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DIGITAL TRANSFORMATION AND GREEN LOGISTICS ADOPTION: A TOE-BASED CONCEPTUAL MODEL IN THE OMAN LOGISTICS SECTOR

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Abstract: Green logistics has become increasingly important in addressing the environmental impacts arising from transport and supply chain activities. In Oman, where the logistics sector plays a central role in national economic diversification under Vision 2040, the adoption of green logistics practices (GLPs) remains uneven. This conceptual article develops a digital Technology–Organisation–Environment (TOE)-based framework to explain how three digital dimensions comprising digital technology, digital organisation, and digital environment shape the adoption of GLPs and, in turn, influence sustainability performance. Drawing on the TOE framework and Dynamic Capabilities Theory (DCT), the study synthesises contemporary scholarship on digital transformation, sustainability, and logistics to derive a set of testable hypotheses. The proposed framework positions GLPs as a mediating mechanism that translates digital readiness into environmental, economic, and social sustainability outcomes. The article contributes to theory by contextualising the digital TOE model within an under-researched Gulf logistics setting and by integrating it with triple-bottom-line sustainability performance. From a practical perspective, the study offers guidance to policymakers and logistics practitioners seeking alignment with Oman Vision 2040, emphasising the importance of digital capabilities, innovation-oriented organisational cultures, and supportive regulatory environments. The framework also provides a foundation for future empirical research exploring how digital transformation can serve as a catalyst for sustainable logistics development in emerging economies.

Keywords: Digital TOE framework; green logistics; sustainability performance; Oman Vision 2040; technology adoption.

1. Introduction

Sustainability has become a defining priority for the global logistics industry, as growing concerns over environmental degradation and climate change place increasing pressure on supply chains to adopt greener practices. Logistics activities particularly freight transportation is among the largest contributors to greenhouse gas emissions, accounting for a substantial share of global emissions (Juan et al., 2018). Green logistics practices (GLPs) have therefore emerged as strategic mechanisms for reducing emissions, optimising resource utilisation, and simultaneously improving environmental and economic performance (Khan, 2019; Wang et al., 2018).

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In Oman, logistics plays a central role in national economic diversification under Oman Vision 2040. While many of the challenges encountered across emerging economies, Oman faces additional pressures arising from its rapid diversification agenda and an evolving regulatory landscape (Youngswaing et al., 2024; Verma, 2024). Digital technologies provide a pathway for addressing these challenges. Advances in the Internet of Things (IoT), artificial intelligence (AI), and big data analytics enable real-time visibility, intelligent routing, and enhanced operational efficiency, thereby aligning digital transformation efforts with environmental objectives (Bing et al., 2020; Nicoletti & Appolloni, 2024; Tianqi et al., 2023).

The TOE framework offers a structured perspective for analysing how technological capabilities, organisational readiness, and external pressures collectively shape innovation adoption. However, its digital application within the domain of green logistics particularly in emerging economies remains underexplored. This limited application highlights a clear conceptual gap that warrants further theoretical development tailored to the Gulf and Omani logistics context.

This study addresses this gap by posing the research question: "How can the digital TOE framework facilitate the adoption of green logistics practices in Oman?" It contributes to both theory and practice by examining the role of digital enablers in advancing sustainability transformation in a context where logistics is central to economic diversification but constrained by environmental and infrastructural challenges. Accordingly, this article pursues three objectives: (1) to conceptualise the digital TOE dimensions within the context of green logistics; (2) to explain their expected influence on GLP adoption; and (3) to propose testable hypotheses linking digital enablers, GLPs, and sustainability performance.

2. Problem Statement

The logistics and transportation sector is a critical driver of global trade and economic growth, but it is also one of the most significant contributors to greenhouse gas (GHG) emissions, accounting for approximately 23% of energy-related CO_2 emissions worldwide (Wenhu et al., 2023). Despite reductions achieved in other sectors, transportation-related emissions continue to increase, driven by rising e-commerce activity, growing freight volumes, and persistent dependence on fossil fuels (Guoyin et al., 2022; Wen et al., 2023). This trajectory threatens the achievement of international climate commitments, including those outlined in the Paris Agreement, and underscores the urgent need for sustainable logistics practices and digital innovation to mitigate environmental impacts (Kaack et al., 2018). While substantial progress has been made in industrialised nations supported by robust regulatory frameworks, financial incentives, and advanced technologies emerging economies, including those in the Gulf Cooperation Council (GCC) region, face distinct challenges. These include limited green infrastructure (such as electric vehicle charging stations and renewable energy systems), harsh climatic conditions that diminish the efficiency of green technologies, and insufficient regulatory enforcement to drive sector-wide sustainability transitions (Ouni & Abdallah, 2024; Alqahtany & Aravindakshan, 2021). These

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global regional disparities highlight the importance of a focused and contextually grounded examination of sustainability challenges in the Gulf region.

In Oman, the transport and logistics sector contribute roughly 23% of national GHG emissions (Al-Wahaibi, 2019), demonstrating the urgency of targeted interventions. Although Vision 2040 identifies logistics as a cornerstone of economic diversification and sustainability, the adoption of Green Logistics Practices (GLPs) remains uneven. Initiatives such as the Port of Duqm's deployment of solar technologies illustrate emerging progress, however Oman still trails regional frontrunners like the United Arab Emirates and Saudi Arabia in integrating renewable energy systems and intelligent logistics technologies into national strategies (Abdul Rahman et al., 2023; Alharbi & Csala, 2021). From an academic standpoint, research on digital transformation in logistics remains heavily concentrated in developed economies, with limited attention given to how emerging markets can leverage advanced technologies including IoT, AI, and big data analytics to enhance sustainability outcomes (Spanaki et al., 2021; Leogrande, 2024). Furthermore, studies applying the TOE framework to examine GLP adoption are scarce in Gulf contexts, where socio-economic structures, regulatory environments, and institutional pressures differ markedly from those in industrialised countries (Agyabeng-Mensah et al., 2020). This underrepresentation of Gulf and Omani perspectives reveals a clear conceptual gap, particularly concerning how digital transformation can enable green logistics adoption under region-specific constraints.

