Resilient Supply Chains in Malaysia's Manufacturing Sector: A Comparative Analysis of Priority Industries Affected by COVID-19

Fadhlur Rahim Azmi[1]*, Nursyahwani Mohd Sukri[1], Nurazree Mahmud[1], Veera Pandiyan Kaliani Sundram[2], Nornajihah Nadia Hasbullah[1], Haslinda Musa[3]

[1]Faculty of Business and Management, Universiti Teknologi MARA, Cawangan Melaka, Kampus Bandaraya Melaka, 10 Off Jalan Hang Tuah 75350 Melaka, Malaysia.

[2]RIG – Sustainable Supply Chain Logistics / Faculty of Business and Management, Universiti Teknologi MARA Selangor, Malaysia/ Institute of Business Excellence, Universiti Teknologi MARA Shah Alam, Malaysia

[3]Faculty of Technology Management and Technopreneurship, Universiti Teknikal Malaysia Melaka, 74100, Melaka, Malaysia

*Corresponding author : fadhlur@uitm.edu.my

ABSTRACT

The COVID-19 pandemic exposed vulnerabilities within global supply chains, with Malaysia's manufacturing sector, a cornerstone of the nation's economy, experiencing significant disruptions. This study explores the interplay between supply chain risk management (SCRM), supply chain resilience (SCR), and sustainability efforts (SE) within the context of Malaysia's priority manufacturing sectors—namely aerospace, chemicals, electrical and electronics (E&E), pharmaceuticals, and medical devices. Employing a quantitative research approach, data were collected from 360 firms, and the hypothesized relationships were analyzed using structural equation modeling. The findings confirm that effective SCRM practices significantly enhance SCR across all sectors, with the E&E industry exhibiting the strongest relationship due to its reliance on globalized networks. Furthermore, SCR positively influences supply chain performance (SCP), highlighting its critical role in maintaining operational efficiency, delivery reliability, and customer satisfaction during disruptions. The study also reveals a nuanced moderating role of SE on the SCRM-SCR relationship, with significant effects observed in the aerospace sector, underscoring the sector-specific dynamics of resilience-building efforts. This research offers one of the first empirical assessments of these dynamics across Malaysia's most strategic manufacturing industries, providing sector-specific insights aligned with the country's New Industrial Master Plan 2030. The findings offer valuable guidance for Malaysian businesses and policymakers seeking to enhance supply chain robustness, sustainability, and competitive advantage in preparation for future disruptions.

KEYWORDS: Supply chain resilience, Supply chain risk management, Sustainability, COVID-19, Malaysia

Received 2 May 2025; Revised 4 June 2025; Accepted 16 June 2025
Doi: https://doi.org/10.59953/paperasia.v41i4b.557

1. INTRODUCTION

The COVID-19 pandemic exposed critical vulnerabilities in global supply chains, particularly within Malaysia's manufacturing sector, a cornerstone of its economic growth. Industries prioritized under the New Industrial Master Plan 2030—including aerospace, chemicals, electrical and electronics (E&E), pharmaceuticals, and medical devices—faced significant disruptions such as supply shortages, logistical constraints, and fluctuating demand (Chowdhury et al., 2021; Ivanov, 2021). These challenges highlighted the urgent need for robust and resilient supply chains that can endure crises while maintaining continuity.

While supply chain resilience (SCR) has gained attention, gaps persist—especially in the Malaysian context. Many studies examine supply chain risk management (SCRM) in isolation, often overlooking how it interacts with sustainability efforts (SE) to strengthen resilience. Moreover, cross-sectoral differences in resilience practices remain underexplored, limiting the ability of industry leaders and policymakers to craft targeted interventions (Ministry of Investment, Trade and Industry, 2023; Hokmabadi et al., 2024). In addition, much of the existing literature has focused on high-income or Western economies, where digital integration and risk governance mechanisms are more advanced (Mayer, 2021). In contrast, Malaysian manufacturing firms often face supply chain fragmentation, limited visibility, and infrastructure constraints (Ishak et al. 2023), especially in globally exposed sectors such as E&E and aerospace. This highlights a critical need to understand how SCRM and SE function in a developing country context, where vulnerabilities are often magnified.

Supply chain management is particularly important for Malaysia's priority industries because of their embeddedness in global value chains, heavy reliance on imported intermediate goods, and strict compliance requirements imposed by international regulatory and quality standards. Compared to advanced economies such as Germany or Japan—where risk anticipation, supply chain transparency, and digital integration are more mature—Malaysia's industries face additional challenges including infrastructural limitations, talent gaps, and policy enforcement variability (Noor et al. 2021; Dehdasht et al., 2022; Wahab et al. 2024). These constraints make efficient supply chain management practices not just beneficial but essential for maintaining competitiveness, especially amid ongoing disruptions related to geopolitical tensions, climate change, and technology shifts. Recent studies further argue that the strategic integration of risk management, digital tools, and sustainability practices is a decisive factor in enhancing the resilience of emerging market manufacturers (Rodríguez-Espíndola et al., 2022).

This study addresses these gaps by examining the relationships between SCRM, SCR, and SCP, and the moderating role of SE. It also conducts a comparative analysis across Malaysia's priority manufacturing sectors. By focusing on strategic industries identified in Malaysia's New Industrial Master Plan 2030, the study not only contributes empirical evidence from a developing economy perspective but also provides sector-specific insights that are often overlooked in general SCM research. Theoretically, this work advances understanding of SCR by incorporating SE as a moderating variable; practically, it informs policy and industry strategies aligned with the objectives of the New Industrial Master Plan 2030.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 Supply Chain Risk Management and Supply Chain Resilience

Supply Chain Risk Management (SCRM) refers to a set of coordinated strategies designed to identify, assess, and mitigate potential disruptions across the supply chain. These strategies are typically categorized into preventive measures—such as supplier monitoring, dual sourcing, and contingency planning—and reactive responses, including crisis management teams, rerouting logistics, and rapid supplier replacement (Ivanov, 2021; Can Saglam et al., 2021). In highly regulated industries like aerospace and pharmaceuticals, risk management frameworks must be tailored to sector-specific compliance and safety standards, making SCRM both more complex and more critical (Hohenstein, 2022; Guerra et al., 2024).

In the context of Malaysia's priority manufacturing sectors, which are deeply embedded in global supply networks, the role of SCRM is particularly pronounced. For example, the E&E industry faces exposure to geopolitical instability, semiconductor shortages, and trade policy shifts, while the aerospace sector must manage intricate certification requirements and supplier dependencies (Debnath et al., 2022; Xuan & Kamaruddin, 2024). To navigate such challenges, firms increasingly deploy proactive measures such as real-time risk monitoring, supply base diversification, predictive analytics, and cross-functional risk teams to preemptively manage vulnerabilities.

