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EXPLORING GREEN-DIGITAL INTEGRATION AND FIRM PERFORMANCE IN MALAYSIA'S AUTOMOTIVE INDUSTRY: A CONCEPTUAL FRAMEWORK

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Abstract:

This article examines the relationship between green resources, digital technology capabilities, and firm performance within the Malaysian automotive industry. Despite growing attention to sustainability, the industry continues to operate under a linear “take-make-dispose” model. Consequently, contributes substantially to greenhouse gas emissions through material and energy consumption. This conceptual article draws from the underpinning theories, the Resource-Based View (RBV) and the Dynamic Capabilities View (DCV). The green resources encompassing eco-friendly materials, waste recovery, water and energy conservation, green technology, and skilled personnel represent valuable, rare, inimitable, and non-substitutable (VRIN) characteristics. However, their potential to enhance firm performance remains partially absent without suitable activation mechanisms. We argue that digital technology capabilities (sensing, learning, integrating, and coordinating) serve as a mediating enabler that transforms static green resources into dynamic performance outcomes. A framework and four testable hypotheses are developed and contribute to the sustainability literature by bridging the RBV and DCV in an emerging economy context. This study offers practical insights for managers and policymakers seeking to align digital transformation with circular economy goals.

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Keyword:

Automotive Industry, Digital Technology Capabilities, Dynamic Capability View (DCV), Green Resources, Resource-Based View (RBV)

Introduction

According Yean (2021), the automotive industry is an essential sector for economic development and contributes significantly to employment, innovation, and GDP growth. In Malaysia, this industry comprises around 679 companies, including vehicle manufacturers and suppliers, which contribute approximately RM30 billion to the domestic economy annually (MITI, 2023). However, this economic contribution is associated with a significant environmental impact. The manufacturing process consumes large amounts of primary steel, aluminum, plastics, and critical mineral resources, and also requires enormous amounts of energy and water (Aguilar Esteva et al., 2021). Although public attention in the past has focused primarily on car exhaust, the manufacturing process itself is a significant factor that has often been neglected because it also releases amounts of greenhouse gases (Szász et al., 2021).

In recent years, the pressure on car manufacturers has increased. The move to low-carbon production has increased globally and nationally. The Paris Agreement, Malaysia's National Determined Contributions, and the 2020 National Automotive Policy call for resource efficiency, the implementation of a circular economy, and the adoption of Industry 4.0 technologies (MITI, 2020; UNEP, 2023). Despite these policy strategies, the Malaysian automotive industry continues to experience low recycling rates and insufficient end-of-life vehicle collection (Jamaluddin et al., 2022; Mohamad-Ali et al., 2024). These resulted in inconsistency and slow progress in green manufacturing initiatives, especially among small and medium-sized suppliers.

Numerous studies have repeatedly shown that adopting green manufacturing practices does not necessarily lead to better firm performance (Nureen et al., 2023; Szász et al., 2021). Past studies have concurred that firms may gain positive effects on operational efficiency, while the financial benefits are small or delayed (Bellantuono et al., 2021). On the other hand, environmental initiatives do not necessarily improve firm performance because the lack of internal capacity leads to the cause (Pathak et al., 2021). This contradiction suggests that there may be a missing mechanism that links the activation, integration, and renewal of green resources (Setiawan et al., 2025).

Digital technologies offer promising solutions. The internet of things (IoT), big data analytics, cyber-physical systems, cloud computing, and artificial intelligence (Li et al., 2020) can be used to monitor material and energy flows in real time, promote predictive maintenance and waste reduction, and optimise the coordination of the entire production network (Syed, 2023). However, the mere introduction of digital tools does not easily lead to a competitive advantage. Instead, the crucial ability is to identify opportunities, learn from data, integrate green resources into a digital infrastructure, and then coordinate activities across departments to develop digital competencies (Pavlou & Sawy, 2011; Teece, 2018).

