INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

Technology Strategy Towards Sustainable Manufacturing Performance: An Empirical Study of the Mediating Role of Leadership Style in Malaysian Manufacturing Firms

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DOI: https://doi.org/10.47772/IJRISS.2026.100601452

Received: 05 July 2026; Accepted: 10 July 2026; Published: 24 July 2026

ABSTRACT

This study empirically examines the relationship between technology strategy, leadership style, and sustainable manufacturing performance (SMP) among Malaysian manufacturing firms. Grounded in the Resource-Based View (RBV), the study investigates how technological resources, including pioneer–follower posture, technological investments, intensity of product upgrades, product and process technologies, manufacturing system and process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories, contribute to economic, environmental, and social sustainability outcomes, with leadership style positioned as a mediating mechanism. A quantitative research approach was adopted, and data were collected from 216 manufacturing firms using a structured questionnaire. The data were analysed using SPSS Version 29 through descriptive analysis, reliability analysis, multiple regression analysis, and Hayes PROCESS Macro Model 4 for mediation testing. The findings indicate that technological investments, manufacturing system and process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories have significant positive effects on sustainable manufacturing performance. However, pioneer–follower posture, intensity of product upgrades, and product and process technology do not demonstrate significant direct effects. Leadership style significantly mediates the relationship between all technology strategy dimensions and sustainable manufacturing performance, highlighting its critical role in transforming technological capabilities into sustainability outcomes. This study contributes to existing literature by developing an integrated technology strategy framework that combines multiple technological dimensions with leadership capability, extending the RBV perspective by demonstrating that technological resources generate greater sustainability value when supported by effective leadership integration. The findings highlight that sustainable manufacturing performance depends not only on technology adoption but also on organisational capabilities that enable successful Industry 4.0 transformation.

Keywords: Sustainable manufacturing, technology strategy, leadership style, Industry 4.0, RBV

INTRODUCTION

The rapid advancement of Industry 4.0 technologies has significantly transformed manufacturing systems worldwide. Technologies such as artificial intelligence, big data analytics, cyber-physical systems, and the Internet of Things have enhanced operational efficiency, production flexibility, decision-making capability, and innovation. However, despite substantial technological progress and increasing investments in advanced manufacturing technologies, many firms continue to experience challenges in converting technological capabilities into sustainable manufacturing performance outcomes.

Sustainable manufacturing performance requires organisations to balance economic, environmental, and social objectives by integrating technological capabilities with sustainability-oriented strategies. Although technology adoption has been widely recognised as an important driver of manufacturing improvement, the availability of advanced technologies alone does not guarantee successful sustainability outcomes. The value generated from technological resources depends on how effectively firms develop strategic capabilities, manage organisational transformation, and align technological initiatives with sustainability goals. In this context, leadership plays an important role in facilitating technology implementation, managing change, and ensuring that technological investments contribute to long-term organisational performance.

Previous studies have primarily focused on individual technology adoption factors, such as digital technologies, automation, and Industry 4.0 implementation, with less attention given to technology strategy as a multidimensional organisational capability involving technological positioning, investment decisions, innovation capabilities, and manufacturing system development. Consequently, limited understanding exists regarding how different technology strategy dimensions collectively influence sustainable manufacturing performance. Furthermore, while leadership has been recognised as an important factor in technology-driven transformation, its role as an organisational mechanism that translates technology strategies into sustainability outcomes remains insufficiently explored, particularly within the Malaysian manufacturing context.

Therefore, this study addresses these gaps by examining the relationships among technology strategy dimensions, leadership style, and sustainable manufacturing performance among Malaysian manufacturing firms. By integrating multiple technology strategy dimensions with leadership capability, this study provides a more comprehensive understanding of how technological resources can be effectively transformed into sustainable manufacturing outcomes.

Problem Statement

Although Industry 4.0 technologies have created significant opportunities for manufacturing firms to enhance operational efficiency, innovation, and competitiveness, many organisations continue to face difficulties in translating technological investments into sustainable manufacturing performance. The implementation of advanced technologies alone does not automatically lead to improvements in economic, environmental, and social sustainability outcomes, as the effectiveness of technology-driven transformation depends on how technological resources are strategically managed and integrated within organisational processes.

Existing research has predominantly focused on specific technology adoption practices, such as digital technologies, automation, and technological investment, while limited attention has been given to technology strategy as a broader multidimensional capability. Technology strategy involves not only the adoption of technologies but also strategic decisions related to technological positioning, investment priorities, innovation capabilities, manufacturing system development, and long-term technology planning. The limited understanding of how these interconnected technology strategy dimensions collectively influence sustainable manufacturing performance creates a significant research gap.

Furthermore, although leadership has been recognised as an important factor in facilitating technological transformation and organisational change, previous studies have provided limited explanation of how leadership style functions as a mechanism that enables firms to convert technological capabilities into sustainability outcomes. Without effective leadership, technological investments may not be fully utilised due to challenges related to strategic alignment, employee adaptation, and implementation effectiveness.