The logistics sector's contribution to climate change, Oman's strategic position in regional trade, and the GCC's structural sustainability challenges collectively underscore the need for research that integrates digital transformation, regulatory frameworks, and GLPs in emerging markets. Accordingly, this study addresses this gap by proposing a conceptual digital TOE-based framework tailored to Oman's logistics sector. The framework clarifies the mechanisms through which digital capabilities may support the adoption of GLPs and contribute to achieving national sustainability objectives.

3. Literature review

This section synthesises existing scholarship on green logistics, the TOE framework, and digital transformation to establish a robust theoretical foundation for the study. Reviewing these domains highlights the intersections between sustainability and digitalisation in the logistics sector while identifying critical gaps in the literature. The discussion begins with an overview of GLPs), followed by an examination of the TOE framework as a conceptual lens for technology adoption. It then considers how digital transformation is embedded within the TOE framework before linking the digital TOE dimensions to GLP adoption. Finally, the review explores sustainability performance in the logistics sector, emphasising its role as a key outcome of digital and environmental innovations.

3.1 Green Logistics Practices

Green logistics (GL) refers to the integration of environmentally responsible strategies into logistics operations to minimise ecological impact while maintaining operational

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efficiency. GLPs span transportation, warehousing, packaging, and inventory management, and are designed to reduce greenhouse gas emissions, optimise resource utilisation, and minimise waste generation (Dukkanci et al., 2019; Saada, 2021). Given the escalating urgency of climate change, GL is now essential for balancing economic growth with environmental stewardship, particularly in emerging economies such as Oman (Aldakhil et al., 2018). Implementing GLPs often involves the adoption of clean technologies, the integration of renewable energy sources, sustainable packaging solutions, and reverse logistics systems to enable product recovery and reuse (Cui et al., 2023; Bortolazzo et al., 2018).

Recent studies indicate a growing shift towards proactive environmental strategies, with organisations increasingly investing in advanced monitoring and reporting systems to ensure regulatory compliance and demonstrate measurable progress towards sustainability targets (Vienažindienė et al., 2021). This reflects a transition from reactive compliance-driven practices to innovation-oriented approaches that deliver long-term value. However, GLP adoption continues to face significant obstacles, particularly in developing regions. High initial investment costs, limited access to advanced green technologies, and the absence of supportive regulatory frameworks remain persistent constraints. In Oman, these challenges are further compounded by infrastructural limitations, organisational resistance to change, and limited awareness of the strategic advantages of green logistics (Wang et al., 2018; Kurbatova et al., 2020).

GLPs aim to embed sustainability into all stages of supply chain operations, with three core objectives: reducing carbon emissions, improving resource efficiency, and minimising waste (Savina et al., 2021; Hove-Sibanda et al., 2018). For example, logistics operators can lower emissions through cleaner technologies and optimised routing, with metrics such as carbon footprint and energy consumption serving as indicators of performance (Wen et al., 2023; Patseva et al., 2024). Practices such as reverse logistics further enhance environmental performance by enabling material recovery and recycling while simultaneously reducing operational costs (Novarlić & Đurić, 2024; Valenzuela et al., 2021; Massaro et al., 2020). Digital technologies, including the Internet of Things (IoT), support data-driven decision-making, facilitating accurate monitoring of resource flows and strengthening operational sustainability (Muhammad Hairie Hanis & Fernando, 2024).

The benefits of GLPs extend beyond environmental gains. Firms that adopt sustainable logistics measures often achieve improved financial performance through cost reductions and enhanced operational efficiency, alongside stronger competitive positioning in markets where sustainability is a priority (Chan & Xu, 2024). Socially, GLPs reinforce corporate reputation and responsibility, fostering greater stakeholder trust and strengthening community relations (Youngswaing et al., 2024). Despite these advantages, barriers to adoption persist. High upfront costs for green infrastructure such as renewable energy systems and electric vehicles remain prohibitive in regions with limited incentives (Nicoletti & Appolloni, 2024). Additionally, insufficient regulatory frameworks and limited technical expertise further impede progress, highlighting the need for targeted education, capacity building, and policy support (Verma, 2024).

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Globally, industrialised economies demonstrate how strong regulations, fiscal incentives, and circular-economy principles can accelerate GL adoption. The European Union's Green Deal, alongside sustainability-driven policies in Japan and South Korea, has advanced innovation in green logistics (Roy & Mohanty, 2023; Sağlam, 2023). Conversely, emerging economies including those in the Gulf region face unique constraints such as heavy dependence on fossil fuels, underdeveloped logistics infrastructure, and competing economic priorities (Vieira et al., 2020). These contexts demand tailored strategies that leverage local conditions, promote public–private collaboration, and facilitate knowledge transfer to support green transitions (Nikseresht et al., 2023).

3.2 The Technology–Organisation–Environment (TOE) Framework

The TOE framework, introduced by Tornatzky and Fleischer in 1990, offers a structured theoretical model for analysing organisational adoption of technological innovations. Unlike models that emphasise only technological or individual-level factors, TOE integrates technological, organisational, and environmental dimensions, providing a holistic perspective on innovation processes (Malik et al., 2021; Dubey et al., 2019). First conceptualised in *The Processes of Technological Innovation*, the framework highlights that the successful implementation of new technologies depends on the interplay between internal resources, organisational attributes, and external pressures (da Silva & de Mattos, 2019). Its comprehensive structure has made it one of the most widely applied frameworks in studies of digital transformation across various industries.

3.2.1 Dimensions of the TOE Framework

The technological dimension concerns the characteristics of the technologies under consideration, including perceived benefits, compatibility, and complexity. Perceived benefits influence investment decisions by offering improved efficiency, cost reductions, or enhanced service quality, while compatibility with existing systems and organisational culture increases the likelihood of successful adoption (Bugawa et al., 2018; Tan, 2022). Conversely, high perceived complexity can hinder adoption, particularly when technologies require extensive training or disrupt established operational routines (Alsulami et al., 2022).