This conceptual article addresses the following research questions: (1) Does the use of green resources affect firm performance? (2) Does the use of green resources influence digital technology capabilities? (3) Do digital technology capabilities affect firm performance? (4) Do digital technology capabilities mediate the relationship between green resources and firm performance? Thus, by synthesizing the Resource-Based View (RBV) and Dynamic Capability View (DCV), this study develops a conceptual framework that positions digital technology capabilities as a mediating mechanism. Consequently, this provides a theoretical model within the literature on sustainability, management, and circular economy, thus providing fundamental insights in subsequent empirical studies (Bag et al., 2021; El-Kassar & Singh, 2019).

Literature Review

Underpinning Theories: RBV and DCV

The Resource-Based View (RBV) posits that firms achieve sustainable competitive advantage by possessing resources that are valuable, rare, inimitable, and non-substitutable (VRIN) (Barney, 1991; Barney et al., 2001). In the context of green manufacturing, Hart (1995) described tangible resources, intangible resources, and people-based resources exhibit VRIN characteristics. Tangible resources reflect the renewable materials and energy-efficient equipment, while intangible resources are green patents, environmental management systems, and people-based resources, such as skilled engineers and environmental compliance expertise. However, RBV has been criticised for its static assumptions. The resources can be effective, but do not explain how firms can fundamentally renew and reconfigure those resources in changing environments (Hart & Dowell, 2011).

The Dynamic Capabilities View (DCV) complements RBV. The DCV focuses on a firm's ability to combine, build, and reconfigure internal and external competencies to address rapidly changing markets (Teece et al., 1997). Teece (2007) emphasise three core dynamic capabilities, sensing (identifying opportunities and threats), seizing (mobilizing resources to capture value), and transforming (continuous renewal). Instead, Pavlou and El Sawy's (2011) framework was adopted as the dynamic capabilities that were classified into four dimensions. The dimensions are sensing, learning, integrating, and coordinating. These dimensions are particularly relevant for digital technology capabilities because they emphasise cognitive and behavioral processes that enable firms to leverage digital tools for resource optimisation (Rashidirad & Salimian, 2020; Schmidt & Scaringella, 2020).

Relevance of RBV and DCV to the Green-Digital Framework

The integration of RBV and DCV is fundamentally important for explaining how green resources affect firm performance within the automotive industry (Alos-Simo et al., 2020; Bag

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et al., 2020). In line with RBV, green resources possessed, such as access to recycled or eco-friendly materials, will automatically generate a competitive advantage. However, many firms in the Malaysian automotive industry retain these resources yet fail to achieve superior financial or operational outcomes (Yahaya et al., 2024). Mostly, RBV assumes environmental stability is relatively achieved, but this paradox arises because the automotive industry is influenced by rapid technological shifts, evolving emissions regulations, and volatile raw material prices (IPCC, 2023).

Accordingly, the DCV addresses this limitation by specifying the processes. The chain of process ensures the resources are activated, combined, and renewed green resources efficiently (Teece, 2014). The digital technology capabilities resulted in acting as an enabler of dynamic capabilities by performing four critical roles. Sensing capability enables automotive firms to detect when virgin material prices rise, when new recycling technologies become available, or when customers begin demanding green products (Pavlou & Sawy, 2011). Unlikely, without sensing, green resources will remain undifferentiated. On the other hand, firms will enhance learning capability by assimilating external knowledge from technology vendors or industry and transform it into internal routines for material tracking and energy management (Rashidirad & Salimian, 2020). Moreover, rather than the resources being standalone, integrating capabilities ensures that green resources are embedded into production planning systems, inventory management, and quality control (Bag et al., 2021). Thus, coordinating capability synchronises actions across departments, ensuring that a decision to use green resources does not create bottlenecks (Savastano et al., 2022). This is explained in **Figure 1**.

