et al., 2023). Their proactive participation facilitates organizational learning and continuous environmental improvement, ultimately strengthening green process innovation. Aboramadan (2022) showed that employees with higher green work engagement exhibit stronger environmental behaviors that contribute to organizational sustainability outcomes. Consequently, manufacturing organizations with highly engaged employees are more likely to achieve successful green process innovation. Thus, the following hypothesis is proposed.

H4: Green work engagement influences green process innovation.

2.6. Information Quality and Green Process Innovation

Information quality provides managers and employees with reliable information necessary for identifying environmental problems, evaluating production efficiency, monitoring resource utilization, and implementing sustainable manufacturing decisions (Karim et al., 2025). High-quality information enables organizations to develop environmentally friendly production processes based on accurate operational data (Tian et al., 2022). Manufacturing organizations possessing accurate environmental information can better identify opportunities for waste reduction, energy conservation, recycling, and process redesign. According to Lu & Li (2023), Information quality is an important organizational capability that supports green innovation. Therefore, manufacturing organizations with superior information quality are expected to exhibit stronger green process innovation. Thus, the following hypothesis is proposed.

H5: Information quality influences green process innovation.

2.7. The Mediating Role of Information Quality

Although technological innovation provides organizations with advanced technological capabilities, these capabilities create environmental value only when they generate reliable information that supports effective managerial and operational decisions (Jum'a et al., 2024). Technological innovation improves organizational information systems, which subsequently enhance environmental planning and sustainable manufacturing practices. According to RBV, complementary organizational resources strengthen the value created by technological capabilities (Ahn et al., 2022). Information quality therefore represents an important mechanism through which technological innovation contributes to green process innovation. Accordingly, information quality is expected to mediate the relationship between technological innovation and green process innovation (Ali, 2023). Thus, the following hypothesis is proposed.

H6: Information quality mediates the relationship between technological innovation and green process innovation.

2.8. The Serial Mediating Roles of Information Quality and Green Work Engagement

The proposed model suggests a sequential mechanism through which technological innovation enhances green process innovation. First, technological innovation improves organizational information quality by generating accurate, timely, and relevant information for environmental decision-making (Hamdat et al., 2024). Second, improved information quality increases employees' understanding of organizational environmental objectives, thereby enhancing their green work engagement (Karatepe et al., 2022). Finally, highly engaged employees actively support environmentally responsible production practices that contribute to green process innovation (Begum et al., 2022). This sequence aligns with both the Resource-Based View and the Ability–Motivation–Opportunity framework. Technological innovation provides organizational capability, information quality strengthens employees' ability to perform environmental tasks, and green work engagement motivates employees to implement environmentally sustainable manufacturing practices (Abdelwahed, 2025). Therefore, technological innovation is expected to influence green process innovation indirectly through the sequential mediating effects of information quality and green work engagement. Thus, the following hypothesis is proposed.

H7: Information quality and green work engagement serially mediate the relationship between technological innovation and green process innovation.

Figure 1 presents the research model.

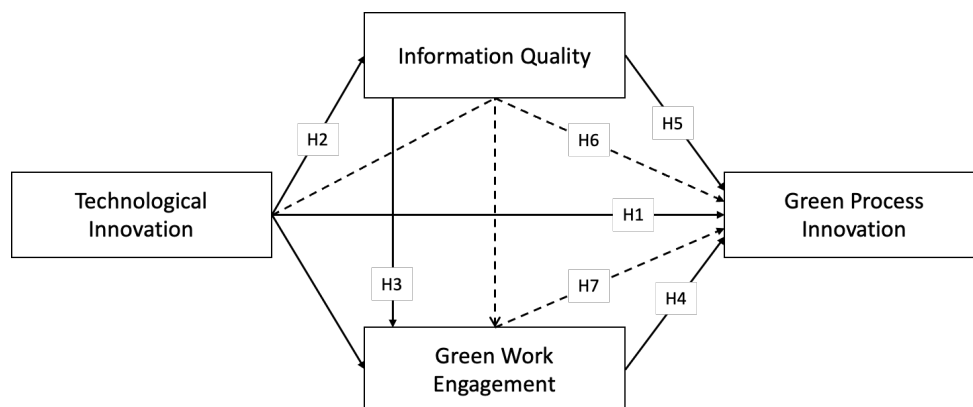


Figure 1. Research model.