Supply Chain Resilience (SCR), on the other hand, is the capacity of a supply chain to anticipate, absorb, and recover from disruptions while maintaining continuity of operations (Adobor, 2020). It is underpinned by attributes such as flexibility, agility, visibility, and collaboration (Mubarik et al., 2021). Robust SCRM practices provide the foundational infrastructure for resilience by enabling early risk identification, adaptive planning, and effective coordination under uncertainty (Norrman & Wieland, 2020).

Cross-national comparisons further highlight the contextual relevance of SCRM in Malaysia. In advanced economies like Germany and South Korea, manufacturing firms benefit from mature digital ecosystems, centralized logistics infrastructure, and real-time data integration—conditions that naturally support high levels of SCR (Lechowski & Krzywdzinski, 2022; Shin, 2024). In contrast, Malaysian manufacturers—particularly mid-tier firms—grapple with operational fragmentation, limited end-to-end visibility, lower digital maturity, and a heavier reliance on manual coordination (Ishak et al., 2023), especially in globally exposed industries like E&E and aerospace. These constraints elevate the strategic importance of SCRM in Malaysia's context, as even incremental improvements in risk management can yield disproportionately large gains in resilience.

Thus, this study positions Malaysia's manufacturing sector as a vital empirical setting to explore how SCRM practices translate into SCR in a resource-constrained yet globally integrated environment. Understanding this relationship contributes to theory-building in emerging market supply chains and provides sector-specific guidance for resilience planning.

H1: Supply chain risk management has a positive effect on supply chain resilience.

2.2 Supply Chain Resilience and Performance

SCR has emerged as a critical determinant of supply chain performance (SCP), particularly in environments marked by volatility, uncertainty, and rapid change. SCP encompasses key operational outcomes such as delivery reliability, production efficiency, responsiveness, and customer satisfaction (Singh & Modgil, 2025). Resilient supply chains are characterized by their ability to withstand disruptions, adapt to unforeseen conditions, and recover quickly—ensuring minimal interruption to value creation processes even under adverse conditions (Tarigan et al., 2021; Mishra et al., 2022).

In high-risk sectors such as aerospace and E&E, where quality assurance, supply continuity, and global compliance are essential, resilience plays a pivotal role. The ability to maintain consistent performance during disruptions is often achieved through structural flexibility, diversified sourcing, and real-time visibility across the supply network (Tahir et al., 2022; Gölgeci et al., 2023). In these sectors, advanced practices such as predictive analytics, collaborative planning, and inventory buffering are increasingly adopted to mitigate performance risks. Tools like scenario modeling, supplier collaboration platforms, and digital twin technologies have demonstrated measurable performance improvements by enabling faster recovery and more accurate responsiveness under uncertainty (Aljohani, 2023).

However, in Malaysia's manufacturing landscape, the link between resilience and performance takes on a more complex and context-sensitive dimension. While firms in advanced economies often benefit from high levels of digitalization, government-supported automation programs, and advanced logistics networks (Rawat et al., 2025), Malaysian firms—especially in the chemical and medical devices sectors—face limitations related to infrastructure and integration with upstream suppliers (Yeo et al., 2023; Zakaria et al., 2023; Amran et al., 2024). These constraints necessitate a more strategic and localized approach to building resilience. As noted by Gruchmann et al. (2024), firms in emerging markets tend to rely more heavily on manual coordination, reactive problem-solving, and interpersonal networks to maintain operational performance during crises.

This makes SCR not merely a competitive advantage, but a fundamental capability for survival in the Malaysian context. In such environments, the marginal benefits of building resilience—through process agility, risk visibility, and cross-functional coordination—can have a disproportionately positive impact on overall performance. By empirically testing the relationship between SCR and SCP across Malaysia's priority sectors, this study sheds light on how resilience mechanisms drive operational effectiveness in developing economies and provides insights into how performance can be improved despite institutional and technological constraints.

H2: Supply chain resilience has a positive effect on supply chain performance.

2.3 Sustainability Efforts and Supply Chain Resilience

Sustainability efforts (SE) encompass a broad set of practices aimed at minimizing environmental harm, enhancing social responsibility, and fostering ethical governance throughout the supply chain. These include eco-friendly process improvements, adoption of green certifications (e.g., ISO 14001), supplier training on environmental compliance, and investments in clean technologies. Such efforts not only promote responsible operations but also contribute significantly to SCR by improving transparency, adaptability, and long-term continuity of supply (Miceli et al., 2021; Ramzan et al., 2022). When embedded effectively, SE enables firms to better anticipate and respond to disruptions related to environmental regulations, reputational risks, or stakeholder pressures (Chowdhury & Quaddus, 2021).

SE also serves as a mechanism to address environmental, social, and governance risks that are often underrepresented in traditional risk management frameworks. By integrating sustainability into supply chain operations—through green procurement policies, supplier sustainability audits, and ESG compliance standards—firms enhance their ability to manage long-term vulnerabilities that may otherwise threaten operational stability (Juettner et al., 2020). These practices are particularly relevant in sectors with high environmental exposure or stakeholder scrutiny, such as aerospace and E&E.

However, the level of SE integration into SCRM varies significantly across industries and regions. In advanced economies like the European Union, SE is increasingly embedded in strategic planning and corporate risk governance. Râmniceanu et al. (2022), supported by regulatory incentives and industry-wide ESG mandates (Carissimi et al., 2023). In contrast, firms in emerging economies often implement SE reactively—to meet customer or export certification demands—rather than proactively incorporating them into their risk mitigation strategies. In Malaysia, for example, SE is often driven by external compliance requirements from multinational clients rather than internalized sustainability culture or long-term resilience planning (Ministry of Investment, Trade and Industry, 2023).

This disconnect may limit the synergistic potential between sustainability and resilience. Although Malaysian firms in sectors like aerospace and E&E are increasingly aligning with international sustainability standards due to export dependency, industries such as chemicals and medical devices still face challenges stemming from cost concerns, legacy systems, and insufficient enforcement mechanisms (Rizos & Bryhn, 2022; McDermott et al., 2022; Fenton et al., 2023; Joeaneke et al., 2024). Understanding this variation is essential to assessing the extent to which SE can enhance the effectiveness of SCRM in building SCR.

By examining SE as a moderating variable in the SCRM–SCR relationship, this study seeks to uncover whether sustainability can enhance resilience beyond traditional risk management strategies, particularly in developing country contexts where institutional support and internal capabilities may be constrained. The findings are expected to offer practical insights for how Malaysian manufacturers can move from compliance-oriented SE to more strategic, resilience-driven integration.

H3: Sustainability efforts positively moderate the relationship between supply chain risk management and supply chain resilience.

