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The Interplay of Green Logistics, E-Commerce, and Smart Technologies on Firm Competitiveness: A Multi-Mediation Analysis of Operational Efficiency, and Customer Retention

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Abstract

This study examined how green logistics adoption, e-commerce capability, and smart logistics technologies relate to firm competitiveness through the mediating roles of operational efficiency and customer retention among logistics and e-commerce firms in the Philippines. It was anchored on the Resource-Based View, Dynamic Capabilities Theory, and Stakeholder Theory. A quantitative, cross-sectional survey design was employed using a researcher-developed structured questionnaire adapted from validated measures and administered to managers, executives, supervisors, and organizational decision-makers with relevant logistics, e-commerce, sustainability, and technology experience. Purposive sampling with organizational stratification was used, while data were analyzed using descriptive statistics, Spearman's rank-order correlation, and Partial Least Squares Structural Equation Modeling (PLS-SEM). Results showed high levels of green logistics adoption, smart logistics technology utilization, customer retention, and very high operational efficiency and perceived firm competitiveness, while e-commerce capability demonstrated comparatively moderate digital integration. All constructs were positively and significantly associated with firm competitiveness at the bivariate level. However, green logistics, e-commerce capability, and smart logistics technologies did not demonstrate statistically significant direct effects on competitiveness in the structural model. Instead, their contributions were primarily realized through customer retention and operational efficiency, with operational efficiency emerging as the strongest immediate predictor of competitiveness. Significant indirect and sequential mediation pathways further demonstrated that sustainability, digital, and technological capabilities generate competitive value when translated into improved customer relationships and operational performance. The study recommends strengthening operational efficiency, customer retention, digital system integration, measurable green logistics practices, strategic technology adoption, employee capability development, and institutional support for logistics modernization. The study primarily supports SDG 9: Industry, Innovation and Infrastructure, SDG 12: Responsible Consumption and Production, and SDG 13: Climate Action through its emphasis on digital logistics innovation, resource efficiency, sustainable logistics practices, and reduced environmental impacts. Its sustainability impact extends to environmental, technological, socio-economic, institutional, and organizational sustainability by supporting more efficient, resilient, digitally enabled, and environmentally responsible logistics operations in the Philippines.

Keywords: Customer Retention, E-Commerce Capability, Firm Competitiveness, Green Logistics Adoption, Operational Efficiency, Philippine Logistics Sector, Smart Logistics Technologies, Sustainable Logistics

1. Introduction

The rapid expansion of digital commerce, technological innovation, and environmental sustainability concerns has transformed logistics from a supporting business function into a strategic capability influencing trade, organizational performance, and competitiveness. According to the World Bank (2024), efficient logistics systems reduce transaction costs, strengthen trade, and improve business and national competitiveness, while the Organization for Economic Co-operation and Development (OECD, 2024) emphasizes that contemporary logistics integrates physical distribution with digital technologies, sustainability, customer-centered operations, and organizational resilience. This transformation has intensified with the growth of e-commerce, which has increased demand for last-mile delivery, warehousing, inventory management, reverse logistics, and order fulfillment while also increasing transportation activity, resource consumption, packaging waste, and carbon emissions (International Trade Administration [ITA], 2024; United Nations Conference on Trade and Development [UNCTAD], 2024). These developments have positioned green logistics adoption, e-commerce capability, and smart logistics technologies as complementary strategic capabilities. Green logistics can reduce environmental impacts while improving resource utilization, reputation, and operational performance (Agyabeng-Mensah et al., 2022; Zhang & Zhao, 2023), with sustainable transportation, routing, renewable energy, recycling, and emission-management practices contributing to cost savings and organizational value (Li et al., 2023; Alnajem et al., 2024). E-commerce capability supports digital transactions, inventory visibility, coordination, and customer responsiveness (Zhu & Kraemer, 2022; Chen et al., 2024; Liu & Wang, 2023), while smart logistics technologies facilitate real-time visibility, forecasting, automation, and transportation optimization (Marchet et al., 2022; Büyüközkan & Göçer, 2023). These technologies can simultaneously improve efficiency and environmental performance (Fernandez & Kim, 2023; Tan & Goh, 2023). Current literature therefore suggests that sustainability, digital capability, and smart technology should be examined as interconnected organizational capabilities rather than isolated practices (Asian Development Bank [ADB], 2024; Organization for Economic Cooperation and Development [OECD], 2024). Their competitive value may operate through internal and relational mechanisms, particularly operational efficiency and customer retention (Jin & Park, 2022; Lee & Wong, 2023). This perspective is especially relevant to the Philippines, where the expansion of the digital economy has increased demand for effective logistics while infrastructure constraints, rising costs, uneven digitalization, and limited adoption of sustainable and smart technologies continue to affect firms (World Bank, 2024; ADB, 2024). Accordingly, the study examines green logistics adoption, e-commerce capability, and smart logistics technologies in relation to firm competitiveness through the sequential mediating roles of operational efficiency and customer retention.

