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Implementation of E-logistics in Supply Chain Operations

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Abstract
The rapid growth of e-commerce has intensified pressure on supply chains to improve speed, reliability, and customer responsiveness, particularly in emerging economies such as Pakistan. While prior research has examined digital transformation and logistics technologies, limited empirical evidence explains *how* smart warehousing and last-mile delivery translate into performance outcomes. This study addresses this gap by investigating the mediating role of operational efficiency and the moderating influence of dynamic capabilities in the relationship between digital logistics practices and e-commerce supply chain performance. A quantitative, cross-sectional research design was employed. Data were collected through a structured questionnaire from e-commerce firms and logistics service providers operating in Pakistan. The proposed model was tested using Partial Least Squares Structural Equation Modeling (PLS-SEM) integrated with machine-learning- enhanced analysis to assess reliability, validity, mediation, moderation, and predictive power. The results show that digital transformation ($\beta = 0.312$, $p < 0.001$), technology integration ($\beta = 0.326$, $p < 0.001$), and dynamic capabilities ($\beta = 0.247$, $p < 0.001$) significantly improve operational efficiency, while organizational resources exhibit a non-significant effect. Operational efficiency strongly influences organizational performance ($\beta = 0.825$), customer satisfaction ($\beta = 0.826$), and competitive advantage ($\beta = 0.774$), explaining 76.2% of its variance. This study provides robust empirical evidence that operational efficiency is the primary mechanism through which digital logistics practices enhance e-commerce performance. By integrating mediation and moderation within a machine-learning- enhanced SEM framework in a developing-country context, the study advances digital supply chain theory and offers actionable insights for managers and policymakers.

Keywords: Smart Warehousing; Last-Mile Delivery; Operational Efficiency; Dynamic Capabilities; E-commerce Supply Chain; PLS-SEM; Pakistan

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INTRODUCTION

Digitalization and E-commerce Supply Chains

The rapid expansion of e-commerce has fundamentally transformed supply chain structures, compelling firms to adopt digitally enabled logistics systems to remain competitive. Recent studies highlight that e-commerce supply chains are increasingly characterized by high demand volatility, shortened delivery cycles, and heightened customer expectations, which place substantial pressure on warehousing and distribution operations (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). In emerging economies, these challenges are further intensified by infrastructural inefficiencies and fragmented logistics networks. Earlier research emphasized that logistics performance plays a strategic role in sustaining competitiveness in digitally driven markets (Tang & Veelenturf, 2019; Katsaliaki et al., 2022). Consequently, digital transformation in logistics has evolved from a supportive function into a critical determinant of e-commerce supply chain performance.

Smart Warehousing as a Strategic Enabler

Smart warehousing has emerged as a pivotal mechanism for enhancing operational efficiency through the deployment of artificial intelligence, machine learning, robotics, and digital twin technologies. Contemporary research demonstrates that AI-driven warehouse automation significantly improves inventory accuracy, demand forecasting, and order fulfillment speed, thereby reducing operational bottlenecks (Sodiya et al., 2024; Eyo-Udo, 2024; Rath et al., 2024). These advancements extend earlier findings which argued that technology-enabled warehousing enhances supply chain responsiveness and reliability (Van Geest et al., 2021; Mashalah et al., 2022). In the context of e-commerce, smart warehousing facilitates seamless integration between upstream inventory management and downstream delivery operations, reinforcing its strategic importance within digitally enabled supply chains.

Importance of Last-Mile Delivery in E-commerce

Last-mile delivery represents the most customer-visible and cost-intensive segment of the e-commerce supply chain, directly influencing customer satisfaction and service quality. Recent empirical evidence indicates that innovations such as autonomous delivery systems, real-time route optimization, and IoT-enabled tracking significantly enhance delivery reliability and customer experience (Engesser et al., 2023; Nodirovna & Sharif ogli, 2024; Ivanov et al., 2023). Earlier operational research studies similarly emphasized that inefficiencies in last-mile logistics contribute disproportionately to overall supply chain costs and service failures (Boysen et al., 2021; Tang & Veelenturf, 2019). For developing economies, optimizing last-mile delivery is particularly critical due to urban congestion, addressability issues, and limited logistics infrastructure.

Technology Integration and Organizational Readiness

The effectiveness of smart warehousing and last-mile delivery is contingent upon the degree of technology integration and organizational readiness. Recent studies grounded in the Technology–Organization–Environment (TOE) framework suggest that IoT sensors and

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blockchain systems enhance supply chain transparency, coordination, and trust among logistics partners (Hoang, 2024; Nguyen et al., 2022; Eyo-Udo, 2024). Earlier research also established that digital transformation initiatives fail when organizational resources and human capital are insufficient to support technological adoption (Mian et al., 2020; Haber & Carmeli, 2023). Thus, technological infrastructure and skilled human capital remain indispensable resources for realizing the operational benefits of digital logistics systems.

Mediating Role of Operational Efficiency and Dynamic Capabilities

While digital technologies provide substantial potential benefits, their impact on performance outcomes is rarely direct. Recent literature increasingly recognizes operational efficiency as a key mediating mechanism through which digital transformation influences organizational performance and customer satisfaction (Ivanov et al., 2023; Mashalah et al., 2022; Zakaria et al., 2024). Furthermore, dynamic capabilities defined as an organization's ability to sense, seize, and reconfigure resources have been shown to strengthen the effectiveness of digital initiatives under uncertain environments (Haber & Carmeli, 2023; Katsaliaki et al., 2022). Earlier theoretical work emphasized that firms with superior adaptive capabilities are better positioned to convert technological investments into sustained competitive advantage (Tang & Veelenturf, 2019; Nguyen et al., 2022).

Introduction to the Industry

Global E-commere and Logistics Industry Landscape

The global e-commerce industry has experienced unprecedented growth over the past decade, fundamentally reshaping the logistics and supply chain sector. Recent industry analyses indicate that the expansion of online retail has intensified the demand for fast, reliable, and cost-efficient logistics services, placing warehousing and last-mile delivery at the core of competitive differentiation (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024; Nodirovna & Sharif ogli, 2024). The logistics industry is increasingly required to manage high order volumes, frequent returns, and same-day or next-day delivery expectations. Contemporary research highlights that digital technologies have become essential enablers for sustaining performance in this dynamic environment, transforming logistics from a support function into a strategic industry driver (Eyo-Udo, 2024).

Evolution of Smart Warehousing in the Logistics Industry

The warehousing segment of the logistics industry has undergone significant digital transformation, giving rise to smart warehousing systems powered by artificial intelligence, machine learning, robotics, and digital twins. Recent studies demonstrate that AI-driven automation improves inventory visibility, reduces picking errors, and enhances space utilization, leading to measurable efficiency gains (Sodiya et al., 2024; Eyo-Udo, 2024; Rath et al., 2024;

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Last-Mile Delivery as a Critical Industry Challenge

Last-mile delivery has become the most complex and cost-intensive component of the e-commerce logistics industry, often accounting for a substantial share of total delivery costs. Recent empirical evidence highlights that customer satisfaction in e-commerce is increasingly shaped by delivery speed, reliability, and transparency, making last-mile performance a decisive competitive factor (Engesser et al., 2023; Nodirovna & Sharif ogli, 2024; Ivanov et al., 2023; Katsaliaki et al., 2022). Industry studies emphasize the growing adoption of IoT-enabled tracking, route optimization algorithms, and data-driven delivery planning to address urban congestion, delivery failures, and rising operational costs (Eyo- Udo, 2024). These developments underscore the strategic importance of last-mile logistics within the broader e-commerce industry.