This research gap is particularly relevant in the Malaysian manufacturing context, where firms are increasingly encouraged to adopt Industry 4.0 technologies while simultaneously improving sustainability performance. Therefore, this study addresses the identified gaps by empirically testing an integrated framework that examines the relationships among technology strategy dimensions, leadership style, and sustainable manufacturing performance among Malaysian manufacturing firms.

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LITERATURE REVIEW

Technology strategy has been increasingly recognised as an important organisational capability that influences competitive advantage and sustainability performance in manufacturing firms. From the Resource-Based View (RBV), firms achieve superior performance by developing valuable, rare, inimitable, and non-substitutable resources that competitors find difficult to replicate (Barney, 1991; Wernerfelt, 1984). Within the context of Industry 4.0, technological capabilities represent strategic resources that enable firms to improve operational efficiency, innovation capability, and sustainability performance. However, the availability of technological resources alone may not generate competitive advantages unless organisations possess the capability to effectively manage, integrate, and utilise these resources. Therefore, leadership capability becomes an important organisational mechanism that determines how effectively technology strategies are transformed into sustainable manufacturing outcomes.

The Technology–Organisation–Environment (TOE) framework provides a complementary perspective by explaining that successful technology adoption is influenced by technological characteristics, organisational readiness, and environmental conditions (Tornatzky & Fleischer, 1990). Previous studies have applied TOE to examine Industry 4.0 adoption, digital transformation, and organisational preparedness for technological change (Luthra et al., 2016; Müller et al., 2018). While TOE explains the conditions that encourage technology adoption, RBV explains how technological resources create organisational value. Therefore, integrating both perspectives provides a more comprehensive understanding of how manufacturing firms adopt, manage, and utilise technology strategies to achieve sustainable performance outcomes.

Leadership capability represents a critical organisational factor in ensuring that technological resources are effectively implemented and aligned with strategic objectives. Leadership theories highlight that transformational and digital leadership styles facilitate organisational change, innovation, and technology-driven transformation. Transformational leadership promotes employee motivation, innovation culture, and strategic alignment, while digital leadership supports the integration of emerging technologies into organisational systems and decision-making processes (Vial, 2019; Chatterjee et al., 2021). However, previous studies have often examined leadership as a direct contributor to technology adoption or performance outcomes, with limited attention given to its mediating role in converting technology strategies into sustainable manufacturing performance.

Technology strategy should therefore be considered as a multidimensional construct rather than a single technology adoption activity. Existing research has frequently examined individual technologies separately, such as automation, digital systems, or technological investment, which provides limited understanding of how different technology-related capabilities collectively contribute to sustainability outcomes. A broader technology strategy perspective incorporates strategic technological positioning, investment decisions, innovation capabilities, manufacturing system development, and advanced production technologies.

Within this perspective, pioneer–follower posture influences firms' strategic positioning and timing of technological innovation adoption (Frank et al., 2019). Technological investments represent strategic commitments that enable resource optimisation, operational improvement, and sustainability enhancement (Bai & Sarkis, 2020). The intensity of product upgrades contributes to innovation responsiveness and product lifecycle improvement (Nunes et al., 2020). Similarly, product and process technologies support manufacturing efficiency and environmental improvement by reducing resource consumption and operational waste (Stock & Seliger, 2016). Manufacturing system and process design technologies enhance production flexibility, resource utilisation, and operational effectiveness (Kiel et al., 2017), while manufacturing process technology innovations contribute to cleaner production systems and waste reduction (Dubey et al., 2019). Digital manufacturing technologies, including Internet of Things (IoT), artificial intelligence (AI), and big data analytics, improve real-time monitoring, predictive decision-making, and production intelligence (Wang et al., 2016; Lu, 2017).

Microfactories further support sustainable manufacturing through decentralised production approaches, improved resource efficiency, and reduced environmental impact (Javaid et al., 2022).

Although previous studies demonstrate that individual technological capabilities contribute to manufacturing improvements, the existing literature provides limited understanding of how multiple technology strategy dimensions interact with organisational leadership capability to influence sustainable manufacturing performance. This gap is particularly significant in emerging manufacturing contexts, where firms are required to balance technological transformation with sustainability objectives.

Sustainable manufacturing performance is commonly conceptualised through the triple bottom line framework, which incorporates economic, environmental, and social dimensions (Elkington, 1997). This perspective emphasises that manufacturing firms must achieve profitability while simultaneously reducing environmental impact and promoting social responsibility (Porter & Kramer, 2011). Therefore, understanding how technology strategies and leadership capabilities jointly contribute to sustainable manufacturing performance is essential for supporting successful Industry 4.0 transformation.

RESEARCH METHODOLOGY

Conceptual Framework

Figure 1 illustrates the conceptual framework developed in this study. The framework is grounded in the Resource-Based View (RBV), which suggests that organisations achieve superior performance by effectively developing and utilising valuable internal resources and capabilities. In the context of Industry 4.0, technology strategy represents a strategic organisational capability that enables firms to improve operational effectiveness, innovation capacity, and sustainability performance. However, technological resources alone may not automatically generate sustainable outcomes unless they are effectively managed and integrated through appropriate organisational capabilities.