3. RESEARCH METHODOLOGY

3.1 Instrument Development

The survey instrument was designed by adapting items from previously validated studies to ensure theoretical rigor and measurement reliability. The constructs included in this study—Supply Chain Risk Management (SCRM), Supply Chain Resilience (SCR), Supply Chain Performance (SCP), and Sustainability Efforts (SE)—were operationalized using multi-item scales as detailed in **Table 1**.

The SCRM construct was modeled as a first-order formative construct, with three items capturing key preventive and reactive risk strategies: identifying potential supply chain risks early (SCRM1), developing risk mitigation plans (SCRM2), and implementing risk monitoring tools (SCRM3). These items were adapted from Can Saglam et al. (2021) and Ivanov (2021).

SCR was measured as a first-order reflective construct, comprising indicators related to the firm's ability to recover from disruptions (SCR1), maintain process flexibility (SCR2), and collaborate with suppliers during crises (SCR3). These items were based on the work of Adobor (2020) and Mubarik et al. (2021).

SCP was also treated as a first-order reflective construct, reflecting outcomes such as improved delivery lead times (SCP1), enhanced operational efficiency (SCP2), and customer satisfaction metrics (SCP3), consistent with Singh and Modgil (2025).

The SE construct was designed as a second-order formative construct, drawing from three core dimensions: implementation of eco-friendly practices (SE1), adoption of green certifications such as ISO 14001 (SE2), and supplier training in sustainability (SE3). These items were sourced from Juettner et al. (2020), Miceli et al. (2021), and Ramzan et al. (2022).

To ensure content validity and contextual appropriateness, the initial survey draft underwent expert evaluation by three academics and two industry professionals. A pilot test was then conducted with 10 supply chain practitioners from diverse sectors to assess clarity, cultural relevance, and item reliability. Feedback led to minor revisions in wording to enhance interpretability for Malaysian manufacturing respondents. All items were measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The survey was administered in English, which is the dominant language of business communication in Malaysia's manufacturing industry.

This study was conducted in full compliance with ethical research standards. Participants were informed of the study's objectives and assured that their participation was voluntary, anonymous, and confidential. Respondents were given the option to decline or withdraw from the study at any time.

Table 1: *Table for items and constructs*

Constructs	Items	Measurement Model
Supply Chain Risk Management (SCRM)	Identifying potential supply chain risks early. (SCRM1) Developing risk mitigation plans. (SCRM2) Implementing risk monitoring tools. (SCRM3)	First-order formative
Supply Chain Resilience (SCR)	Quick recovery from supply disruptions. (SCR1) Flexibility in supply chain processes. (SCR2) Collaboration with suppliers to handle crises. (SCR3)	First-order reflective
Supply Chain Performance (SCP)	Improved delivery lead times. (SCP1) Enhanced operational efficiency. (SCP2) Customer satisfaction metrics. (SCP3)	First-order reflective
Sustainability Efforts (SE)	Implementation of eco-friendly practices. (SE1) Adoption of green certifications (e.g., ISO 14001). (SE2) Supplier training in sustainability. (SE3)	Second-order formative

Informed consent was obtained from all participants: digitally via a checkbox in online surveys and in writing for face-to-face sessions. Although this research posed minimal risk, the design and implementation were guided by principles of academic integrity and respect for participant autonomy. All collected data were stored securely and used strictly for academic purposes.

The constructs were assessed through rigorous statistical analyses to confirm their reliability and validity. SCRM was measured as a formative construct using preventive and reactive risk mitigation strategies, operationalized with items such as identifying potential risks early, developing mitigation plans, and implementing monitoring tools. Formative models assume that the indicators define the construct rather than reflect it, requiring the evaluation of outer weights and variance inflation factors (VIF) to assess multicollinearity and relevance of the indicators (Diamantopoulos & Winklhofer, 2001). The results for these assessments are presented in **Table 2**.

Outer weights represent the relative importance of indicators in formative constructs, and significance is tested using bootstrapping methods (Chin, 2009). VIF values below the commonly accepted threshold of 5 indicate the absence of critical multicollinearity issues (Kalnins & Praitis, 2025).

The SCR construct was modeled as a reflective construct focusing on the dimensions of quick recovery, flexibility, and collaboration in handling disruptions. Reflective models assume that the construct influences the indicators, and reliability is assessed using outer loadings. High outer loadings (≥ 0.7) indicate that the indicators are strongly associated with the latent variable (Hair et al., 2012). The results are shown in **Table 3**.

SE encompassed environmental, social, and supplier development dimensions, operationalized through practices such as eco-friendly initiatives, green certifications, and supplier training programs. These formative constructs demonstrated strong statistical support for all dimensions.

Discriminant validity was confirmed using the Fornell-Larcker criterion, which states that the square root of the AVE for each construct should exceed its correlation with other constructs (Fornell & Larcker, 1981). As shown in **Table 4**, the constructs in this study meet this requirement, confirming their conceptual distinctiveness.

This comprehensive assessment of measures and constructs establishes a robust foundation for the subsequent analysis and ensures that the study's findings are both reliable and valid. This approach aligns with established practices in structural equation modeling and contributes to the growing body of research on SCR.

3.2 Sampling Approach and Limitations

This study employed a systematic random sampling technique to select participating firms from the Federation of Malaysian Manufacturers (FMM) directory, which served as a reliable and comprehensive sampling frame. The FMM directory includes firms operating within Malaysia's five priority manufacturing sectors: aerospace, chemicals, E&E, pharmaceuticals, and medical devices. Systematic sampling ensured that the selection process was both unbiased and proportionally representative of these sectors.

Table 2: *Table for Assessment of Formative Indicators*

Formative Constructs	Formative Indicators	Mean	SD	VIF	Outer Weights	Outer Loadings
SCRM	SCRM1	4.12	0.78	2.9	0.765**	0.921***
	SCRM2	4.05	0.85	3.1	0.815***	0.948***
	SCRM3	4.00	0.80	2.7	0.678**	0.901***
SE	SE1	4.08	0.72	2.5	0.755**	0.872***
	SE2	4.18	0.70	2.8	0.845***	0.930***
	SE3	4.22	0.75	2.6	0.768***	0.890***

Table 3: *Table for Assessment of Reflective Measurement Models*

Reflective Constructs	Reflective Indicators	Mean	SD	Outer Loadings
SCR	SCR1	4.15	0.74	0.920***
	SCR2	4.18	0.76	0.937***
	SCR3	4.20	0.79	0.945***
SCP	SCP1	4.10	0.77	0.910***
	SCP2	4.08	0.78	0.890***
	SCP3	4.12	0.74	0.925***

Table 4: *Table for Discriminant Validity Using Fornell-Larcker Criterion*

Constructs	SCRM	SCR	SCP	SE
SCRM	0.915	0.710	0.680	0.650
SCR	0.710	0.928	0.720	0.695
SCP	0.680	0.720	0.917	0.690
SE	0.650	0.695	0.690	0.905

A total of 500 firms were contacted using this method, and 360 valid responses were collected, yielding a response rate of 72%. Respondents were targeted based on their positions in supply chain-related functions (e.g., operations managers, logistics heads, procurement leads), ensuring that data were gathered from informed decision-makers.

