Technology Strategy Towards Sustainable Manufacturing Performance: A Conceptual Framework of the Mediating Role of Leadership Style

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ABSTRACT

The rapid advancement of Industry 4.0 has created new opportunities for manufacturing firms to enhance sustainable manufacturing performance through the strategic adoption of advanced technologies. However, existing studies have largely examined technology strategy, leadership, and sustainability as separate research streams, resulting in limited understanding of the organisational mechanisms through which technological capabilities are transformed into sustainable outcomes. Addressing this gap, this conceptual paper develops a conceptual framework that explains the relationship between technology strategy and sustainable manufacturing performance through the mediating role of leadership style. The framework was developed through a systematic literature review of peer-reviewed academic studies published between 2014 and 2025 and synthesised using a narrative approach. Guided by the Resource-Based View (RBV), Technology–Organisation–Environment (TOE) framework, and leadership theory, the review identifies technology strategy as a multidimensional organisational capability encompassing technological investments, innovation capabilities, digital manufacturing technologies, production system design, and other strategic technology capabilities that collectively support sustainability outcomes. The findings suggest that transformational and digital leadership facilitate organisational change, align technological initiatives with strategic objectives, and enable firms to effectively translate technological capabilities into economic, environmental, and social performance improvements. Unlike previous conceptual studies that examine these constructs independently, the proposed framework integrates multiple dimensions of technology strategy with leadership style as a mediating mechanism, providing a clearer explanation of how technological capabilities contribute to sustainable manufacturing performance. The study contributes by developing a conceptual model and research propositions for future empirical validation while offering practical insights for manufacturing organisations and policymakers seeking sustainable competitive advantage in the Industry 4.0 era.

Keywords: Technology Strategy, Sustainable Manufacturing, Leadership Style

INTRODUCTION

The rapid advancement of Industry 4.0 has fundamentally transformed manufacturing through the adoption of advanced technologies such as artificial intelligence, big data analytics, cyber-physical systems, robotics, cloud computing, and the Internet of Things (Vial, 2019; Xu et al., 2018). These technologies have enhanced operational efficiency, automation, and data-driven decision-making, enabling manufacturing firms to improve productivity and remain competitive in an increasingly dynamic business environment. Consequently, technology adoption has become a strategic priority for organisations seeking to achieve both competitive advantage and sustainable growth.

Despite these advancements, the successful adoption of Industry 4.0 technologies does not necessarily translate into sustainable manufacturing performance, particularly in emerging economies such as Malaysia (Müller et al., 2018). Although many manufacturing firms have invested in digital technologies, technology adoption is often implemented in a fragmented manner without a coherent technology strategy that aligns technological capabilities with organisational objectives. This fragmented approach limits firms' ability to achieve consistent economic, environmental, and social sustainability outcomes.

Existing studies have extensively examined technology adoption, technology strategy, leadership, and sustainable manufacturing as separate streams of research. However, limited attention has been given to understanding how multiple dimensions of technology strategy collectively influence sustainable manufacturing performance and the organisational mechanisms through which these relationships occur. In particular, the mediating role of leadership style in translating technology strategy into sustainable manufacturing outcomes remains underexplored, particularly in emerging manufacturing contexts.

To address this gap, this conceptual paper proposes a conceptual framework grounded in the Resource-Based View (RBV). The framework integrates multiple dimensions of technology strategy and positions leadership style as a mediating mechanism linking technological resources with sustainable manufacturing performance. By proposing this conceptual framework, the study contributes to the literature on Industry 4.0 and sustainable manufacturing by providing an integrated understanding of the relationships among technology strategy, leadership style, and sustainable manufacturing performance, while offering insights for manufacturing organisations seeking to align technology strategy with long-term sustainability objectives.

Research Objectives

The objectives of this conceptual paper are:

1. To develop an integrated framework linking technology strategy to sustainable manufacturing performance.

2. To examine the role of leadership style in explaining the relationship between technology strategy and sustainability outcomes.

3. To propose the mediating role of leadership style in translating technology strategy into sustainable manufacturing performance within Industry 4.0 contexts.

LITERATURE REVIEW

The Resource-Based View (RBV) proposes that firms achieve sustained competitive advantage through the development and deployment of resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). Within the manufacturing context, technological capability has increasingly been recognised as a strategic resource that enables firms to enhance productivity, innovation, operational efficiency, and competitiveness. However, technological resources alone may not generate superior outcomes unless they are effectively integrated with organisational capabilities and managerial competencies. In the context of Industry 4.0, technology strategy represents an important organisational capability that determines how firms acquire, deploy, and utilise technological resources to achieve strategic objectives. While RBV provides a strong foundation for explaining the importance of technological resources, it provides limited explanation regarding the organisational mechanisms that enable firms to transform these resources into sustainable manufacturing outcomes. Therefore, complementary organisational capabilities, particularly leadership capability, are essential in ensuring that technology strategies are effectively transformed into sustainable manufacturing outcomes.