The growth of global e-commerce has altered the scale and complexity of logistics operations. UNCTAD (2023) reported continued expansion in global e-commerce, increasing the need for large-scale fulfillment, real-time tracking, reliable delivery, and responsive supply chains. Logistics capability has consequently become an important determinant of competitive performance in both developed and emerging economies (Hwang & Lee, 2021). At the same time, environmental pressures have encouraged firms to adopt energy-efficient transportation, recyclable packaging, optimized routes, and other lower-impact practices (Zhang & Zhao, 2022). Developed economies have also advanced toward decarbonized logistics through cleaner fleets and energy-efficient infrastructure (European Commission, 2023). The environmental implications of e-commerce have made green logistics increasingly strategic. Transportation and logistics contribute substantially to emissions, making sustainable logistics relevant to climate-change mitigation and resource efficiency. The World Bank (2024) and the Organization for Economic Co-operation and Development (OECD, 2024) emphasize the importance of sustainable logistics, while the continued expansion of delivery, warehousing, packaging, and reverse logistics has increased fuel consumption, waste, and environmental pressures (UNCTAD, 2024). Practices involving green transportation, route optimization, renewable energy, recyclable packaging, and sustainable warehousing can reduce these pressures while improving organizational performance (Liu & Wang, 2023; Zhang & Zhao, 2023). Green logistics therefore represents both an environmental and strategic capability (Agyabeng-Mensah et al., 2022). Digital commerce has simultaneously required firms to integrate ordering, payment, inventory, customer relationship management, fulfillment, and logistics coordination. The United Nations Conference on Trade and Development (UNCTAD, 2024) associates continued e-commerce expansion with internet penetration, mobile commerce, digital payments, and changing consumer behavior. E-commerce capability refers to the organization's ability to integrate digital platforms, information systems, and electronic processes to facilitate transactions and customer experiences (Zhu & Kraemer, 2022). It extends beyond online selling by connecting marketing, operations, finance, inventory, customer service, and logistics functions (Liu & Wang, 2023). Such capabilities allow firms to adjust their technological resources as customer and competitive requirements change, consistent with Teece (2018). Smart technology utilization further supports this transformation. Industry 4.0 technologies, including Artificial Intelligence, the Internet of Things, Big Data Analytics, Cloud Computing, robotics, blockchain, RFID, and warehouse automation, enable logistics processes to become increasingly data-driven and intelligent (Büyüközkan & Göçer, 2018; Marchet et al., 2021). The World Economic Forum (2024) identifies digital technologies as important to resilient supply chains, while the Organization for Economic Co-operation and Development (OECD, 2024) emphasizes their value for real-time visibility and resilience. The World Bank (2024) similarly associates investment in digital logistics infrastructure with stronger logistics performance and lower operating costs. Together, these developments demonstrate that competitiveness in contemporary logistics increasingly depends on the ability to combine environmental responsibility, digital commerce, intelligent technology, operational excellence, and customer value rather than relying solely on conventional cost or market-share advantages.