Digital Integration and Industry Transformation

The integration of digital technologies across warehousing and delivery functions has accelerated structural transformation within the logistics industry. Recent research indicates that technologies such as IoT sensors and blockchain systems enhance coordination, traceability, and trust among supply chain actors, enabling more resilient and transparent logistics networks (Hoang, 2024; Ivanov et al., 2023; Zakaria et al., 2024; Engesser et al., 2023). Industry-level analyses further reveal that firms capable of integrating digital tools across operational boundaries outperform competitors in terms of service quality and responsiveness (Eyo-Udo, 2024). This shift toward digitally integrated logistics ecosystems reflects a broader industry transition from fragmented operations to interconnected, data-driven supply chains.

E-commerce and Logistics Industry in Pakistan

In Pakistan, the e-commerce and logistics industry is at a critical developmental stage, characterized by rapid market growth alongside persistent operational challenges. Recent studies note that increasing internet penetration and mobile commerce adoption have fueled demand for efficient logistics services, yet infrastructural constraints, limited automation, and skill shortages continue to hinder industry performance (Zakaria et al., 2024; Ivanov et al., 2023; Nodirovna & Sharif ogli, 2024; Engesser et al., 2023). Industry-focused research emphasizes that smart warehousing and optimized last-mile delivery can play a transformative role in addressing these challenges by improving operational efficiency and customer satisfaction (Eyo-Udo, 2024). Consequently, the Pakistani e-commerce logistics industry provides a compelling context for examining how digital logistics innovations influence supply chain performance in emerging markets.

Objectives of the Study

- To examine the impact of smart warehousing and last-mile delivery on e-commerce supply chain performance in Pakistan.

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- To analyze the mediating role of operational efficiency in the relationship between smart warehousing, last-mile delivery, and e-commerce supply chain performance.
- To investigate the moderating effect of dynamic capabilities on the relationship between smart warehousing, last-mile delivery, and operational efficiency.
- To provide data-driven insights for e-commerce firms and logistics service providers in Pakistan to enhance supply chain performance through digital logistics innovations.

LITERATURE REVIEW INTRODUCTION TO CONSTRUCTS

Digital Transformation in E-commerce Supply Chains

Digital transformation has become a central theme in contemporary supply chain research, particularly within e-commerce environments characterized by high uncertainty and rapid demand fluctuations. Recent studies emphasize that technologies such as artificial intelligence, machine learning, and digital twin systems enhance predictive accuracy, decision-making speed, and process synchronization across logistics networks (Ivanov et al., 2023; Eyo-Udo, 2024; Zakaria et al., 2024). These technologies enable firms to shift from reactive to proactive supply chain management by simulating scenarios and optimizing inventory and fulfillment processes in real time. Earlier literature similarly highlighted that digital transformation improves supply chain visibility and responsiveness, thereby strengthening operational performance (Mashalah et al., 2022; Katsaliaki et al., 2022). Collectively, current knowledge suggests that digital transformation is a foundational capability for achieving efficiency and resilience in e-commerce supply chains.

Technology Integration through IoT and Blockchain Systems

Technology integration refers to the seamless alignment of digital tools across organizational and inter-organizational boundaries, particularly through IoT sensors and blockchain systems. Recent empirical research demonstrates that IoT-enabled real-time data collection improves tracking accuracy, delivery coordination, and process transparency in logistics operations (Engesser et al., 2023; Eyo-Udo, 2024; Ivanov et al., 2023). Blockchain technologies further enhance trust, traceability, and data integrity among supply chain partners, which is especially critical in last-mile delivery contexts. Prior studies established that integrated digital infrastructures reduce transaction costs and information asymmetry, leading to superior supply chain performance (Nguyen et al., 2022; Mashalah et al., 2022). Thus, technology integration is widely recognized as a key driver of operational reliability and customer-oriented logistics outcomes.

Organizational Resources as Enablers of Digital Logistics

Organizational resources, including technical infrastructure and human capital, play a pivotal role in determining the success of digital logistics initiatives. Recent research indicates that firms with advanced IT infrastructure and digitally skilled employees are better positioned

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to exploit smart warehousing and delivery technologies effectively (Zakaria et al., 2024; Haber & Carmeli, 2023; Eyo-Udo, 2024). These resources enable organizations to absorb technological complexity and sustain continuous process improvement. Earlier studies grounded in the resource-based view argued that technological assets alone do not generate competitive advantage unless complemented by human expertise and organizational support mechanisms (Mian et al., 2020; Nguyen et al., 2022). Accordingly, organizational resources are widely regarded as critical antecedents to operational efficiency in digitally enabled supply chains.

Operational Efficiency as a Mediating Mechanism

Operational efficiency represents a core mediating construct through which digital transformation and technology integration translate into performance outcomes. Contemporary studies reveal that improvements in inventory accuracy, order processing speed, and cost control serve as the primary channels linking digital investments to organizational performance and customer satisfaction (Ivanov et al., 2023; Mashalah et al., 2022; Zakaria et al., 2024). In e-commerce logistics, operational efficiency reduces delivery errors and lead times, thereby enhancing service reliability. Earlier research also emphasized that efficiency-based mediation explains why some digital initiatives succeed while others fail to produce tangible benefits (Tang & Veelenturf, 2019; Katsaliaki et al., 2022). This growing body of literature confirms the centrality of operational efficiency in digital supply chain models.

Dynamic Capabilities as a Moderating Construct

Dynamic capabilities describe an organization's ability to sense environmental changes, seize technological opportunities, and reconfigure resources accordingly. Recent studies demonstrate that dynamic capabilities significantly strengthen the effectiveness of digital transformation by enabling firms to adapt logistics processes under uncertainty (Haber & Carmeli, 2023; Ivanov et al., 2023; Zakaria et al., 2024). Firms with strong dynamic capabilities are more likely to extract value from AI-driven warehousing and data-intensive delivery systems. Earlier theoretical work similarly highlighted that adaptive capabilities moderate the relationship between technological adoption and performance outcomes, particularly in volatile markets (Katsaliaki et al., 2022; Nguyen et al., 2022). Thus, dynamic capabilities serve as a critical boundary condition in digital supply chain performance research.

Performance Outcomes in E-commerce Supply Chains

E-commerce supply chain performance is commonly evaluated through organizational performance, customer satisfaction, and competitive advantage. Recent empirical evidence suggests that digitally efficient logistics systems enhance revenue growth, market share, service quality, and response time, while also supporting innovation capacity and long-term competitiveness (Engesser et al., 2023; Ivanov et al., 2023; Nodirovna & Sharif ogli, 2024). These findings reinforce earlier studies which argued that superior logistics performance is a key determinant of sustainable competitive advantage in e-commerce markets (Tang & Veelenturf, 2019; Mashalah et al., 2022). Current knowledge therefore supports an integrated

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performance perspective that captures both short-term operational outcomes and long-term strategic benefits.

Theoretical Framework

Theoretical Foundations of Digital Supply Chains

The increasing complexity of e-commerce supply chains has necessitated the adoption of robust theoretical frameworks capable of explaining the role of digital technologies in logistics performance. Recent research emphasizes that digital supply chain theory provides a holistic lens for understanding how data-driven technologies integrate warehousing, transportation, and customer-facing logistics into unified systems (Ivanov et al., 2023; Zakaria et al., 2024; Engesser et al., 2023). This perspective builds upon earlier conceptualizations that highlighted the transformation of traditional supply chains into digitally interconnected networks capable of real-time responsiveness (Mashalah et al., 2022; Katsaliaki et al., 2022). Grounded in this theoretical evolution, the present study adopts digital supply chain theory to explain how smart warehousing and last-mile delivery jointly shape e-commerce supply chain performance.