3. Methodology

3.1. Research Design

This study employed a quantitative research design with a cross-sectional survey approach to investigate the relationships among technological innovation, information quality, green work engagement, and green process innovation in Malaysian manufacturing organizations. A quantitative approach was appropriate because it enables empirical examination of theoretical relationships among multiple latent constructs and supports hypothesis testing using structural equation modeling. The cross-sectional design allowed data to be collected from respondents at a single point in time, providing an efficient way to capture employees' perceptions of technological innovation and environmental management practices within their organizations.

3.2. Sample and Data Collection

The target population comprised employees working in manufacturing organizations located in Malaysia. Employees were selected as respondents because they possess firsthand knowledge of their organizations'

technological capabilities, information management systems, environmental initiatives, and operational practices. Data were collected in April 2026 using a structured, self-administered questionnaire distributed electronically or in print, depending on organizational preference. The study used convenience sampling because respondents were accessible and willing to participate. Before completing the questionnaire, respondents were informed of the research objectives and assured that participation was entirely voluntary. They were also informed that all responses would remain anonymous and confidential and would be used solely for academic research purposes.

3.3. Measurement of Variables

The measurement instrument consisted of four established constructs adapted from previous empirical studies. Technological innovation was measured using nine items adapted from Chege and Wang (2020), capturing organizational investment in research and development, adoption of new production technologies, innovative manufacturing methods, and technology-enabled marketing practices. Information quality was measured using three items adapted from Zia and Alzahrani (2022), assessing the accuracy, adequacy, and usefulness of organizational information. Green work engagement was measured using six items adopted from Aboramadan (2022), reflecting employees' enthusiasm, dedication, vigor, and involvement in environmentally related work activities. Green process innovation was measured using five items adapted from Chiou et al. (2011) to evaluate environmentally sustainable production practices such as resource conservation, recycling, renewable technologies, and environmentally friendly process redesign. All questionnaire items were measured using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

3.4. Data Analysis

The collected data were analyzed using SmartPLS 4 following the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique. PLS-SEM was selected because it suits complex research models with multiple latent variables, mediation effects, and predictive relationships while imposing minimal assumptions about data normality. The analysis was conducted in two stages. First, the measurement model was assessed by evaluating indicator reliability, internal consistency reliability through Cronbach's alpha and composite reliability, convergent validity using the average variance extracted (AVE), and discriminant validity. Second, the structural model was evaluated by examining collinearity, path coefficients, and coefficients of determination (R^2). Hypotheses were tested using the bootstrapping procedure with 5,000 resamples, and the significance of direct, indirect, and serial mediation effects was determined based on bias-corrected bootstrap confidence intervals.

3.5. Ethical Considerations

The study adhered to established ethical principles for research involving human participants. Prior to data collection, respondents were informed of the purpose of the study and provided with information regarding the voluntary nature of their participation. No personally identifiable information was collected, and respondents were assured that their identities and responses would remain confidential. Participation was entirely voluntary, and respondents were free to withdraw from the survey at any stage without penalty. The collected data were used exclusively for academic research and reported only in aggregate form.

4. Results

Among the 391 respondents, 238 (60.9%) were male and 153 (39.1%) were female. The largest age group was 30–39 years (39.9%), followed by 40–49 years (27.9%), below 30 years (21.0%), and 50 years and above (11.2%). Regarding educational attainment, the majority of respondents held a bachelor's degree (51.4%), while 24.3% possessed a diploma, 19.4% held a master's degree, and 4.9% had obtained a doctoral degree. With respect to organizational experience, 38.1% of the respondents had 5–10 years of working experience, followed by 25.1% with less than five years, 22.3% with 11–15 years, and 14.5% with more than fifteen years of experience. Most respondents occupied non-managerial positions (56.8%), followed by supervisors (21.5%), middle managers

(14.3%), and senior managers (7.4%). Participants represented a diverse range of manufacturing industries, with the largest proportion coming from the electrical and electronics sector (26.6%), followed by the food and beverage industry (19.4%), automotive manufacturing (15.6%), chemical and pharmaceutical manufacturing (12.5%), machinery and equipment manufacturing (11.0%), and other manufacturing sectors (14.9%).