The framework consists of eight dimensions of technology strategy as independent variables, namely pioneer–follower posture, technological investments, intensity of product upgrades, product and process technology, manufacturing system and process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories. These dimensions represent different forms of technological capabilities that support manufacturing transformation and sustainability improvement.

Leadership style is positioned as the mediating variable because effective leadership is essential in transforming technological resources into organisational outcomes. Leadership capability enables firms to align technology strategies with sustainability objectives, manage technological change, encourage employee adaptation, and ensure successful implementation of Industry 4.0 initiatives. Therefore, leadership style is expected to strengthen the relationship between technology strategy dimensions and sustainable manufacturing performance.

Sustainable manufacturing performance is positioned as the dependent variable, reflecting economic, environmental, and social sustainability outcomes. The framework proposes that technology strategy dimensions influence sustainable manufacturing performance both directly and indirectly through leadership style. By integrating technology strategy, leadership capability, and sustainability outcomes, this framework provides a comprehensive explanation of how manufacturing firms can convert technological resources into sustainable performance improvements.

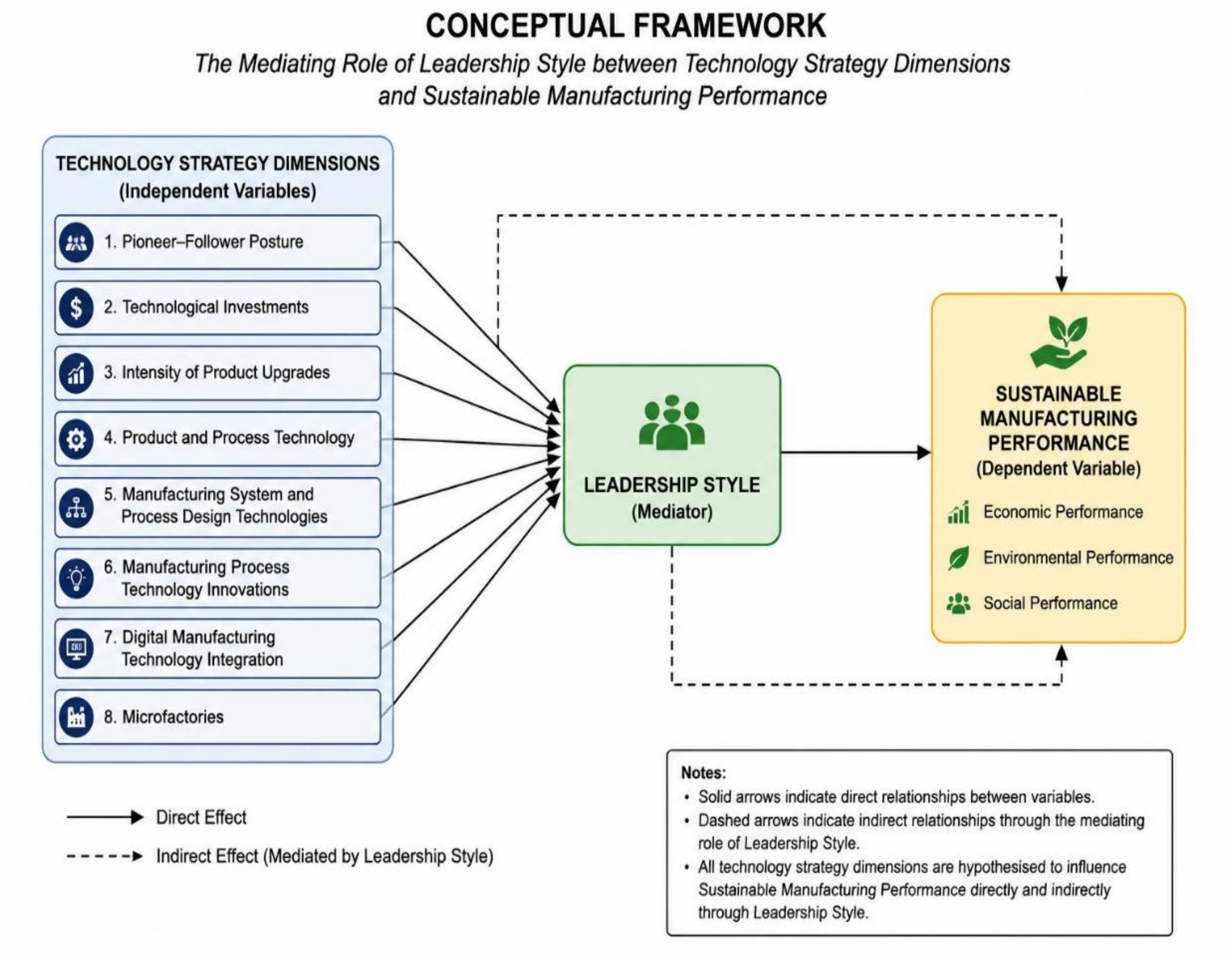

Figure 1 Conceptual Framework

Research Design

This study adopts a quantitative research approach using a structured questionnaire as the primary instrument for data collection. A quantitative design was selected because the study aims to empirically examine the relationships among technology strategy dimensions, leadership style, and sustainable manufacturing performance through statistical analysis. This approach enables the researcher to measure the proposed constructs and evaluate the direct and indirect relationships specified in the conceptual framework.