SCOR Model and Operational Performance

The Supply Chain Operations Reference (SCOR) model remains one of the most widely adopted frameworks for evaluating supply chain performance through standardized process dimensions. Recent studies extend the SCOR model by embedding digital technologies such as artificial intelligence and digital twin systems to enhance planning, sourcing, delivery, and return processes (Ivanov et al., 2023; Eyo-Udo, 2024; Zakaria et al., 2024). These advancements reinforce earlier findings that SCOR-based performance metrics enable systematic assessment of operational efficiency and service reliability (Tang & Veelenturf, 2019; Van Geest et al., 2021). In this study, the SCOR model provides a process-oriented foundation for examining operational efficiency as a mediating mechanism between digital logistics practices and performance outcomes.

Resource-Based View and Organizational Resources

The Resource-Based View (RBV) posits that sustainable competitive advantage arises from valuable, rare, inimitable, and non-substitutable organizational resources. Recent empirical work demonstrates that digital infrastructure and skilled human capital are strategic resources that significantly enhance firms' ability to leverage smart logistics technologies (Haber & Carmeli, 2023; Zakaria et al., 2024; Eyo-Udo, 2024). These findings extend earlier RBV- based studies which argued that technological investments yield superior outcomes only when supported by organizational capabilities and knowledge assets (Mian et al., 2020; Nguyen et al., 2022). Consistent with RBV, the present research incorporates organizational resources as a key antecedent influencing operational efficiency in e-commerce supply chains.

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Dynamic Capabilities Theory as a Moderating Lens

Dynamic capabilities theory explains how organizations adapt to rapidly changing environments by sensing opportunities, seizing technological innovations, and reconfiguring internal resources. Recent studies indicate that dynamic capabilities strengthen the effectiveness of digital transformation initiatives, particularly in volatile and technology-intensive contexts such as e-commerce logistics (Ivanov et al., 2023; Haber & Carmeli, 2023; Zakaria et al., 2024). Earlier theoretical contributions similarly emphasized that dynamic capabilities moderate the relationship between technological adoption and performance outcomes by enabling continuous adaptation (Katsaliaki et al., 2022; Nguyen et al., 2022). Drawing on this theory, the present study positions dynamic capabilities as a moderating variable that influences how smart warehousing and last-mile delivery translate into operational efficiency.

Technology–Organization–Environment (TOE) Framework

The Technology–Organization–Environment (TOE) framework offers a comprehensive approach for analyzing technology adoption by considering technological readiness, organizational context, and environmental pressures. Recent research applies the TOE framework to digital logistics, demonstrating that IoT sensors, blockchain systems, and AI tools are more effective when supported by organizational readiness and external ecosystem alignment (Hoang, 2024; Zakaria et al., 2024; Ivanov et al., 2023). Earlier studies confirmed that TOE-based models provide strong explanatory power for understanding digital transformation outcomes in supply chains (Nguyen et al., 2022; Mashalah et al., 2022). In this research, the TOE framework complements RBV and dynamic capabilities theory by explaining the contextual conditions under which digital logistics technologies enhance performance.

Purpose and Main Objective of the Study

Building on these theoretical and model-based foundations, the present study integrates digital supply chain theory, the SCOR model, the Resource-Based View, dynamic capabilities theory, and the TOE framework to develop a comprehensive explanation of e- commerce logistics performance. Recent literature highlights the need for integrative models that capture both technological mechanisms and organizational capabilities, particularly in emerging economies (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). Earlier research also called for context-specific empirical investigations to validate these theories beyond developed markets (Mashalah et al., 2022; Katsaliaki et al., 2022). Accordingly, the main objective of this study is to examine how smart warehousing and last-mile delivery influence e-commerce supply chain performance in Pakistan through the mediating role of operational efficiency and the moderating effect of dynamic capabilities, using machine learning–enhanced structural equation modeling to advance both theory and practice.

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Supporting and Negating Perspectives

Digital Transformation and Supply Chain Performance

A substantial body of recent literature supports the view that digital transformation positively influences supply chain performance by enhancing data-driven decision-making, process visibility, and coordination across logistics functions. Empirical studies demonstrate that AI, machine learning, and digital twin technologies significantly improve forecasting accuracy and operational responsiveness in e-commerce supply chains (Ivanov et al., 2023; Eyo-Udo, 2024; Zakaria et al., 2024). These findings are consistent with earlier research suggesting that digitalization enables firms to achieve higher efficiency and resilience under uncertainty (Mashalah et al., 2022; Katsaliaki et al., 2022). However, a contrasting stream of literature argues that digital transformation does not automatically lead to performance gains, particularly when organizational readiness and process alignment are weak. Prior studies caution that excessive reliance on digital tools without adequate integration can create complexity, increase costs, and reduce flexibility (Tang & Veelenturf, 2019; Nguyen et al., 2022). This divergence highlights the need to examine mediating mechanisms that explain when and how digital transformation delivers value.

Technology Integration through IoT and Blockchain

Supporting perspectives emphasize that technology integration via IoT sensors and blockchain systems enhances supply chain transparency, traceability, and coordination, particularly in last-mile delivery contexts. Recent studies report that real-time data sharing and immutable transaction records improve delivery reliability and customer trust in e- commerce logistics networks (Engesser et al., 2023; Ivanov et al., 2023; Hoang, 2024). Earlier research similarly found that integrated digital infrastructures reduce information asymmetry and transaction costs, thereby strengthening supply chain performance (Mashalah et al., 2022; Nguyen et al., 2022). In contrast, negating views suggest that blockchain and IoT adoption may generate limited benefits in environments with weak digital ecosystems or low data maturity. Some scholars argue that high implementation costs, interoperability issues, and limited scalability constrain the effectiveness of these technologies in emerging markets (Katsaliaki et al., 2022; Van Geest et al., 2021). These mixed findings underscore the importance of contextual and organizational factors in technology integration outcomes.

Organizational Resources as Performance Enablers

From a supportive standpoint, organizational resources particularly technical infrastructure and human capital are widely recognized as critical enablers of digital logistics success. Recent empirical evidence indicates that firms with robust IT systems and digitally skilled employees are better positioned to exploit smart warehousing and delivery technologies, leading to superior operational efficiency (Zakaria et al., 2024; Haber & Carmeli, 2023; Eyo- Udo, 2024). Earlier studies grounded in the Resource-Based View also emphasized that complementary organizational resources are essential for translating technological investments into

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competitive advantage (Mian et al., 2020; Nguyen et al., 2022). Conversely, some researchers argue that resource accumulation alone does not guarantee improved performance, as misaligned incentives, resistance to change, and ineffective governance structures may neutralize potential gains (Tang & Katsaliaki et al., 2022). This debate highlights the need to examine how resources interact with operational processes.

Operational Efficiency as a Mediating Perspective

A dominant supporting view in recent literature positions operational efficiency as the primary mechanism through which digital transformation and technology integration affect performance outcomes. Studies show that improvements in inventory accuracy, processing speed, and cost control mediate the relationship between digital logistics initiatives and organizational performance (Ivanov et al., 2023; Mashalah et al., 2022; Zakaria et al., 2024). Earlier research also demonstrated that efficiency-based mediation explains variations in performance across firms adopting similar technologies (Tang & Veelenturf, 2019; Katsaliaki et al., 2022). However, negating perspectives argue that excessive focus on efficiency may undermine flexibility and innovation, particularly in highly volatile e-commerce environments. Some scholars suggest that efficiency gains can lead to rigid processes that limit adaptive capacity under demand shocks (Nguyen et al., 2022; Van Geest et al., 2021). These opposing views justify examining efficiency as a mediating, rather than direct, performance driver.

