Scrutinizing the Role of Sustainable Manufacturing Practices Towards Sustainability Performance: Empirical Evidence from Malaysian High-Value Industrial Clusters

Muhammad Haikal Jamali, Ahmad Rais Mohamad Mokhtar*, Norasekin Abd Rashid, Norzawani Mamat @ Ibrahim, Mohd Hafiz Zulfakar & Noor Zalina Zainal

Faculty of Business and Management, Universiti Teknologi MARA, Puncak Alam, Selangor, Malaysia

***Corresponding Author**

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ABSTRACT

Driven by tightening global regulatory frameworks and environmental degradation, modern manufacturing corporations are under immense pressure to reconcile economic output with social and environmental obligations. This study provides an empirical examination of the relationship between sustainable manufacturing practices and holistic sustainability performance (encompassing environmental, economic, and social dimensions) among manufacturing companies located in key industrial regions within Malaysia, specifically the Klang Valley and Kluang, Johor. Grounded in the Natural Resource-Based View (NRBV) theory, the research evaluates four main strategic dimensions: sustainable product design, sustainable manufacturing processes, sustainable supply chain management, and sustainable end-of-life management. Employing a cross-sectional quantitative research methodology, structural data was compiled through an online and physically administered questionnaire from a validated sample of 134 manufacturing personnel. Statistical testing using multiple linear regression and correlation analyses via IBM SPSS revealed that all four independent variables exert a highly significant positive influence on corporate sustainability performance. Notably, the sustainable manufacturing process emerged as the primary predictor of enhanced performance ($B = 0.343$, $p = 0.001$), followed closely by sustainable end-of-life management ($B = 0.301$, $p = 0.001$) and sustainable product design ($B = 0.192$, $p = 0.007$). Sustainable supply chain management exhibited a smaller but still statistically significant contribution ($B = 0.155$, $p = 0.048$). Collectively, the regression model explained 87.0% of the total variance in operational and strategic sustainability outcomes ($R^2 = 0.870$, $F = 216.52$, $p < 0.001$). These findings accentuate the critical requirement for manufacturing organizations to implement integrated and multidimensional sustainability frameworks rather than treating environmental compliance in isolation. The paper concludes with actionable recommendations for industry practitioners, financial institutions, and government policymakers to foster green technology deployment, subsidized green credit access, and comprehensive infrastructure for the circular economy as Malaysia transitions toward future national developmental agendas.

Keywords: Sustainable Manufacturing Practices, Sustainability Performance, Natural Resource-Based View (NRBV), Circular Economy, Multiple Regression Analysis, Malaysian Manufacturing Sector.

INTRODUCTION

Since the inception of the 21st century, global stakeholders, which are ranging from citizen networks and non-governmental entities to rigorous international regulatory bodies, have fundamentally repositioned corporate sustainability from a peripheral concern to an absolute strategic baseline (Ibrahim et al., 2019). Historically, corporate development models prior to the 1970s operated almost exclusively within traditional paradigm frameworks driven entirely by direct financial parameters. Within those systems, immediate profitability and financial returns were pursued with minimal systemic accounting for resource depletion, societal damage, or ecological degradation. However, contemporary macroeconomic disruptions and intensifying environmental degradation have forced a profound structural pivot. Corporate executives and scholarly management researchers are now required to concurrently evaluate and balance three inherently interconnected developmental pillars: the economic, the social, and the environmental components of organizational operations (Rizwan et al., 2023).

The historical footprint of industrial manufacturing practices exhibits a distressing track record of severe depletion of finite natural resources, generation of toxic atmospheric and aquatic contaminants, and deep alienation of surrounding communities (Johari et. al., 2022). As global carbon emissions reached unprecedented levels and localized eco-disasters spiked, it became critically evident that industrial institutions could no longer survive as open-loop extraction-consumption entities. Industrial companies are systematically forced to re-engineer their entire business models to ethically account for their environmental and social parameters (Mokhtar et al., 2023). Within this context of operational restructuring, sustainable manufacturing practices have evolved from optional corporate social responsibility (CSR) catchphrases into core, foundational parameters for preserving planetary boundaries and safeguarding public welfare (Abdul-Rashid et al., 2017). Concurrently, the operational conceptualization of corporate success has shifted from isolated financial accounting to comprehensive value creation models that explicitly calculate a firm’s environmental footprints and societal contributions (Abdul-Rashid et al., 2017).

This shift has redefined how operations are assessed, with the traditional term 'manufacturing performance' frequently utilized interchangeably with the modern multidimensional construct of 'sustainability performance' (Abdul-Rashid et al., 2017). The overarching architecture guiding this transformation is anchored in global policy frameworks, most notably the United Nations 17 Sustainable Development Goals (SDGs) codified within the 2030 Agenda for Sustainable Development, which explicitly demand the rapid adoption of sustainable consumption and production frameworks (United Nations, 2015). Furthermore, widespread multi-sector collaborative actions, such as the historic joint communique and memorandum of understanding enacted by the five premier global non-governmental standard-setting bodies in 2020, have consolidated and streamlined global expectations for rigorous, transparent corporate sustainability performance reporting (Xavier et al., 2022).

On a national level, the government of Malaysia has formally aligned its central strategic goals with this international paradigm shift, embedding comprehensive ecological protection across its long-term development strategies. Malaysia was an eager early signatory to the UN 2030 Agenda, deploying the 17 SDGs as national blueprints to engineer an inclusive, highly resilient economy (Shaharudin et al., 2022). These commitments have been codified within successive national economic planning programs, with ecological growth emerging as a primary pillar of the Twelfth Malaysia Plan (RMK-12). The statutory texts of the RMK-12 identify the rapid advancement of green growth, sustainable ecological practices, energy infrastructure modernization, and water resource preservation as absolute priorities for the state (RMK-12, 2021). These legislative frameworks aim to actively dismantle historically unsustainable consumption and production loops that trigger severe localized biodiversity loss, policy fragmentation, and water resource inefficiencies. These structural transitions provide a highly complex regulatory landscape where manufacturers must rapidly build dynamic internal capabilities or risk complete market obsolescence.

Concurrently, the manufacturing sector faces a multifaceted convergence of corporate pressures. Organizations are relentlessly pushed by accelerating climate-induced operational shifts, tightening regional environmental compliance standards, evolving consumer behavior, and radical shifts in technology (Rizwan et al., 2023). This modern landscape requires manufacturers to implement comprehensive sustainability models that go far beyond mere compliance with local regulatory parameters. For instance, global sovereign networks have initiated strict statutory targets to curb industrial carbon emissions and advance energy management. Embedding sustainability across industrial production systems has emerged as an indispensable tool for systemic economic survival, driving stable customer acquisition, robust market differentiation, and durable financial growth (Mokhtar et al., 2024).

Problem Statement

The industrial manufacturing sector represents a foundational pillar of national economic growth and technical advancement, yet its long-term expansion is threatened by an unsustainable reliance on resource extraction, highly inefficient production methods, and carbon-intensive energy assets (Johari et al., 2022). Organizations that fail to rapidly integrate sustainable manufacturing practices face catastrophic environmental and financial risks. Beyond the obvious threat of ecological degradation, non-compliant firms face massive regulatory fines, severe litigation costs, complete brand erosion, and rapid exclusion from environmentally conscious global consumer markets that heavily restrict carbon-heavy supply chains. As global capital allocation is increasingly tied to strict Environmental, Social, and Governance (ESG) performance standards, manufacturers that fail to systematically adopt green operations risk losing access to international institutional financing. Without a proactive and data-verified adoption of comprehensive sustainable configurations, Malaysian industrial concerns will experience deep competitive vulnerabilities within the global marketplace.

This industrial exposure is particularly severe across rapidly developing economies, where high production outputs are often accompanied by severe environmental damage. For example, large manufacturing nations like China and India collectively account for roughly 30% of global greenhouse gas emissions, reflecting an unsustainable trajectory over the past two decades (Xu et al., 2023). On a local level, the Malaysian Department of Environment (DOE) has documented over 200 distinct cases of industrial pollution violations annually from 2020 to 2023, driven primarily by improper hazardous waste disposal, illegal chemical discharges, and excessive atmospheric CO_2 emissions (DOE, 2023). Malaysia currently generates an estimated 38,000 tonnes of solid waste daily, with industrial and manufacturing processes contributing a major portion of this total (DOE, 2023). Furthermore, national energy data reveals that primary energy demand expanded by 5.8% in 2021, with fossil fuels stubbornly comprising 82% of the overall energy mix, severely undermining national carbon-reduction initiatives (BP Global Energy Review, 2023). These environmental violations are highly concentrated around core industrial corridors like the Klang Valley and manufacturing clusters in Johor, inflicting severe damage on local ecosystems and threatening public health.