Data were collected through survey questionnaires consisting of measurement items related to the study variables. The questionnaire included items measuring eight technology strategy dimensions as independent variables, namely pioneer–follower posture, technological investments, intensity of product upgrades, product and process technology, manufacturing system and process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories. Leadership style was examined as the mediating variable, while sustainable manufacturing performance was measured as the dependent variable.

The conceptual framework and measurement instrument were developed based on previous theoretical and empirical studies. Data collection was conducted among Malaysian manufacturing firms to examine the proposed relationships between technology strategy, leadership style, and sustainable manufacturing performance. The collected data were analysed using SPSS Version 29 through descriptive analysis, reliability analysis, correlation analysis, multiple regression analysis, and mediation analysis using Hayes PROCESS Macro Model 4.

To improve data quality and minimise missing responses, all questionnaire items were designed as compulsory questions. This ensured complete responses and supported the accuracy of subsequent statistical analyses, particularly regression and mediation testing.

Population And Sample

The population of this study consists of manufacturing firms in Malaysia, particularly organisations involved in Industry 4.0 adoption, technological transformation, and sustainability-related activities. The unit of analysis for this study is the organisation, as the research examines organisational-level capabilities, including technology strategy, leadership style, and sustainable manufacturing performance. The target respondents were individuals representing these manufacturing firms, including managers, engineers, supervisors, and employees who possess relevant knowledge and involvement in technological implementation, operational processes, and sustainability practices within their organisations.

Due to the large number of manufacturing firms operating in Malaysia, this study refers to the sampling guideline proposed by Krejcie and Morgan (1970) to determine the appropriate sample size. Based on this guideline, the recommended sample size was considered in determining the adequacy of responses required for the study. However, considering the targeted nature of manufacturing respondents and accessibility constraints during data collection, a total of 216 valid responses were obtained. The sample size was considered adequate for conducting the statistical analyses employed in this study, including multiple regression analysis and mediation analysis.

A purposive sampling technique was employed to ensure that respondents had sufficient knowledge and experience related to their organisation’s technology strategies, leadership practices, and sustainability performance. Respondents aged 21 years and above were included, as they represent individuals with relevant workplace experience and involvement in organisational activities related to technology implementation and manufacturing operations.

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	246
25	24	130	97	320	175	950	274	4000	351
30	26	140	103	340	181	1000	276	4500	351
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	181	1200	291	6000	361
45	40	180	118	400	196	1300	297	7000	364
50	44	190	123	420	201	1400	302	8000	367
55	48	200	127	440	205	1500	306	9000	368
60	52	210	132	460	210	1600	310	10000	373
65	56	220	136	480	214	1700	313	15000	375
70	59	230	140	500	217	1800	317	20000	377
75	63	240	144	550	225	1900	320	30000	379
80	66	250	148	600	234	2000	322	40000	380
85	70	260	152	650	242	2200	327	50000	381
90	73	270	155	700	248	2400	331	75000	382
95	76	270	159	750	256	2600	335	100000	384

Note: “N” is Population Size
“S” is Sample Size.

Figure 2 Krejcie and Morgan Table ,1970

Study Instrument

A structured questionnaire was used as the primary research instrument for data collection in this study. The instrument was developed to examine the relationships among technology strategy dimensions, leadership style, and sustainable manufacturing performance (SMP) among Malaysian manufacturing firms. The development of the questionnaire was guided by the Resource-Based View (RBV), which emphasises the importance of organisational resources and capabilities in achieving sustained competitive advantage and improved sustainability outcomes (Barney, 1991; Wernerfelt, 1984).

The measurement items for all constructs were adapted from established empirical studies to ensure content validity and alignment with previous research. The independent variables consist of eight technology strategy dimensions: pioneer–follower posture, technological investments, intensity of product upgrades, product and process technology, manufacturing system and process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories. Leadership style was measured as the mediating variable based on established leadership literature, incorporating transformational and digital leadership dimensions. Sustainable manufacturing performance was measured as the dependent variable through three dimensions: economic, environmental, and social sustainability performance.

The questionnaire consisted of 13 sections covering demographic information, eight technology strategy dimensions, leadership style, sustainable manufacturing performance dimensions, and relevant control information. Minor contextual modifications were made to ensure that the measurement items were appropriate for the Malaysian manufacturing context while maintaining consistency with the original measurement scales.

All measurement items were assessed using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) (Joshi et al., 2015). This scale was selected as it provides a consistent approach for measuring respondents' assessments of organisational practices and performance-related constructs. To improve data completeness, all questionnaire items were designed as compulsory responses, reducing missing data and supporting the accuracy of subsequent statistical analyses, particularly regression and mediation analysis.