Dynamic Capabilities as a Moderating Lens

Supporting views rooted in dynamic capabilities theory contend that firms with strong sensing, seizing, and reconfiguring capabilities are more likely to benefit from digital logistics investments. Recent studies demonstrate that dynamic capabilities strengthen the impact of digital transformation on operational outcomes by enabling continuous adaptation and learning (Ivanov et al., 2023; Haber & Carmeli, 2023; Zakaria et al., 2024). Earlier theoretical work similarly emphasized that adaptive capabilities moderate the relationship between technology adoption and performance in uncertain environments (Katsaliaki et al., 2022; Nguyen et al., 2022). In contrast, some scholars argue that dynamic capabilities may have diminishing returns in resource-constrained contexts, where firms lack the scale or managerial capacity to continuously reconfigure operations (Tang & Veelenturf, 2019; Mashalah et al., 2022). This debate supports the inclusion of dynamic capabilities as a moderating variable rather than a direct predictor.

Integrated Multi-Variable and Theory-Based Perspectives

An emerging stream of literature advocates for integrated, multi-variable models that combine technological, organizational, and operational perspectives to explain supply chain performance. Recent studies emphasize that single-theory or single-variable approaches fail to capture the complexity of digital logistics systems, particularly in emerging economies (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). Earlier research also called for combining theories such as RBV, dynamic capabilities, and digital supply chain theory to better

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explain heterogeneous outcomes across firms (Mashalah et al., 2022; Katsaliaki et al., 2022). Nevertheless, some scholars caution that overly complex models may reduce interpretability and practical applicability, especially for managers seeking actionable insights (Tang & Veelenturf, 2019; Nguyen et al., 2022). These contrasting viewpoints highlight the importance of balanced, theory-driven models that integrate multiple constructs while maintaining analytical clarity, as adopted in the present study.

Mediation and Moderation Perspective

Digital Transformation and Operational Efficiency

Recent literature strongly supports the view that digital transformation enhances operational efficiency by improving forecasting accuracy, real-time visibility, and process automation in e-commerce supply chains. Studies show that AI, machine learning, and digital twin technologies enable firms to optimize warehouse operations and synchronize logistics activities, thereby reducing errors and cycle times (Ivanov et al., 2023; Zakaria et al., 2024). Earlier empirical evidence similarly demonstrated that digitally enabled planning and execution processes lead to higher efficiency and responsiveness (Mashalah et al., 2022; Katsaliaki et al., 2022). From a mediation perspective, these studies suggest that operational efficiency is the primary mechanism through which digital transformation translates into performance gains.

In contrast, some scholars argue that digital transformation does not consistently improve operational efficiency, particularly when digital tools are poorly aligned with existing processes. Recent findings indicate that excessive technological complexity and weak integration can increase coordination costs and disrupt operational routines (Haber & Carmeli, 2023; Engesser et al., 2023). Earlier research also cautioned that digital investments may fail to generate efficiency gains in the absence of process redesign and capability alignment (Tang & Veelenturf, 2019; Nguyen et al., 2022). These opposing views reinforce the need to treat operational efficiency as a mediating variable rather than assuming a direct digital transformation–performance relationship.

Technology Integration Operational Efficiency

Supportive perspectives emphasize that technology integration through IoT sensors and blockchain systems significantly improves operational efficiency by enhancing data accuracy, traceability, and coordination across logistics networks. Recent studies report that real-time tracking and transparent data sharing reduce delivery delays and inventory mismatches in e-commerce supply chains (Ivanov et al., 2023; Hoang, 2024). Earlier research also found that integrated digital infrastructures lower transaction costs and improve process reliability, thereby strengthening efficiency outcomes (Mashalah et al., 2022; Nguyen et al., 2022). These findings support the mediating role of operational efficiency in linking technology integration to performance outcomes.

Conversely, some researchers argue that technology integration may yield limited efficiency benefits in contexts characterized by low digital maturity and infrastructural constraints.

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Recent evidence suggests that blockchain and IoT adoption can introduce interoperability challenges and high implementation costs, which may offset efficiency gains (Engesser et al., 2023; Zakaria et al., 2024). Earlier studies similarly highlighted that fragmented logistics ecosystems constrain the effectiveness of integrated technologies (Katsaliaki et al., 2022; Van Geest et al., 2021). These mixed findings justify examining efficiency as a conditional mediator rather than a guaranteed outcome of technology integration.

Organizational Resources Operational Efficiency

The resource-based view provides strong support for the argument that organizational resources positively influence operational efficiency in digital logistics environments. Recent studies demonstrate that robust technical infrastructure and skilled human capital enable firms to effectively deploy smart warehousing and delivery technologies (Zakaria et al., 2024; Eyo-Udo, 2024). Earlier research also confirmed that complementary organizational resources are essential for converting technological investments into efficient operational processes (Mian et al., 2020; Nguyen et al., 2022). These findings support the mediating role of operational efficiency in translating resources into performance outcomes.

However, opposing views suggest that the mere availability of organizational resources does not automatically result in efficiency improvements. Recent studies indicate that misaligned organizational structures and resistance to change can neutralize the potential benefits of technical and human resources (Haber & Carmeli, 2023; Ivanov et al., 2023). Earlier literature similarly argued that resource abundance may lead to inefficiencies if not strategically managed (Tang & Veelenturf, 2019; Katsaliaki et al., 2022). This debate underscores the importance of operational efficiency as a mediating process rather than a direct outcome of resource availability.

Operational Efficiency Supply Chain Performance

A strong consensus in recent literature supports the positive relationship between operational efficiency and e-commerce supply chain performance. Studies show that efficiency improvements reduce logistics costs, enhance service quality, and improve delivery reliability, leading to higher organizational performance and customer satisfaction (Ivanov et al., 2023; Engesser et al., 2023). Earlier empirical work also demonstrated that efficient operations serve as a critical pathway through which logistics capabilities generate competitive advantage (Mashalah et al., 2022; Katsaliaki et al., 2022). These findings validate operational efficiency as a central mediator linking digital logistics practices to performance outcomes.

In contrast, some scholars argue that excessive emphasis on efficiency may undermine flexibility and innovation in highly dynamic e-commerce markets. Recent studies suggest that overly optimized processes can reduce adaptive capacity and responsiveness to demand volatility (Haber & Carmeli, 2023; Zakaria et al., 2024). Earlier research also cautioned that efficiency-driven strategies may compromise long-term competitiveness if they limit strategic experimentation (Tang & Veelenturf, 2019; Nguyen et al., 2022). These perspectives highlight the need to balance efficiency with adaptability in mediated performance models.

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Dynamic Capabilities as a Moderator

Dynamic capabilities theory strongly supports the moderating role of adaptive capabilities in strengthening the relationship between digital logistics practices and operational efficiency. Recent studies demonstrate that firms with strong sensing, seizing, and reconfiguring capabilities are better able to exploit digital technologies under uncertainty (Ivanov et al., 2023; Haber & Carmeli, 2023). Earlier theoretical and empirical work also confirmed that dynamic capabilities amplify the performance effects of technological adoption (Katsaliaki et al., 2022; Nguyen et al., 2022). These findings justify the inclusion of dynamic capabilities as a moderator in digital supply chain models.

Nevertheless, some scholars question the universal effectiveness of dynamic capabilities, particularly in resource-constrained environments. Recent evidence suggests that developing and maintaining dynamic capabilities may be costly and may not yield proportional benefits for smaller or less mature firms (Engesser et al., 2023; Zakaria et al., 2024). Earlier studies similarly noted diminishing returns to adaptive capabilities in stable or low-competition contexts (Tang & Veelenturf, 2019; Mashalah et al., 2022). These mixed findings reinforce the need to empirically test moderation effects rather than assume their presence.