Table 1. Demographic profile of respondents (n=391).

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	238	60.9
	Female	153	39.1
Age (Years)	Below 30	82	21.0
	30–39	156	39.9
	40–49	109	27.9
	50 years and above	44	11.2
Educational Level	Diploma	95	24.3
	Bachelor's Degree	201	51.4
	Master's Degree	76	19.4
	Doctorate	19	4.9
Organizational Experience	Less than 5 years	98	25.1
	5–10 years	149	38.1
	11–15 years	87	22.3
	More than 15 years	57	14.5
Job Position	Non-managerial Employee	222	56.8
	Supervisor	84	21.5
	Middle Management	56	14.3
	Senior Management	29	7.4
Manufacturing Sector	Electrical & Electronics	104	26.6
	Food & Beverage	76	19.4
	Automotive	61	15.6
	Chemical & Pharmaceutical	49	12.5
	Machinery & Equipment	43	11.0
	Others	58	14.9

Table 2 presents the measurement model assessment. The outer loadings range from 0.748 to 0.886, exceeding the commonly recommended minimum threshold of 0.70. This indicates that all measurement items have satisfactory indicator reliability and adequately represent their respective constructs. The reliability results also demonstrate satisfactory internal consistency. Cronbach's alpha values range from 0.726 to 0.831, while composite reliability values range from 0.742 to 0.829, all exceeding the recommended threshold of 0.70. Furthermore, the AVE values range from 0.523 to 0.646, which are above the minimum acceptable value of 0.50. Therefore, the constructs demonstrate adequate convergent validity, indicating that each construct explains more than half of the variance in its indicators.

Table 2. Measurement model assessment.

Construct	Code	Measurement Item	Outer Loading	Cronbach's α	Composite Reliability	Average Variance Extracted
Technological Innovation (TI)	TI1	"Our company invested in research and development to produce quality products"	0.812	0.831	0.742	0.646
	TI2	"Our company used new technology in the production process"	0.845			
	TI3	"Our company used new methods/procedures in production and service delivery"	0.831			
	TI4	"Our company used new technology in marketing new products"	0.864			
	TI5	"Our company market share has increased due to the use of new technology in marketing"	0.853			
	TI6	"Using technology, we pay only for what we use"	0.776			
	TI7	"Customization using technology is easy"	0.789			
	TI8	"When we use technology, we find it difficult to integrate existing work with web-based services"	0.748			

Construct	Code	Measurement Item	Outer Loading	Cronbach's α	Composite Reliability	Average Variance Extracted
Information Quality (IQ)	TI9	"Performing many tasks together using technology takes too much of my time"	0.771	0.742	0.805	0.561
	IQ1	"E-marketing platforms provide output that is exactly what I need"	0.879			
	IQ2	"E-marketing platforms provide sufficient information to enable me to sell products"	0.886			
	IQ3	"E-marketing platforms provide accurate information"	0.852			
Green Work Engagement (GWE)	GWE1	"My environmental-related tasks inspire me"	0.842	0.726	0.742	0.629
	GWE2	"I am proud of the environmental work that I do"	0.861			
	GWE3	"I am deeply involved in my environmental work"	0.847			
	GWE4	"I am enthusiastic about my environmental tasks at my job"	0.878			
	GWE5	"I feel happy when working intensely on environmental tasks"	0.853			
	GWE6	"Environmental tasks at my job make me feel bursting with energy"	0.843			
Green Process Innovation (GPI)	GPI1	"Less consumption of natural resources during production"	0.829	0.804	0.829	0.523
	GPI2	"Recycling, reusing, and remanufacturing resources"	0.852			
	GPI3	"Focus on using renewable technology"	0.871			
	GPI4	"Redesigning manufacturing and logistics processes for environmental effectiveness"	0.846			
	GPI5	"Redesigning products/services according to environmental criteria"	0.857			

Table 3 presents the Fornell–Larcker criterion for discriminant validity. The diagonal values, representing the square root of AVE, are 0.804 for TI, 0.872 for IQ, 0.854 for GWE, and 0.850 for GPI. In each case, the diagonal value is higher than the corresponding correlations with the other constructs. The inter-construct correlations range from 0.541 to 0.672, whereas the square roots of AVE range from 0.804 to 0.872. Thus, the Fornell–Larcker criterion is satisfied, confirming that the four constructs demonstrate adequate discriminant validity and are empirically distinct from one another.