The organisational dimension refers to internal factors such as resource availability, firm size, managerial support, and organisational culture. These elements shape a firm's readiness to adopt new technologies. Larger firms may benefit from greater resources but can experience bureaucratic inertia, while smaller firms may be more agile yet constrained by financial or technical limitations (Xuefei et al., 2018). Leadership support and an innovation-oriented culture are vital for overcoming resistance to change and facilitating successful implementation (Shirandula et al., 2022; Ha, 2024).

The environmental dimension captures external influences such as regulatory frameworks, customer expectations, and competitive pressures, all of which can encourage or compel organisations to adopt new technologies (Sharma et al., 2020). For example, stringent emissions regulations and rising customer demand for sustainable services have motivated logistics firms to invest in advanced routing technologies and electric vehicle fleets

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(Xuefei et al., 2018; Ha, 2024). These factors create strategic imperatives that make technological adoption increasingly necessary.

3.2.2 Strengths and Limitations of the TOE Framework

The TOE framework is widely valued for its comprehensive explanatory power, as it integrates multiple determinants rather than focusing on isolated factors. Its widespread application across diverse domains such as big data analytics (Yuanyuan et al., 2018), enterprise cloud systems (Yu-Wei, 2020), and mobile health technologies (Naeem et al., 2024) demonstrates its versatility (Jovevski et al., 2018; Mezghani et al., 2022). Nonetheless, it has been criticised for its static orientation, which underrepresents organisational adaptation over time. While TOE identifies key adoption determinants, it does not fully capture processes such as organisational learning, resource reconfiguration, or evolving stakeholder interactions (Adade & de Vries, 2024; Kriti Priya Gupta, 2023). Studies of Industry 5.0 and SMEs further emphasise this limitation, noting that while TOE effectively identifies adoption drivers, it offers limited insight into the long-term sustainability of innovation post-implementation (Sarkar et al., 2024).

3.2.3 Integrating Dynamic Capabilities Theory (DCT)

Dynamic Capabilities Theory (DCT), introduced by Teece et al. (1997), complements the TOE framework by focusing on a firm’s capacity to sense opportunities, seize initiatives, and reconfigure resources in response to rapidly changing environments (Teece, 2018). While TOE identifies contextual determinants, DCT provides a dynamic perspective that explains how organisations adapt, evolve, and innovate over time. This integration offers a more comprehensive understanding of technology adoption, particularly in complex sectors such as logistics. Firms with strong dynamic capabilities are better positioned to respond to regulatory shifts, integrate emerging technologies, and sustain innovation-driven growth (Liboni et al., 2022; Xiu-e et al., 2022).

Applying TOE and DCT together is especially valuable in emerging markets like Oman, where logistics firms encounter distinctive challenges such as infrastructure constraints, regulatory pressures, and ambitious national sustainability goals (Karamperidis & Valantasis-Kanellos, 2022). Technology–Organisation–Environment identifies the structural determinants of adoption, while DCT explains how firms build resilience and adaptability, providing a comprehensive model to guide innovation strategies (Zeleti & Ojo, 2019).

3.3 Digital Transformation Within the TOE Framework

Digital transformation represents a comprehensive organisational shift in which digital technologies are integrated across all operational activities, reshaping processes, decision-making, and value creation (Jafari-Sadeghi et al., 2021). It extends beyond basic process digitisation by enabling firms to reconfigure business models and enhance strategic agility, allowing them to respond more effectively to evolving market and environmental demands (Torres & Augusto, 2020; Halpern et al., 2021). In today’s volatile business landscape, digital

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transformation is a catalyst for continuous innovation, supporting long-term competitiveness and organisational resilience (Rojas-Segura et al., 2023).

Emerging technologies including artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and cloud computing have transformed logistics operations. Rather than operating as discrete tools, these technologies form an integrated digital infrastructure that strengthens transparency, predictive capabilities, and operational coordination. AI-driven analytics enable firms to forecast demand and allocate resources more efficiently (Gradillas & Thomas, 2023), while IoT devices enhance real-time visibility across supply chains (Iyamu et al., 2021). Big data analytics supports evidence-based decision-making, and cloud platforms facilitate scalable and collaborative logistics networks (Dąbrowska et al., 2022). Within the TOE framework, these technologies constitute the technological context that drives the adoption of sustainable and innovation-led logistics practices.

3.3.1 Digital Transformation and the Technological Dimension

The technological dimension of the TOE framework highlights how innovations improve operational efficiency and sustainability performance. Digital tools have advanced logistics capabilities, particularly in real-time tracking, route optimisation, and predictive analytics. Rather than functioning as isolated applications, these technologies collectively enhance data availability, accuracy, and responsiveness across logistics processes.

IoT-enabled tracking systems improve supply chain visibility and reliability, strengthening customer trust and enhancing inventory management (Savina et al., 2021). Route optimisation algorithms reduce travel time, fuel consumption, and carbon emissions, contributing directly to environmental goals while lowering costs (Hove-Sibanda et al., 2018). Artificial intelligence enhances predictive capacity, enabling firms to anticipate disruptions and streamline operations by reducing inefficiencies (Wen et al., 2023). On the whole, these capabilities support proactive decision-making and reinforce sustainable operational performance. However, successful integration depends on the perceived compatibility of these technologies with existing systems and the complexity involved in implementation, both of which strongly influence adoption decisions (Hausberg et al., 2019; Verhal, 2023).

3.3.2 Organisational and Environmental Perspectives in Digital Transformation

The effectiveness of digital transformation also hinges on organisational and environmental readiness. Internally, firms require adequate financial and human resources, strong managerial commitment, and an innovation-oriented culture to successfully implement large-scale digital initiatives (Patseva et al., 2024). These internal capabilities determine whether firms can translate digital investments into substantive operational improvements, particularly where adoption requires cross-functional alignment and process redesign. Investment in digital skills development is essential, ensuring employees are equipped to utilise these technologies and supporting long-term organisational adaptability (Khurniawan et al., 2024).