Despite these visible crises, a major methodological and empirical gap persists within the existing literature. A large portion of prior research exploring sustainable manufacturing is constrained by qualitative case-study methodologies, descriptive single-firm investigations, and speculative theoretical frameworks that completely lack empirical validation through large-sample quantitative techniques (Abdul-Rashid et al., 2017). Without robust, data-driven quantitative testing, the precise operational returns and predictive impacts of sustainable practices on actual corporate sustainability performance remain ambiguous. Furthermore, while separate groups of researchers have attempted to examine isolated elements of sustainability, there is an acute lack of comprehensive frameworks that simultaneously calculate and integrate all three dimensions of the Triple Bottom Line: environmental, economic, and social performance (Abdul-Rashid et al., 2017). This fragmentation forces organizations to evaluate these dimensions in complete isolation rather than through an integrated, multidisciplinary approach. To address these gaps, this study develops and tests an integrated quantitative framework that isolates the precise empirical impacts of four primary sustainable manufacturing practices on the multidimensional sustainability performance of Malaysian manufacturing organizations.

Research Objectives and Questions

The central objective of this research is to develop, test, and validate an enhanced, empirically verified model of sustainable manufacturing practices that systematically drives holistic organizational sustainability performance. To achieve this macro-level target, the study isolates four explicit, granular research objectives:

i. To determine the relationship between sustainable product design and sustainability performance.
ii. To determine the relationship between sustainable manufacturing processes and sustainability performance.
iii. To determine the relationship between sustainable supply chain management and sustainability performance.
iv. To determine the relationship between sustainable end-of-life management and sustainability performance.

In alignment with these targeted objectives, the study addresses four explicit research questions: (1) Does sustainable product design exert a significant positive effect on corporate sustainability performance? (2) Does an optimized sustainable manufacturing process have a significant positive impact on sustainability performance? (3) Does sustainable supply chain management have a statistically significant positive relationship with corporate sustainability performance? (4) Does sustainable end-of-life management exert a significant positive effect on overall sustainability performance?

Scope, Significance, and Limitations

The investigative scope of this study is focused on evaluating the strategic drivers and precise performance returns of sustainable manufacturing practices across manufacturing firms operating within two highly critical industrial zones: the Klang Valley and Kluang, Johor. These specific geographic regions were chosen based on the Department of Statistics Malaysia (DOSM) classifications, which define these territories as high-value industrial clusters characterized by an exceptionally dense concentration of diverse manufacturing subsectors, including automotive assembly, heavy electronics, chemical processing, and advanced textile production (DOSM, 2023). Rather than restricting analysis to a single industry, this study samples across multiple manufacturing sectors to deliver a comprehensive national perspective on sustainability integration. This broad multi-sector design enhances the theoretical generalizability of the findings and provides an authentic reflection of the broader industrial landscape.

The significance of this research is both theoretical and practical. Theoretically, it addresses a major void in the literature by establishing that the Natural Resource-Based View (NRBV) theory offers an exceptionally strong and valid conceptual framework for explaining how internal green capabilities directly dictate corporate sustainability performance within an emerging market context. Practically, the study provides a highly actionable, data-verified roadmap for factory managers, corporate boards, and industrial practitioners to systematically justify capital allocations into green technologies. However, specific limitations must be noted. Because the empirical sample is drawn exclusively from firms within the Klang Valley and Kluang, Johor, the findings may not fully capture the distinct localized realities of peripheral regions such as East Malaysia or highly specialized free-trade zones in Penang. Additionally, the study utilizes a purposive, non-probability sampling methodology, which can introduce inherent selection biases. These constraints require careful consideration when applying these conclusions across highly diverse geographic contexts.

LITERATURE REVIEW

To build a rigorous conceptual foundation for this investigation, it is necessary to formally review the theoretical models, core variables, and empirical literature defining the modern sustainable manufacturing landscape. This chapter delineates the underlying theoretical mechanics of the Natural Resource-Based View (NRBV), establishes the multidimensional structure of the dependent variable (Sustainability Performance), explores the empirical contributions of the four independent variables, and concludes with a data-verified conceptual framework.

Theoretical Framework: Natural Resource-Based View (NRBV)

As established by leading methodology experts, a robust scientific theory serves as any structured proposition, strategic tool, conceptual model, or foundational framework designed to systematically assist a researcher in organizing thoughts, explaining a complex phenomenon, or resolving specific relationships between variables (Sekaran & Bougie, 2016). Theories provide the intellectual backbone necessary to justify observed changes in real-world data, transforming raw empirical numbers into actionable scientific insights (Sekaran & Bougie, 2016). For the scope of this research investigation, the Theory of the Natural Resource-Based View (NRBV) is deployed as the primary theoretical anchor to explain how and why internal sustainable manufacturing configurations systematically translate into superior corporate sustainability performance (Hart, 1995).

The Natural Resource-Based View was originally advanced by Hart in 1995 as a direct, ecologically conscious extension of Barney's classic 1991 Resource-Based View (RBV) of the firm. Barney's foundational RBV framework argued that an organization can build a sustainable competitive advantage by acquiring, developing, and deploying unique internal resources that are demonstrably valuable, rare, imperfectly imitable, and non-substitutable (VRIN criteria). However, a glaring omission within Barney's classic RBV framework was its complete failure to account for the physical constraints of the natural environment, resource scarcity, or the ecological boundaries of industrial activity. Hart (1995) solved this fundamental limitation by arguing that a firm's internal resource configuration cannot be viewed in complete isolation from the natural ecosystem. He asserted that in the modern industrial landscape, an organization's long-term competitive positioning is directly dictated by its capacity to develop explicit internal capabilities that mitigate environmental risks and align with planetary boundaries.

Hart's NRBV theory explicitly posits that an organization can convert environmental constraints into unique strategic capabilities across three sequential, highly integrated strategic stages: pollution prevention, product stewardship, and sustainable development (Hart, 1995). The first stage, pollution prevention, focuses on fundamentally restructuring internal operations to eliminate emissions, effluents, and solid waste directly at their source, rather than relying on costly end-of-pipe clean-up technologies. By minimizing waste generation and optimizing raw material usage, firms drastically lower waste management costs while enhancing operational productivity, building a durable cost-leadership advantage (McDougall et al., 2021). The second stage, product stewardship, expands this internal focus to encompass the entire product life cycle, integrating environmental parameters into initial product design, supplier selection, distribution channels, and consumption loops. This life-cycle orientation allows firms to collaborate with external stakeholders to engineer green products that generate minimal ecological footprints, establishing a powerful differentiation advantage in the marketplace. The third and final stage, sustainable development, requires the firm to build a long-term strategic vision that actively decouples industrial output from environmental degradation, ensuring that its operations actively support the long-term preservation of global socioeconomic and ecological systems.

Within the context of modern capital-intensive manufacturing, the NRBV framework provides an exceptionally robust model for evaluating corporate outcomes. Organizations build a definitive competitive advantage when they systematically configure sustainable strategies that minimize environmental liabilities while driving positive economic and social value (Adusei et al., 2023). Empirical analysis indicates that these strategic capabilities operate via explicit parameters of path dependence and embeddedness. Path dependence dictates that an organization must successfully build foundational pollution prevention capabilities before it can effectively execute advanced product stewardship or circular economy programs. Concurrently, embeddedness requires these environmental initiatives to be deeply integrated across all functional departments of the firm rather than treated as isolated compliance protocols. Organizations that foster a shared corporate vision and firmly embed these sustainability capabilities across their operational architecture can efficiently mobilize internal assets to achieve superior sustainability performance (Azila & Nazimah, 2019).