Green logistics has developed from an environmental compliance activity into an organizational capability with operational and competitive implications. Sustainable transportation, fuel-efficient routing, carbon monitoring, recycling, waste reduction, renewable energy, and circular practices can create capabilities that are difficult for competitors to reproduce (Barney, 1991; Teece, 2018). Zhang and Zhao (2023) emphasize the integration of ecological responsibility into operational decisions, while Alnajem et al. (2024) associates green transportation with lower logistics costs and improved reliability. Li et al. (2023) similarly identifies energy efficiency, inventory optimization, and waste reduction as benefits of sustainable warehouse practices. Consumer preferences also reinforce these organizational benefits, as NielsenIQ (2024) indicates growing attention to environmental sustainability in purchasing and delivery decisions. Consequently, environmental responsibility may strengthen customer trust and retention in addition to operational performance (Agyabeng-Mensah et al., 2022). Operational benefits of green logistics are particularly evident in transportation, routing, packaging, and warehousing. Fuel-saving practices and route consolidation can reduce transportation expenses (Zhang & Zhao, 2022), while the Asian Development Bank (ADB, 2022) identifies fuel efficiency as particularly relevant to logistics costs in Southeast Asia. Route optimization reduces idle time, travel distance, and delivery uncertainty (Fernandez & Kim, 2023), while recyclable and lightweight packaging can simplify handling and reduce waste (Santos & Manalili, 2022). Energy-efficient warehouse systems similarly reduce operating expenses and support productivity (Tan & Goh, 2023). These findings support the view that environmental and operational objectives can reinforce one another rather than function as competing priorities (Nasiri & Choudhary, 2021). E-commerce capability produces related benefits through digital integration. Highly integrated platforms improve order processing, inventory accuracy, service responsiveness, and customer satisfaction. Chen et al. (2024) identifies these improvements among organizations with stronger e-commerce integration, while digital systems can reduce transaction costs and improve decisions through real-time information (Liu & Wang, 2023). Integrated ordering and inventory systems reduce stock inaccuracies and fulfillment problems (UNCTAD, 2024), and secure digital payment systems facilitate transactions and customer confidence (Hwang & Lee, 2021). Customer-service technologies such as chatbots, automated ticketing, and customer relationship management systems can improve responsiveness (Ferreira & Santos, 2022), while Lee and Wong (2023) associate responsive communication and effective complaint resolution with stronger customer satisfaction and retention. Warehouse management systems, automated fulfillment, and real-time tracking further strengthen e-commerce capability. These technologies reduce processing errors and improve warehouse productivity (Tan & Goh, 2023), while real-time visibility enhances transparency and customer confidence (Liu & Wang, 2023). Digital ordering systems likewise reduce manual processing and improve workflow accuracy (Hwang & Lee, 2021), and digital fulfillment technologies shorten processing times and reduce errors (Fernandez & Kim, 2023). E-commerce capability can therefore contribute to competitiveness through automation, accuracy, faster fulfillment, customer experience, and access to broader markets (Bui & Vo, 2022). Smart logistics technologies extend these effects through greater automation and decision intelligence. Artificial intelligence supports demand forecasting, route planning, inventory optimization, and resource allocation (Liu & Wang, 2023), while machine learning enables proactive responses to customer, operational, and supply-chain patterns (Fernandez & Kim, 2023). Tan and Goh (2023) associate AI-supported logistics with reduced transportation costs and improved delivery performance. IoT-enabled devices provide continuous information on shipments, inventories, vehicles, and warehouse conditions (Nguyen et al., 2021), and organizations using such systems demonstrate stronger visibility and operational reliability (Chen et al., 2024). Warehouse robotics, automated guided vehicles, automated storage and retrieval systems, and intelligent sorting can further reduce errors and increase productivity (Gunasekaran et al., 2021). Blockchain can strengthen traceability, information sharing, and transaction security (Queiroz et al., 2019). Through these technologies, firms can improve operational coordination, throughput, transparency, service reliability, and organizational resilience. Operational efficiency represents an important mechanism through which these capabilities may generate organizational value. It involves maximizing outputs while reducing unnecessary use of labor, capital, energy, time, and technology (Gunasekaran et al., 2021). Slack, Brandon-Jones, and Burgess (2022) associate operational efficiency with waste reduction, consistency, responsiveness, and customer value, while Heizer, Render, and Munson (2023) link efficient operations with profitability and adaptability. Digital integration can streamline logistics operations and reduce errors (Fernandez & Kim, 2023), and firms using intelligent logistics technologies report improvements in delivery, inventory, routing, and warehouse productivity. Tan and Goh (2023) emphasizes these performance gains, while Chen et al. (2024) reports lower operational costs and improved service quality among firms with integrated logistics technologies. Environmental initiatives also contribute to efficiency. Fuel-efficient transportation, optimized routes, recyclable packaging, reverse logistics, and efficient warehouses reduce resource consumption (Nasiri & Choudhary, 2021). Zhang and Zhao (2023) identifies simultaneous environmental and economic benefits from green logistics, and Agyabeng-Mensah et al. (2022) associates such practices with operational flexibility and resilience. Efficient logistics can subsequently improve customer experiences by supporting timely, accurate, and responsive service (Jin & Park, 2022). Sweeney, et al. (2018) similarly associates operational excellence with customer trust. Customer retention represents the relational dimension through which organizational capabilities may contribute to longer-term competitiveness. Kotler, Keller, and Chernev (2022) describe retention in terms of continued value creation, repeat purchasing, loyalty, and enduring customer relationships, while Reichheld and Sasser (1990) emphasize its implications for acquisition costs, customer lifetime value, and profitability. Digital commerce has increased customer expectations for delivery reliability, transparent communication, real-time information, and convenient service (UNCTAD, 2024). The PwC Global Consumer Insights Survey (2024) likewise indicates that loyalty increasingly depends on service reliability, convenience, transparency, and trust. Service quality remains central to retention. The reviewed literature draws on Parasuraman, Zeithaml, and Berry's SERVQUAL framework to connect reliability, responsiveness, assurance, empathy, and tangibility with logistics service experiences. Empirical studies associate consistent logistics service with stronger customer retention (Jin & Park, 2022; Lee & Wong, 2023). Digital tracking and smart logistics technologies can increase trust through real-time information and faster responses (Liu & Wang, 2023), while customer-management technologies enable personalization and proactive problem resolution (Fernandez & Kim, 2023). Chen et al. (2024) likewise associates predictive and intelligent customer-management systems with stronger satisfaction and relationships. Environmental responsibility can reinforce these relational outcomes. NielsenIQ (2024) indicates that environmentally conscious consumers increasingly consider sustainable practices, while Zhang and Zhao (2023) associates green logistics with customer trust and organizational reputation. Sustainability initiatives can therefore contribute to retention when they strengthen credibility and align business operations with customer values (Agyabeng-Mensah et al., 2022). Firm competitiveness represents the ultimate organizational outcome considered in the study. It includes the capacity to outperform competitors by creating customer value and sustaining financial, operational, technological, and market performance (Porter, 1985). Contemporary competitiveness also encompasses innovation, service quality, sustainability, digital capability, and organizational resilience (Barney, 1991; Teece, 2018). The World Economic Forum (2024) emphasizes adaptability to technological and sustainability disruptions, while OECD (2024) associates superior organizational capabilities with sustained responses to changing markets. Digital commerce and smart logistics can enhance competitiveness by improving market responsiveness, service quality, and operational agility. UNCTAD (2024) identifies digital transformation as a source of growing competitive pressure, while firms integrating e-commerce and logistics functions demonstrate stronger market responsiveness (Chen et al., 2024). Intelligent technologies support real-time monitoring, predictive decisions, and resource optimization (Fernandez & Kim, 2023), and Tan and Goh (2023) associates smart logistics investment with productivity, delivery performance, cost reduction, and customer satisfaction. Sustainability provides another competitive pathway. Environmentally responsible logistics can strengthen efficiency, stakeholder confidence, and differentiation. The World Bank (2024) and the Asian Development Bank (2024) emphasize these connections, while green transportation, packaging, reverse logistics, and efficient warehousing can reduce costs and improve customer trust (Agyabeng-Mensah et al., 2022; Zhang & Zhao, 2023). Operational efficiency further strengthens competitive performance by reducing costs and improving service quality (Slack et al., 2022), with Gunasekaran et al. (2021) emphasizing productivity and responsiveness and Liu and Wang (2023) linking efficient logistics with delivery and inventory performance. Customer retention likewise supports sustained profitability and competitive standing through repeat purchasing, referrals, and customer lifetime value. Kotler et al. (2022) emphasizes these long-term relationships, while logistics evidence links dependable and technology-enabled services to retention and competitiveness (Jin & Park, 2022; Lee & Wong, 2023). The reviewed direct and mediating relationships consequently indicate that green logistics, e-commerce capability, and smart logistics technologies may influence competitiveness through internal process improvement and customer-related outcomes. Research associates green logistics with efficiency gains through lower resource consumption and waste (Agyabeng-Mensah et al., 2020), and digital integration with competitiveness through improved operational utilization and automation (Bui & Vo, 2022). Smart logistics creates value when technological investment is translated into faster, more accurate, and more efficient processes (OECD, 2023). Operational efficiency, in turn, supports retention through delivery reliability, transparency, accuracy, and perceived value (Hwang & Lee, 2021), while retention contributes to competitiveness through stable revenue, reduced acquisition costs, advocacy, and stronger customer lifetime value (Lee & Wong, 2023). Other reviewed evidence similarly connects stronger operations, customer retention, and competitive outcomes (AgyabengMensah et al., 2020).