Externally, regulatory frameworks and environmental standards increasingly shape digital adoption, as firms must comply with sustainability requirements through automated

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monitoring and reporting systems (Singh, 2024). Customer expectations for transparency and greener practices have also intensified, compelling firms to provide real-time information on sourcing, emissions, and environmental performance (Junbo et al., 2024; Jebum & Jin, 2021). Competitive pressures further accelerate digital adoption, as firms that fail to keep pace with technological advancements risk losing market relevance (De Sousa Jabbour et al., 2020; Hey & Chang, 2021). These external conditions generate both coercive and market-driven pressures that influence firms' strategic decisions relating to digital innovation. Overall, the organisational and environmental dimensions create a mutually reinforcing context within the TOE framework, shaping not only the likelihood of digital tool acquisition but also the depth and effectiveness of their integration into sustainable logistics practices.

3.3.3 Digital Transformation as a Driver of Sustainability and Oman Vision 2040

Digital transformation is closely aligned with sustainability objectives, especially in logistics, where it plays a foundational role in supporting Green Logistics Practices (GLPs). IoT-enabled systems and AI-driven optimisation models help reduce emissions, minimise waste, and support circular economy initiatives (Zhang et al., 2021; Surajit Bag et al., 2022). Blockchain technologies enhance transparency in reverse logistics and recycling processes, increasing stakeholder confidence in sustainability claims (Pflaum et al., 2021). Big data analytics generates actionable sustainability indicators, enabling organisations to track and evaluate their environmental performance in real time (Giudice et al., 2020; Abdelhalim, 2023).

In Oman, digital transformation is a central pillar of Vision 2040, which emphasises innovation, environmental stewardship, and economic diversification (Guirguis, 2020; Sardi et al., 2020). Logistics firms adopting digital solutions can improve operational efficiency, meet regulatory expectations, and enhance competitiveness in global markets (Ferraris et al., 2019; da Silva & de Mattos, 2019). Importantly, Vision 2040 positions digital technologies as enablers of sustainability transitions, underscoring their role in improving resource efficiency, supporting emissions reporting, and strengthening compliance with environmental regulations.

Within the TOE framework, digital transformation integrates the technological, organisational, and environmental dimensions by providing firms with the tools, capabilities, and external incentives needed to embed sustainability into logistics operations. This holistic perspective underscores that digitalisation is not merely an operational enhancement but a strategic mechanism for advancing sustainable logistics development particularly in emerging economies seeking ecological resilience and competitive advantage.

3.4 Linking the Digital TOE Framework to Green Logistics Practices

Integrating the TOE framework with GLPs provides a comprehensive theoretical foundation for understanding how sustainable logistics practices are adopted. Embedding digital transformation within the TOE model deepens insights into how technological capabilities, organisational readiness, and environmental pressures collectively influence GLP

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implementation. This approach moves beyond a focus on individual technologies and instead highlights how digital infrastructures enhance data visibility, operational coordination, and sustainability reporting across logistics networks.

The digital evolution of the TOE framework underscores the increasing role of advanced technologies including the Internet of Things (IoT), blockchain, big data analytics, and artificial intelligence (AI) in enabling sustainable logistics operations. This integrated perspective demonstrates the interplay between internal resources, organisational culture, and external forces, offering a holistic approach to supporting sustainability transitions. In this framework, digital technologies act as enablers, organisational structures determine absorptive capacity, and environmental pressures provide strategic motivation for the adoption of GLPs. This synthesis advances theoretical work by illustrating how interdependencies between resources, culture, and regulatory conditions shape sustainability transitions in the logistics sector (Ciliberto et al., 2021; Zhang et al., 2021).

3.4.1 Theoretical Integration of TOE and GLPs

The TOE framework offers a robust structure for analysing the adoption of sustainability initiatives, emphasising that GLP implementation requires alignment across technological, organisational, and environmental dimensions. From a technological perspective, digital innovations enhance supply chain transparency, optimise logistics operations, and reduce environmental impacts. Rather than viewing these tools as discrete enhancements, the technological dimension captures how data integration and real-time analytics underpin sustainable logistics decision-making. Technologies such as real-time tracking, predictive analytics, and automated systems enable firms to minimise waste and emissions while improving operational efficiency (Zhang et al., 2021; Mukherjee, 2024). Organisational factors such as leadership commitment, innovation culture, and resource allocation are equally critical, as they determine the extent to which digital tools can be leveraged effectively. In the context of GLPs, organisational readiness functions as the internal mechanism that converts technological capability into meaningful behavioural and operational change.

The environmental dimension adds further complexity by highlighting the role of regulatory pressures, stakeholder expectations, and institutional norms. These external forces shape both the urgency and direction of GLP adoption, particularly in regions aligning their strategies with national sustainability agendas. Taken together, the three dimensions demonstrate that integrating TOE with GLPs provides a more analytical understanding of how internal capabilities, digital infrastructures, and institutional pressures jointly determine sustainability transitions in logistics. This theoretical synthesis clarifies how organisations adopt, institutionalise, and scale GLPs, moving the discussion beyond descriptive accounts of technology use (Borges et al., 2024; Miao, 2022).

3.4.2 Digital Technologies, Organisational Readiness, and Environmental Pressures

Digitalisation significantly strengthens the TOE framework's relevance to GLP adoption by embedding Industry 4.0 technologies within logistics operations. Tools such as IoT sensors

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and blockchain systems facilitate circular economy practices by enabling traceability in reverse logistics, enhancing waste management, and allowing real-time monitoring of carbon emissions (Ciliberto et al., 2021; Zhang et al., 2021). Within the technological dimension, these tools operate as integrated infrastructures that support data-driven sustainability decisions rather than as isolated operational add-ons.