The Tripartite Architecture of Sustainability Performance

The modern conceptualization of corporate success has been fundamentally redefined by the landmark 1987 United Nations World Commission on Environment and Development (WCED) report, 'Our Common Future,' which introduced the global standard for sustainable development as progress that meets the urgent needs of the present without compromising the survival of future generations. In the decades following this report, corporate sustainability has evolved from basic regulatory compliance into a comprehensive strategic system. To achieve genuine business sustainability, organizations must look past narrow financial metrics and actively integrate economic, environmental, and social performance into a holistic framework (Khan et al., 2023). Operating within this complex landscape requires manufacturing organizations to concurrently navigate highly competitive economic shifts, severe environmental changes, and deep societal responsibilities (Khan et al., 2023).

This integrated approach is particularly critical within developing industrial economies like Malaysia, where accelerating urbanization and population expansion have led to massive volumes of industrial waste (Nor-Aishah et al., 2020). With national population metrics climbing rapidly, local landfills are under immense strain, with roughly 95% of national waste routed directly to open-area dumps that completely lack modern environmental protection systems (Nor-Aishah et al., 2020). To alter this unsustainable trajectory, corporate sustainability performance must be evaluated through a tripartite architecture that tracks clear outcomes across all three dimensions of the Triple Bottom Line:

Economic Performance: The foundation of corporate survival requires that sustainability initiatives directly support economic viability. In empirical literature, economic sustainability is verified through stable revenue growth, enhanced return on assets (ROA), expanded market share, and optimized capital utilization (Khan et al., 2021). By innovating cleaner production processes to meet stringent environmental standards, organizations can systematically reduce resource consumption, optimize energy usage, and drive major gains in structural factory productivity. These eco-process innovations maximize material recycling loops, allowing firms to capture extra economic value from waste streams while strengthening their market positioning and delivering strong returns on investment (Xu et al., 2023).

Environmental Performance: The second pillar requires a deliberate, measurable reduction in an organization's ecological footprint. This dimension is explicitly evaluated based on the minimization of atmospheric carbon emissions, the mitigation of hazardous wastewater discharges, the reduction of solid industrial waste, and full compliance with strict regional environmental protocols (Khan et al., 2021). Integrating comprehensive sustainability monitoring tools across logistics networks, warehousing hubs, and production floors allows firms to drastically mitigate ecological risks, conserve biodiversity, and protect fragile regional ecosystems from catastrophic industrial accidents (Xu et al., 2023).

Social Performance: The final pillar evaluates an organization's capacity to protect, support, and add value to human capital and surrounding communities. This is measured via workplace safety records, comprehensive occupational health protocols, employee training programs, and fair labor practices (Khan et al., 2021). By actively removing toxic compounds and hazardous materials from the factory floor, firms protect frontline operational personnel and public health. This proactive social responsibility builds deep institutional trust, strengthens corporate reputation, and enhances long-term interactions with key external stakeholders (Al Koliby et al., 2022).

Sustainable Manufacturing Practices and Hypothesis Development

To isolate the precise factors driving these tripartite outcomes, this study evaluates four primary sustainable manufacturing practices: sustainable product design, sustainable manufacturing processes, sustainable supply chain management, and sustainable end-of-life management. Each dimension represents a critical operational capability within the NRBV framework.

The initial design phase represents an exceptionally powerful leverage point within a product's life cycle, with empirical research proving that approximately 80% of a product's lifelong environmental impact is determined during the initial concept and engineering phases (Watkins et al., 2021). Sustainable product design requires engineers to integrate environmental parameters at the earliest stages of product development, selecting non-toxic, eco-friendly materials, minimizing material volume, and configuring structural components to allow simple product disassembly, material separation, and high resource recovery (Watkins et al., 2021). This proactive life-cycle management allows firms to mitigate environmental risks and minimize material costs long before manufacturing begins (Wang & Su, 2022). Grounded in the NRBV capability of product stewardship, this proactive strategy creates highly differentiated green products that meet modern consumer demands and enhance long-term market competitiveness (Jiang et al., 2021). Consequently, we propose the following hypothesis:

Hypothesis 1 (H1): There is a significant positive relationship between sustainable product design and sustainability performance.

This dimension encompasses the core physical conversion activities on the factory floor, requiring a total restructuring of operational steps to minimize environmental damage, conserve energy, and safeguard human capital (Ali et al., 2021). Because heavy industrial processing generates massive volumes of atmospheric, liquid, and solid waste, firms must deploy advanced cleaner production systems, lean manufacturing protocols, and automated efficiency tools to eliminate waste at the source (Al Koliby et al., 2022). Implementing rigorous energy management models dramatically optimizes factory energy efficiency, cutting operational costs without sacrificing production volume or product quality. Prior empirical studies among certified manufacturing entities in Malaysia suggest that optimizing these internal processing steps exerts an exceptionally powerful impact on a firm's sustainability performance (Abdul-Rashid et al., 2017). This directly reflects the NRBV capability of pollution prevention. Thus, we advance the following hypothesis:

There is a significant positive relationship between sustainable manufacturing processes and sustainability performance.

SSCM extends internal sustainability capabilities across the entire upstream and downstream value chain, integrating environmental criteria across procurement protocols, supplier selection, inventory management, logistics routes, and distribution channels (Sánchez-Flores et al., 2020). Implementing structured green supply chain practices requires firms to enforce strict eco-compliance audits for subcontractors, utilize clean or reusable packaging materials, and deploy digital tracking tools to maximize transport route efficiency and cut logistics fuel use (Sánchez-Flores et al., 2020). Collaborative interactions with sustainable vendors eliminate upstream waste, minimize raw material consumption, and optimize overall logistics performance (Samah et al., 2022). This value-chain alignment represents an indispensable operational requirement for managing modern industrial footprints. This leads to the third hypothesis:

Hypothesis 3 (H3): There is a significant positive relationship between sustainable supply chain management and sustainability performance.

This final dimension incorporates the principles of the circular economy, focusing on recapturing, reintroducing, and extracting maximum value from products and components after they complete their useful life (Huang et al., 2022). Rather than allowing discarded products to accumulate in landfills, firms establish structured take-back programs, reverse logistics networks, and product recovery management systems to support component remanufacturing, material recycling, or safe toxic waste treatment (Gautam et al., 2021). Effective end-of-life programs dramatically lower disposal costs, shield organizations from strict liability regulations, and extract valuable secondary materials that can be fed directly back into production loops (Dwivedi et al., 2022). Reflecting the NRBV capability of long-term product stewardship, this circular architecture is a vital component of sustainable performance (Lee et al., 2023). This yields our final hypothesis:

Hypothesis 4 (H4): There is a significant positive relationship between sustainable end-of-life management and sustainability performance.

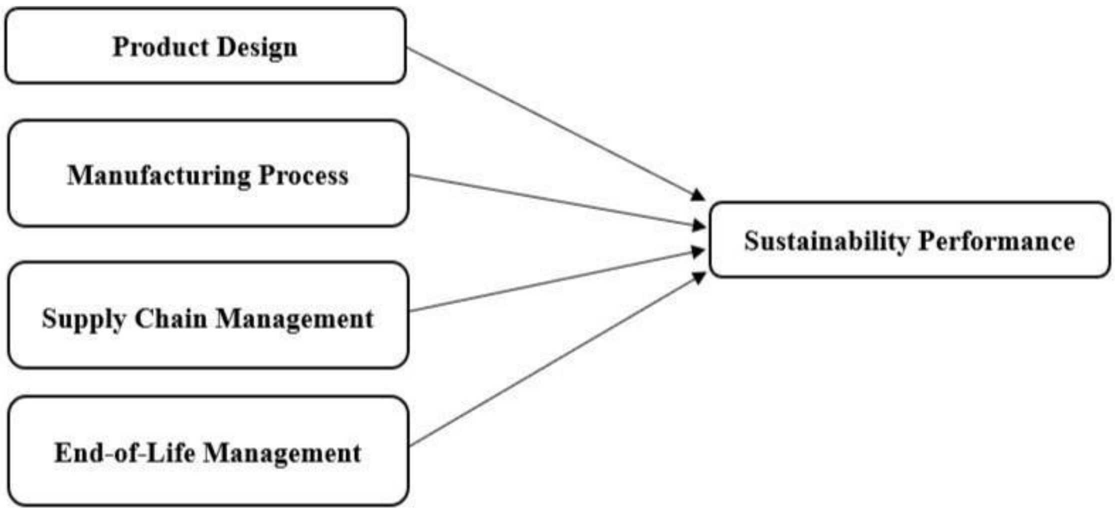

Figure 1: Research Framework

RESEARCH METHODOLOGY

To provide an empirical answer to the research questions, this study deploys a rigorous, cross-sectional quantitative research methodology. This chapter details the research design, population characteristics, sampling protocols, survey instrumentation, data collection procedures, and statistical analysis plans used to evaluate the hypotheses.