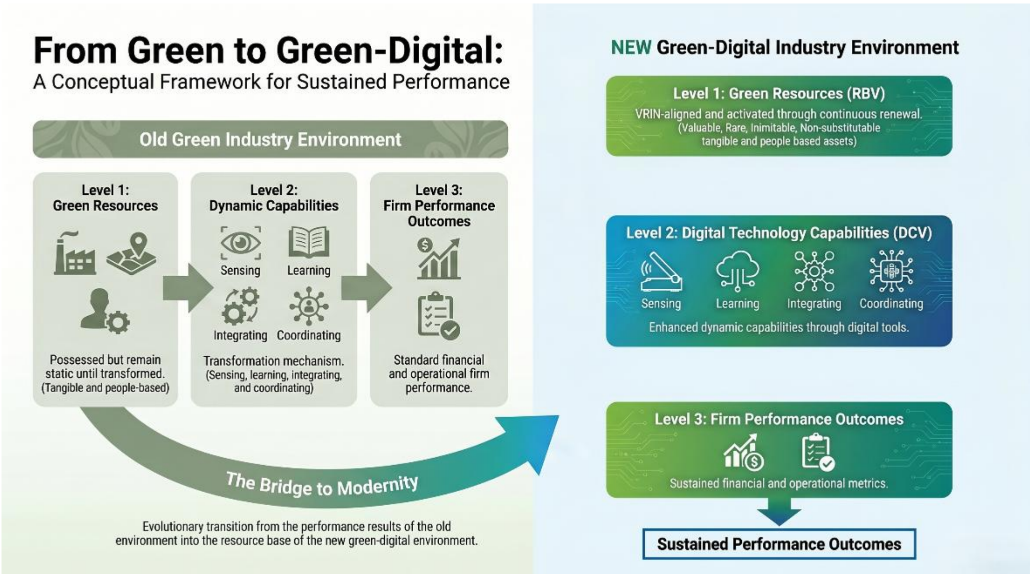

Figure 1: Proposed Green-Digital RBV and DCV Framework
Source: Adapted from Newbert (2007) and Pavlou and Sawy (2011)

The relevance of RBV and DCV will be more evident based on the hierarchical nature of Malaysia's automotive industry. Many large original equipment manufacturers (OEMs) may possess VRIN green resources internally, and their parts suppliers often lack equivalent assets (Azman & Ahmad, 2023; Gohoungodji et al., 2020). Most of the suppliers concentrate their competitive advantage on developing the capability to sense the needs of OEM customers, learn new processing methods, integrate digital tracking systems, and coordinate just-in-time deliveries rather than on owning rare resources (Raziff et al., 2024). Evidently, DCV extends a pathway for resource constrained firms to compete, particularly without accumulating extensive green resources (Teece, 2018).

Moreover, green resources are not static. Over time, a recycling process that is innovative today can be imitated by competitors and vastly adapted (Kifor & Grigore, 2023). The RBV's assumption of resource immobility does not fully hold, particularly when green technologies diffuse through industry networks or when compelled to minimum recycled policies (Okorie et al., 2023). Therefore, the DCV provides the theoretical mechanism for resource renewal. The automotive industry firms must continuously enhance their sensing, learning, integrating, and coordinating routines to prevent green resources from depreciating in value (Warner & Wäger, 2019). Therefore, adopting and leveraging these digital technologies acts as an amplifier in renewal processes by providing real-time feedback, predictive analytics, and cross-functional visibility (Li et al., 2020).

In a nutshell, RBV identifies VRIN green resources as important, and DCV explains how those resources are transformed into performance outcomes by enhancing the digital technology capabilities (S. Khan et al., 2026). Hence, the two theories are not competing or standalone, but extend to be complementary (Matarazzo et al., 2021). The proposed framework clearly positions digital technology capabilities as the mediating mechanism that bridges resource possession (RBV) and resource activation (DCV). This integration is particularly relevant for emerging economies. Countries such as Malaysia, particularly in the automotive industry, are still developing the institutional frameworks for green manufacturing, and the momentum for digital transformation is uneven across firm sizes and tiers of the supply chain (Jamaluddin et al., 2022; Tsou & Kim, 2025).