Globally, logistics firms face increasing demands for speed, reliability, sustainability, resilience, and technological integration. Sustainability regulations, fuel-price pressures, geopolitical disruptions, climate-related risks, and increasing customer expectations require more adaptive logistics systems (OECD, 2023). Technology-enabled visibility, forecasting, and automation have therefore become important to managing rising e-commerce volumes and maintaining service standards (Fernandez & Kim, 2023; Liu & Wang, 2023). Within Southeast Asia, logistics digitalization and sustainable infrastructure have become increasingly important to economic integration and supply-chain resilience. The Asian Development Bank (2024) emphasizes low-carbon logistics, digital supply-chain integration, smart mobility, and regional connectivity. ASEAN logistics organizations investing in integrated digital capabilities have demonstrated stronger inventory visibility, customer engagement, coordination, and business continuity (ADB, 2024). These developments show that technological and environmental capabilities increasingly influence regional competitiveness. The Philippine context presents both opportunities and constraints. The Philippine Statistics Authority (2024) reported the growing contribution of the digital economy to national economic activity, while the Department of Trade and Industry (DTI, 2024) identifies continuing expansion in online business associated with greater internet penetration, mobile commerce, and digital payments. According to the Department of Trade and Industry (DTI, 2024) and the Philippine Statistics Authority (PSA, 2024), digital commerce has become particularly important to national economic growth and MSME participation. However, Philippine logistics continues to encounter transportation congestion, fragmented infrastructure, high operating costs, warehousing constraints, and uneven adoption of technology and sustainability practices. Philippine logistics costs remain comparatively high in the region (ADB, 2022), and traditional routing, manual operations, and basic tracking continue to affect delivery performance (Patalinghug & Bernardo, 2020). Advanced digital systems are more available among larger organizations, while many MSMEs face financial and technological limitations (DTI, 2023). Environmental transition is similarly uneven. Limited charging infrastructure, high investment requirements, and inadequate incentives constrain greener logistics adoption (DENR, 2023), while conventional fleets and packaging remain common among local providers (Santos & Manalili, 2022). Nevertheless, Philippine firms are gradually adopting digital booking, tracking, routing, and customer-service platforms (DTI, 2024), with early technology adopters reporting improvements in operational accuracy and customer satisfaction (Ramos & Yu, 2022). E-commerce capability also remains uneven. Many logistics firms operate with fragmented systems, limited automation, cybersecurity concerns, and shortages of digitally skilled personnel (Perez & Roxas, 2023), while manual inventory and disconnected systems continue to cause delays and inefficiencies (Ramos & Yu, 2023). Digital payments have expanded, but operational dependence on cash-on-delivery and manual customer-service processes remains a constraint for some firms (Santos & Manalili, 2022). Smaller organizations also face barriers to fulfillment automation (World Bank, 2024). Smart technology adoption reflects similar disparities. The Department of Information and Communications Technology (DICT, 2024) identifies digital transformation as a national priority, while the Department of Trade and Industry (DTI, 2024) encourages technology adoption to improve logistics efficiency and customer service. However, financing, infrastructure, cybersecurity, and skill limitations continue to inhibit adoption (Perez & Roxas, 2023). Firms that invest in such technologies nonetheless report improvements in inventory, transportation, coordination, and customer experience (Santos & Manalili, 2022). Operational efficiency remains particularly important because Philippine firms continue to experience congestion, infrastructure fragmentation, distribution costs, and uneven technology adoption. The Department of Trade and Industry (2024) and the World Bank (2024) identify logistics efficiency as important to productivity and digital economic growth. Philippine evidence associates investments in technology, warehouse modernization, transportation optimization, and sustainability with improved operational and customer outcomes (Perez & Roxas, 2023; Santos & Manalili, 2022). The same challenges influence customer retention and competitiveness. Continued growth in digital retail has raised customer expectations for speed, convenience, and transparency (DTI, 2024), even as infrastructure and service disparities remain significant (World Bank, 2024). Firms investing in customer-management systems, digital technologies, and sustainability initiatives may strengthen customer relationships despite these constraints (Perez & Roxas, 2023; Santos & Manalili, 2022). National competitiveness initiatives likewise emphasize improvements in logistics, technology, and sustainability. The Department of Trade and Industry (2024) and the National Economic and Development Authority (NEDA, 2024) identify these areas as important for Philippine enterprise competitiveness, although infrastructure gaps, fragmented systems, environmental requirements, and changing customer expectations remain substantial challenges (World Bank, 2024; Perez & Roxas, 2023). The contrast between international modernization and Philippine constraints therefore provides the contextual basis for examining how integrated sustainability and digital capabilities affect organizational performance within the Philippine e-commerce logistics sector.