While systematic random sampling supports the generalizability of findings, some limitations remain. Non-response bias may still exist, as firms that declined participation may differ systematically from those that responded, potentially influencing the external validity of the study.

Moreover, Malaysia's business culture may have influenced how participants interpreted and responded to certain questions. Organizational hierarchies, risk-aversion tendencies, and a preference for maintaining internal harmony may lead respondents to answer cautiously, especially on topics perceived as sensitive or evaluative. To minimize this potential bias, all items were neutrally worded and pilot-tested, and respondents were assured of strict confidentiality and anonymity to encourage honest and accurate responses.

3.3 Structural Equation Modeling

The research model depicted in **Figure 1** was tested using Partial Least Squares Structural Equation Modeling (PLS-SEM) via the SmartPLS 3.0 application (Ringle et al., 2015). The study employed a two-stage approach as recommended by Hair et al., (2012). In the first stage, latent variable scores were extracted for higher-order constructs, while in the second stage, these scores were used to estimate the structural relationships among the constructs.

To address issues of missing data, a case-wise deletion method was applied, ensuring that the final dataset contained complete responses (Afghari et al., 2019). As a result, the final sample size was 360, which included responses from Malaysia's aerospace, chemicals, E&E, pharmaceuticals, and medical device sectors. This sample size meets the minimum threshold for PLS-SEM analysis, considering the number of paths in the structural model and the statistical power requirements (Hair et al., 2017).

The structural relationships were evaluated based on path coefficients, R^2 values, and the effect size (f^2) for each construct. The R^2 value for the dependent construct, SCP, was 0.452, indicating that the model explains 45.2% of the variance in SCP. This represents a moderate level of explanatory power (Cohen, 2013). To test the moderating effect of SE on the relationship between SCRM and SCR, the f^2 effect size was calculated. The inclusion of SE as a moderating variable yielded an R^2 value of 0.398, compared to an R^2 value of 0.334 when the interaction terms were excluded. The calculated f^2 value of 0.154 indicates a medium effect size, signifying that SE contributes significantly to the enhancement of SCR (Chin, 2009; Cohen, 2013). Additionally, the model's predictive relevance was assessed using the Stone-Geisser Q^2 statistic via the blindfolding procedure. Q^2 values greater than zero for the dependent constructs confirmed the model's predictive accuracy. The Q^2 value for SCP was 0.291, further supporting the model's robustness in predicting SCP outcomes (Geisser, 1974; Stone & Brooks, 1990).

The results also revealed variations in the moderating effect of SE across different industries. For example, the aerospace and E&E sectors exhibited stronger interaction effects compared to the pharmaceutical and chemical sectors, suggesting that SE are more integral to resilience-building in industries with complex and globalized supply chains. These findings emphasize the necessity of tailoring resilience strategies to the unique characteristics of each sector. The structural model validation demonstrates the significant role of SCRM and SE in enhancing SCR and SCP in Malaysia's manufacturing sectors. By providing empirical evidence for these relationships, the study contributes to a deeper understanding of resilience-building practices in the Malaysian context and offers actionable insights for policymakers and practitioners.

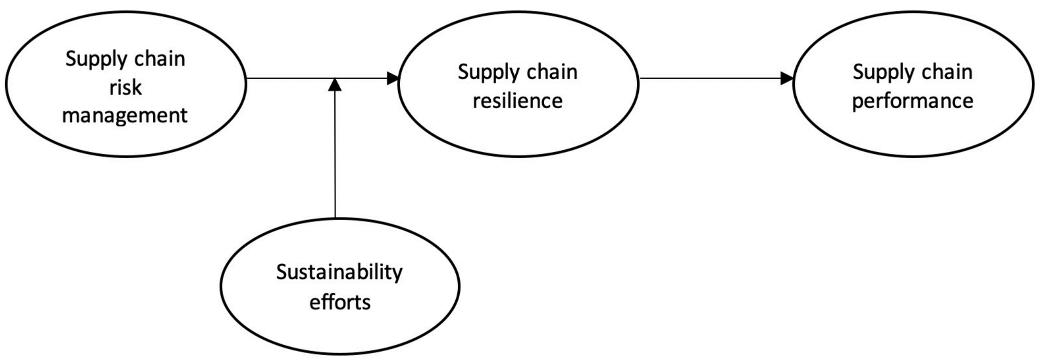

Figure 1: *Research Model*

5. RESULTS AND DISCUSSION

The analysis of the Malaysian manufacturing sector's priority industries—namely aerospace, chemicals, E&E, pharmaceuticals, and medical devices—yields significant insights into the role of SCRM, SCR, SE, and their combined effects on SCP. **Table 5** summarizes the findings for each hypothesis across the five sectors, accompanied by their respective sample sizes and variance explained (R^2).

5.1 The Impact of Supply Chain Risk Management on Resilience Across Sectors

SCRM demonstrated a strong and statistically significant positive relationship with SCR across all the studied sectors, emphasizing its foundational role in fostering resilience. The β-coefficients, which ranged from 0.432 in the chemical sector to 0.612 in the E&E sector, highlight the varying degrees of reliance on effective risk management practices across industries. These findings align with recent studies that underscore the importance of both proactive and reactive risk mitigation strategies in building resilient supply chains capable of adapting to disruptions (Can Saglam et al., 2021; Sarkar et al., 2022).

The relatively lower β-coefficient observed in the chemical sector can be attributed to the sector's stable and less globalized supply chains, which face fewer disruptions compared to sectors with highly complex and international networks. The chemical industry often benefits from stringent safety regulations and well-established operational standards, which inherently reduce risk exposure and mitigate potential disruptions (Guerra et al., 2024). These structural factors may diminish the relative intensity of reliance on proactive risk management practices in driving resilience. Within the SCRM construct, items such as the early identification of supply chain risks and the implementation of risk monitoring tools play a supporting yet less critical role in the chemical sector. Unlike sectors like aerospace and E&E, where such practices are crucial due to globalized supplier bases and higher risk variability, the chemical industry may achieve a baseline level of resilience through compliance-driven processes and standardized operating procedures (Sarkar et al., 2022). Recent studies suggest that the contribution of risk management to resilience can vary significantly based on industry characteristics, supply chain complexity, and exposure to external shocks (Ivanov, 2021; Chowdhury et al., 2021).