Firm performance in the Automotive Industry

Past studies argued that financial performance measures the real firm's success (Sakrabani and Teoh, 2021) and, at the same time, must reflect the firm's objective and subjective performance in optimising resource efficiency (Khan et al., 2022). In line with Mai et al. (2026), financial and operational performance are important to reflect the internal efficiency and the effectiveness of sustainability implementation in achieving sustained firm performance. Thus, many past studies elaborate that practising green manufacturing and accelerating with digital technology capabilities can increase the firm's profit, turnover, and market share, enhance resource efficiency, decrease operational costs, improve the quality of supply chain operations, speed of delivery, and enhance process performance (Bag et al., 2020; Calış Duman & Akdemir, 2021; Sakrabani & Teoh, 2020; Varela et al., 2019; Y. Yu et al., 2021). According to Martínez-Caro et al. (2020), building the internal capabilities through digital technologies that can be adapted, modified, and reconfigured contributes significantly to profitability and competitiveness.

On the contrary, past empirical findings elucidated that green manufacturing adoption has no direct effect on firm performance due to the early stages of green initiatives implementation (Nureen et al., 2023). Concurred with Szász et al., (2021), green practices among automotive firms positively influence operational performance but have less impact on financial performance. As such, green practices increase a firm's turnover in the short term. However, the impact on long-term financial performance is inconclusive. This demonstrates that the automotive industry gained operational performance more than financial performance. Hence,

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the findings of this research will have direct implications on firm performance for the integration of green resources with digital capabilities, which may underestimate financial effects if firms are in the early stages. Consequently, firm performance is represented by a dual outcome comprising financial and operational measures. Financial measures are characterised by profitability, revenue growth, market share, and sales growth. On the other hand, operational measures include cost reduction, quality improvement, production efficiency, and production speed.

Green Resources in the Automotive Industry

Green resources refer to the tangible and intangible inputs used in production that minimise environmental harm and achieve resource efficiency (Ng et al., 2017). In line with past studies, the green resources are characterised in five dimensions: (1) eco-friendly materials (Aguilar Esteva et al., 2021), (2) waste and recovery materials (Z. Yu et al., 2022), (3) water and energy conservation practices (Kasava et al., 2020), (4) green technology adoption (Setiawan et al., 2025), and (5) green technical skills (Rahim & Zainuddin, 2019). These resources are not uniformly distributed across firms in the automotive industry. The larger original equipment manufacturers often possess greater access to green resources and technologies compared to small and medium parts suppliers (Habidin et al., 2018).

There has been mixed empirical evidence on the performance effects of green resources. Some studies find positive impacts on operational metrics such as waste reduction and energy efficiency (Abdul-Rashid et al., 2017; Varela et al., 2019). On the other hand, indicates insignificant or delayed financial returns (Nureen et al., 2023; Szász et al., 2021). The inconsistent findings can be explained mainly due to regulatory enforcement, market demand for green products, and the presence or absence of complementary organisational capabilities (Bellantuono et al., 2021). Notably, green resources may generate operational benefits relatively quickly, but financial benefits often require a longer time with supportive market conditions (Setiawan et al., 2025).

Digital Technology Capabilities as a Mediator

In fostering digital technology capabilities, firms need to deploy digital technologies effectively to perform in the higher-order organisational routines (Pavlou & Sawy, 2011). Sensing capability requires continuous scanning of the environment for resource inefficiencies, regulatory shifts, and emerging green technologies (Teece, 2007). Learning capability refers to the routines for acquiring, assimilating, and transforming digital and environmental knowledge (Rashidirad & Salimian, 2020). Integrating capability enables the firm to combine the green resources with digital platforms (Bag et al., 2020). While coordinating capability ensures that tasks, information flows, and decisions are synchronised across departments and supply chain partners (Savastano et al., 2022).