Organisational readiness remains a decisive factor, requiring adequate financial resources, digital skills, leadership commitment, and a clear strategic vision for sustainability. Within the TOE framework, readiness reflects a firm's absorptive capacity, determining whether digital solutions can be effectively harnessed to support GLP implementation. Without these organisational foundations, even sophisticated technologies may fail to achieve transformative outcomes (Mukherjee, 2024).

Externally, regulatory frameworks, market pressures, and consumer expectations for greener products exert strong influence on sustainability strategies. Heightened demand for transparency and eco-consciousness is reshaping competitive dynamics, making sustainability performance and digital monitoring essential differentiators (Suranjit Bag & Shivam Gupta, 2019; Miao, 2022). These environmental pressures act as institutional drivers that reduce the discretionary nature of GLP adoption, positioning digital transformation as a strategic requirement. Consequently, firms in the logistics sector increasingly adopt digital systems to meet compliance obligations and to strengthen their competitive standing in global markets (Aubakirova, 2024).

3.4.3 Application in the Omani and Gulf Context and the Research Gap

Despite growing research on the integration of TOE and GLPs in advanced economies, applications within emerging markets particularly in the GCC region remain limited. Oman represents a particularly significant context, given its national commitment to sustainability and digital innovation under Oman Vision 2040, which prioritises economic diversification, technological modernisation, and environmental stewardship (Yang et al., 2022). Nevertheless, barriers such as limited green infrastructure, dependence on fossil fuels, and high costs associated with adopting sustainable technologies pose significant challenges to GLP implementation (Suranjit Bag & Shivam Gupta, 2019). These conditions underscore the need for a contextualised understanding of how digital capabilities, organisational readiness, and environmental pressures interact within the Omani logistics sector. Existing research offers limited insights into how TOE-based digital transformation frameworks operate under the structural and institutional constraints characteristic of Gulf economies.

Addressing this gap, the present study applies the digital TOE framework to Oman's logistics industry to explain how technological readiness, organisational capacity, and regulatory environments jointly shape the adoption of GLPs. This approach provides a theoretically grounded explanation of how digital transformation can help overcome local constraints, rather than offering purely descriptive observations. By contextualising the digital TOE framework within Oman's logistics sector, the study provides insight into how firms can leverage digital tools, organisational strategies, and supportive policy environments to achieve national sustainability objectives.

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In doing so, the research bridges a critical gap between global theories of digital transformation and the practical realities of GLP implementation in Gulf economies, where institutional dynamics differ substantially from those in developed markets. The findings aim to guide policymakers and logistics practitioners seeking to align operational strategies with both national sustainability goals and global market requirements (Chun & Juanru, 2023).

3.5 Sustainability Performance in the Logistics Sector

Sustainability performance in the logistics sector is a multidimensional concept that integrates environmental, economic, and social outcomes to foster resilient and responsible supply chains. This comprehensive perspective enables organisations to evaluate their long-term impact on society and the environment while maintaining competitiveness in global markets. Green logistics practices have emerged as strategic enablers of sustainability, helping firms reduce their ecological footprint, enhance operational efficiency, and strengthen corporate reputation. Beyond operational improvements, GLPs provide measurable indicators such as emissions reduction, resource efficiency, and stakeholder engagement that allow firms to assess sustainability outcomes systematically. Given the logistics sector's pivotal role in global supply chains, particularly as transportation and related operations significantly contribute to greenhouse gas emissions and resource depletion, sustainability performance has become a key benchmark for evaluating how effectively logistics organisations integrate environmental responsibility with long-term economic and social value creation.

3.5.1 The Environmental, Economic, and Social Dimensions of Sustainability

A holistic approach to sustainability relies on three interconnected pillars. Environmental sustainability focuses on mitigating ecological harm through emissions reduction, waste management, and energy efficiency initiatives. Implementing practices such as electric vehicles, renewable energy in warehousing, and reverse logistics can substantially lower carbon footprints while supporting compliance with environmental regulations (Xiaoyuan, 2023). Economic sustainability emphasises cost efficiency, resource optimisation, and long-term profitability through streamlined operations and lean logistics strategies (Arifia, 2024). Social sustainability highlights ethical governance, employee well-being, and community engagement, thereby fostering trust among stakeholders and aligning organisations with societal values (Mahmood et al., 2024). Across these three dimensions, sustainability performance provides a structured framework for assessing how effectively logistics firms integrate environmental responsibility with operational and social value creation. This multidimensional perspective ensures that GLPs are evaluated not only for their ecological impact but also for their contributions to cost reduction, stakeholder satisfaction, and long-term organisational resilience.

3.5.2 Technology as a Catalyst for Sustainability Performance

Technological innovation has emerged as a critical driver of sustainable logistics. Tools such as the IoT, AI, and big data analytics enable firms to improve efficiency, transparency, and environmental stewardship. Internat of Thing sensors and GPS tracking systems provide

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real-time visibility, facilitating optimised routing and reduced fuel consumption. Predictive analytics support more effective inventory management and demand forecasting, while blockchain technology enhances supply chain transparency, ensuring traceability of products and verification of eco-friendly practices.

Beyond operational benefits, digital technologies provide quantifiable sustainability data such as emissions levels, energy consumption, and waste patterns allowing firms to measure performance against environmental targets. By integrating these capabilities into planning, monitoring, and decision-making processes, organisations can shift sustainability from a compliance-driven activity to a data-driven strategic function (Savina et al., 2021; Zhang et al., 2021). In this way, technology acts as a catalyst, linking logistics operations with measurable sustainability outcomes, supporting alignment with international environmental standards, and strengthening long-term organisational resilience.

3.5.3 Research and Implementation Gaps in Oman

While many global logistics leaders have embedded sustainability frameworks into their core strategies, Oman's logistics sector remains at an early stage of institutionalising sustainability performance. Limited access to standardised metrics, fragmented reporting mechanisms, and weak regulatory enforcement hinder efforts to benchmark performance against global standards (Tianqi et al., 2023). Furthermore, a lack of localised research tailored to Oman's unique socio-economic and environmental context creates a disconnect between national objectives under Oman Vision 2040 and operational practices (Khakwani et al., 2024). This absence of context-specific evidence constrains understanding of how digital capabilities, organisational readiness, and environmental pressures interact to influence sustainability outcomes within the Omani logistics sector.