Variables And Items

The variables examined in this study consist of technology strategy dimensions as independent variables, leadership style as the mediating variable, and sustainable manufacturing performance as the dependent variable. The study adopts an organisational perspective, where respondents provided assessments representing their respective manufacturing firms.

The independent variables comprise eight technology strategy dimensions: pioneer–follower posture, technological investments, intensity of product upgrades, product and process technology, manufacturing systemand process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories. Leadership style was measured as a mediating construct,capturingtransformational and digital leadership characteristics. Sustainable manufacturing performance was measured through economic, environmental, and social sustainability indicators.

All measurement items were adapted from previous studies to support content validity and measurement consistency. Each construct was measured using multiple items to capture the different dimensions of the respective variables. The measurement constructs and sources are presented in Table 1.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

Table 1 Variables and Items

Variable Type	Variable	Measurement Items	Sources	No. of Items
IV1	Pioneer–Follower Posture	PFP01–PFP08	Lieberman and Montgomery (1998); Zahra and Covin (1993)	8
IV2	Technological Investments	TI01–TI07	Hitt et al. (1997); Gunasekaran et al. (2015); Olan et al. (2022)	7
IV3	Intensity of Product Upgrades	IPU01–IPU06	Teece et al. (1997); Calantone et al. (1996); Ahsan et al. (2023)	6
IV4	Product and Process Technology	PPT01–PPT06	Hayes & Wheelwright (1984); Buer et al. (2018); Frank et al. (2019)	6
IV5	Manufacturing System and Process Design Technologies	MSPD01–MSPD03	Duflou et al. (2012); Buer et al. (2018); Kiel et al. (2017)	3
IV6	Manufacturing Process Technology Innovations	MPTI01–MPTI03	Ford and Despeisse (2016); Moktadir et al. (2020)	3
IV7	Digital Manufacturing Technologies	DMT01–DMT03	Kusiak (2018); Frank et al. (2019); Tortorella et al. (2023)	3
IV8	Microfactories	MF01–MF05	Hermann et al. (2019); Mourtzis (2022); Javaid et al. (2022)	5
MV	Leadership Style	LS01–LS09	Bass and Avolio (1994); Northouse (2021); Jagadisen et al. (2022)	9
DV1	Environmental Sustainability Indicators	ENV01–ENV08	Elkington (1997); Dangelico & Pujari (2010); Chowdhury et al. (2023)	8
DV2	Social Sustainability Indicators	SOC01–SOC07	Carter & Rogers (2008); Govindan et al. (2015); Bag & Pretorius (2022)	7
DV3	Economic Sustainability Indicators	ECO01–ECO04	Elkington (1997); Hitt et al. (1997); Ahsan et al. (2023)	4

Source: Survey Data (2025)

Ethical Considerations

Ethical principles were observed throughout the research process, including data collection, analysis, and reporting. Before completing the questionnaire, participants were informed of the purpose of the study and that their participation was entirely voluntary. A consent statement was provided at the beginning of the questionnaire, and respondents could decide whether to participate. All responses were treated confidentially, and no identifying information about the respondents or their organisations was disclosed. The collected data were stored securely, accessed only by the researcher, and used solely for academic purposes. These measures were implemented to protect participants' privacy and ensure the integrity of the research process.

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RESEARCH FINDINGS

Table 2 Descriptive Statistics

Descriptive Statistics							
	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
PFP	216	4.6134	1.03219	-.596	.166	-1.175	.330
TI	216	4.6587	1.10894	-.735	.166	-.873	.330
IPU	216	4.6335	1.01440	-.544	.166	-.917	.330
PPT	216	4.6667	1.00181	-.725	.166	-.762	.330
MSPD	216	4.6914	1.09893	-1.055	.166	-.028	.330
MPTI	216	4.6219	1.07042	-.873	.166	-.298	.330
DMTI	216	4.6127	1.08676	-.830	.166	-.575	.330
MF	216	4.6704	.98067	-.797	.166	-.680	.330
LS	216	4.6348	.96912	-.635	.166	-1.084	.330
DV	216	4.6440	.98625	-.559	.166	-1.371	.330
Valid N (listwise)	216						

Source: Survey Data (2025)

Table 2 presents the descriptive statistics of the study variables based on 216 valid responses representing Malaysian manufacturing firms. The analysis summarises the mean, standard deviation, skewness, and kurtosis values for the technology strategy dimensions, leadership style, and sustainable manufacturing performance.

The mean values for all constructs ranged from 4.6127 to 4.6914, indicating that the sampled manufacturing firms demonstrated relatively high levels of technology strategy implementation, leadership practices, and sustainable manufacturing performance. Among the technology strategy dimensions, Manufacturing System and Process Design Technologies (MSPD) recorded the highest mean value (M = 4.6914, SD = 1.09893), followed by Microfactories (MF) (M = 4.6704, SD = 0.98067) and Product and Process Technology (PPT) (M = 4.6667, SD = 1.00181). Sustainable Manufacturing Performance (SMP) also recorded a high mean score (M = 4.6440, SD = 0.98625), indicating favourable sustainability outcomes among the sampled firms.