Digital technologies adoption has been a rising interest among recent scholars. The digital technology capabilities eventually can amplify the value of green resources (Belhadi et al., 2020; Y. Li et al., 2020). The use of Internet of Things (IoT) sensors can track real-time energy consumption, allowing firms to adjust production schedules dynamically (Syafrudin et al., 2018). Moreover, big data analytics can identify patterns in material waste, guiding remanufacturing decisions (Khan et al., 2022). Additionally, cloud-based platforms facilitate information sharing between assemblers and suppliers, able to improve material traceability

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and reduce redundant inventory (Gupta et al., 2020). Notwithstanding, without such capabilities, green resources will remain underutilised, and the potential to enhance firm performance will not be fully achieved (Kankanamge et al., 2026).

Despite that, the effect of digital technology capabilities on firm performance is not always directly significant. This resulted in some past studies that digital capabilities influence performance only indirectly, particularly through mediating variables such as operational agility or green process innovation (Li et al., 2022; Setiawan et al., 2025). Thus, this suggests that digital technology capabilities being an enabler is important to test as a mediator rather than a direct driver.

Conceptual Gaps and Contributions

Several gaps motivate this conceptual article. First, existing research on green manufacturing in Malaysia has focused predominantly on practices and certifications rather than on resource efficiency (Pathak et al., 2021; Wen Chiet et al., 2019). Second, the role of digital technology capabilities as a mediator between green resources and firm performance remains underexplored, especially in emerging economies such as Malaysia, particularly in automotive contexts (Azman & Ahmad, 2023; Gohoungodji et al., 2020). Third, previous studies have produced inconsistent findings on whether digital technology capabilities directly enhance firm performance or require activation mechanisms (Li et al., 2022; Setiawan et al., 2025). Fourth, although circular economies are gaining attention globally, their application in Malaysia's automotive sector is nascent, with limited empirical evidence (Jamaluddin et al., 2022; Yahaya et al., 2024).

As such, this article addresses these gaps by proposing an integrated framework that includes RBV and DCV. The framework specifies green resources as the independent variable, digital technology capabilities (sensing, learning, integrating, coordinating) as the mediator, and firm performance (financial and operational) as the dependent variable.

Conceptual Framework

Drawing on the theoretical synthesis, **Figure 2** presents the conceptual framework. Green resources are hypothesised to have both a direct effect on firm performance and an indirect effect mediated by digital technology capabilities. The four dimensions of digital technology capabilities are treated as a higher-order formative construct, consistent with Pavlou and El Sawy's (2011) conceptualisation.

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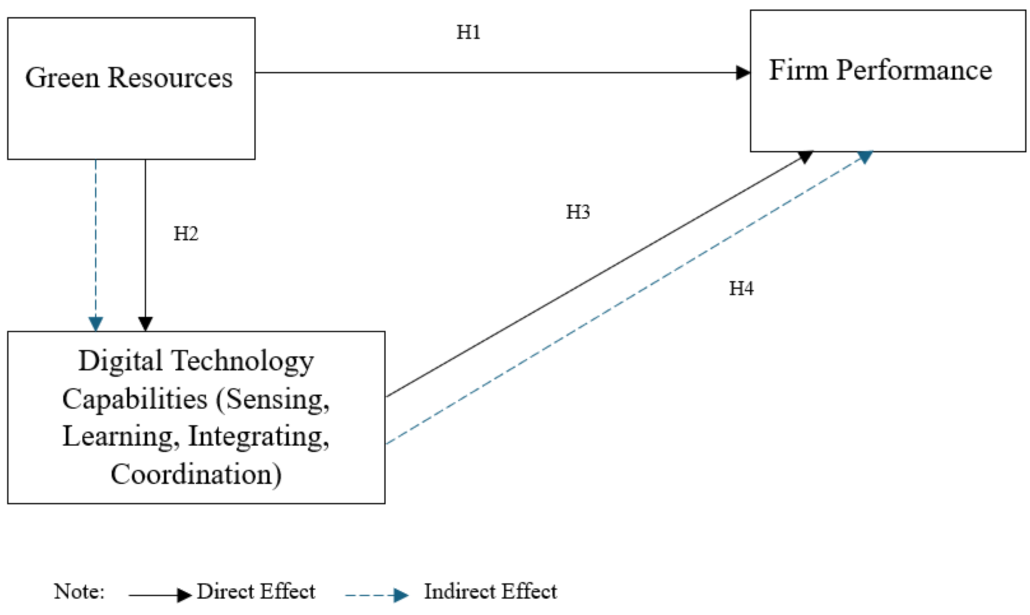

Figure 2: Green-Digital Conceptual Framework

Hypothesis Development

Hypothesis 1 (H1): Green Resource Usage Positively Influences Firm Performance in Malaysia's Automotive Industry.