Addressing these gaps requires investment in data infrastructure, harmonised sustainability reporting, and stronger policy enforcement to facilitate green transformation. Additionally, research is needed to clarify how digital technologies can support the measurement, monitoring, and enhancement of sustainability performance in Oman, particularly given the sector's institutional constraints and evolving regulatory landscape. With its strategic geographic location and growing logistics industry, Oman has significant potential to become a sustainability leader in the Gulf region, provided it leverages digital innovation and develops frameworks tailored to local needs. By identifying these research and implementation gaps, this study emphasises the necessity of applying a digital TOE perspective to understand how Omani logistics firms can advance sustainability performance in alignment with Vision 2040.

4. Conceptual Framework

This study proposes an integrated conceptual framework that combines the TOE framework with DCT to examine the adoption of GLPs and their impact on sustainability performance. By integrating these two perspectives, the model captures both the static contextual factors influencing technology adoption and the dynamic capabilities organisations require to adapt, innovate, and maintain competitive advantage in a rapidly

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evolving environment. This integration addresses a critical theoretical gap by linking external and internal determinants of digital adoption with the firm's capacity to reconfigure resources and respond effectively to environmental pressures. Within the framework, GLPs serve as a central mediating mechanism, translating digital readiness into tangible sustainability outcomes.

By positioning GLPs as a mediator, the model elucidates how technological and organisational drivers are transformed into environmental, economic, and social benefits. Sustainability outcomes are assessed across the environmental, economic, and social dimensions, offering a comprehensive evaluation of organisational performance in the logistics sector. The framework is particularly applicable to Oman's logistics industry, where Vision 2040 emphasises both digital transformation and sustainability, providing a context in which TOE conditions and dynamic capabilities jointly shape the adoption of GLPs.

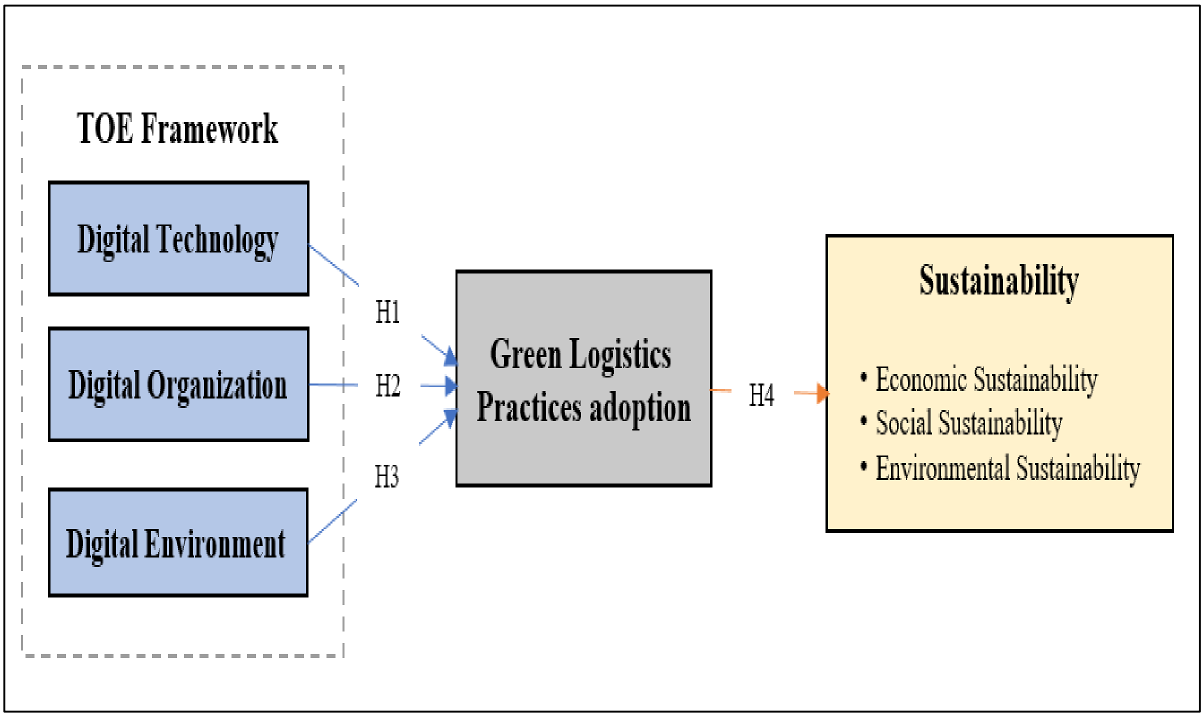

Figure 1. The Conceptual Framework of TOE Framework, Green Logistics and Sustainability

As illustrated in Figure 1, the proposed framework positions three key enablers—digital technology, digital organisation, and digital environment as independent variables influencing the adoption of Green Logistics Practices (GLPs), which, in turn, impact sustainability performance. This representation highlights the mediating role of GLPs in connecting digital capabilities with sustainable outcomes and provides a structured foundation for empirical analysis within Oman's logistics context. By emphasising how digital readiness is channelled through GLPs to generate environmental, economic, and social benefits, the framework aligns closely with national priorities under Oman Vision 2040, where digital transformation and sustainability are jointly prioritised.

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4.1 Rationale for Integrating TOE and DCT

The TOE framework provides a well-established structure for identifying technological, organisational, and environmental factors that affect innovation adoption decisions (Yuan-yuan et al., 2020). However, its static nature limits its ability to explain how organisations continuously adapt their capabilities in response to evolving market conditions and technological advancements. Dynamic Capabilities Theory addresses this limitation by emphasising the processes that enable firms to sense opportunities, seize innovation, and reconfigure resources, thereby ensuring resilience and long-term competitiveness (Enggi et al., 2024; Webber et al., 2018). Integrating TOE with DCT offers a comprehensive lens to understand both the enabling conditions for adopting innovation and the dynamic capability-building required to implement and sustain these innovations effectively. This combination is particularly valuable in the logistics sector, where companies face accelerating digitalisation and mounting environmental pressures (Jiyeon et al., 2024; Zagarrì et al., 2023). In the context of Oman, combining these frameworks strengthens the study's theoretical grounding by explaining not only why digital technologies are adopted but also how logistics firms can develop the adaptive capabilities necessary to align with Vision 2040's sustainability and digital transformation priorities.