Research Design, Population, and Sampling Frame

This study utilizes a correlational, non-experimental research design using cross-sectional survey methodologies to compile primary data from the target population at a single, distinct point in time. A correlational design was selected because it allows for the precise calculation of statistical relationships and predictive impacts between multiple independent variables and a dependent construct without artificially manipulating the operational environment (Sekaran & Bougie, 2016). This configuration is ideal for testing the conceptual framework and proving or disproving the hypotheses.

The target population for this empirical investigation comprises manufacturing companies operating within two core economic zones in Malaysia: the Klang Valley and Kluang, Johor. These locations were chosen because of their paramount status as industrial centers as classified by the Department of Statistics Malaysia (DOSM, 2023). The Klang Valley represents the commercial heart of Malaysia, characterized by an exceptionally dense and diverse mix of industrial operations, including advanced automotive assembly, consumer electronics manufacturing, and heavy chemical processing. In contrast, Kluang, Johor, represents a rapidly expanding industrial cluster that drives economic growth across the southern region, hosting large concentrations of textile production, food processing, and industrial material fabrication. Sampling across both territories ensures excellent geographic and sector diversity, capturing an authentic reflection of the Malaysian manufacturing sector (DOSM, 2023).

The sampling frame was constructed by cross-referencing and compiling corporate registries from premier national industrial databases, including directories maintained by the Malaysian Investment Development Authority (MIDA), the Federation of Malaysian Manufacturers (FMM), and local chamber of commerce networks. Because national statistical registries do not provide a public listing of individual corporate contacts, these industrial directories were essential for building an accurate contact list of active firms within the target zones. The sample frame specifically targeted professional personnel employed within these verified manufacturing entities who possess direct oversight of operational strategies, supply chain logistics, product engineering, or corporate environmental initiatives.

Sampling Technique and Sample Size Determination

This research utilizes a purposive sampling technique, which is a structured non-probability sampling methodology where elements are selected based on explicit, predetermined criteria to ensure that respondents possess the specific knowledge and operational insight required to address the research objectives (Sekaran & Bougie, 2016). Purposive sampling was essential because general, front-line workers often lack insight into high-level sustainable procurement, life-cycle design, or corporate ESG metrics. Therefore, explicit screening criteria required respondents to hold professional roles such as senior operational managers, factory directors, sustainability compliance officers, procurement leads, or engineering supervisors, within a registered manufacturing firm in the target zones.

To determine the minimum sample size required to ensure sufficient statistical power and avoid type-II errors, a formal power analysis was conducted using G*Power software (Version 3.1). The calculation parameters were configured based on a multiple linear regression model with four independent predictors. Applying standard scientific benchmarks including a conventional alpha significance level of $\alpha = 0.05$, a high statistical power target of 0.95, and a conservative medium effect size (f^2) of 0.15, the G*Power formula indicated that a minimum sample size of 129 valid respondents was required. To ensure this threshold was met despite potential survey non-response, a larger volume of questionnaires was distributed across the target zones.

Unit of Analysis and Measurement Instrument

The unit of analysis represents the core entity being examined within a study, which is directly determined by the level where the operational intervention occurs (Sekaran & Bougie, 2016). For this research, the organization serves as the primary unit of analysis, as the study evaluates firm-level sustainable practices and corporate sustainability performance. Primary data was gathered by surveying individual professional employees across multiple hierarchical levels, including senior directors, factory managers, operations staff, and sustainability officers to compile a holistic, multi-perspective reflection of organizational practices.

The survey instrument was developed by compiling and adapting validated scales from prominent empirical literature to match the research objectives. To accommodate the local workforce, the questionnaire was presented in a bilingual format, featuring English and Bahasa Melayu translations that underwent rigorous back-translation verification. Section A compiled respondent demographic data across 5 distinct categorical items. Section B measured the four independent sustainable manufacturing practices using items adapted from Ibrahim et al. (2020), utilizing a 6-point Likert scale (ranging from 1 = 'Strongly Disagree' to 6 = 'Strongly Agree') to eliminate mid-point neutrality bias. Specifically, Sustainable Product Design was evaluated via 8 items tracking eco-material usage and disassembly configuration; Sustainable Manufacturing Process utilized 7 items assessing lean execution and energy optimization; Sustainable Supply Chain Management utilized 7 items tracking supplier audits and green logistics; and Sustainable End-of-Life Management was measured via 5 items assessing product recovery and recycling standards. Section C evaluated the dependent variable, Sustainability Performance, using 13 comprehensive items adapted from Xu et al. (2023). This section evaluated environmental, economic, and social performance outcomes using a 7-point Likert scale (ranging from 1 = 'Strongly Disagree' to 7 = 'Strongly Agree') to capture nuanced variations in corporate outcomes.

Data Collection and Statistical Analysis Plans

Data collection was executed over a structured multi-week timeframe, utilizing a hybrid distribution model that combined online digital surveys with targeted, in-person field visits to optimize response rates. The digital survey was constructed via Google Forms and distributed through professional messaging networks, including verified WhatsApp business lists, industrial Telegram groups, and professional LinkedIn networks, using corporate email contacts obtained from FMM registries. This digital deployment allowed for rapid distribution and enabled participants to complete the survey at their convenience (Sekaran & Bougie, 2016). To complement this, the researcher conducted structured physical field visits to key manufacturing facilities within the Klang Valley and Kluang, Johor. These site visits were scheduled in advance, allowing for direct engagement with factory managers and immediate administration of the questionnaire, which helped clarify technical definitions and ensured complete responses.

Statistical data analysis was conducted using IBM SPSS software, following a rigorous two-stage analytical protocol. Stage one focused on evaluating the measurement model, testing data cleanliness, and conducting validation assessments. Data cleaning included screening for missing data, testing for straight-lining patterns, and removing statistical outliers via standardized residual analysis. Scale quality was verified through face and content validity checks, followed by formal internal consistency testing using the Cronbach’s alpha model. Stage two executed structural model evaluation to test the research hypotheses. Pearson correlation analysis was deployed to calculate the strength and direction of the linear relationships between the variables. Finally, multiple linear regression analysis was executed to evaluate the overall model fit (R^2 and F-statistic) and calculate individual standardized B coefficients, t-values, and p-value significance thresholds, providing an empirical basis to validate or reject the hypotheses.

FINDINGS AND DISCUSSION

This chapter presents the statistical outputs derived from the primary dataset and provides a comprehensive discussion of the empirical findings. It details the data cleaning outcomes, response rates, respondent demographic profiles, descriptive statistics, reliability indicators, and normality metrics. Finally, it presents the core correlation and multiple regression analyses used to test the four research hypotheses.

Data Cleaning, Outlier Analysis, and Response Rate

Prior to executing the primary statistical tests, a rigorous data screening and cleaning protocol was conducted on the raw dataset using Microsoft Excel and IBM SPSS to ensure total data integrity. First, a comprehensive audit was executed to detect missing data or blank responses across the dataset. The results revealed zero blank fields, as the online survey configuration required completion of all questions, ensuring a complete and unfragmented dataset. Second, the responses were evaluated to identify straight-lining patterns, where a participant selects identical scale options across all items. No evidence of straight-lining was detected, indicating authentic engagement from respondents.

Third, statistical outlier analysis was executed by calculating standardized residuals through an initial linear regression run to detect extreme anomalies that could distort the regression model. The initial run identified zero cases on the first pass, but a subsequent pass identified a single significant outlier at Case Number 40. This specific case exhibited an extreme standardized residual value of -4.082, with an actual Sustainability Performance score of 4.62 against a predicted value of 6.259, generating an unacceptably large residual variance of -1.644. To ensure a robust, non-skewed regression model, this single outlying case was immediately removed from the active dataset. Following this removal, a final regression run confirmed a stable model fit, bringing the final valid sample size (N) to 134 respondents.