The E&E sector demonstrated the strongest relationship between SCRM and SCR (β = 0.612). This significant result reflects the sector's heavy dependence on globalized supply chains, which are characterized by complex supplier networks, frequent cross-border transactions, and heightened exposure to geopolitical and logistical uncertainties. In this high-risk environment, integrated risk management practices—such as conducting supplier risk assessments, adopting diversification strategies, and implementing robust risk mitigation plans—are essential for maintaining operational resilience. Key items within the SCRM construct, including the development of comprehensive risk mitigation plans and the early identification of potential risks, are likely to be more rigorously applied in the E&E sector. The intricate nature of global supply chains in this industry, coupled with its vulnerability to external shocks, necessitates a proactive and intensive approach to managing risks. This focus allows E&E manufacturers to better anticipate disruptions, respond effectively, and sustain continuity in their operations. The strength of the β-coefficient highlights the critical role of well-executed SCRM practices in enhancing the sector's capacity to recover from disruptions and maintain performance. Recent studies consistent with these findings, emphasizing the importance of tailored SCRM strategies in sectors with complex global supply chains. For instance, Chowdhury et al. (2021) and Ivanov (2021) highlight the need for integrated risk management practices that address both upstream and downstream risks in globalized networks.

Table 5: *Summary of Results for Priority Sectors in Malaysia*

Hypothesis	Aerospace (N = 65)	Chemical (N = 72)	E&E (N = 85)	Pharmaceutical (N = 70)	Medical Devices (N = 68)
H1: SCRM → SCR	Yes, significant (β = 0.512***)	Yes, significant (β = 0.432***)	Yes, significant (β = 0.612***)	Yes, significant (β = 0.482***)	Yes, significant (β = 0.530***)
H2: SCR → SCP	Yes, significant (β = 0.438***)	Yes, significant (β = 0.371***)	Yes, significant (β = 0.523***)	Yes, significant (β = 0.468***)	Yes, significant (β = 0.456***)
H3: SE × SCRM → SCR	Yes, significant (β = -0.312**)	Not significant (β = -0.081)	Not significant (β = -0.256)	Yes, significant (β = -0.220**)	Yes, significant (β = -0.208**)
f^2 (Effect Size for SE × SCRM → SCR)	0.154 (medium)	0.012 (small)	0.048 (small)	0.101 (medium)	0.093 (medium)
R^2	42.8%	30.2%	51.6%	44.9%	48.3%

Note: According to Cohen's (2013) guidelines, $f^2 \geq 0.02$, $f^2 \geq 0.15$, and $f^2 \geq 0.35$ represent small, medium, and large effect sizes, respectively.

Additionally, research by Mishra et al. (2024) underscores the effectiveness of diversified sourcing and predictive analytics in mitigating risks and enhancing resilience in volatile markets. These insights collectively underscore the criticality of targeted SCRM efforts in the E&E sector, where operational success heavily depends on the ability to navigate and manage multifaceted risks effectively.

Furthermore, the strong positive relationship across all sectors reinforces the notion that effective risk management practices are essential not only for addressing immediate disruptions but also for fostering long-term resilience. Proactive strategies, such as monitoring supplier performance and developing contingency plans, are particularly effective in mitigating risks before they escalate into critical issues. Reactive strategies, including activating alternative suppliers and deploying recovery teams, further bolster resilience by ensuring a swift response to unforeseen challenges. These practices, as captured in the SCRM construct, reflect an overarching approach to risk management that is critical for resilience building across diverse sectors. These findings align with broader research emphasizing the dual importance of anticipation and response in developing resilient supply chains (Sarkar et al., 2022; Gruchmann, 2024).

The results of Hypothesis 1 underscore the universal importance of SCRM in fostering SCR across different industries while also highlighting the varying degrees of impact based on sector-specific characteristics. These insights emphasize the need for tailored risk management strategies that address the unique operational and market challenges of each sector, ensuring that resilience-building efforts are both effective and contextually relevant. By aligning risk management practices with sector-specific requirements and leveraging the operational dimensions captured within the SCRM construct, firms can enhance their resilience and sustain long-term competitiveness.

5.2 The Impact of Supply Chain Resilience on Supply Chain Performance Across Sectors

The relationship between SCR and SCP was significant across all industries, with β-coefficients ranging from 0.371 in the chemical sector to 0.523 in the E&E sector. These results underscore the critical role of resilience in improving SCP by enabling organizations to maintain operational efficiency, ensure delivery reliability, and achieve customer satisfaction despite disruptions. The findings align with prior studies, such as Chowdhury et al. (2021) and Gölgeci et al. (2023), which emphasize the value of resilience-enhancing strategies in driving superior performance outcomes.

For the chemical sector, the relatively lower β-coefficient (0.371) indicates that while SCR positively influences performance, the sector's inherent operational stability and lower global exposure moderate the strength of this relationship. Resilience elements such as supplier collaboration during crises and process flexibility play a role in sustaining performance, yet the impact appears less substantial than in more dynamic sectors. This aligns with findings that industries characterized by stable demand patterns and stringent regulatory environments often experience fewer fluctuations, thereby reducing the perceived need for extensive resilience investments (Ivanov, 2021; Joseph, 2025). The chemical sector's reliance on long-term contracts and highly regulated supply chains serves as a natural buffer against disruptions, limiting the urgency for advanced resilience strategies. While these practices ensure compliance and stability, they may also limit the sector's adaptability to sudden, unexpected risks. Recent studies emphasize that sectors with lower external volatility often prioritize compliance-driven risk management over agility-focused strategies, resulting in a moderated relationship between resilience and performance (Chowdhury et al., 2021; Mishra et al., 2024). This finding highlights the importance of tailoring resilience-building practices to sector-specific characteristics, ensuring that strategies align with the unique operational and market dynamics of the chemical industry.

In contrast, the E&E sector demonstrated the strongest relationship between SCR and SCP ($\beta = 0.523$), which can be attributed to the sector's high supply chain complexity and reliance on global networks. Extensive supplier relationships, rapidly evolving technology, and frequent cross-border operations necessitate robust resilience-enhancing practices such as rapid recovery, process flexibility, and strong supplier collaboration. Flexibility allows E&E manufacturers to adjust production schedules efficiently, addressing sudden supply or demand changes, thereby reducing lead times and improving delivery reliability. Moreover, the ability to recover quickly from disruptions ensures operational continuity, directly enhancing customer satisfaction and securing a competitive edge in an unpredictable market (Chowdhury et al., 2021; Gölgeci et al., 2023).

Similarly, the aerospace sector exhibited a notable positive relationship between SCR and SCP, with a β-coefficient closely aligned with that of the E&E sector. Aerospace supply chains, characterized by their reliance on highly specialized components and stringent quality requirements, face unique challenges in managing disruptions. Resilience practices, such as quick recovery capabilities and collaborative supplier partnerships to address critical shortages, play a pivotal role in maintaining operational performance. Key performance outcomes, including delivery precision and customer satisfaction, are heavily influenced by the sector's ability to mitigate cascading disruptions. Recent research emphasizes that the adoption of resilience strategies, including enhanced supply chain visibility and contingency planning, is essential for sustaining performance in sectors with complex and specialized supply chains (Akram et al, 2024; Gruchmann et al., 2024). These findings highlight the importance of tailored resilience approaches to address the distinctive operational dynamics of high-stakes industries like E&E and aerospace.