The Technology–Organisation–Environment (TOE) framework provides a complementary perspective by explaining technology adoption through three contextual dimensions: technological readiness, organisational capability, and environmental pressure (Tornatzky & Fleischer, 1990). Technological readiness refers to the availability, compatibility, and suitability of technological solutions within an organisation, while organisational capability reflects internal resources, managerial support, and structural readiness to implement innovation.

Environmental pressure includes competitive forces, regulatory requirements, and market conditions that influence firms' adoption decisions. In Industry 4.0 research, TOE has been widely applied to explain the factors influencing digital technology adoption and implementation decisions (Luthra et al., 2016). Nevertheless, TOE primarily focuses on the contextual determinants of technology adoption rather than explaining how implemented technologies contribute to long-term sustainability performance. Therefore, TOE complements RBV by explaining the contextual conditions that influence technology implementation, while RBV explains how technological capabilities can become strategic resources that contribute to sustainable competitive advantage.

Leadership plays a critical role in facilitating organisational transformation, particularly in environments characterised by rapid technological advancement. Transformational leadership supports technological change by promoting vision sharing, employee motivation, innovation, and organisational readiness, whereas digital leadership emphasises the ability of leaders to utilise digital technologies to enhance strategic decision-making, organisational agility, and operational effectiveness. Within Industry 4.0 environments, leadership ensures that technological investments are not implemented as isolated initiatives but are integrated into broader organisational strategies. Although previous studies have highlighted the importance of leadership in digital transformation, limited attention has been given to leadership style as a mediating mechanism that explains how technology strategy influences sustainable manufacturing performance. Therefore, leadership style may serve as an important mediating mechanism between technological capabilities and sustainability outcomes.

Technology strategy in manufacturing is a multidimensional organisational capability involving various technological decisions and capabilities that influence sustainable manufacturing performance. One important dimension is pioneer–follower strategic posture, where pioneer firms adopt emerging technologies earlier to obtain innovation advantages, while follower firms adopt technologies after observing market developments and reducing uncertainty. Pioneer strategies provide greater opportunities for innovation but involve higher risks, whereas follower strategies allow firms to benefit from existing knowledge and reduced implementation uncertainty (Frank et al., 2019). Another important dimension is technological investment, which refers to the allocation of financial and organisational resources towards advanced manufacturing technologies. Such investments enhance operational efficiency, reduce production waste, improve resource utilisation, and support environmental performance (Bai & Sarkis, 2020). However, the effectiveness of technological investment depends on how strategically these resources are managed and integrated within organisational processes.

The intensity of product upgrades reflects a firm's ability to continuously improve existing products in response to technological developments and market requirements. Higher upgrade intensity can enhance product lifecycle efficiency, improve product performance, and reduce environmental impacts associated with outdated designs (Nunes et al., 2020). Similarly, product and process technologies contribute to manufacturing improvement by increasing production accuracy, reducing defects, and improving resource utilisation (Stock & Seliger, 2016). Manufacturing system and process design technologies further enhance operational flexibility and resource optimisation by enabling firms to adapt production systems according to changing market requirements. Process technology innovations support sustainability by enabling cleaner production methods, reducing waste generation, and improving operational efficiency (Dubey et al., 2019).

Digital manufacturing technologies, including the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, have become fundamental components of Industry 4.0 manufacturing systems. These technologies enable real-time monitoring, predictive decision-making, and improved resource management, thereby contributing to operational efficiency and sustainability performance (Wang et al., 2016). In addition, microfactories represent an emerging manufacturing approach that promotes decentralised, flexible, and localised production systems. By reducing transportation requirements and improving resource efficiency, microfactories contribute to more sustainable and resilient manufacturing ecosystems (Javaid et al., 2022). Although previous studies have demonstrated the importance of individual technology strategy dimensions, much of the existing research has examined these capabilities independently rather than considering them as interconnected elements of a broader technology strategy. Consequently, limited understanding exists regarding how multiple technology strategy dimensions collectively influence sustainable manufacturing performance.