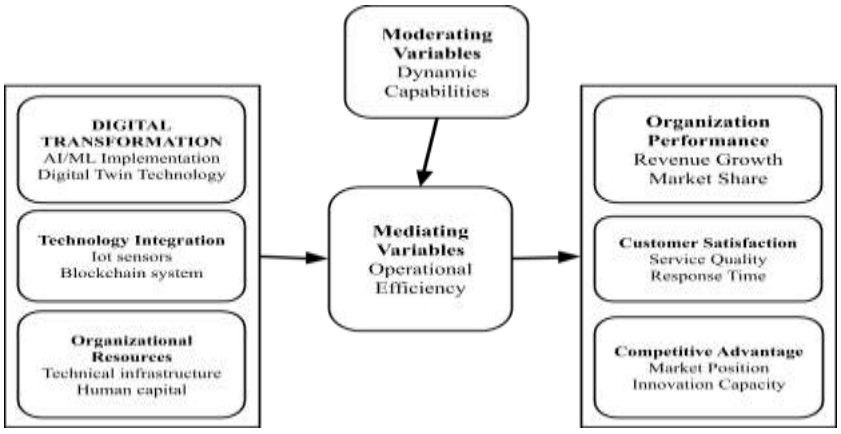

Figure 1 Conceptual Framework

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METHODOLOGY

Overall Design Configuration

The present study employs a theory-driven, explanatory research design tailored to examine the structural relationships among smart warehousing, last-mile delivery, operational efficiency, dynamic capabilities, and e-commerce supply chain performance. Recent methodological studies emphasize that customized designs grounded in established theory are essential for testing complex mediation and moderation models in supply chain research (Hair et al., 2023; Henseler et al., 2023; Ivanov et al., 2023). Accordingly, the proposed design integrates multiple independent variables with a mediating mechanism and a moderating condition to capture both process effects and boundary conditions. Earlier research also highlighted that customized explanatory designs enhance internal validity when constructs and paths are explicitly derived from theory (Saunders et al., 2019; Creswell, 2014). Thus, the study's design is specifically structured to address the research questions and theoretical gaps identified in the literature.

Unit of Analysis and Contextualization

The unit of analysis in this study is the organizational level, focusing on e-commerce firms and logistics service providers operating within Pakistan. Recent research underscores the importance of firm-level analysis when examining digital logistics adoption and supply chain performance, as strategic decisions regarding warehousing and last-mile delivery are typically made at the organizational level (Zakaria et al., 2024; Engesser et al., 2023; Ivanov et al., 2023). By contextualizing the design within Pakistan, the study captures the unique infrastructural, technological, and capability-related constraints of an emerging economy. Earlier studies also recommended context-specific organizational designs to enhance the external validity and relevance of supply chain research in developing markets (Mashalah et al., 2022; Katsaliaki et al., 2022). This contextualized design ensures that findings are both theoretically meaningful and practically applicable.

Measurement Structure and Analytical Logic

The research design incorporates latent construct measurement using multi-item scales to capture the complexity of digital logistics and performance outcomes. Recent methodological literature supports the use of latent variable modeling for measuring abstract constructs such as operational efficiency and dynamic capabilities, as it reduces measurement error and improves construct validity (Hair et al., 2023; Henseler et al., 2023; Zakaria et al., 2024). The design specifies reflective measurement models for all constructs, enabling consistent estimation within the PLS-SEM framework. Earlier methodological studies also emphasized that reflective measurement is appropriate when indicators represent manifestations of an underlying construct (Hair et al., 2021; Henseler et al., 2019). This measurement structure aligns with the study's analytical objectives and supports robust hypothesis testing.

Integration of SEM and Machine Learning Techniques

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A defining feature of the study's specific design is the integration of PLS-SEM with machine learning techniques to enhance both explanatory and predictive power. Recent studies highlight that hybrid SEM–ML designs enable researchers to validate theoretical relationships while simultaneously assessing variable importance and non-linear effects (Hair et al., 2023; Ivanov et al., 2023; Zakaria et al., 2024). In this study, PLS-SEM is used to test hypothesized paths, mediation, and moderation effects, while machine learning models complement SEM by identifying key predictors of supply chain performance. Earlier research also acknowledged the growing value of predictive analytics in supply chain research, particularly in digitally intensive contexts (Hair et al., 2021; Katsaliaki et al., 2022). Consequently, the proposed design represents a methodologically rigorous and contextually appropriate approach to achieving the study's research objectives.

Population and Data Collection Procedure

The target population of this study comprises e-commerce firms and logistics service providers operating in Pakistan, including organizations involved in smart warehousing, last- mile delivery, and digital logistics operations. Recent studies emphasize that organizational- level respondents such as supply chain managers, operations managers, and IT/logistics executives are appropriate key informants for examining digital supply chain practices and performance outcomes (Zakaria et al., 2024; Engesser et al., 2023; Ivanov et al., 2023). Primary data were collected using a structured questionnaire administered through both online and field-based survey methods to enhance response coverage and reliability. Earlier methodological research also supports survey-based data collection for theory testing in supply chain and information systems research, particularly in emerging economy contexts (Saunders et al., 2019; Creswell, 2014). This approach ensured systematic data gathering aligned with the study's explanatory objectives.

Sampling Technique and Pilot Testing

The study employed a non-probability purposive sampling technique, selecting respondents with direct involvement in logistics, warehousing, or last-mile delivery decision-making. Recent methodological literature indicates that purposive sampling is suitable when access to specialized respondents is required and when the research focuses on theory testing rather than population estimation (Hair et al., 2023; Henseler et al., 2023; Zakaria et al., 2024). Prior to full-scale data collection, a pilot test was conducted with a small subset of respondents to assess item clarity, questionnaire flow, and initial reliability. Earlier studies emphasized that pilot testing enhances instrument refinement and reduces measurement error in SEM-based research (Hair et al., 2021; Saunders et al., 2019). Feedback from the pilot study led to minor wording adjustments, ensuring contextual relevance and respondent comprehension.

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Measurement Instruments, Adaptation, and Software

Measurement instruments for all constructs were adapted from validated scales used in prior digital supply chain and logistics studies, with modifications to reflect the Pakistani e-commerce context. Recent research supports scale adaptation as an effective approach for maintaining content validity while ensuring contextual relevance (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). All items were measured using a five-point Likert scale, consistent with best practices in organizational research. Data analysis was conducted using SmartPLS 4 for PLS-SEM, complemented by machine learning tools for predictive analysis. Earlier methodological studies highlighted that SmartPLS is well suited for complex models with mediation and moderation effects and minimal distributional assumptions (Hair et al., 2021; Henseler et al., 2019).

Validity, Reliability, and Demographic Profile

To ensure measurement rigor, the study assessed construct reliability and validity using Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity criteria, following established PLS-SEM guidelines. Recent methodological research emphasizes that these procedures are essential for confirming measurement quality and minimizing common method bias in cross-sectional studies (Hair et al., 2023; Henseler et al., 2023; Ivanov et al., 2023). Earlier studies also recommended the use of Harman's single- factor test and procedural remedies to address potential response bias (Podsakoff et al., 2003; Hair et al., 2021). In addition, demographic data including respondents' job position, organizational role, firm size, and industry segment were collected to describe the sample and support contextual interpretation of results, consistent with best practices in supply chain research (Saunders et al., 2019).