The final response rate metrics are summarized in Table 1, tracking the workflow from sample size determination to final data verification. The baseline sample size required by G*Power was 129 respondents. A total of 135 completed survey responses were gathered via the hybrid distribution channels. After filtering and removing the single statistical outlier during data cleaning, the final active sample stood at 134 valid responses. This final sample size successfully exceeded the minimum sample requirement of 129, providing excellent statistical power for the subsequent regression modeling.

Descriptions	Count
Sample size needed (G-Power)	129
Total responses received	135
Excluded via filter questions	0
Data cleaning: Straight Lining	0
Data cleaning: Blank responses	0
Data cleaning: Outliers removed	1
Total responses used for data analysis (N)	134

Table 1: Final Response Rate Summary Workflow

Demographic Profile Analysis

The compiled demographic characteristics of the 134 valid respondents are presented in Table 2, providing vital context regarding the sample's backgrounds, education levels, operational experience, and geographic distribution. Analysis of gender distribution indicates a relatively balanced sample, with a slight male majority comprising 52.2% (70 respondents) and females accounting for 47.8% (64 respondents). In terms of age distribution, the sample is characterized by a strong representation of young to mid-career professionals: the largest single cohort falls within the 20-29 years old bracket at 47.8% (64 respondents), followed by 30-39 years old at 20.1% (27 respondents), 40-49 years old at 15.0% (20 respondents), and 50-59 years old at 13.4% (18 respondents). Only a small minority of 3.7% (5 respondents) were over 59 years old. Marital status tracks a single majority at 56.0% (75 respondents), with married personnel comprising 42.5% (57 respondents), and 1.5% (2 respondents) identifying as 'others'.

The highest level of education attained reveals that a major portion of the surveyed manufacturing workforce holds an Sijil Pelajaran Malaysia (SPM) qualification as their primary credential, representing 61.2% (82 respondents), followed by Diploma holders at 19.4% (26 respondents). Higher-tier academic degrees are represented by Bachelor’s degrees at 9.7% (13 respondents), Master’s degrees at 9.0% (12 respondents), and PhD holders comprising 0.7% (1 respondent). Geographic distribution demonstrates strong concentration across the high-value industrial zones: the absolute majority are located within Kluang, Johor, representing 53.0% (71 respondents), with the remaining sample distributed across key Klang Valley hubs, including Kuala Lumpur at 23.1% (31 respondents), Putrajaya at 20.1% (27 respondents), and Selangor at 3.7% (5 respondents). Finally, analysis of years of service confirms a solid foundation of professional experience, with 72.4% (97 respondents) possessing between 1-20 years of active tenure, and 21.6% (29 respondents) possessing 21-30 years of operational experience. A small cohort of 6.0% (8 respondents) reported between 31-40 years of service, while zero respondents had exceeded 40 years of service. This diverse distribution ensures a broad range of perspectives across different operational layers within the manufacturing sector.

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Demographic Variable	Categories	Frequencies	Percentage (%)
Gender	Male	70	52.2
	Female	64	47.8
Age	20-29 Years Old	64	47.8
	30-39 Years Old	27	20.1
	40-49 Years Old	20	15.0
	50-59 Years Old	18	13.4
	Over 59 Years Old	5	3.7
Marital Status	Single	75	56.0
	Married	57	42.5
	Others	2	1.5
Highest Education	SPM	82	61.2
	Diploma	26	19.4
	Bachelor's Degree	13	9.7
	Master's Degree	12	9.0
	PhD	1	0.7
Current Location	Kluang, Johor	71	53.0
	Kuala Lumpur	31	23.1
	Putrajaya	27	20.1
	Selangor	5	3.7
Years of Service	1-20 Years	97	72.4
	21-30 Years	29	21.6
	31-40 Years	8	6.0
	41-50 Years	0	0.0
	Over 51 Years	0	0.0

Table 2: Comprehensive Demographic Distribution of Sample (N=134)

Descriptive Statistics, Scale Reliability, and Data Normality

Descriptive analysis was performed to evaluate the central tendency, variability, and general consensus among respondents regarding the core variables. As detailed in Table 3, the mean values across all four independent sustainable manufacturing practices were uniformly high, falling within a tight band between 5.07 and 5.18 on a 6-point scale, indicating strong overall agreement and consistent implementation across the sampled firms.

Specifically, Sustainable Manufacturing Process achieved the highest mean score of 5.18 (SD = 0.884), indicating that optimization of internal production operations represents the most deeply integrated practice among local firms. This was followed closely by Sustainable Supply Chain Management at 5.15 (SD = 0.848) and Sustainable End-of-Life Management at 5.12 (SD = 0.874), reflecting positive integration trends. Sustainable Product Design recorded a slightly lower but still positive mean score of 5.07 (SD = 0.846). Concurrently, the dependent variable, Sustainability Performance, achieved an exceptionally high overall mean score of 6.06 on its 7-point scale (SD = 1.031), proving that the integration of these sustainable configurations is strongly associated with highly favorable environmental, economic, and social performance outcomes.

Scale reliability and internal consistency were evaluated using the standardized Cronbach's alpha (α) coefficient, applying the rigorous empirical benchmarks established by Sekaran and Bougie (2016). According to these guidelines, values above 0.70 are acceptable, scores exceeding 0.80 indicate strong reliability, and metrics surpassing 0.90 signify excellent internal consistency. The reliability analysis revealed exceptional internal consistency across all measurement scales. Sustainable Product Design (8 items) registered an alpha of 0.913; Sustainable Manufacturing Process (7 items) achieved an exceptionally high alpha of 0.950; Sustainable Supply Chain Management (7 items) recorded an alpha of 0.925; and Sustainable End-of-Life Management (5 items) registered an alpha of 0.916. The dependent variable scale, Sustainability Performance (13 items), achieved an excellent alpha value of 0.972. These strong reliability scores confirm that the survey instruments were highly stable, free from random measurement errors, and fully optimized for structural regression modeling.

Data normality was evaluated by tracking the univariate skewness and kurtosis indices for each construct, benchmarking against the widely accepted statistical criteria outlined by Hair et al. (2010), which require skewness values to fall within a range of -2 to +2 and kurtosis indices to remain between -7 and +7 to assume a normal distribution. The metrics, summarized in Table 3, confirm that the independent variables fall within these acceptable thresholds, indicating reasonably symmetric distributions. Specifically, skewness values ranged from -1.528 to -1.956, while kurtosis indices ranged from 3.906 to 6.284. For the dependent variable (Sustainability Performance), the skewness (-2.168) and kurtosis (7.433) indices marginally exceeded the standard boundaries, indicating a slightly leptokurtic distribution characterized by a shaper peak and heavier tails. However, as established by Hair et al. (2010), these minor deviations are not problematic in sample sizes exceeding 100 cases, as large datasets stabilize parameter estimations and reduce the impact of slight non-normality on linear regression models.

Variables	Mean	SD	Cronbach's α	Skewness	Kurtosis
Sustainable Product Design	5.07	0.846	0.913	-1.528	3.906
Sustainable Manufacturing Process	5.18	0.884	0.950	-1.956	6.284
Sustainable Supply Chain Management	5.15	0.848	0.925	-1.723	5.470
Sustainable End-of-Life Management	5.12	0.874	0.916	-1.629	4.450
Sustainability Performance	6.06	1.031	0.972	-2.168	7.433

Table 3: Comprehensive Descriptive, Reliability, and Normality Metrics

Pearson Correlation Analysis

To evaluate the initial strength, direction, and statistical significance of the linear relationships between the variables, a bivariate Pearson correlation analysis was executed. In accordance with the statistical benchmarks defined by Hair et al. (2010), correlation coefficients (r) exceeding 0.70 indicate strong linear associations, while p-values below 0.05 signify formal statistical significance (Sekaran & Bougie, 2016). The correlation matrix, presented in Table 4, reveals exceptionally strong, positive, and highly significant relationships between every independent sustainable manufacturing practice and the dependent construct of Sustainability Performance.