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Sustainable manufacturing performance is commonly conceptualised through multiple dimensions that reflect the ability of firms to achieve improved business outcomes while maintaining environmental responsibility and operational effectiveness. Economic performance relates to profitability, productivity, and cost efficiency, while environmental performance focuses on resource efficiency, emissions reduction, and waste minimisation. Operational performance includes productivity improvement, process efficiency, resource utilisation, and manufacturing effectiveness. The integration of these dimensions reflects the evolving expectations placed on manufacturing firms, where success is no longer measured solely through financial outcomes but also through environmental responsibility and operational excellence. However, achieving sustainable manufacturing performance requires more than technological adoption alone. Firms must possess the strategic capability to align technological resources with organisational practices and leadership approaches.

Based on the reviewed literature, previous studies provide valuable insights into technology strategy, leadership, and sustainable manufacturing performance. However, limited research has examined how multiple dimensions of technology strategy collectively influence sustainable manufacturing performance through the mediating role of leadership style, particularly within emerging manufacturing contexts. Therefore, this study proposes a conceptual framework grounded in RBV to explain the relationship between technology strategy, leadership style, and sustainable manufacturing performance.

RESEARCH METHODOLOGY

This study adopts a systematic literature review (SLR) approach to develop a conceptual framework linking technology strategy, leadership style, and sustainable manufacturing performance. The review was conducted using academic databases and research platforms, including Scopus and Google Scholar, with ResearchGate used as an additional source for accessing relevant academic publications. The search strategy utilised keywords such as “Industry 4.0”, “technology strategy”, “digital manufacturing”, “sustainable manufacturing”, and “leadership style”, covering relevant publications between 2014 and 2025.

The selection of studies followed predefined inclusion and exclusion criteria. Only peer-reviewed journal articles focusing on manufacturing, digital transformation, sustainability, technology strategy, and leadership were included, while non-academic sources, duplicated studies, and studies outside the research scope were excluded. Following the screening process, more than 200 studies related to the eight dimensions of technology strategy were identified and analysed. These studies provided insights into recurring themes, theoretical relationships, and key constructs associated with technology strategy, leadership roles, and sustainable manufacturing outcomes.

A systematic synthesis approach was then applied to analyse the reviewed literature. Rather than employing statistical analysis or qualitative coding techniques, this study utilised narrative synthesis to identify and compare key findings across studies. The analysis focused on extracting recurring concepts, patterns, and relationships related to technology strategy dimensions, leadership mechanisms, and sustainable manufacturing performance. Through cross-study comparison, the identified constructs were organised into conceptual categories representing different dimensions of technology strategy and sustainability outcomes.

The synthesis process was guided by established theoretical perspectives, namely the Resource-Based View (RBV), Technology–Organisation–Environment (TOE) framework, and leadership theory. These theories provided a structured foundation for interpreting the reviewed literature and identifying the relationships among technology strategy, leadership style, and sustainable manufacturing performance. The identified relationships were subsequently used to develop the proposed conceptual framework presented in this study. The framework provides a foundation for future empirical investigation and offers practical insights for manufacturing organisations seeking to strategically manage technology capabilities towards achieving sustainable competitive advantage.

LITERATURE FINDINGS AND CONCEPTUAL FRAMEWORK DEVELOPMENT

The synthesis of the reviewed literature indicates that technology strategy is a multidimensional construct that influences sustainable manufacturing performance. Previous studies demonstrate that technology strategy dimensions, including technological investments, digital manufacturing technologies, process innovations, and advanced manufacturing systems, contribute to improvements in operational efficiency, innovation capability, and sustainability outcomes (Bai & Sarkis, 2020; Ghobakhloo, 2020). However, the effectiveness of these technological capabilities depends on organisational readiness, managerial support, and the strategic alignment of technology initiatives with organisational objectives.

The literature further highlights that digital manufacturing technologies and microfactory systems have significant potential in improving environmental and operational sustainability outcomes. These technologies support real-time monitoring, resource optimisation, decentralised production, and data-driven decision-making, which contribute to improved efficiency and reduced environmental impact (Javaid et al., 2022). Nevertheless, technology adoption alone does not guarantee sustainable manufacturing performance, as successful implementation requires effective organisational capabilities and management practices.

The synthesis also identifies leadership style as an important mechanism in translating technological capabilities into sustainable outcomes. Transformational leadership facilitates innovation, employee engagement, and organisational adaptability, while digital leadership supports the effective integration and utilisation of Industry 4.0 technologies within manufacturing systems (Vial, 2019). These leadership capabilities enable organisations to align technology strategies with sustainability objectives and maximise the value derived from technological investments.

Furthermore, the reviewed literature reveals that previous studies have largely examined technology capabilities, leadership practices, and sustainability outcomes as separate research areas. Limited attention has been given to understanding how multiple dimensions of technology strategy collectively influence sustainable manufacturing performance through the mediating role of leadership style. This highlights the need for an integrated perspective that considers technological capabilities and leadership mechanisms as interconnected organisational factors.