The standard deviation values ranged from 0.96912 to 1.10894, suggesting moderate variation among organisations in terms of their technology capabilities, leadership practices, and sustainability performance. This variation is expected due to differences in organisational characteristics, technological maturity, and operational practices.

The normality of the data was assessed using skewness and kurtosis values. Skewness values ranged from -1.055 to -0.544, while kurtosis values ranged from -1.371 to -0.028. These values fall within acceptable limits, indicating that the data distribution was approximately normal and suitable for subsequent parametric analyses.

Gender

Table 3 Gender

Gender		
	N	%
Female	69	31.9%
Male	147	68.1%

Source: Survey Data (2025)

The gender distribution of respondents indicates that the majority of participants were male. Specifically, out of 216 respondents, 68.1% (n = 147) were male, while 31.9% (n = 69) were female. This reflects the continued male dominance within the manufacturing sector, which is commonly associated with technical, operational, and engineering-related roles. However, the presence of female respondents also indicates increasing gender diversity in managerial and technical positions within Malaysian manufacturing firms.

Nature Of The Company

Table 4 Nature of the Company

	N	%
Joint Venture	20	9.3%
Locally-owned	195	90.3%
Multinational Corporation Subsidiary (MNC)	1	0.5%

Source: Survey Data (2025)

The analysis of the nature of companies involved in this study shows that the sample is predominantly composed of locally owned firms. A total of 90.3% (n = 195) of the respondents represented locally owned manufacturing companies. This was followed by joint venture firms, which accounted for 9.3% (n = 20), while multinational corporation (MNC) subsidiaries represented only a small proportion of the sample at 0.5% (n = 1). This distribution suggests that the findings of this study are largely reflective of domestic manufacturing operations in Malaysia, with limited representation from foreign-owned or multinational manufacturing entities.

Reliability Analysis

Table 5 Reliability Analysis Table

Construct	**Cronbach's Alpha**	**Interpretation**
Pioneer-Follower Posture (PFP)	0.867	Good
Technological Investments (TI)	0.866	Good
Intensity of Product Upgrades (IPU)	0.824	Good
Product and Process Technology (PPT)	0.820	Good
Manufacturing System and Process Design Technologies (MSPD)	0.698	Acceptable
Manufacturing Process Technology Innovations (MPTI)	0.669	Acceptable
Digital Manufacturing Technologies Integration (DMTI)	0.709	Acceptable
Microfactories (MF)	0.781	Acceptable
Leadership Style (LS)	0.866	Good
Sustainable Manufacturing Performance (SMP/DV)	0.942	Excellent

Source: Survey Data (2025)

The reliability of the measurement instrument was assessed using Cronbach's alpha to evaluate the internal consistency of each construct. Cronbach's alpha values of 0.70 and above generally indicate acceptable reliability, while values between 0.60 and 0.69 may be considered acceptable for exploratory studies (Hair et al., 2019).

As shown in Table 5, Cronbach's alpha values ranged from 0.669 to 0.942, demonstrating acceptable to excellent internal consistency across all constructs. Sustainable Manufacturing Performance recorded the highest reliability coefficient (α = 0.942), followed by Pioneer–Follower Posture (α = 0.867), Technological Investments (α = 0.866), Leadership Style (α = 0.866), Intensity of Product Upgrades (α = 0.824), and Product and Process Technology (α = 0.820).

Although Manufacturing System and Process Design Technologies (α = 0.698) and Manufacturing Process Technology Innovations (α = 0.669) were slightly below the conventional 0.70 threshold, these values exceeded the minimum acceptable level of 0.60 and were considered adequate for further statistical analysis.

Multiple Regression Analysis Results

Model Summary

Table 6 Model Summary Results

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.956[a]	.913	.909	.29708	1.970
a. Predictors: (Constant), LS, MPTI, MSPD, DMTI, IPU, PPT, MF, TI, PFP					
b. Dependent Variable: DV					

Table 6 presents the regression model summary for examining the effects of technology strategy dimensions and leadership style on Sustainable Manufacturing Performance (SMP). The model demonstrates strong explanatory power, with a correlation coefficient of R = 0.956 and an R^2 value of 0.913. This indicates that 91.3% of the variance in sustainable manufacturing performance can be explained by the combined effects of technology strategy dimensions and leadership style. The adjusted R^2 value of 0.909 further confirms the robustness of the model after considering the number of predictors included. In addition, the Durbin–Watson value of 1.970 indicates that the assumption of independence of residuals was satisfied, as the value falls within the acceptable range.