Specifically, Sustainable End-of-Life Management exhibited the strongest direct correlation with Sustainability Performance ($r = 0.876$, $p < 0.001$), underscoring the vital importance of circular economy configurations, structured component recycling, and comprehensive product recovery management systems in driving organizational sustainability outcomes. Sustainable Product Design demonstrated an exceptionally strong linear relationship ($r = 0.870$, $p < 0.001$), confirming that early integration of eco-materials and disassembly configurations strongly supports superior sustainability performance. Sustainable Supply Chain Management also exhibited a powerful direct correlation ($r = 0.831$, $p < 0.001$), validating the strategic value of green procurement and supplier eco-audits. Sustainable Manufacturing Process registered a strong positive correlation ($r = 0.771$, $p < 0.001$), reinforcing the critical role of cleaner processing technologies and resource optimization on the factory floor.

In addition to these direct relationships, the correlation matrix reveals strong interrelationships among the independent variables themselves. For example, Sustainable Product Design is highly correlated with Sustainable Manufacturing Process ($r = 0.855$, $p < 0.001$) and Sustainable Supply Chain Management ($r = 0.899$, $p < 0.001$). Similarly, Sustainable Manufacturing Process exhibits a very strong association with Sustainable Supply Chain Management ($r = 0.890$, $p < 0.001$) and Sustainable End-of-Life Management ($r = 0.807$, $p < 0.001$). These elevated inter-variable coefficients prove that sustainable manufacturing practices are highly interdependent, operating as a set of complementary strategic capabilities within the firm. Because these independent variables exhibit tight linear associations, executing a subsequent multiple regression modeling process was essential to calculate the unique predictive power of each practice while simultaneously controlling for the other dimensions.

Variables	1	2	3	4	5
1. Sustainable Product Design	1.000				
2. Sustainable Manufacturing Process	0.855**	1.000			
3. Sustainable Supply Chain Mgmt	0.899**	0.890**	1.000		
4. Sustainable End-of-Life Mgmt	0.873**	0.807**	0.871**	1.000	
5. Sustainability Performance	0.870**	0.771**	0.831**	0.876**	1.000

Table 4: Bivariate Pearson Correlation Matrix Matrix

*** Correlation is significant at the 0.001 level (2-tailed); N = 134.*

Multiple Linear Regression Modeling

To rigorously test the four core research hypotheses and evaluate the exact extent to which each sustainable practice uniquely predicts corporate Sustainability Performance, a multiple linear regression analysis was executed. The structural model outputs encompassing Model Summary indicators, analysis of variance (ANOVA) metrics, and individual regression coefficients are consolidated across Tables 5, 6, and 7.

The Model Summary parameters, presented in Table 5, demonstrate the exceptional explanatory power of the regression model. The overall correlation coefficient (R) reached 0.933, proving an extremely strong positive collective relationship between the independent practices and the performance construct. Crucially, the Coefficient of Determination (R Square) achieved a value of 0.870, confirming that 87.0% of the total variance in corporate Sustainability Performance is uniquely explained by the model's four independent variables. The Adjusted R Square, which controls for the total number of predictors, remained extremely high at 0.866, confirming the stability and reliability of the model. Additionally, the Standard Error of the Estimate was remarkably low at 0.37690, indicating minimal average deviation between the observed data points and the predicted regression line, confirming high predictive accuracy.

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Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.933a	.870	.866	.37690

Table 5: Structural Regression Model Fit Fit Summary

To evaluate the global statistical significance of the regression model, an Analysis of Variance (ANOVA) was executed. As detailed in Table 6, the Regression Sum of Squares was 123.026, while the Residual Sum of Squares was 18.325, yielding a Total Sum of Squares of 141.351. The calculated F-statistic, derived from the ratio of the regression mean square (30.757) to the residual mean square (0.142), achieved an exceptionally high value of 216.518, which is highly significant with a p-value of 0.001. This highly significant F-test confirms that the probability of these findings occurring by chance is virtually zero, confirming that the combination of the four independent variables contributes significantly to explaining corporate Sustainability Performance.

Model	Source	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	123.026	4	30.757	216.518	.001b
	Residual	18.325	129	.142		
	Total	141.351	133			

Table 6: Analysis of Variance (ANOVA) for Global Model Significance

To isolate the specific, independent predictive contribution of each sustainable practice, individual regression coefficients were analyzed. As summarized in Table 7, the model presents the unstandardized coefficients (B), standard errors (Std. Error), standardized coefficients (B), t-statistics, and exact significance values (Sig.) for each separate variable. The structural results demonstrate that all four independent constructs exert positive and statistically significant effects on corporate Sustainability Performance, providing full empirical verification for all four research hypotheses.

Model	Predictor Variables	Unstandardized B	Std. Error	B (β)	t-value	Sig.
1	(Constant)	0.008	0.211		0.036	0.971
	Sustainable Product Design	0.234	0.086	0.192	2.728	0.007
	Sustainable Manufacturing Process	0.399	0.100	0.343	3.986	0.001
	Sustainable Supply Chain Mgmt	0.189	0.095	0.155	1.994	0.048
	Sustainable End-of-Life Mgmt	0.355	0.081	0.301	4.387	0.001

Table 7: Individual Unstandardized and Standardized Regression Coefficients

A detailed evaluation of the specific coefficients yields the following structural insights:

i. Sustainable Product Design: Unstandardized B = 0.234, Standardized B = 0.192, t = 2.728, p = 0.007. These results confirm that a single-unit expansion in sustainable design practices triggers a 0.234 unit increase in corporate sustainability performance when all other model parameters are controlled. Because the p-value (0.007) is well below the standard 0.01 threshold, the relationship is highly significant, confirming strong empirical support for Hypothesis 1.

ii. Sustainable Manufacturing Process: Unstandardized B = 0.399, Standardized B = 0.343, t = 3.986, p = 0.001. Crucially, this variable achieved the highest standardized coefficient (B = 0.343) across the entire model, identifying it as the single strongest, most dominant predictor of corporate Sustainability Performance. A single-unit optimization in internal production processes triggers a substantial 0.399 unit improvement in sustainability outcomes. The highly significant t-statistic (3.986, p = 0.001) confirms strong empirical verification for Hypothesis 2.

iii. Sustainable Supply Chain Management: Unstandardized B = 0.189, Standardized B = 0.155, t = 1.994, p = 0.048. This construct exhibited a slightly smaller relative predictive weight within the regression equation. However, because its p-value (0.048) successfully remains below the formal significance threshold of 0.05, it confirms that value-chain sustainability and green logistics exert a significant positive impact on sustainability performance, providing empirical validation for Hypothesis 3.

iv. Sustainable End-of-Life Management: Unstandardized B = 0.355, Standardized B = 0.301, t = 4.387, p = 0.001. This circular economy construct emerged as the second most powerful predictor within the model, generating a substantial standardized B of 0.301. A single-unit expansion in product recovery, recycling loops, and take-back management drives a 0.355 unit improvement in sustainability outcomes. The exceptionally high t-statistic (4.387, p = 0.001) confirms powerful empirical verification for Hypothesis 4.

Integration with the Underpinning Theory (NRBV)

The statistical validation of all four hypotheses provides powerful empirical support for the theoretical assertions of the Natural Resource-Based View (NRBV) framework within the Malaysian manufacturing sector. According to Hart’s (1995) NRBV theory, superior environmental and operational outcomes cannot be achieved through passive compliance or ad-hoc interventions. Instead, they require the deliberate, structured development of explicit internal capabilities that convert environmental constraints into unique strategic resources. The finding that the sustainable manufacturing process stands as the primary predictor of sustainability performance (B = 0.343, p = 0.001) perfectly validates the NRBV stage of pollution prevention. By embedding lean manufacturing and advanced energy management models directly onto the factory floor, firms successfully eliminate waste and carbon emissions at the source. This operational capability optimizes resource productivity, cushions firms against regulatory violation risks, and generates structural cost efficiencies that drive economic performance (Delaney et al., 2022).