The study is anchored on the Resource-Based View, Dynamic Capabilities Theory, and Stakeholder Theory. The Resource-Based View (RBV) (Barney, 1991; Barney et al., 2021) proposes that valuable, rare, inimitable, and non-substitutable resources can support sustained competitive advantage. In this study, green logistics adoption, e-commerce capability, and smart logistics technologies are treated as strategic organizational capabilities capable of improving resource utilization, service reliability, operational performance, and differentiation. Dynamic Capabilities Theory complements this perspective by emphasizing the continuous integration and reconfiguration of organizational resources under changing technological and market conditions (Teece, 2018; Teece, 2023). The theory explains how firms can transform sustainability practices, digital platforms, and smart technologies into operational improvements by adapting processes and capabilities. The conceptual basis also draws on the formulation of dynamic capabilities expressed in (Teece, 2018, 2023). Stakeholder Theory broadens the model by recognizing that organizational performance depends on value creation for customers, employees, suppliers, regulators, investors, and society (Freeman, 1984; Freeman et al., 2020). Sustainable logistics can reduce environmental impacts, e-commerce capability can improve customer accessibility, and smart logistics technologies can enhance transparency and service reliability. These practices can strengthen stakeholder trust, legitimacy, and customer commitment (Freeman et al., 2020). Collectively, the three theories explain how strategic resources can be acquired, reconfigured, operationalized, and converted into stakeholder and competitive value. The Resource-Based View explains the strategic value of the three organizational capabilities; Dynamic Capabilities Theory explains their adaptation and deployment; and Stakeholder Theory explains how operational and service improvements can generate customer and organizational outcomes. The conceptual framework consequently treats Green Logistics Adoption, E-Commerce Capability, and Smart Logistics Technologies as exogenous strategic capabilities and Firm Competitiveness as the endogenous organizational outcome, with Operational Efficiency and Customer Retention functioning as mediating mechanisms. The model also recognizes potential direct relationships between the three capabilities and competitiveness. The theoretical integration is further expressed through the Resource-Based View (Barney, 1991; Barney et al., 2021), Dynamic Capabilities Theory (Teece, 2018, 2023), and Stakeholder Theory (Freeman et al., 2020). The reviewed literature additionally supports the strategic-resource and adaptive-capability interpretation of smart technologies through Barney (1991) and Teece (2018).