These results align with broader research suggesting that resilient supply chains are better equipped to handle volatility and uncertainty, leading to improved operational outcomes across industries. The study highlights the necessity of sector-specific strategies to optimize the relationship between resilience and performance. For example, sectors with complex and globalized supply chains, such as E&E and aerospace, may require greater investments in collaborative partnerships and adaptive capabilities. Conversely, sectors like chemicals, which operate in relatively stable environments, can achieve significant performance gains through targeted resilience practices that align with their unique operational contexts. The significant and positive relationship between SCR and SCP underscores the transformative impact of resilience on performance outcomes across industries. By prioritizing resilience-building initiatives tailored to their specific supply chain dynamics, firms can achieve higher levels of operational efficiency, delivery reliability, and customer satisfaction, ensuring sustainable success in an increasingly uncertain global landscape.

5.3 The Impact of Sustainability Efforts Across Sectors

The moderating effect of SE on the relationship between SCRM and SCR was found to be statistically significant in the aerospace ($\beta = -0.312$, $f^2 = 0.154$), pharmaceutical ($\beta = -0.220$, $f^2 = 0.101$), and medical device ($\beta = -0.208$, $f^2 = 0.093$) sectors. Among these, the aerospace sector demonstrated a medium effect size based on Cohen's (2013) benchmarks, indicating a meaningful moderating influence. Although the negative β-coefficient may appear counterintuitive, it highlights the complexity of aligning sustainability practices with risk management priorities. In highly regulated and safety-critical industries like aerospace, an overemphasis on SE—such as pollution control or eco-certification—may unintentionally divert resources and management attention from immediate risk mitigation strategies, potentially weakening the effectiveness of SCRM (Fritz, 2022).

This finding underscores the need for a balanced and integrated approach to sustainability and risk management, particularly in sectors with complex global supplier networks and stringent compliance environments. While initiatives like supplier training, green procurement, and environmental reporting can enhance long-term resilience by fostering collaboration and transparency, these efforts must complement rather than compete with core risk governance systems. For instance, aligning sustainability goals with risk mitigation objectives—such as conducting environmentally conscious supplier assessments or implementing dual sourcing based on ESG criteria—can create synergy. Studies by Chowdhury et al. (2021) and Dubey et al. (2023) support this notion, emphasizing that SE must be embedded within broader supply chain management frameworks to avoid misalignment and strategic dilution.

In contrast, the moderating role of SE was not significant in the chemical ($\beta = -0.081$, $f^2 = 0.012$) and E&E sectors ($\beta = -0.256$, $f^2 = 0.048$). These findings suggest that in such industries, sustainability and risk management may still operate in silos, limiting their interactive potential. In the E&E sector, despite significant investment in SCRM through digital tools and predictive analytics, SE may remain compliance-driven or CSR-oriented, with limited integration into operational resilience strategies. Similarly, in the chemical sector, SE may be treated as a standalone regulatory obligation rather than an embedded mechanism for building agility and adaptability (Chowdhury et al., 2021; Fritz, 2022).

These patterns are consistent with recent findings by Carissimi et al. (2023) and Gölgeci et al. (2023), who argue that firms which successfully integrate sustainability into their risk management processes tend to demonstrate stronger resilience, especially in the face of compound disruptions. However, this integration requires firms to address internal trade-offs, invest in training and systems development, and build a culture of cross-functional coordination between sustainability and supply chain teams.

The findings from Hypothesis 3b reveal the nuanced and sector-specific role of SE in enhancing the SCRM–SCR link. While the aerospace sector illustrates the potential misalignment risks, the pharmaceutical and medical device sectors demonstrate growing synergy between sustainability and resilience practices, albeit at a modest level. The lack of moderation in other sectors points to an opportunity for greater strategic alignment, especially for firms aiming to build resilient, sustainable supply chains under the goals of the New Industrial Master Plan 2030.

6. CONCLUSION AND RECOMMENDATIONS

This study investigated the interrelationships between SCRM, SCR, and SCP, and examined the moderating effect of SE across five of Malaysia's priority manufacturing sectors. The findings confirm that effective risk management strategies significantly enhance resilience, which in turn improves operational performance—particularly in globally integrated sectors like E&E and aerospace. Moreover, this study provides empirical evidence that the influence of sustainability on resilience is sector-specific, with SE playing a significant moderating role in the aerospace, pharmaceutical, and medical device sectors. These findings contribute original insights by highlighting how sustainability and risk management interact differently across industrial contexts, particularly within an emerging economy setting.

The study makes a theoretical contribution by advancing the understanding of resilience-building through a multi-dimensional lens—integrating risk mitigation, sustainability practices, and sectoral characteristics. While prior research has explored these constructs independently, this study is among the first to empirically examine their combined effects within Malaysia's strategic manufacturing landscape, thereby filling a critical gap in the literature on developing economies and mid-tier industrial sectors.

Despite these contributions, several limitations must be acknowledged. First, the study was cross-sectional in nature and relied on perceptual data from supply chain professionals, which may be subject to bias. Second, the research focused exclusively on five priority sectors; therefore, the findings may not be fully generalizable to other industries such as automotive, food processing, or services. Lastly, although the sample size was robust, the analysis was limited to firms listed in the FMM directory, which may exclude informal or micro-enterprises.

In terms of practical implications, the results suggest that firms—especially SMEs—should embed sustainability into their risk management systems to enhance long-term resilience. For example, medical device and pharmaceutical firms could improve responsiveness and compliance by integrating green procurement and supplier sustainability training into their contingency planning. Policymakers can facilitate this shift by providing sector-specific guidelines, capacity-building initiatives, and incentives to encourage alignment between sustainability and risk objectives. These recommendations are directly informed by the sectoral patterns observed in the analysis, where SE's moderating effects were evident only in industries already under regulatory and international scrutiny.

Future research could address the limitations mentioned above by employing longitudinal data to capture resilience and performance trends over time. Comparative studies across ASEAN countries or between public and private firms would also deepen understanding of contextual influences. Additionally, researchers may explore the role of digitalization, artificial intelligence, or circular economy practices as mediators or moderators in the SCRM–SCR–SCP framework.

In conclusion, this study offers both theoretical and applied contributions by demonstrating how sector-specific strategies in risk management and sustainability can jointly influence SCR and performance. The insights support a more integrated and context-aware approach to supply chain planning, aligned with the strategic priorities of Malaysia's New Industrial Master Plan 2030.