Table 3. Discriminant validity (Fornell-Larcker Criterion).

Construct	TI	IQ	GWE	GPI
Technological Innovation (TI)	0.804			
Information Quality (IQ)	0.582	0.872		
Green Work Engagement (GWE)	0.541	0.636	0.854	
Green Process Innovation (GPI)	0.603	0.598	0.672	0.850

Table 4 reports the direct path coefficients and hypothesis-testing results. All five hypothesized direct relationships are statistically significant at $p < 0.001$, and therefore all direct hypotheses (H1–H5) are supported. H1: Technological innovation has a positive and significant effect on green process innovation ($\beta = 0.231$, $t = 4.125$, $p < 0.001$). This indicates that higher levels of technological innovation are associated with greater green process innovation. H2: Technological innovation has a strong positive and significant effect on information quality ($\beta = 0.618$, $t = 14.372$, $p < 0.001$), suggesting that technological innovation is positively associated with the quality of information available through organizational systems. H3: Information quality positively and significantly influences green work engagement ($\beta = 0.544$, $t = 10.667$, $p < 0.001$). This indicates that better information quality is associated with greater employee engagement in environmental-related work. H4: Green work engagement has a positive and significant effect on green process innovation ($\beta = 0.381$, $t = 6.458$, $p < 0.001$), indicating that employees' engagement in green-related work is positively associated with green process innovation. H5: Information quality also has a positive and significant direct effect on green process innovation ($\beta = 0.214$, $t = 3.963$, $p < 0.001$). Among the direct relationships, the strongest effect is

observed between technological innovation and information quality ($\beta = 0.618$), followed by information quality and green work engagement ($\beta = 0.544$).

Table 4. Path coefficients (Direct).

Hypothesis	Direct Paths	Direct Effect (β)	t-value	p-value	Decision
H1	Technological Innovation $\rightarrow$ Green Process Innovation	0.231	4.125	< 0.001	Supported
H2	Technological Innovation $\rightarrow$ Information Quality	0.618	14.372	< 0.001	Supported
H3	Information Quality $\rightarrow$ Green Work Engagement	0.544	10.667	< 0.001	Supported
H4	Green Work Engagement $\rightarrow$ Green Process Innovation	0.381	6.458	< 0.001	Supported
H5	Information Quality $\rightarrow$ Green Process Innovation	0.214	3.963	< 0.001	Supported

Table 5 presents the indirect effects and provides evidence for the proposed mediation relationships. Both indirect paths are statistically significant at $p < 0.001$, supporting H6 and H7. For H6, Technological innovation has a significant indirect effect on green process innovation through information quality ($\beta = 0.132$, $t = 3.824$, $p < 0.001$). This indicates that technological innovation contributes to green process innovation partly by improving information quality. For H7, technological innovation has a significant sequential indirect effect on green process innovation through information quality $\rightarrow$ green work engagement ($\beta = 0.128$, $t = 4.517$, $p < 0.001$). This suggests that technological innovation can contribute to green process innovation by improving information quality, which in turn is associated with greater green work engagement.

Table 5. Path coefficients (Indirect).

Hypothesis	Indirect Paths	Indirect Effect (β)	t-value	p-value	Decision
H6	Technological Innovation $\rightarrow$ Information Quality $\rightarrow$ Green Process Innovation	0.132	3.824	< 0.001	Supported
H7	Technological Innovation $\rightarrow$ Information Quality $\rightarrow$ Green Work Engagement $\rightarrow$ Green Process Innovation	0.128	4.517	< 0.001	Supported

The R^2 values in Figure 2 indicate the proportion of variance in each endogenous construct that is explained by its predictor(s). For information quality, the r^2 value is 0.382, indicating that technological innovation explains 38.2% of the variance in information quality. The remaining 61.8% of the variance is attributable to other factors not included in the model. This represents moderate explanatory power. For green work engagement, the r^2 value is 0.296, indicating that information quality explains 29.6% of the variance in green work engagement. The remaining 70.4% is explained by factors outside the proposed model. Thus, the model demonstrates weak-to-moderate explanatory power for green work engagement. For green process innovation, the r^2 value is 0.641, showing that technological innovation, information quality, and green work engagement collectively explain 64.1% of the variance in green process innovation. The remaining 35.9% is attributable to other factors not incorporated into the model. This indicates moderate-to-substantial explanatory power and suggests that the predictors collectively explain green process innovation.