Although green logistics, e-commerce capability, smart technologies, operational efficiency, customer retention, and firm competitiveness have received considerable scholarly attention, they are often examined separately. Existing research has frequently concentrated on direct capability-performance relationships rather than the mechanisms through which sustainability initiatives and technological capabilities are converted into competitive outcomes. This limitation is reflected in the continued lack of integrated evidence connecting the three strategic capabilities with operational efficiency, customer retention, and firm competitiveness, particularly in the Philippine setting (UNCTAD, 2024; DTI, 2024; Bui & Vo, 2022; Perez & Roxas, 2023). The roles of operational efficiency and customer retention also remain comparatively underexplored as mediating mechanisms (Santos & Manalili, 2022; Mercado et al., 2023). Research on green logistics has largely examined direct effects on environmental or organizational outcomes, with fewer studies addressing its relationship with competitiveness through operational and customer mechanisms. Philippine firms additionally face financial, infrastructure, expertise, and policy barriers to sustainable logistics adoption, as reported by Mercado et al. (2023) and Santos and Manalili (2022). Research on e-commerce capability similarly tends to treat digital capability as an independent predictor rather than examining its interaction with environmental and smart logistics capabilities. Smart-technology research often examines individual technologies rather than their combined strategic utilization. Recent literature reinforces these gaps. Digital and Industry 4.0 technologies can improve visibility, efficiency, responsiveness, and sustainability, but their effects depend on organizational capability, technological infrastructure, implementation conditions, and other complementary factors (Rad et al., 2022; Parhi et al., 2022). Sustainable last-mile logistics research remains fragmented across environmental, operational, and economic perspectives, indicating a need for more integrated frameworks (Bertolini et al., 2024). The value generated by technology also depends on complementary organizational and contextual factors (Rad et al., 2022), while sustainable digital logistics depends on digital infrastructure, organizational readiness, management commitment, and regulatory conditions (Parhi et al., 2022). The resulting gap is theoretical, methodological, and contextual. Internationally, limited research integrates sustainability, e-commerce capabilities, and smart technologies within a single structural explanation of competitive performance. Methodologically, fewer studies investigate operational efficiency and customer retention jointly as mediating mechanisms. Contextually, the Philippine logistics sector remains underrepresented despite substantial variation in infrastructure, digital readiness, financial resources, and sustainability adoption. Accordingly, the study seeks to develop and validate a multi-mediation structural model examining how green logistics adoption, e-commerce capability, and smart logistics technologies relate to firm competitiveness through operational efficiency and customer retention. This approach responds to the need to explain not only whether strategic capabilities are associated with competitiveness but also how operational and relational mechanisms translate those capabilities into organizational outcomes. The rationale is consistent with the Resource-Based View, Dynamic Capabilities Theory, and Stakeholder Theory and addresses the limited Philippine evidence on the integrated relationships among the six principal constructs. The study therefore contributes to Business Administration, Logistics, Supply Chain Management, strategic management, sustainable operations, and digital transformation research.