According to RBV, green resources that are valuable, rare, inimitable, and non-substitutable (VRIN) should enable firms to achieve superior performance outcomes (Barney, 1991; Hart, 1995). In the Malaysian automotive industry context, the use of recycled materials, energy-efficient processes, and skilled green personnel can reduce production costs, improve product quality, and enhance brand reputation among environmentally conscious customers (Abdul-Rashid et al., 2017; Varela et al., 2019). Although financial returns may lag operational improvements, the overall effect on firm performance is expected to be positive (Nureen et al., 2023; Setiawan et al., 2025).

Hypothesis 2 (H2): Green Resource Usage Positively Influences Digital Technology Capabilities in Malaysia's Automotive Industry.

The adoption of green resources often requires digital monitoring and control systems (Belhadi et al., 2020). Digital technologies enhance the firm's capabilities in capturing the data and analysing the information through tracking renewable material, energy consumption, and waste usage (Syed, 2023). Moreover, Khan et al.,(2022) stressed that firms that invest in green resources are likely to develop complementary digital skills to maximise resource efficiency. Thus, green resources as a driver required tools to build digital technology capabilities.

Hypothesis 3 (H3): Digital Technology Capabilities Positively Influence Firm Performance in Malaysia's Automotive Industry.

Digital technology capabilities enable firms to reduce operational costs, improve production speed, enhance product quality, and respond more quickly to market changes (Bag et al., 2020, 2021). Sensing capability helps identify efficiency opportunities, while learning capability accelerates knowledge diffusion. Additionally, integrating capability embeds digital tools into production systems, and coordinating capability synchronizes activities across the value chain (Pavlou & Sawy, 2011; Savastano et al., 2022). These capabilities are expected to improve both financial and operational performance (Calış Duman & Akdemir, 2021; Varela et al., 2019).

Hypothesis 4 (H4): Digital Technology Capabilities Mediate the Relationship Between Green Resource Usage and Firm Performance in Malaysia's Automotive Industry.

Green resources alone will not be sufficient to improve sustained performance due to the dynamic environments where technologies and regulations are evolving rapidly (Teece, 2007; Warner & Wager, 2019). Digital technology capabilities need to act as an activation mechanism that enables to transform the static green resources into more dynamic firm performance drivers (Kankanamge et al., 2026; Setiawan et al., 2025). Without building the internal digital capabilities, automotive industry firms may overlook opportunities to substitute virgin materials with recycled alternatives (Pavlou & El Sawy, 2011), and green knowledge will remain siloed (Rashidrad & Salimian, 2020). Moreover, the adopted digital tools will operate in isolation (Bag et al., 2021). Therefore, the indirect effect of green resources on firm performance through digital technology capabilities is expected to be significant (Nitzl et al., 2016; Zhao et al., 2010).

Discussion

Theoretical Implications

There are several theoretical contributions. First, this study extends RBV by characterising the green resources as VRIN assets in the automotive industry (Barney, 1991; Hart, 1995). Despite a generic discussion of green manufacturing, this conceptual framework identifies specific resource categories that can serve as sources of competitive advantage (Aguilar Esteva et al., 2021; Kasava et al., 2020). Second, this study addresses the static limitation of RBV by integrating DCV, demonstrating that digital technology capabilities provide the renewal and activation mechanisms that RBV lacks (Hart & Dowell, 2011; Teece et al., 1997). Third, by proposing digital technology capabilities as a mediator, the framework resolves inconsistencies in prior literature regarding direct versus indirect effects of digitalisation on performance (Li et al., 2022; Setiawan et al., 2025). Fourth, the article applies RBV and DCV integration to an emerging economy context, particularly in Malaysia, where resource constraints, policy uncertainty, and technological catch-up create unique boundary conditions (Jamaluddin et al., 2022; Yahaya et al., 2024).