4.2 Green Logistics Practices (GLPs) as a Mediator

Green Logistics Practices function as the operational mechanism through which investments in digital capabilities yield measurable sustainability outcomes. Implementing practices such as energy-efficient warehousing, low-emission transportation systems, and reverse logistics enables organisations to translate advanced technological insights into tangible benefits for both the environment and business operations (Lazar et al., 2021; Syed et al., 2019). Empirical research consistently shows that sustainability practices often mediate the relationship between technology adoption and organisational performance, underscoring their importance in aligning digital transformation efforts with long-term environmental and economic objectives (Conroy et al., 2024). Positioning GLPs as a mediator therefore enhances the explanatory power of the framework, demonstrating how organisations can bridge the gap between digital readiness and sustainability goals through well-designed logistics practices. This mediating role is particularly relevant in Oman, where the logistics sector's digital maturity is increasing, yet sustainability outcomes remain uneven; GLPs provide the mechanism through which digital investments can be translated into the national sustainability priorities articulated under Vision 2040.

4.3 Digital TOE Dimensions

In the proposed framework, the digital technology dimension focuses on advanced tools such as artificial intelligence, big data analytics, and IoT systems, which facilitate predictive analytics, emissions monitoring, and supply chain optimisation. These technologies allow organisations to achieve regulatory compliance while enhancing operational efficiency and reducing environmental impact (Ünen, 2024). The digital organisation dimension emphasises internal enablers such as leadership support, an innovation-driven culture, organisational agility, and workforce digital competencies. Firms with strong leadership and a culture of

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innovation are better positioned to adopt and scale sustainability-oriented logistics solutions (Serebrisky et al., 2018).

The digital environment dimension examines external pressures, including regulatory frameworks, market competition, and stakeholder expectations, which drive investments in digital and sustainable transformation. These forces increasingly compel organisations to operate in an environmentally responsible manner and align with global and national sustainability agendas (Lazar et al., 2021). In Oman, these three dimensions collectively reflect the country's push towards digital readiness under Vision 2040, where technological investment, organisational reform, and evolving regulatory expectations create the conditions necessary for adopting green logistics practices. Overall, these dimensions form the foundation of the model, explaining how contextual factors and internal readiness interact to shape sustainable logistics innovation.

4.4 Research Gap and Contextual Relevance to Oman

Despite global advances in research on digital transformation and sustainability, studies focusing specifically on the Gulf region, and Oman in particular, remain limited. Oman's logistics sector is strategically important for economic diversification but faces challenges such as the absence of standardised sustainability metrics, fragmented reporting systems, and regulatory gaps (De Jong et al., 2022; De Toro et al., 2023). By applying this integrated TOE+DCT model to Oman's logistics industry, the study addresses a critical gap in the literature, providing a localised understanding of how digital readiness and GLPs can drive sustainability performance.

Existing studies rarely examine how digital enablers, organisational capabilities, and environmental pressures interact to influence GLP adoption in emerging economies, making the conceptual integration presented here both timely and theoretically significant. The framework offers a practical tool for policymakers and logistics providers seeking to align operations with Vision 2040 objectives, providing actionable insights on leveraging digital transformation to generate environmental, economic, and social benefits. Its contextual relevance strengthens the study's contribution by linking global theoretical models with Oman's unique institutional and infrastructural realities.

4.5 Hypotheses Development

The study's hypotheses are grounded in the TOE framework and supported by prior empirical and conceptual research. Each dimension of the digital TOE model is theorised to influence the adoption of GLPs through technological benefits, organisational readiness, and environmental pressures identified in previous studies. The following subsections present the theoretical justification for each hypothesis.

H1 Development (Digital Technology → GLPs): Digital technologies, including IoT, AI, and big data analytics, enhance visibility, efficiency, and emissions monitoring within logistics systems. Prior research demonstrates that advanced digital tools directly support green routing, waste minimisation, and environmental monitoring (Zhang et al., 2021; Savina et al., 2021). Studies applying the TOE framework consistently identify technological capability as a

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primary driver of environmental innovation adoption (Tan, 2022; Hausberg et al., 2019). Accordingly, it is hypothesised that:

H1: There is a positive relationship between digital technology and the adoption of green logistics practices.

H2 Development (Digital Organisation → GLPs): Organisational readiness—including leadership support, innovation culture, and workforce digital competencies—is essential for implementing sustainability initiatives (Mukherjee, 2024; Shirandula et al., 2022). The TOE framework emphasises internal capacity as a decisive factor in technology-driven environmental practices. Firms with strong digital mindsets and trained personnel are better positioned to integrate GLPs into logistics operations (Patseva et al., 2024). Therefore:

H2: There is a positive relationship between digital organisation and the adoption of green logistics practices.

H3 Development (Digital Environment → GLPs): External pressures, such as regulations, customer expectations, and competitive forces, are well-established triggers for sustainability-oriented innovation within the TOE literature (Sharma et al., 2020; Suranjit Bag & Shivam Gupta, 2019). In logistics, regulatory requirements for emissions reporting and rising market expectations for transparency incentivise firms to adopt green practices (Miao, 2022). Hence:

H3: There is a positive relationship between the digital environment and the adoption of green logistics practices.

H4 Development (GLPs → Sustainability Performance): Green logistics practices are widely associated with enhanced environmental, economic, and social performance. Empirical evidence shows that GLPs reduce emissions and waste (Wen et al., 2023), improve resource efficiency (Novarlić & Đurić, 2024), and strengthen corporate reputation and stakeholder trust (Youngswaing et al., 2024). Accordingly, it is hypothesised that:

H4: Green logistics practices positively impact sustainability performance across environmental, economic, and social dimensions.