ACKNOWLEDGEMENT

This research was funded by the SKIM GERAN DALAMAN TEJA 2024 under Universiti Teknologi MARA (UiTM), Cawangan Melaka [File No.: GDT2024/1-9]. The authors gratefully acknowledge the support provided by the Research & Industrial Linkages (PJI), Universiti Teknologi MARA (UiTM), Cawangan Melaka for the facilitation and administration of this project.

REFERENCES

Adobor, H. (2020). Supply chain resilience: An adaptive cycle approach. *The International Journal of Logistics Management, 31*(3), 443–463.

Afghari, A. P., Washington, S., Prato, C., & Haque, M. M. (2019). Contrasting case-wise deletion with multiple imputation and latent variable approaches to dealing with missing observations in count regression models. *Analytic Methods in Accident Research, 24*, 100104.

Akram, M. U., Islam, N., Chauhan, C., & Yaqub, M. Z. (2024). Resilience and agility in sustainable supply chains: a relational and dynamic capabilities view. *Journal of Business Research, 183*, 114855.

Aljohani, A. (2023). Predictive analytics and machine learning for real-time supply chain risk mitigation and agility. *Sustainability, 15*(20), 15088.

Amran, M. E., Aziz, S. A. A., Muhtazaruddin, M. N., Masrom, M., Haron, H. N., Bani, N. A., Mohd Izhar, M. A., Usman, S., Sarip, S., Najamudin, S. S., & Zamzam, A. H. (2024). Critical assessment of medical devices on reliability, replacement prioritization and maintenance strategy criterion: Case study of Malaysian hospitals. *Quality and Reliability Engineering International, 40*(2), 970–1001.

Can Saglam, Y., Yildiz Çankaya, S., & Sezen, B. (2021). Proactive risk mitigation strategies and supply chain risk management performance: An empirical analysis for manufacturing firms in Turkey. *Journal of Manufacturing Technology Management, 32*(6), 1224–1244.

Carissimi, M. C., Creazza, A., & Colicchia, C. (2023). Crossing the chasm: Investigating the relationship between sustainability and resilience in supply chain management. *Cleaner Logistics and Supply Chain, 7*, 100098. https://doi.org/10.1016/j.clscn.2023.100098

Chin, W. W. (2009). Bootstrap cross-validation indices for PLS path model assessment. In *V. Esposito Vinzi, W. W. Chin, J. Henseler, & H. Wang (Eds.), Handbook of partial least squares: Concepts, methods and applications* (pp. 83–97). Springer.

Chowdhury, M. M. H., & Quaddus, M. A. (2021). Supply chain sustainability practices and governance for mitigating sustainability risk and improving market performance: A dynamic capability perspective. *Journal of Cleaner Production, 278,* 123521.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge.

Debnath, B., Shakur, M. S., Tanjum, F., Rahman, M. A., & Adnan, Z. H. (2022). Impact of additive manufacturing on the supply chain of aerospace spare parts industry: A review. *Logistics, 6*(2), 28.

Dehdasht, G., Ferwati, M. S., Abidin, N. Z., & Oyedeji, M. O. (2022). Trends of construction industry in Malaysia and its emerging challenges. *Journal of Financial Management of Property and Construction, 27*(2), 161–178.

Diamantopoulos, A., & Winklhofer, H. M. (2001). Index construction with formative indicators: An alternative to scale development. *Journal of Marketing Research, 38*(2), 269–277.

Dubey, R., Bryde, D. J., Dwivedi, Y. K., Graham, G., Foropon, C., & Papadopoulos, T. (2023). Dynamic digital capabilities and supply chain resilience: The role of government effectiveness. *International Journal of Production Economics, 258*, 108790. https://doi.org/10.1016/j.ijpe.2023.108790

Fenton, K., Simske, S., & Luu, J. (2023). Mitigation of chemical reporting liabilities through systematic modernization of chemical hazard and safety data management systems. *ACS Omega, 8*(5), 4928–4936.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18(1), 39–50.

Fritz, M. M. C. (2022). A supply chain view of sustainability management. *Cleaner Production Letters, 3*, 100023. https://doi.org/10.1016/j.clpl.2022.100023

Geisser, S. (1974). A predictive approach to the random effect model. *Biometrika, 61*(1), 101–107.

Gölgeci, I., Gligor, D. M., Bayraktar, E., & Delen, D. (2023). Reimagining global value chains in the face of extreme events and contexts: Recent insights and future research opportunities. *Journal of Business Research, 160*, 113721. https://doi.org/10.1016/j.jbusres.2023.113721

Gruchmann, T., Stadtfeld, G. M., Thürer, M., & Ivanov, D. (2024). Supply chain resilience as a system quality: Survey-based evidence from multiple industries. *International Journal of Physical Distribution & Logistics Management, 54*(1), 92–117.

Guerra, J. H. L., Bernardi de Souza, F., Pires, S. R. I., Salgado, M. H., & Sá, A. L. R. D. (2024). Supply chain risk management (SCRM) process: An analysis in the aerospace industry. *Benchmarking: An International Journal*. Advance online publication. https://doi.org/10.1108/BIJ-12-2023-0844

Hair, J. F., Hollingsworth, C. L., Randolph, A. B., & Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management & Data Systems, 117*(3), 442–458.

Hair, J. F., Sarstedt, M., Ringle, C. M., & Mena, J. A. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *Journal of the Academy of Marketing Science, 40*, 414–433.

Hohenstein, N. O. (2022). Supply chain risk management in the COVID-19 pandemic: Strategies and empirical lessons for improving global logistics service providers' performance. *The International Journal of Logistics Management, 33*(4), 1336–1365

Hokmabadi, H., Rezvani, S. M., & de Matos, C. A. (2024). Business resilience for small and medium enterprises and startups by digital transformation and the role of marketing capabilities: A systematic review. *Systems, 12*(6), 220.

Ishak, S., Shaharudin, M. R., Salim, N. A. M., Zainoddin, A. I., & Deng, Z. (2023). The effect of supply chain adaptive strategies during the COVID-19 pandemic on firm performance in Malaysia's semiconductor industries. *Global Journal of Flexible Systems Management, 24*(3), 439–458

Ivanov, D. (2021). Supply chain viability and the COVID-19 pandemic: A conceptual and formal generalisation of four major adaptation strategies. *International Journal of Production Research, 59*(12), 3535–3552.

Joeaneke, P., Kolade, T. M., Obioha Val, O., Olisa, A. O., Joseph, S., & Olaniyi, O. O. (2024). Enhancing security and traceability in aerospace supply chains through blockchain technology. *SSRN*, 4995935.

Joseph, G. (2025). Embracing resilience in pharmaceutical manufacturing:"digital twins"–forging a resilient path in the VUCA maze. *International Journal of Pharmaceutical and Healthcare Marketing*.