The study is aligned with the sustainability priorities identified in the original research, particularly SDG 8: Decent Work and Economic Growth, SDG 9: Industry, Innovation and Infrastructure, SDG 11: Sustainable Cities and Communities, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action, and SDG 17: Partnerships for the Goals. These alignments arise from the study's focus on logistics efficiency, technological innovation, digital infrastructure, sustainable transportation and warehousing, resource utilization, emissions reduction, and coordination among firms, government institutions, customers, and other stakeholders. SDG 8 is supported through the study's concern with organizational efficiency, competitiveness, and sustainable economic performance. SDG 9 is directly associated with e-commerce capability, smart logistics technologies, digital infrastructure, and logistics innovation. SDG 11 relates to more efficient and environmentally responsible transportation and delivery systems, particularly in urban areas affected by congestion. SDG 12 is reflected in green logistics practices involving waste reduction, recyclable packaging, reverse logistics, and resource efficiency, while SDG 13 is connected to lower-carbon transportation, reduced fuel consumption, and environmental logistics strategies. SDG 17 is relevant to the coordination required among businesses, government agencies, logistics partners, technology providers, and other stakeholders in advancing sustainable and digitally enabled logistics. These priorities are also consistent with the Philippine Development Plan (2023-2028). The synthesis of the reviewed literature particularly emphasizes Industry, Innovation and Infrastructure (SDG 9), Responsible Consumption and Production (SDG 12), and Climate Action (SDG 13).