Based on the literature synthesis, this study develops a conceptual framework explaining the relationship between technology strategy, leadership style, and sustainable manufacturing performance. The proposed framework positions technology strategy as the independent construct, leadership style as a mediating mechanism, and sustainable manufacturing performance as the outcome construct. The framework suggests that technological capabilities contribute to sustainability outcomes both directly and indirectly through leadership practices that facilitate strategic alignment, organisational change, and effective technology implementation.

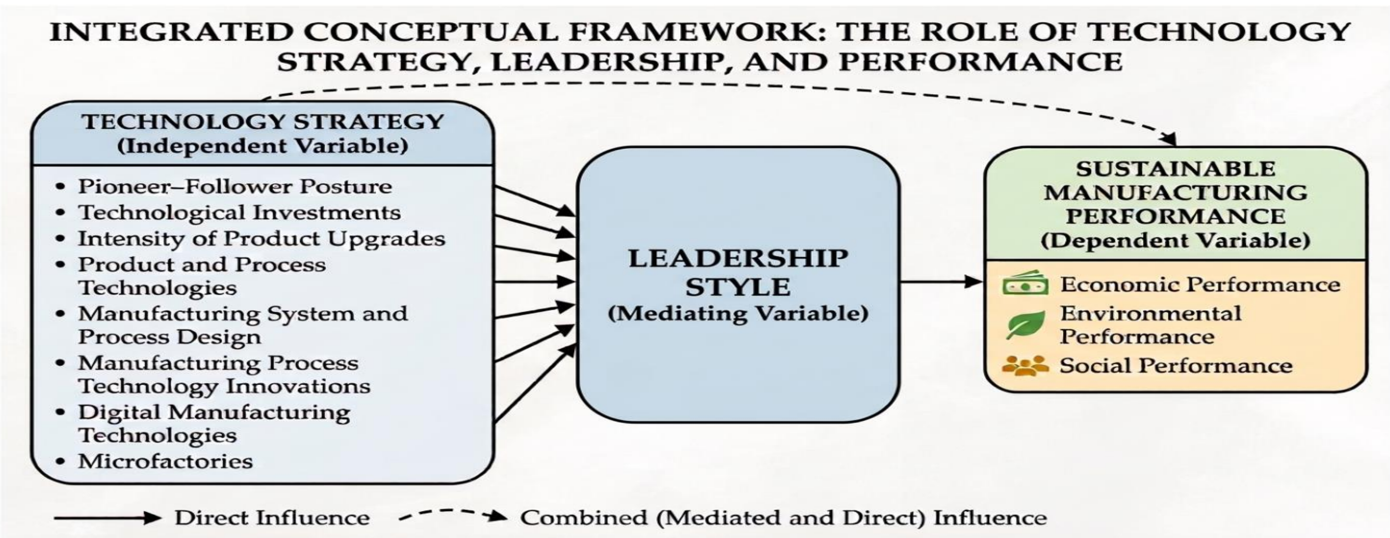

Figure 1 Conceptual Framework

CONCLUSION

This conceptual paper develops a conceptual framework linking technology strategy, leadership style, and sustainable manufacturing performance within the context of Industry 4.0. The study highlights that technology strategy alone may not be sufficient to achieve sustainable manufacturing outcomes, as its effectiveness depends on the ability of organisations to align technological capabilities with appropriate leadership practices and strategic objectives. Leadership is therefore conceptualised as an important mechanism that facilitates the translation of technological capabilities into sustainability outcomes.

By integrating the Resource-Based View (RBV), Technology–Organisation–Environment (TOE) framework, and leadership theory, this study contributes to a more comprehensive understanding of how technological and organisational factors jointly influence sustainable manufacturing performance. The proposed framework addresses gaps in existing literature by integrating multiple dimensions of technology strategy and positioning leadership style as a mediating mechanism in explaining the relationship between technology strategy and sustainability outcomes.

From a practical perspective, the proposed framework provides insights for manufacturing firms seeking to strategically utilise Industry 4.0 technologies to achieve economic, environmental, and social sustainability outcomes. It also offers guidance for policymakers in supporting digital transformation initiatives that promote sustainable industrial development. Future research should empirically examine and validate the proposed relationships using quantitative approaches, such as structural equation modelling (SEM), to assess the applicability and robustness of the framework across different manufacturing contexts. Ultimately, this conceptual framework provides a foundation for understanding how organisations can integrate technological capabilities and leadership practices to achieve sustainable competitive advantage.

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