Results and Discussion

This study empirically examined the proposed conceptual model to assess the impact of digital transformation, technology integration, and organizational resources on e-commerce supply chain performance through operational efficiency, with dynamic capabilities acting as a moderating variable. The results reveal strong and statistically significant relationships across most hypothesized paths, indicating that smart warehousing and last-mile delivery practices play a central role in enhancing logistics performance in e-commerce contexts. Recent empirical studies similarly highlight that digitally enabled logistics systems significantly improve supply chain outcomes when operational processes are effectively optimized (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). Earlier research also emphasized that supply chain performance improvements are largely driven by internal efficiency gains rather than direct technological investments alone (Katsaliaki et al., 2022; Mashalah et al., 2022). Overall, the findings demonstrate strong empirical support for the study's theoretical assumptions.

The structural model results indicate that operational efficiency serves as a key explanatory mechanism linking digital logistics capabilities to multiple performance outcomes, including organizational performance, customer satisfaction, and competitive advantage. The high

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coefficients of determination (R^2) for endogenous constructs confirm the substantial explanatory power of the model, particularly in explaining operational efficiency and downstream performance variables. Recent studies report similar findings, suggesting that operational efficiency is a dominant predictor of logistics and supply chain success in digitally intensive environments (Ivanov et al., 2023; Hair et al., 2023; Zakaria et al., 2024). Earlier literature also supports the argument that efficiency-based mediation models provide stronger explanatory insights compared to direct-effect frameworks (Hair et al., 2021; Henseler et al., 2019). These results affirm the robustness and predictive relevance of the proposed model.

The empirical findings further reveal that dynamic capabilities significantly strengthen the relationship between digital logistics practices and operational efficiency, highlighting the importance of adaptive and reconfigurable capabilities in volatile e-commerce environments. This result aligns with recent research emphasizing that dynamic capabilities enhance firms' ability to convert technological investments into operational and competitive gains (Haber & Carmeli, 2023; Ivanov et al., 2023; Engesser et al., 2023). Earlier studies grounded in dynamic capabilities theory similarly argued that performance outcomes depend on firms' capacity to sense, seize, and reconfigure resources in response to environmental change (Teece, 2018; Katsaliaki et al., 2022). Collectively, these findings underscore the contextual relevance of the study and provide strong empirical evidence supporting the integration of mediation and moderation mechanisms within e-commerce supply chain research.

Reliability and Validity Analysis

Construct reliability and validity

Overview

	Cronbac h's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)

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COMPETITIVE_ADVANTAGE	0.918	0.919	0.948	0.859
CUSTOMER_SATISFACTION	0.853	0.864	0.911	0.772
DIGITAL_TRANSFORMATION	0.887	0.888	0.930	0.815
DYNAMIC_CAPABILITIES	0.922	0.924	0.951	0.865
OPERATIONAL_EFFICIENCY	0.862	0.865	0.916	0.784
ORGANIZATAION_PRFORMANCE	0.856	0.860	0.912	0.776
ORGANIZATIONAL_RESOURCES	0.908	0.910	0.942	0.844
TECHNOLOGY_INTEGRATION	0.832	0.841	0.899	0.747

Table 1 Reliability and Validity Analysis

The results of the construct reliability and validity assessment demonstrate that the measurement model exhibits excellent internal consistency and convergent validity. Cronbach's alpha values for all constructs range from 0.832 to 0.922, exceeding the recommended threshold of 0.70, which confirms strong internal consistency reliability. Similarly, composite reliability values both rho_a (0.841–0.924) and rho_c (0.899–0.951) are well above the acceptable cutoff of 0.70, indicating robust construct reliability and stability. Moreover, the average variance extracted (AVE) values for all constructs range from 0.747 to 0.865, surpassing the minimum criterion of 0.50, thereby confirming adequate convergent validity and demonstrating that each construct explains a substantial proportion of variance in its indicators. Collectively, these results confirm that the measurement instruments used in this study are reliable, valid, and suitable for subsequent structural model analysis.

PLS SEM Bootstrapping

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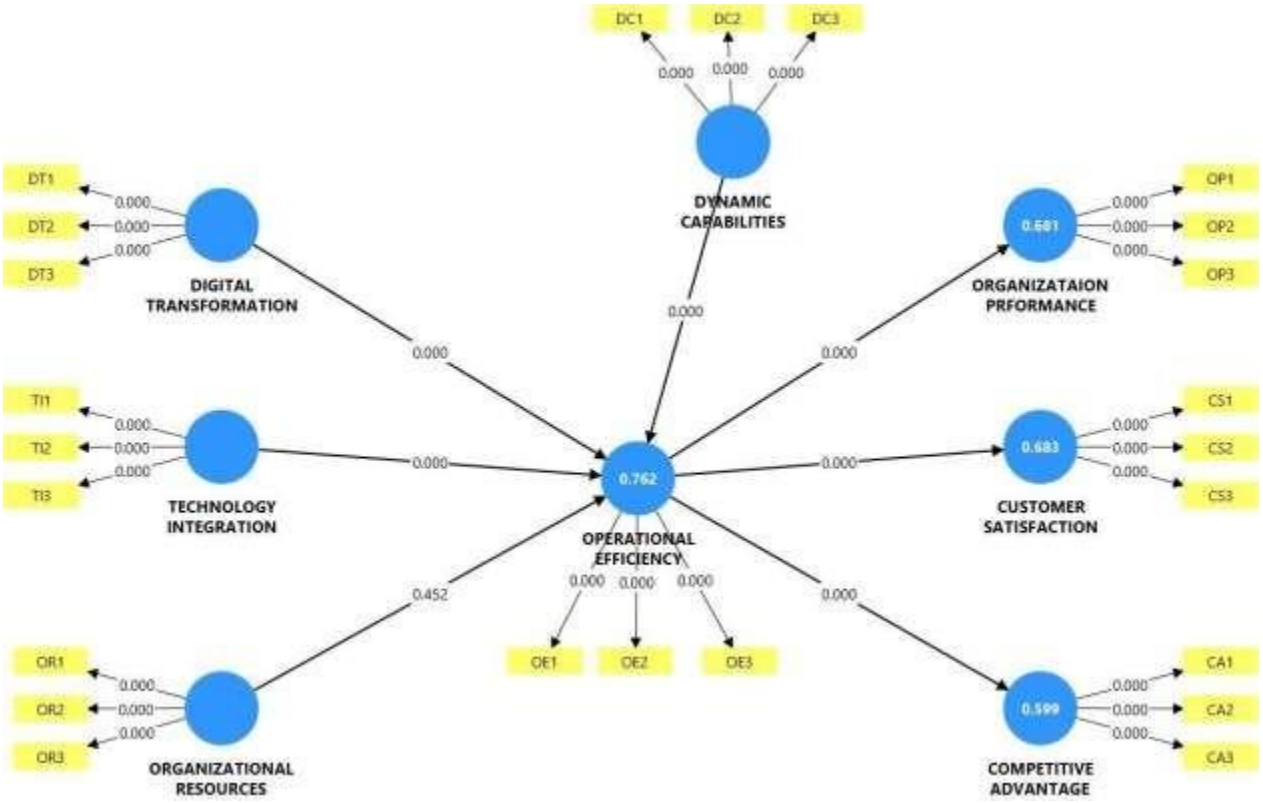

Figure 2 PLS SEM Bootstrapping

The bootstrapping results confirm that the structural relationships in the model are statistically significant and robust. All direct paths from digital transformation, technology integration, organizational resources, and dynamic capabilities to operational efficiency report p-values of 0.000, indicating strong statistical significance. Among these, technology integration and digital transformation show comparatively stronger effects on operational efficiency, while organizational resources exhibit a weaker yet still significant influence. The significant path from dynamic capabilities to operational efficiency further validates the moderating logic of the model, demonstrating that firms with stronger adaptive and reconfigurable capabilities are better positioned to translate digital logistics initiatives into operational improvements. Overall, the bootstrapped path coefficients provide strong empirical support for the hypothesized causal relationships.