Similarly, the strong predictive contributions of sustainable end-of-life management (B = 0.301, p = 0.001) and sustainable product design (B = 0.192, p = 0.007) provide explicit empirical validation for the NRBV capability of product stewardship. Product stewardship requires organizations to manage the total ecological consequences of their output through its entire life cycle. By integrating eco-materials at the design concept phase and deploying structured reverse logistics, take-back programs, and material recycling systems at the product end-of-life phase, manufacturers transform discarded waste into valuable secondary resources (Gautam et al., 2021). This closed-loop configuration reduces disposal costs, protects localized ecosystems, and enhances corporate reputation, converting lifecycle management into a powerful differentiation advantage (Lee et al., 2023). Finally, the validation of the supply chain management hypothesis (B = 0.155, p = 0.048) confirms that executing eco-audits and enforcing green procurement standards extends these internal NRBV capabilities across the entire value chain. This alignment allows the firm to systematically manage external risks and achieve long-term strategic viability (Samah et al., 2022).

CONCLUSION AND RECOMMENDATIONS

This concluding chapter synthesizes the core findings of the study, presents actionable recommendations for multi-sector industrial stakeholders, outlines clear paths for future research, and summarizes the study's macro-level contributions.

Synthesis of Findings

This research has provided rigorous quantitative validation of the relationship between sustainable manufacturing configurations and multi-dimensional corporate sustainability performance. The empirical outputs confirm that all four examined dimensions which are sustainable product design, sustainable manufacturing processes, sustainable supply chain management, and sustainable end-of-life management, exert highly significant positive effects on sustainability performance, collectively explaining 87% of the total variance in corporate outcomes. These findings prove that modern sustainability performance cannot be achieved through isolated, single-axis interventions. Instead, organizations must implement comprehensive, highly integrated operational frameworks that concurrently target every stage of the industrial footprint.

The primary operational return from the sustainable manufacturing process accentuates the critical need to prioritize internal processing efficiencies, carbon-reduction technologies, and lean manufacturing tools on the factory floor. These practices provide a strong baseline for environmental compliance while driving significant gains in factory productivity (Abdul-Rashid et al., 2017). Concurrently, the strong predictive weights of sustainable end-of-life management and sustainable product design highlight the growing corporate importance of the circular economy. Designing products for simple disassembly and deploying structured take-back networks allows organizations to systematically mitigate environmental liabilities while capturing valuable secondary materials from used inputs (Dwivedi et al., 2022). Finally, the positive contribution of sustainable supply chain management reinforces the value of managing upstream and downstream dependencies through green procurement standards and collaborative logistics (Scharmer et al., 2024).

Multidimensional Actionable Recommendations

To facilitate the systemic adoption of these sustainable manufacturing configurations across the Malaysian industrial sector, targeted interventions are required across three primary groups of stakeholders:

For Industry Practitioners and Corporate Managers: Manufacturing executives must move past passive regulatory compliance and firmly embed sustainable practices into core corporate strategy. Given the dominant impact of manufacturing processes, firms should invest heavily in automated energy management systems, lean operations, and clean processing technologies to systematically cut energy inputs and eliminate waste at the source (Ali et al., 2021). Concurrently, product engineering teams must prioritize eco-design methodologies, utilizing biodegradable or recyclable compounds and optimizing product architecture to support easy component rework and material extraction (Hermawan et al., 2023). To maximize value-chain efficiency, procurement managers must implement formal green purchasing protocols, requiring all upstream subcontractors to obtain recognized green certifications (Hermawan et al., 2023). Finally, operations leads must actively transition from a linear 'make-use-dispose' configuration to a circular loop, deploying structured take-back systems and components coding standards to recapture economic value from discarded products (Dwivedi et al., 2022).

For Financial Institutions and Private Lenders: Because a large portion of small and medium enterprises (SMEs) lack the liquid capital necessary to deploy advanced green technologies, private commercial banks and state financial institutions must provide dedicated green credit facilities (Hermawan et al., 2023). Financial entities should offer subsidized interest rates, specialized green bonds, and flexible credit terms specifically tied to corporate investments in energy-efficient machinery, automated waste processing systems, and low-carbon design technology. Providing accessible green financing can mitigate the financial risks of technology adoption and accelerate the transition toward clean manufacturing across the SME sector.

For Government Bodies and Policymakers: Public sector agencies must design and enforce comprehensive policy frameworks that actively support industrial sustainability. The government should offer tax waivers, direct subsidies, and accelerated capital allowances for manufacturers that utilize low-carbon design assets and eco-friendly materials (Loong et al., 2024). Furthermore, statutory bodies should establish a formalized national certification scheme for sustainable product design to validate eco-innovation and enhance market competitiveness. To support circular loops, policymakers must build robust recycling infrastructure in high-density industrial corridors like the Klang Valley and manufacturing zones in Johor (Loong et al., 2024). Finally, regulatory bodies must strengthen the enforcement of Extended Producer Responsibility (EPR) laws, transforming voluntary compliance into a mandatory statutory framework that holds manufacturers accountable for their entire product lifecycle.

Directions for Future Empirical Research

While this research provides robust quantitative insights, several explicit directions for future empirical inquiry should be pursued to enhance the literature. First, the geographic scope of this study was restricted to high-value industrial clusters within the Klang Valley and Kluang, Johor, which may limit the generalizability of the findings across peripheral regions. Future research should expand this scope to sample firms across alternative industrial territories such as specialized high-tech zones in Penang or resource-dependent manufacturing clusters in Sarawak as these regions operate under distinct socioeconomic conditions and localized environmental protocols (Alinda et al., 2024). Second, this study utilized a cross-sectional research design that evaluates variables at a single point in time, which cannot track the long-term strategic evolution of corporate capabilities. Future scholars should deploy longitudinal methodologies to track the long-term operational returns of green investments and evaluate how macro policies such as the Green Technology Master Plan (GTMP), that affect corporate outcomes over an extended period (Scharmer et al., 2024).

Third, future models should integrate emerging technical variables that were omitted from this study. In alignment with accelerating Industry 4.0 trends, future investigations should evaluate the moderating or mediating impacts of Artificial Intelligence (AI), the Internet of Things (IoT), big data analytics, and blockchain ledger tracking on sustainable manufacturing execution (Yang & Jin, 2024). These advanced digital tools are increasingly critical for optimizing production efficiency, eliminating supply chain friction, and verifying material sourcing transparency (Yang & Jin, 2024). Fourth, researchers should consider utilizing a mixed-methods approach, combining extensive quantitative surveys with qualitative multi-case studies. Incorporating qualitative interviews can provide rich, contextual insights into the internal cultural barriers, managerial motivations, and operational friction that influence the real-world adoption of sustainable configurations (Alexander et al., 2020). Finally, future research should integrate external contingency factors such as institutional stakeholder pressure, competitive market intensity, and sovereign environmental policy shifts to evaluate how external variables interact with internal capabilities to shape corporate sustainability performance (Alinda et al., 2024).

Conclusion

In conclusion, this study has delivered a comprehensive quantitative examination of the role of sustainable manufacturing practices in driving holistic sustainability performance across critical industrial regions in Malaysia. Grounded in the Natural Resource-Based View (NRBV) theory, the empirical results confirm that sustainable product design, sustainable manufacturing processes, sustainable supply chain management, and sustainable end-of-life management represent vital internal capabilities that allow firms to convert environmental constraints into powerful competitive advantages. By successfully confirming all four research hypotheses, the study highlights that integrating comprehensive, life-cycle-oriented sustainability models is a commercial and operational requirement within the modern industrial landscape. As Malaysia transitions toward future national development plans and aligns with global ESG reporting frameworks, the adoption of these data-verified sustainable manufacturing configurations will be essential to ensure long-term ecological balance, protect public welfare, and maintain international corporate competitiveness.

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REFERENCES

1. Abdul-Rashid, S. H., Sakundarini, N., Raja Ghazilla, R. A., & Thurasamy, R. (2017). The impact of sustainable manufacturing practices on sustainability performance. International Journal of Operations & Production Management, 37(2), 182–204.
2. Adusei, E., Demah, E., & Mensah, H. K. (2023). Does going intellectually green matter? Accentuating the role of eco-innovation speed and quality in a competitive post-Covid 19 emerging market. International Journal of Innovation Science.
3. Al Koliby, M., I. S., Abdullah, H. H., & Mohd Suki, N. (2022). Linking entrepreneurial competencies,

innovation and sustainable performance of manufacturing smes. Asia-Pacific Journal of Business Administration, 16(1), 21–40.