Juettner, U., Windler, K., Podleisek, A., Gander, M., & Meldau, S. (2020). Implementing supplier management strategies for supply chain sustainability risks in multinational companies. *The TQM Journal, 32*(5), 923–938.

Kalnins, A., & Praitis Hill, K. (2025). The VIF score: What is it good for? Absolutely nothing. *Organizational Research Methods, 28*(1), 58–75.

Lechowski, G., & Krzywdzinski, M. (2022). Emerging positions of German firms in the industrial internet of things: A global technological ecosystem perspective. *Global Networks, 22*(4), 666–683.

Mayer, J. (2021). Development strategies for middle-income countries in a digital world—Insights from modern trade economics. *The World Economy, 44*(9), 2515–2546.

McDermott, O., Foley, I., Antony, J., Sony, M., & Butler, M. (2022). The impact of Industry 4.0 on the medical device regulatory product life cycle compliance. *Sustainability, 14*(21), 14650.

Miceli, A., Hagen, B., Riccardi, M. P., Sotti, F., & Settembre-Blundo, D. (2021). Thriving, not just surviving in changing times: How sustainability, agility, and digitalization intertwine with organizational resilience. *Sustainability, 13*(4), 2052.

Ministry of Investment, Trade and Industry. (2023). *New Industrial Master Plan 2030 (NIMP 2030)*. https://www.nimp2030.gov.my/

Mishra, N. K., Pande Sharma, P., & Chaudhary, S. K. (2024). Redefining agile supply chain practices in the disruptive era: A case study identifying vital dimensions and factors. *Journal of Global Operations and Strategic Sourcing*. Advance online publication. https://doi.org/10.1108/JGOSS-04-2023-0031

Mishra, R., Singh, R. K., & Subramanian, N. (2022). Impact of disruptions in agri-food supply chain due to COVID-19 pandemic: Contextualised resilience framework to achieve operational excellence. *The International Journal of Logistics Management, 33*(3), 926–954.

Mubarik, M. S., Naghavi, N., Mubarik, M., Kusi-Sarpong, S., Khan, S. A., Zaman, S. I., & Kazmi, S. H. A. (2021). Resilience and cleaner production in Industry 4.0: Role of supply chain mapping and visibility. *Journal of Cleaner Production, 292*, 126058

Noor, M. N. H. M., Kadir, R., & Muhamad, S. (2021). Issues of forest enforcement against illegal logging and forest offences in peninsular Malaysia. *Journal of Sustainability Science and Management, 16*(7), 261.

Norrman, A., & Wieland, A. (2020). The development of supply chain risk management over time: Revisiting Ericsson. *International Journal of Physical Distribution & Logistics Management, 50*(6), 641–666.

Râmniceanu, V. T. (2022). European Union initiatives and regulations on sustainable corporate governance. *International Investment Law Journal, 2*(1), 83–92.

Ramzan, M., Raza, S. A., Usman, M., Sharma, G. D., & Iqbal, H. A. (2022). Environmental cost of non-renewable energy and economic progress: Do ICT and financial development mitigate some burden? *Journal of Cleaner Production, 333*, 130066.

Rawat, U., Kumar, A., & Anbanandam, R. (2025). Evaluating the preparedness of freight logistics firms for cyber-physical systems integration: A SAP-LAP methodology for sustainable development. *Global Journal of Flexible Systems Management, 26*(1), 1-23.

Ringle, C. M., Wende, S., & Becker, J. M. (2015). SmartPLS 3. *Journal of Service Science and Management, 10*(3), 32–49.

Rizos, V., & Bryhn, J. (2022). Implementation of circular economy approaches in the electrical and electronic equipment (EEE) sector: Barriers, enablers and policy insights. *Journal of Cleaner Production, 338*, 130617.

Rodríguez-Espíndola, O., Chowdhury, S., Dey, P. K., Albores, P., & Emrouznejad, A. (2022). Analysis of the adoption of emergent technologies for risk management in the era of digital manufacturing. *Technological Forecasting and Social Change, 178*, 121562.

Sarkar, P., Mohamed Ismail, M. W., & Tkachev, T. (2022). Bridging the supply chain resilience research and practice gaps: Pre- and post-COVID-19 perspectives. *Journal of Global Operations and Strategic Sourcing, 15*(4), 599–627. https://doi.org/10.1108/JGOSS-09-2021-0082

Shin, Y. H. (2024). Korean multinational corporations' global expansion strategies in manufacturing sector: Mother factory approach. *International Journal of Internet, Broadcasting and Communication, 16*(1), 269–279.

Singh, R. K., & Modgil, S. (2025). Adapting to disruption: the impact of agility, absorptive capacity and ambidexterity on supply chain resilience. *International Journal of Productivity and Performance Management, 74*(2), 637-658.

Stone, M., & Brooks, R. J. (1990). Continuum regression: Cross-validated sequentially constructed prediction embracing ordinary least squares, partial least squares, and principal components regression. *Journal of the Royal Statistical Society: Series B (Methodological), 52*(2), 237–258.

Tahir, P. R., Abdul Ghani, M., & Abdul Razak, N. S. (2022). Sustaining competitive advantage during the COVID-19 pandemic: A preliminary case study of aerospace manufacturing industry in Malaysia. *Journal of Information System and Technology Management, 7*(29), 42–57.

Tarigan, Z. J. H., Siagian, H., & Jie, F. (2021). Impact of internal integration, supply chain partnership, supply chain agility, and supply chain resilience on sustainable advantage. *Sustainability, 13*(10), 5460.

Wahab, S. N., Tan, A., & Roche, O. (2024). Identifying supply chain manager leadership skills and competencies gaps in Malaysia. *Higher Education, Skills and Work-Based Learning, 14*(5), 921–937.

Xuan, C. H., & Kamaruddin, N. K. (2024). The relationship between supply chain digitalization and organizational performance among the electronics and electrical multinational corporation manufacturing industries in Penang. *Research in Management of Technology and Business, 5*(1), 419–434.

Yeo, L. S., Ng, W. P. Q., Lim, C. H., Leong, W. D., Lam, H. L., Wong, Y. C., Sunarso, J., Teng, S. Y., & How,

B. S. (2023). Circular synergy between biomass and petroleum industry in process and supply chain integration. *ACS Sustainable Chemistry & Engineering, 11*(35), 12916–12933.

Zakaria, Z., Kamarudin, S. K., Salehmin, M. N. I., Ahmad, N. N. R., Aminuddin, M. A., Hanapi, I. H., Osman, S. H., & Mohamad, A. A. (2023). Energy scenario in Malaysia: Embarking on the potential use of hydrogen energy. *International Journal of Hydrogen Energy, 48*(91), 35685–35707.