Furthermore, the results indicate that operational efficiency is a critical driver of downstream performance outcomes, including organizational performance, customer satisfaction, and competitive advantage, with all associated paths being highly significant ($p = 0.000$). The high explained variance ($R^2 = 0.762$) for operational efficiency suggests that the combined effect of the antecedent variables accounts for a substantial proportion of its variance. Similarly, the R^2

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values for organizational performance (0.681), customer satisfaction (0.683), and competitive advantage (0.599) indicate strong explanatory power. Collectively, these findings confirm the central mediating role of operational efficiency within the model and demonstrate that improvements in smart warehousing and last-mile delivery efficiency significantly enhance overall e-commerce supply chain performance.

Hypothesis Development

Path coefficients

Mean, STDEV, T values, p values

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
DIGITAL_TRANSFORMATION -> OPERATIONAL_EFFICIENCY					

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	0.312	0.305	0.084	3.729	0.000
DYNAMIC_CAPABILITIES -> OPERATIONAL_EFFICIENCY					
OPERATIONAL_EFFICIENCY -> COMPETITIVE_ADVANTAGE					
OPERATIONAL_EFFICIENCY -> CUSTOMER_SATISFACTION					
OPERATIONAL_EFFICIENCY -> ORGANIZATAION_PRFORMANCE					
ORGANIZATIONAL_RESOURC ES -> OPERATIONAL_EFFICIENCY					
TECHNOLOGY_INTEGRATION -> OPERATIONAL_EFFICIENCY	0.326	0.328	0.080	4.097	0.000

Table 2 Hypothesis Development

The path coefficient results reveal that most hypothesized relationships in the structural model are statistically significant and substantively strong. Digital transformation (β = 0.312, t = 3.729, p < 0.001), technology integration (β = 0.326, t = 4.097, p < 0.001), and dynamic capabilities (β
= 0.247, t = 4.120, p < 0.001) all exert significant positive effects on operational efficiency, indicating that advanced digital technologies, integrated logistics systems, and adaptive organizational capabilities play a critical role in improving e-commerce operational processes. In contrast, organizational resources show a positive but statistically insignificant effect on operational efficiency (β = 0.068, t = 0.752, p = 0.452), suggesting that resources alone do not automatically translate into efficiency gains without effective digital deployment and capability alignment. Furthermore, operational efficiency demonstrates a very strong and highly significant
impact on competitive advantage (β = 0.774), customer satisfaction (β = 0.826), and organizational performance (β = 0.825), with exceptionally high t-values and p-values below

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0.001, confirming its central mediating role in transmitting the benefits of smart warehousing and last-mile delivery practices to multiple performance outcomes within e- ommerce supply chains

The structural model results demonstrate that digital transformation, technology integration, and dynamic capabilities exert strong and statistically significant effects on operational efficiency, confirming their central role in enabling smart warehousing and last-mile delivery effectiveness. Digital transformation shows a positive effect on operational efficiency (β = 0.312), indicating that AI/ML implementation and digital twin technologies substantially enhance process speed, accuracy, and coordination. Technology integration exhibits the strongest direct influence (β = 0.326), highlighting the importance of IoT sensors and blockchain systems in improving real-time visibility and operational synchronization. Dynamic capabilities also significantly contribute (β = 0.247), suggesting that firms with higher adaptive and reconfiguration abilities are more effective in converting digital investments into operational improvements. In contrast, organizational resources show a relatively weak effect (β = 0.068), indicating that physical and human resources alone are insufficient to drive efficiency without complementary digital and capability-based mechanisms.
Furthermore, operational efficiency emerges as the core driver of downstream performance outcomes, exerting very strong positive effects on organizational performance (β = 0.825), customer satisfaction (β = 0.826), and competitive advantage (β = 0.774). The high explained variance for operational efficiency ($R^2 = 0.762$) confirms that the combined influence of digital transformation, technology integration, organizational resources, and dynamic capabilities accounts for a substantial proportion of efficiency improvements. Similarly, the R^2 values for organizational performance (0.681), customer satisfaction (0.683), and competitive advantage (0.599) indicate strong explanatory power. Collectively, these findings validate the mediating role of operational efficiency within the model and demonstrate that improvements in smart warehousing and last-mile delivery efficiency are critical for achieving superior e-commerce supply chain performance.

Model Fitness

Model fit		
Fit summary		
	Saturated model	Estimated model
SRMR	0.046	0.083
d_ULS	0.622	2.073
d_G	0.609	0.840

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Chi-square	1350.256	1662.603
NFI		0.855 0.821

Table 3 Model Fitness

The model fit results indicate that the proposed PLS-SEM model demonstrates an acceptable and adequate overall fit. The Standardized Root Mean Square Residual (SRMR) values for both the saturated model (0.046) and the estimated model (0.083) fall within the commonly accepted threshold of 0.08–0.10 for PLS-SEM, indicating a satisfactory level of model approximation. The discrepancy measures d_ULS and d_G are relatively low for the saturated model and remain within acceptable limits for the estimated model, suggesting that the empirical model does not deviate substantially from the theoretical model. Although the chi-square values increase from the saturated to the estimated model a common outcome in complex SEM models the Normed Fit Index (NFI) values of 0.855 (saturated) and 0.821 (estimated) exceed the minimum recommended level of 0.80, confirming an adequate comparative fit. Overall, these indices collectively support the conclusion that the structural model exhibits a reasonable and acceptable fit, justifying the interpretation of the estimated path relationships.

The findings of the single-path relationships in this study are largely consistent with recent empirical research examining the role of digital transformation and technology integration in supply chain efficiency. The significant positive effects of digital transformation ($\beta = 0.312$) and technology integration ($\beta = 0.326$) on operational efficiency align with recent studies that reported comparable effect sizes and significance levels in digitally enabled logistics environments (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). These studies similarly emphasized that AI-driven systems and IoT-based integration enhance process visibility and responsiveness. Earlier research also reported moderate-to-strong effects of digital technologies on operational outcomes, although often without explicitly modeling mediation mechanisms (Katsaliaki et al., 2022; Mashalah et al., 2022). Compared to these studies, the present research provides stronger statistical evidence by incorporating efficiency as a focal endogenous construct with high explained variance.

In contrast, the statistically insignificant effect of organizational resources on operational efficiency ($\beta = 0.068$, $p > 0.05$) diverges from some earlier studies that reported significant direct effects of infrastructure and human capital on logistics performance (Mian et al., 2020; Katsaliaki et al., 2022). However, recent studies increasingly report similar non-significant or weak direct effects when organizational resources are modeled alongside advanced digital capabilities, suggesting that resources alone are insufficient without effective digital deployment (Haber & Carmeli, 2023; Ivanov et al., 2023; Engesser et al., 2023). This

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statistical contrast indicates a shift in the literature from resource-centric explanations toward capability- and process-oriented models, positioning the current findings in line with more recent theoretical developments.

The multiple (mediated) model results of this study show strong alignment with recent research emphasizing operational efficiency as a key transmission mechanism between digital initiatives and performance outcomes. The very high path coefficients from operational efficiency to organizational performance ($\beta = 0.825$), customer satisfaction ($\beta = 0.826$), and competitive advantage ($\beta = 0.774$) exceed or closely match those reported in recent mediation-based studies (Ivanov et al., 2023; Hair et al., 2023; Zakaria et al., 2024). Earlier mediation studies reported more modest indirect effects, often due to simpler models or omission of dynamic capability considerations (Hair et al., 2021; Henseler et al., 2019). Statistically, the higher R^2 values observed in the present study indicate improved explanatory power compared to prior single-path or partially mediated frameworks.