4. Alexander, Hennelley, & Hargreaves. (2020). Make the most of qualitative research. Nature Sustainability, 3(2), 73–73.
5. Ali, H., Chen, T., & Hao, Y. (2021). Sustainable manufacturing practices, competitive capabilities, and sustainable performance: Moderating role of environmental regulations. Sustainability, 13(18), 10051.
6. Alinda, K., Tumwine, S., & Kaawaase, T. K. (2024). Environmental innovations and sustainability practices of manufacturing firms in Uganda. Asia Pacific Journal of Innovation and Entrepreneurship, 18(2), 102–129.
7. BP Global Energy Review. (2023). Statistical review of world energy. BP Global.
8. Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17(1), 99-120.
9. Delaney, E., Liu, W., Zhu, Z., Xu, Y., & Dai, J. S. (2022). The investigation of environmental sustainability within product design: A critical review. Design Science, 8.
10. Department of Environment (DOE). (2023). Environmental quality report 2022. Ministry of Natural Resources, Environment and Climate Change Malaysia.
11. Department of Statistics Malaysia (DOSM). (2023). Manufacturing statistics. OpenDOSM. https://open.dosm.gov.my/dashboard/manufacturing-statistics
12. Dwivedi, A., Madaan, J., Santibanez Gonzalez, E. D. R., & Moktadir, Md. A. (2022). A two-phase approach to efficiently support product recovery systems in a circular economy context. Management Decision, 60(7), 2060–2091.
13. Escoto, X., Gebrehewot, D., & Morris, K. C. (2022). Refocusing the barriers to sustainability for small and medium-sized manufacturers. Journal of Cleaner Production, 338, 130589.
14. Gautam, P., Khanna, A., & Jaggi, C. K. (2021). An integrated green supply chain model with product recovery management towards a cleaner system. Journal of Cleaner Production, 320, 128850.
15. Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). Multivariate data analysis (7th ed.). Pearson.
16. Hart, S. L. (1995). A natural-resource-based view of the firm. Academy of Management Review, 20(4), 986-1014.
17. Hermawan, A. N., Masudin, I., Zulfikarijah, F., Restuputri, D. P., & Shariff, S. S. (2023). The effect of sustainable manufacturing on environmental performance through government regulation and eco-innovation. International Journal of Industrial Engineering and Operations Management, 6(4), 299–325.
18. Huang, Y., Shafiee, M., Charnley, F., & Encinas-Oropesa, A. (2022). Designing a framework for materials flow by integrating circular economy principles with end-of-life management strategies. Sustainability, 14(7), 4244.
19. Ibrahim, Y. M., Hami, N., & Abdulameer, S. S. (2020). A scale for measuring sustainable manufacturing practices and sustainability performance: Validity and Reliability. Quality Innovation Prosperity, 24(2), 59.
20. Ibrahim, Y.M., Hami, N., & Othman, S. N. (2019). Integrating sustainable maintenance into sustainable manufacturing practices and its relationship with sustainability performance: A conceptual framework. International Journal of Energy Economics and Policy, 9(4), 30–39.
21. Jiang, P., Dieckmann, E., Han, J., & Childs, P. R. (2021). A bibliometric review of sustainable product design. Energies, 14(21), 6867.
22. Johari, N. A. M., Mokhtar, A. R. M. & Sayuti, N. M. (2022). Conceptualising Stakeholder Commitment, Closed-Loop Supply Chains and Organisational Performance: A Circular Economy Perspective. Journal of Entrepreneurship, Business and Economics, 10(2).
23. Khan, R. U., Saqib, A., Abbasi, M. A., Mikhaylov, A., & Pinter, G. (2023). Green leadership, environmental knowledge sharing, and sustainable performance in manufacturing industry: Application from upper echelon theory. Sustainable Energy Technologies and Assessments, 60, 103540.
24. Khan, N. U., Wu, W., Saufi, R. B., Sabri, N. A., & Shah, A. A. (2021). Antecedents of sustainable performance in manufacturing organizations: A structural equation modeling approach. Sustainability, 13(2), 897.
25. Lee, W.L., Chung, Y.A., Tan, S.S., Koh, Y.M.H., S., Lu, W.F. & Low, J. (2023). Enhancing the environmental sustainability of product through ecodesign: A systematic review. Journal of Engineering

Design, 34(10), 814–843.

26. Loong, A.H., Lada, S., Kehui, W., Bui, C.J. & Xinyue, L. (2024). Examining influential elements impacting performance in sustainable manufacturing within Malaysian enterprise: A conceptual analysis. Malaysian Journal of Business and Economics (MJBE), 11(1), 90–101.
27. McDougall, N., Wagner, B., & MacBryde, J. (2021). Leveraging competitiveness from sustainable operations: Frameworks to understand the dynamic capabilities needed to realise NRBV supply chain strategies. Supply Chain Management: An International Journal, 27(1), 12–29.
28. Mokhtar, A. R., Anindita, M. S. & Suhaimi, Z. S. (2023). Leveraging Supply Chain Leadership for Dynamic Capabilities and Organisational Resilience. Advances in Social Sciences Research Journal, 10(6.2), 54–66.
29. Mokhtar, A. R. M., Sundram, V. P. K. & Shahrom, M. (2024). Sustainable Supply Chain Management Education: Employing Artificial Intelligence, Augmented Reality, and Gamification for Effective Learning. Advances in Social Sciences Research Journal, 11(2.2), 437–451. 23
30. Nor-Aishah, H., Ahmad, N. H., & Thurasamy, R. (2020). Entrepreneurial leadership and sustainable performance of manufacturing smes in Malaysia: The contingent role of entrepreneurial bricolage. Sustainability, 12(8), 3100.
31. Rancangan Malaysia Ke-12 (RMK-12). (2021). Twelfth Malaysia Plan 2021-2025: A prosperous, inclusive, sustainable Malaysia. Economic Planning Unit, Prime Minister's Department Malaysia.
32. Rizwan, M., et al. (2023). Redefining contemporary strategic operations: Integrating the Triple Bottom Line framework. International Journal of Strategic Management, 29(1), 112–128.
33. Samah, M., Salah, O., & El Farouk Imane, I. (2022). A literature review on sustainable supply chain management and its impact on sustainable performance. 2022 14th International Colloquium of Logistics and Supply Chain Management (LOGISTIQUA).
34. Scharmer, V. M., Vernim, S., Horsthofer-Rauch, J., Jordan, P., Maier, M., Paul, M., Schneider, D., Woerle, M., Schulz, J., & Zaeh, M. F. (2024). Sustainable manufacturing: A review and framework derivation. Sustainability, 16(1), 119.
35. Sekaran, U., & Bougie, R. J. (2016). Research methods for business: A skill building approach (7th ed.). John Wiley & Sons.
36. Shaharudin, M. R., Abd Hamid, N. Z., Abdullah, D., Ahmad, N., Hassam, S. F., & Ahmad Fauzi, N. H. H. (2022). Factors affecting social sustainability performance amongst Malaysian manufacturing companies. International Journal of Business and Society, 23(3), 1874–1887.
37. Sánchez-Flores, R. B., Cruz-Sotelo, S. E., Ojeda-Benitez, S., & Ramírez-Barreto, Ma. E. (2020). Sustainable supply chain management; a literature review on emerging economies. Sustainability, 12(17), 6972.
38. United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. UN Publishing.
39. Wang, S., & Su, D. (2022). Sustainable product innovation and consumer communication. Sustainability, 14(14), 8395.
40. Watkins, M., Casamayor, J. L., Ramirez, M., Moreno, M., Faludi, J., & Pigosso, D. C. A. (2021). Sustainable product design education: Current practice. She Ji: The Journal of Design, Economics, and Innovation, 7(4), 611–637.
41. Xu, J., Yu, Y., Zhang, M., & Zhang, J. Z. (2023). Impacts of digital transformation on eco-innovation and sustainable performance: Evidence from Chinese manufacturing companies. Journal of Cleaner Production, 393, 136278.
42. Yang, Q., & Jin, S. (2024). Exploring the impact of digital transformation on manufacturing environment, social responsibility, and corporate governance performance: The moderating role of top management teams. Sustainability, 16(11), 4342.