Practical and Managerial Implications

For automotive firm managers, the framework highlights the need to move beyond separately adoption of green practices or digital tools (Savastano et al., 2022). Instead, investments in

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green resources should be accompanied by parallel investments in digital capabilities (Bag et al., 2021; Belhadi et al., 2020). Managers should assess their current sensing, learning, integrating, and coordinating routines and identify gaps that hinder resource optimization (Pavlou & Sawy, 2011). For example, a firm that uses recycled materials but lacks IoT-enabled waste tracking may be underutilizing those materials (Syed, 2023). Similarly, a firm with advanced analytics but no green skills training may fail to translate data insights into environmental improvements that lead to improved firm performance (Rahim & Zainuddin, 2019; Yahaya et al., 2024).

The framework also has implications for policymakers. The National Automotive Policy 2020 and the National Energy Transition Roadmap emphasise technology adoption but pay less attention to the capabilities that make adoption effective (MITI, 2020, 2023). The capability building programs could be included in the policy interventions. The programs such as digital upskilling for resource management, cross-firm learning platforms, and subsidies for firms to integrate green-digital systems rather than isolated technology purchases (Azman & Ahmad, 2023; Gohoungodji et al., 2020) can be embedded to enhance resource efficiency.

Limitations and Future Research Directions

As a conceptual framework, this study does not provide empirical testing. However, future research should operationalise the constructs and test the propositions using survey or case study methods (Hair et al., 2017). A common method bias can be identified when a survey study is adopted. Common method bias influences the variables when adopting measurement methods. Thus, Podsakoff et al. (2003) recommendations can be implemented to address common method variance by using diverse scale types for the questionnaire, validating the questionnaire for clarity, and ensuring respondent anonymity. Additionally, Harman's one-factor statistical test can be used to determine the presence of common method bias. In terms of analysis method, partial least squares structural equation modelling (PLS-SEM) would be appropriate (Becker et al., 2023; Ramayah et al., 2018) particularly the Hierarchical Component Model (HCM), as digital technology capabilities are of a formative nature. Additionally, the framework assumes a linear causal comparison. However, a longitudinal study could be needed to examine how the relationships evolve as firms mature in their green-digital overtime (Kifor & Grigore, 2023). Moreover, cross-country comparisons focusing on Southeast Asian countries, such as Malaysia, Thailand, and Indonesia, could reveal how institutional contexts moderate the proposed effects (Jamaluddin et al., 2022; Setiawan et al., 2025). Finally, future research could explore potential moderators, such as firm size, ownership structure, and regulatory pressure (Habidin et al., 2018; Tsou & Kim, 2025).

Conclusion

This conceptual article emphasised a green-digital framework that associates green resources, digital technology capabilities, and firm performance in Malaysia's automotive industry context. Grounded with RBV and DCV theories, the green-digital framework proposes that green resources positively influence firm performance both directly and indirectly through digital technology capabilities. The mediating role of digital technology capabilities components, such as sensing, learning, integrating, and coordinating, addresses a critical gap in understanding how static green resources are transformed into dynamic and sustained firm performance. Therefore, integrating sustainability and digitalisation literatures, the article provides a roadmap for empirical investigation. As well, offers actionable insights for managers and policymakers seeking to align circular economy goals with Industry 4.0 transformation (MITI, 2020; Okorie et al., 2023), particularly focusing on the Malaysian automotive industry.

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Author Contribution Statement:	All authors contributed significantly to the development of this manuscript. Author[1,2] is responsible for identifying the research gap, developing the conceptual framework, literature review, and discussion. Author[3,4] are acted as primary supervisor and co-supervisors, guiding the development of the research conceptual framework and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission.

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