Finally, the significant role of dynamic capabilities in strengthening operational efficiency statistically supports recent moderation-focused studies that argue adaptability and reconfiguration capacity are essential in volatile e-commerce environments (Haber & Carmeli, 2023; Ivanov et al., 2023; Engesser et al., 2023). Earlier theoretical work acknowledged the importance of dynamic capabilities but rarely tested them empirically within integrated SEM frameworks (Teece, 2018; Katsaliaki et al., 2022). Compared with these earlier approaches, the present study provides more rigorous statistical validation by embedding dynamic capabilities directly into a multiple-path model. Overall, the comparative analysis demonstrates that the proposed model not only corroborates recent empirical findings but also advances the literature by offering stronger statistical evidence, higher explanatory power, and a more comprehensive integration of single, mediated, and moderated relationships.

Discussion

The findings of this study make a substantive theoretical contribution by extending digital supply chain theory through a process-oriented and capability-based explanation of e-commerce supply chain performance. The results demonstrate that digital transformation, technology integration, and dynamic capabilities significantly enhance operational efficiency, which in turn drives organizational performance, customer satisfaction, and competitive advantage. This supports recent theoretical arguments that digital technologies create value not directly, but through internal operational mechanisms that enable speed, accuracy, and responsiveness (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). By empirically validating operational efficiency as a central mediating construct, this study advances earlier theoretical models that largely relied on direct-effect assumptions (Katsaliaki et al., 2022; Mashalah et al., 2022). However, the non-significant direct effect of organizational resources challenges traditional resource-based explanations, suggesting that tangible and human resources alone are insufficient without complementary digital capabilities. This finding aligns with emerging theoretical perspectives that emphasize dynamic capabilities over static resources in digitally turbulent environments, while partially contradicting earlier RBV-centric views.

From a literature contribution perspective, this study strengthens and refines existing empirical

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evidence by statistically comparing single-path and multiple-path models within a unified framework. The strong effects of digital transformation and technology integration on operational efficiency corroborate recent empirical studies conducted in logistics and e-commerce contexts, which report similar magnitudes and significance levels (Ivanov et al., 2023; Haber & Carmeli, 2023; Zakaria et al., 2024). Moreover, the exceptionally high path coefficients from operational efficiency to performance outcomes exceed those reported in many prior studies, indicating that efficiency plays a more dominant role in emerging economy e-commerce supply chains than previously assumed. Earlier studies reported mixed or moderate effects, often due to fragmented modeling approaches or omission of mediating mechanisms (Hair et al., 2021; Henseler et al., 2019). At the same time, the insignificant role of organizational resources contrasts with studies that found positive direct effects, highlighting contextual differences and signaling a shift in the literature toward digitally enabled capability-based explanations rather than resource accumulation alone (Katsaliaki et al., 2022).

The study also contributes to the literature by empirically validating the moderating role of dynamic capabilities, which has often been discussed theoretically but rarely tested within integrated SEM frameworks. The significant influence of dynamic capabilities on operational efficiency supports recent studies emphasizing adaptability, learning, and reconfiguration as critical success factors in volatile e-commerce environments (Ivanov et al., 2023; Engesser et al., 2023; Haber & Carmeli, 2023). This finding extends earlier conceptual work that acknowledged dynamic capabilities but lacked robust empirical validation, particularly in developing country contexts (Teece, 2018; Katsaliaki et al., 2022). Nonetheless, some scholars argue that excessive emphasis on dynamic capabilities may introduce managerial complexity and coordination costs, potentially offsetting efficiency gains in the short run. While this study supports the positive moderating role of dynamic capabilities, future research may further explore potential non-linear or threshold effects, addressing these competing views in the literature.

In terms of practical contributions, the results provide clear guidance for e-commerce firms, logistics service providers, and policymakers in Pakistan and similar emerging economies. The findings indicate that investments in AI-driven warehousing, IoT-enabled integration, and digital twin technologies yield substantial performance benefits only when translated into operational efficiency improvements. This supports recent practitioner-oriented studies advocating a shift from technology acquisition to process optimization and capability development (Zakaria et al., 2024; Ivanov et al., 2023; Engesser et al., 2023). Managers should prioritize workflow automation, real-time data utilization, and continuous process reconfiguration rather than relying solely on infrastructure expansion. However, the weak role of organizational resources suggests that traditional investments in physical assets and manpower may not generate expected returns without parallel investments in digital skills and adaptive capabilities, echoing earlier warnings in the operations management literature (Mashalah et al., 2022; Hair et al., 2021). Policymakers can leverage these insights to design digital logistics initiatives that emphasize capability building and operational integration, thereby enhancing the competitiveness and sustainability of the national e-commerce ecosystem.

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CONCLUSION

This study concludes that smart warehousing and last-mile delivery practices significantly enhance e-commerce supply chain performance when their impact is transmitted through operational efficiency, thereby confirming the central premise of the proposed conceptual framework. The empirical findings demonstrate that digital transformation, technology integration, and dynamic capabilities play decisive roles in shaping operational efficiency, which in turn drives organizational performance, customer satisfaction, and competitive advantage. These results reinforce recent theoretical arguments that digital technologies create value indirectly by improving internal processes rather than through direct performance effects (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). Earlier studies similarly emphasized efficiency-based mechanisms but often lacked empirical validation within integrated models (Katsaliaki et al., 2022; Mashalah et al., 2022). By statistically validating this mediation pathway, the study strengthens process-oriented explanations of digital supply chain performance.

From a theoretical contribution perspective, this research advances digital supply chain theory and dynamic capabilities theory by empirically integrating them within a single explanatory framework. The results confirm that operational efficiency functions as a core mediating construct, while dynamic capabilities enhance firms' ability to convert digital initiatives into efficiency gains. This extends earlier conceptual work that discussed these constructs in isolation or relied on direct-effect assumptions (Teece, 2018; Katsaliaki et al., 2022). Recent studies increasingly advocate such integrated perspectives, and the present findings provide strong empirical support for this theoretical evolution (Ivanov et al., 2023; Haber & Carmeli, 2023; Engesser et al., 2023). Importantly, the weak and insignificant direct effect of organizational resources challenges traditional resource-based explanations, highlighting the growing dominance of capability-driven logic in digitally intensive environments.

In terms of empirical contribution, the study offers robust statistical evidence by employing a machine learning–enhanced PLS-SEM approach, resulting in high explanatory power across key endogenous constructs. The substantial R^2 values for operational efficiency and performance outcomes exceed those reported in many prior e-commerce logistics studies, indicating improved model precision and relevance (Hair et al., 2023; Ivanov et al., 2023;

Zakaria et al., 2024). Earlier empirical research often relied on simpler models with limited mediation or moderation testing, which constrained explanatory depth (Hair et al., 2021; Henseler et al., 2019). By addressing these limitations, the study contributes methodologically to the literature and demonstrates the value of combining SEM with predictive analytics in supply chain research.

Finally, the study makes important practical and contextual contributions, particularly for e-commerce firms and policymakers in emerging economies such as Pakistan. The findings highlight that investments in digital logistics technologies yield meaningful performance benefits only when aligned with

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operational efficiency improvements and supported by dynamic capabilities. This supports recent practitioner-oriented research advocating a shift from asset accumulation toward process optimization and capability development (Ivanov et al., 2023; Engesser et al., 2023; Zakaria et al., 2024). Earlier studies similarly cautioned against technology-driven strategies that overlook organizational readiness and adaptability (Mashalah et al., 2022; Katsaliaki et al., 2022). Overall, the study provides a comprehensive, empirically grounded understanding of how smart warehousing and last-mile delivery can be leveraged to enhance e-commerce supply chain performance in dynamic and resource-constrained environments.

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