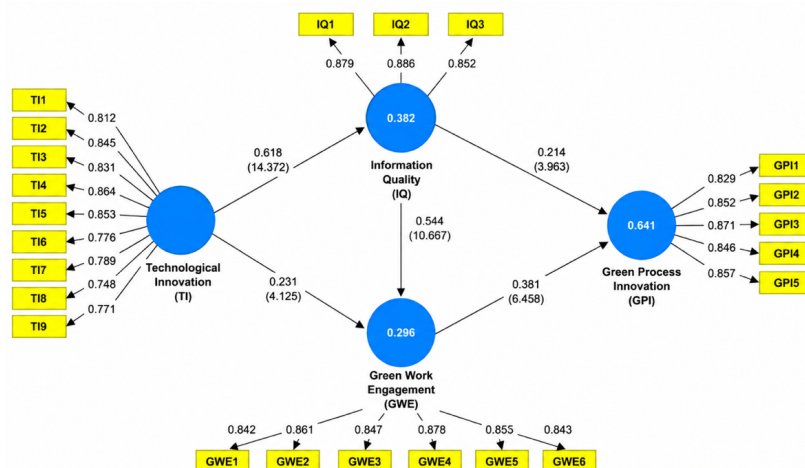


Figure 2. Structural model.

5. Discussion

This study investigated the effect of technological innovation on green process innovation through the mediating roles of information quality and green work engagement among manufacturing organizations in Malaysia. The findings provide empirical evidence that technological innovation enhances green process innovation both directly and indirectly through sequential organizational mechanisms. The results support the proposed theoretical framework based on the Resource-Based View (RBV) and the Ability–Motivation–Opportunity (AMO) framework, suggesting that technological capabilities create greater environmental value when accompanied by high-quality information and employees' active engagement in environmental activities.

The first hypothesis proposed that technological innovation positively influences green process innovation. The results support this relationship, indicating that manufacturing firms investing in research and development, advanced production technologies, innovative manufacturing methods, and digital technologies are better able to implement environmentally sustainable production processes (Yin et al., 2022). These findings are consistent with Chege and Wang (2020), who argued that technological innovation strengthens firms' environmental sustainability practices and organizational performance. Likewise, the findings support Chiou et al. (2011), who demonstrated that technological capabilities facilitate cleaner production, efficient resource utilization, recycling initiatives, and environmentally friendly manufacturing processes. The results suggest that Malaysian manufacturing organizations can achieve greater environmental sustainability by continuously investing in technological advancement.

The findings also reveal that technological innovation significantly improves information quality. This result indicates that organizations adopting advanced technologies generate more accurate, timely, relevant, and reliable information to support operational and environmental decision-making. According to Okuyelu et al. (2024), advanced manufacturing technologies enable firms to collect and process real-time operational data, thereby improving production planning and environmental monitoring. This finding is consistent with Zia and Alzahrani (2022), who emphasized that technology-enabled information systems improve information quality and organizational effectiveness. Within Malaysian manufacturing organizations, enhanced information quality appears to be an important organizational capability that supports sustainable manufacturing practices.

The study further demonstrates that information quality positively influences green work engagement. Employees who receive accurate and meaningful environmental information better understand organizational sustainability objectives and become more committed to environmentally responsible work practices (Bashirun et al., 2025). High-quality information reduces uncertainty, improves communication, and enables employees to participate actively in green initiatives. This finding extends Aboramadan (2022) by showing that information quality is an important organizational resource that strengthens employees' psychological engagement in environmental activities. Consequently, manufacturing organizations should ensure that environmental information is accurate, accessible, and timely to encourage greater employee participation in sustainability initiatives.

Consistent with expectations, green work engagement significantly enhances green process innovation. According to the Sethumadhavan et al. (2025), employees who are enthusiastic, dedicated, and highly involved in environmental tasks actively contribute innovative ideas for improving manufacturing processes, reducing waste, conserving natural resources, and implementing environmentally friendly technologies. These findings align with Aboramadan (2022), who reported that employees with stronger green work engagement are more likely to demonstrate environmental behaviors that support organizational sustainability. The results highlight the importance of employee participation in transforming organizational sustainability strategies into practical manufacturing improvements.