Regression Coefficients and Predictor Effects

Table 7 Coefficients

Coefficients[a]										
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.087	.107		.814	.417	-.124	.299		
	PFP	.096	.059	.101	1.641	.102	-.019	.212	.111	8.974
	TI	.214	.049	.240	4.356	<.001	.117	.311	.139	7.217
	IPU	-.023	.046	-.023	-.491	.624	-.114	.069	.186	5.374
	PPT	.002	.048	.002	.038	.970	-.093	.096	.179	5.602
	MSPD	.077	.036	.086	2.162	.032	.007	.147	.267	3.743
	MPTI	.103	.033	.112	3.085	.002	.037	.169	.320	3.126
	DMTI	.108	.038	.120	2.881	.004	.034	.183	.245	4.077
	MF	.157	.050	.156	3.139	.002	.058	.256	.170	5.884
	LS	.246	.058	.241	4.201	<.001	.130	.361	.128	7.829
a. Dependent Variable: DV										

Source: Survey Data (2025)

Table 7 presents the regression results showing the effects of the independent variables and mediating variable on Sustainable Manufacturing Performance (SMP). The regression coefficients explain the direction and strength of each variable's relationship with SMP while considering the influence of all other variables in the model.

The findings show that Leadership Style demonstrated the strongest standardized effect, followed closely by Technological Investments on SMP (β = 0.241, t = 4.201, p < 0.001). This indicates that organisations with effective leadership practices are more likely to achieve better sustainable manufacturing performance. Similarly, Technological Investments (TI) also had a significant positive effect on SMP (β = 0.240, t = 4.356, p < 0.001), suggesting that investment in technology plays an important role in supporting sustainability improvements within manufacturing organisations.

Among the technology strategy dimensions, several variables were found to significantly contribute to SMP. Manufacturing System and Process Design Technologies (MSPD) showed a significant positive relationship with SMP (β = 0.086, t = 2.162, p = 0.032). In addition, Manufacturing Process Technology Innovations (MPTI) (β = 0.112, t = 3.085, p = 0.002), Digital Manufacturing Technologies Integration (DMTI) (β = 0.120, t = 2.881, p = 0.004), and Microfactories (MF) (β = 0.156, t = 3.139, p = 0.002) were also significant predictors of SMP. This suggests that adopting advanced manufacturing technologies and integrating digital and flexible production approaches can support organisations in improving their sustainability performance.

However, not all technology strategy dimensions showed significant effects on SMP. Pioneer–Follower Posture (PFP) had a positive but insignificant relationship with SMP (β = 0.101, t = 1.641, p = 0.102), indicating that being a technology pioneer or follower alone may not directly influence sustainability performance. Similarly, Intensity of Product Upgrades (IPU) showed a negative and insignificant relationship (β = –0.023, t = –0.491, p = 0.624), while Product and Process Technology (PPT) had no significant effect on SMP (β = 0.002, t = 0.038, p = 0.970). These results indicate that these factors did not significantly explain variations in SMP when other variables in the model were considered simultaneously.

The collinearity analysis showed tolerance values ranging from 0.111 to 0.320 and VIF values ranging from 3.126 to 8.974. Since all VIF values were below the recommended threshold of 10, multicollinearity was not considered a serious concern. Therefore, the regression coefficients can be interpreted with confidence.

SUMMARY OF HYPOTHESIS

Summary Of Direct Effect Hypothesis Testing

Table 8 Summary of Hypothesis Testing

Hypothesis	Relationship	β	t-value	p-value	Result
H1	Pioneer–Follower Posture (PFP) significantly influences Sustainable Manufacturing Performance (SMP).	0.101	1.641	0.102	Rejected
H2	Technological Investments (TI) significantly influences Sustainable Manufacturing Performance (SMP).	0.240	4.356	<0.001	Accepted
H3	Intensity of Product Upgrades (IPU) significantly influences Sustainable Manufacturing Performance (SMP).	-0.023	-0.491	0.624	Rejected
H4	Product and Process Technology (PPT) significantly influences Sustainable Manufacturing Performance (SMP).	0.002	0.038	0.970	Rejected
H5	Manufacturing System and Process Design Technologies (MSPD) significantly influences Sustainable Manufacturing Performance (SMP).	0.086	2.162	0.032	Accepted
H6	Manufacturing Process Technology Innovations (MPTI) significantly influences Sustainable Manufacturing Performance (SMP).	0.112	3.085	0.002	Accepted
H7	Digital Manufacturing Technology Integration (DMTI) significantly influences Sustainable Manufacturing Performance (SMP).	0.120	2.881	0.004	Accepted
H8	Microfactories (MF) significantly influences Sustainable Manufacturing Performance (SMP).	0.156	3.139	0.002	Accepted

H9	Leadership Style (LS) significantly influences Sustainable Manufacturing Performance (SMP).	0.241	4.201	<0.001	Accepted

Source: Survey Data (2025)

Table 8 summarises the results of the direct effect hypothesis testing examining the relationships between technology strategy dimensions, Leadership Style, and Sustainable Manufacturing Performance (SMP). The findings indicate that six hypotheses were supported, while three hypotheses were not supported.

Among the significant predictors, Leadership Style (LS) demonstrated the strongest positive effect on SMP ($\beta = 0.241$, $p < 0.001$), followed closely by Technological Investments (TI) ($\beta = 0.240$, $p < 0.001$). These findings highlight that technological resources alone are insufficient to achieve sustainability outcomes; effective leadership capability is also required to successfully integrate and utilise technological resources within manufacturing organisations.