5. Discussion

This conceptual study offers a theoretical explanation of how the digital dimensions of the TOE framework interact with organisational dynamic capabilities to facilitate the adoption of GLPs and enhance sustainability performance in Oman. Rather than presenting empirical findings, this discussion interprets the proposed framework through existing theories and prior literature, elucidating the mechanisms by which digital readiness can drive sustainability-oriented transformation in logistics. From a conceptual standpoint, the digital technology dimension of the TOE framework is a critical enabler of green logistics. It provides firms with tools that enhance operational visibility, optimise resources, and support data-driven environmental monitoring. The literature consistently emphasises that digital tools including IoT, AI, and big data analytics offer the informational and operational foundations

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necessary for effective GLP implementation. By integrating these technologies, organisations can redesign logistics processes to reduce emissions, minimise waste, and comply with environmental regulations. In this model, digital technology functions as a catalyst that expands the technical capacity required for deploying GLPs.

The organisational dimension of the TOE framework underscores the internal readiness needed to leverage digital tools for sustainability purposes. Leadership support, innovation-oriented cultures, and workforce digital competencies are consistently identified as essential drivers of green practice adoption. Dynamic Capabilities Theory reinforces this perspective by highlighting that organisations must not only possess resources but also the ability to sense emerging opportunities, seize them strategically, and reconfigure internal processes. Within the proposed framework, GLPs represent the operational manifestation of these dynamic capabilities. Firms that cultivate digital skills, invest in innovation, and promote adaptive organisational structures are more likely to embed GLPs into logistics systems, thereby aligning internal transformation with sustainability objectives.

The digital environment dimension further strengthens the framework by recognising regulatory, competitive, and societal pressures that shape organisational behaviour. External expectations including tightening environmental regulations, consumer demand for transparency, and competitive pressures create a compelling context for pursuing green logistics initiatives. In Oman, Vision 2040 reinforces this dynamic by positioning digital transformation and environmental stewardship as national priorities. The framework thus conceptualises the external environment not merely as a backdrop but as an active driver that shapes organisational incentives to adopt GLPs.

A central conceptual contribution of this framework is the positioning of GLPs as a mediating mechanism that translates digital readiness into sustainability outcomes. Across the literature, GLPs have been linked to reductions in emissions, improvements in resource efficiency, and social benefits, including enhanced corporate reputation and stakeholder trust. By treating GLPs as the bridge between digital enablers and sustainability performance, the framework explains how digital transformation can generate tangible environmental, economic, and social benefits. This insight is particularly relevant in emerging markets, where digital maturity and sustainability practices often develop at differing rates.

The integration of TOE and DCT adds further conceptual value by linking static contextual determinants with dynamic organisational processes. TOE explains why organisations adopt innovations, while DCT describes how they build adaptive capabilities to sustain those innovations. In the logistics sector particularly in emerging economies such as Oman, these dual perspective captures both the structural conditions and the adaptive processes necessary to support sustainability transitions. Consequently, the proposed model provides a more holistic explanation than either framework could offer independently.

The discussion also highlights important implications for policy and practice. Conceptually, the framework suggests that policymakers should strengthen environmental regulations, promote digital infrastructure, and create supportive ecosystems to encourage GLP adoption. For practitioners, the model underscores the need to invest in digital

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competencies, nurture innovation-driven cultures, and align logistics strategies with sustainability objectives. These implications stem from theoretical synthesis rather than empirical claims, reflecting the conceptual nature of the study.

Finally, the conceptual framework offers several avenues for future research. Scholars may empirically test the proposed relationships, investigate additional mediators such as supply chain transparency or eco-innovation, or examine moderating factors including organisational size and digital maturity. Future studies in Oman and the wider Gulf region could validate, refine, or extend the model, providing deeper insight into how digital transformation can support sustainability transitions in emerging markets. As global digitalisation accelerates, understanding these mechanisms remains essential for both researchers and practitioners.

6. Conclusion

This conceptual study examined how digital transformation, interpreted through the TOE framework and complemented by DCT, can theoretically enable the adoption of GLPs and facilitate sustainability-oriented transitions within Oman's logistics sector. Rather than presenting empirical findings, the study synthesises existing literature to propose a model that explains how digital capabilities, organisational readiness, and environmental pressures interact to drive sustainability-focused logistics innovation. The framework emphasises that digital technologies, organisational structures, and external institutional forces collectively create the conditions for GLPs to emerge and contribute to environmental, economic, and social performance.

The study offers both theoretical and practical contributions. Theoretically, it advances understanding of digital transformation in logistics by integrating TOE and DCT, demonstrating how static contextual determinants and dynamic organisational capabilities complement one another in enabling GLP adoption. This integration provides a holistic conceptual foundation particularly applicable to emerging economies, where digital maturity and sustainability practices are still evolving. Practically, the framework offers policymakers and logistics stakeholders a structured perspective on how investments in digital infrastructure, institutional reform, and capability development may support sustainability ambitions in line with Oman Vision 2040. The findings highlight that digital readiness and sustainability strategies must be developed in tandem to achieve meaningful progress.

Despite these contributions, the study acknowledges certain limitations. The framework has not yet been empirically validated within the Omani context, leaving opportunities for future research to test, refine, or extend its assumptions. Moreover, factors such as consumer expectations, supply chain collaboration, and eco-innovation dynamics fall outside the current scope but could provide additional explanatory value. Future studies could employ empirical, comparative, or longitudinal methods to assess how the relationships proposed in this model manifest across different industries, regions, or levels of digital maturity.

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Overall, the study underscores that digital transformation when supported by organisational capabilities and favourable institutional conditions constitutes a powerful enabler of green logistics development. By articulating these relationships conceptually, this research lays a foundation for scholars and practitioners seeking to advance sustainability transitions within Oman's logistics sector and the wider Gulf region.

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