The study additionally found that information quality directly contributes to green process innovation. Accurate, reliable organizational information enables managers to identify production inefficiencies, monitor environmental performance, evaluate resource use, and make informed decisions about cleaner production

technologies (Hegab et al., 2023). This finding suggests that information quality is not merely a supporting organizational resource but also a direct driver of environmental innovation. Manufacturing firms that can use high-quality information implement environmentally sustainable production processes more effectively than organizations with poor information systems (Miao & Zhao, 2023).

The mediation analysis provides further theoretical insights. Information quality significantly mediates the relationship between technological innovation and green process innovation, indicating that technological investments create environmental value partly by improving organizational information systems. This finding supports the Resource-Based View, which argues that technological resources generate sustainable competitive advantage when combined with complementary organizational capabilities. Therefore, organizations should not focus exclusively on technology acquisition but should also ensure that technological systems produce accurate and actionable information for environmental decision-making.

More importantly, the results support the proposed serial mediation model involving information quality and green work engagement. Technological innovation first improves information quality, which subsequently enhances employees' green work engagement and ultimately promotes green process innovation. This sequential relationship confirms that technological innovation influences environmental sustainability through both organizational and human resource mechanisms. The findings extend previous research by integrating technological capability, information management, and employee engagement into a unified framework explaining green process innovation. The results also align with the AMO framework, which suggests that employees become more effective contributors to organizational performance when organizations provide the abilities, motivation, and opportunities needed to perform environmentally responsible work.

5.1. Theoretical Implications

This study makes several important theoretical contributions. First, it extends the Resource-Based View by demonstrating that information quality and green work engagement function as complementary organizational capabilities through which technological innovation enhances green process innovation. Second, the study contributes to the green innovation literature by identifying information quality as an important organizational mechanism that has received limited empirical attention in previous sustainability research. Third, by validating the serial mediation model, the study integrates technological capability, information management, employee engagement, and green innovation into a comprehensive framework that advances understanding of organizational sustainability within the manufacturing sector.

5.2. Practical Implications

The findings provide several practical implications for manufacturing managers and policymakers in Malaysia. Managers should continue investing in advanced manufacturing technologies and digital transformation initiatives to improve production efficiency and environmental performance. However, technology investments alone are insufficient to maximize sustainability outcomes. Organizations should simultaneously strengthen information management systems to ensure that accurate, timely, and reliable information is available for environmental decision-making. Furthermore, managers should encourage employees' green work engagement by promoting environmental awareness, providing sustainability training, recognizing green initiatives, and fostering an organizational culture that supports environmental responsibility. Such integrated efforts can significantly improve green process innovation and strengthen firms' long-term environmental and competitive performance.

5.3. Limitations and Future Research

Despite its contributions, this study has several limitations. First, the cross-sectional research design limits the ability to establish causal relationships among the study variables. Future research should employ longitudinal designs to examine changes in technological innovation and green process innovation over time. Second, the study used convenience sampling from manufacturing organizations in Malaysia, which may limit

the generalizability of the findings to other industries or countries. Future studies should employ probability sampling techniques and include organizations from different sectors and national contexts. Third, the study relied on self-reported questionnaire data, which may introduce common method bias. Future research could combine survey data with objective organizational performance indicators. Finally, future studies may incorporate additional variables such as green organizational culture, environmental leadership, digital transformation capability, environmental strategy, or organizational learning to further explain the mechanisms through which technological innovation promotes sustainable manufacturing.

6. Conclusion

This study demonstrates that technological innovation is a significant driver of green process innovation in Malaysian manufacturing organizations. More importantly, the findings show that technological innovation enhances environmental innovation by improving information quality and strengthening employees' green work engagement. The validated serial mediation model highlights the importance of integrating technological capability, high-quality organizational information, and employee engagement to achieve sustainable manufacturing outcomes. These findings provide valuable theoretical and practical insights for organizations seeking to improve environmental performance while maintaining long-term competitiveness in an increasingly sustainability-oriented business environment.

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