Other significant technology strategy dimensions included Microfactories (MF), Digital Manufacturing Technology Integration (DMTI), Manufacturing Process Technology Innovations (MPTI), and Manufacturing System and Process Design Technologies (MSPD). These results suggest that technology strategies related to digital capability, process improvement, and flexible manufacturing systems contribute positively to sustainable manufacturing performance.

However, Pioneer–Follower Posture (PFP), Intensity of Product Upgrades (IPU), and Product and Process Technology (PPT) did not demonstrate significant direct effects on SMP. This indicates that strategic positioning, product upgrading activities, and existing product/process technologies may not independently improve sustainability outcomes unless they are supported by effective organisational capabilities and implementation mechanisms.

Summary Of Mediation Hypothesis Testing Using Hayes Process Macro Model 4

Table 9 Mediation Hypothesis Summary (HAYES Process Model 4)

Hypothesis	Mediation Relationship	Indirect Effect	Boot SE	95% Bootstrapped CI	Result
H9a	PFP → Leadership Style → SMP	0.4381	0.0656	[0.3163, 0.5729]	Supported
H9b	TI → Leadership Style → SMP	0.3887	0.0475	[0.3026, 0.4939]	Supported
H9c	IPU → Leadership Style → SMP	0.5999	0.0653	[0.4844, 0.7392]	Supported
H9d	PPT → Leadership Style → SMP	0.5471	0.0591	[0.4374, 0.6720]	Supported
H9e	MSPD → Leadership Style → SMP	0.4911	0.0519	[0.4033, 0.6065]	Supported
H9f	MPTI → Leadership Style → SMP	0.5214	0.0502	[0.4298, 0.6266]	Supported
H9g	DMTI → Leadership Style → SMP	0.4954	0.0503	[0.4074, 0.5993]	Supported
H9h	MF → Leadership Style → SMP	0.5183	0.0538	[0.4152, 0.6287]	Supported

Source: Survey Data (2025)

Table 9 presents the mediation analysis results obtained using Hayes PROCESS Macro Model 4. The analysis examined whether Leadership Style mediates the relationship between each technology strategy dimension and Sustainable Manufacturing Performance (SMP).

The results indicate that all mediation hypotheses (H9a–H9h) were supported. The bootstrapped confidence intervals for all indirect effects did not include zero, confirming that Leadership Style significantly mediates the relationship between technology strategy dimensions and SMP.

The findings demonstrate that Leadership Style acts as an organisational mechanism that converts technological capabilities into sustainability outcomes. Although technology strategies provide the necessary resources and capabilities, effective leadership enables successful implementation, manages technological transformation, and aligns technology initiatives with sustainability objectives. Therefore, the results reinforce the RBV perspective that technological resources create greater value when combined with organisational capabilities such as leadership competence.

CONCLUSION

This study examined the relationship between technology strategy dimensions, leadership style, and sustainable manufacturing performance (SMP) among Malaysian manufacturing firms. Guided by the Resource-Based View (RBV), the study explored how technological resources and organisational capabilities interact to enhance economic, environmental, and social sustainability outcomes.

The findings demonstrate that technology strategy dimensions contribute differently to sustainable manufacturing performance. While technological investments, manufacturing system and process design technologies, manufacturing process technology innovations, digital manufacturing technologies, and microfactories show significant direct effects on SMP, pioneer–follower posture, intensity of product upgrades, and product and process technology do not demonstrate significant direct relationships. These findings suggest that technological capabilities alone do not automatically generate sustainability benefits; rather, their effectiveness depends on how organisations integrate, manage, and strategically utilise these resources.

The mediation analysis further highlights the critical role of leadership style as an organisational mechanism that transforms technological capabilities into sustainability outcomes. The significant indirect effects across all technology strategy dimensions indicate that leadership capability enables firms to overcome implementation challenges, manage technological transformation, and align technology initiatives with sustainability objectives.

The study contributes to the RBV literature by extending the understanding of how technological resources create competitive and sustainability advantages when combined with managerial capabilities. Unlike previous studies that primarily examine individual technology adoption factors, this study conceptualises technology strategy as a multidimensional construct and demonstrates the mediating role of leadership style in explaining how technological capabilities are translated into sustainable manufacturing performance, particularly within the Malaysian manufacturing context.

From a managerial perspective, manufacturing firms should adopt an integrated approach by investing in appropriate technologies while simultaneously strengthening leadership capabilities. Developing transformational and digital leadership practices can enhance the successful implementation of Industry 4.0 technologies and maximise their contribution towards sustainability goals. Policymakers may further support manufacturing transformation through technology adoption initiatives, sustainability programmes, and leadership development frameworks.

Future research may extend this study by examining additional organisational factors, such as organisational culture, employee capability, and digital readiness, which may further explain the mechanisms through which technology strategies influence sustainability performance. Future studies may also employ longitudinal designs or investigate different industrial contexts to provide broader insights into sustainable manufacturing transformation.

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