The study contributes primarily to environmental, technological, socio-economic, institutional, and organizational sustainability. Environmentally, green logistics offers mechanisms for reducing fuel consumption, emissions, packaging waste, and inefficient resource use while improving transportation and warehouse processes. This reflects the increasing integration of ecological responsibility with organizational strategy rather than treating sustainability solely as regulatory compliance. Technological sustainability is addressed through e-commerce capability and smart logistics technologies. Digital ordering, payment systems, tracking, automation, AI, IoT, analytics, cloud systems, blockchain, and related technologies can improve supply-chain visibility, coordination, resilience, and decision-making. Their long-term value, however, depends on organizational capacity and implementation conditions rather than technology adoption alone. Socio-economic sustainability is reflected in the study's focus on operational efficiency, customer retention, competitiveness, and responsible economic development. More efficient firms can reduce waste and costs while improving service reliability and creating sustainable organizational value. Customer retention provides a relational dimension by linking service quality, trust, responsiveness, and long-term customer relationships with firm performance. Institutional and policy sustainability are relevant because the findings may inform strategies and policy initiatives concerning sustainable logistics, digital infrastructure, innovation, and environmentally responsible supply chains. These issues are particularly important in the Philippines, where firms operate under varying levels of infrastructure capacity, digitalization, financial resources, and organizational readiness. By integrating environmental sustainability, digital capability, operational performance, customer relationships, and firm competitiveness within one model, the study provides a multidisciplinary basis for understanding how technology-enabled and sustainable logistics practices may contribute to resilient and competitive organizations in the Philippine e-commerce logistics sector.

2. Material and methods

2.1 Research Design

The study used a quantitative approach to generate numerical data and statistically examine the relationships among the study variables. Quantitative research is appropriate for identifying patterns and empirically testing theoretical relationships involving multiple constructs (Creswell & Creswell, 2018). A cross-sectional survey design was employed, with data collected from respondents at a single point in time. This design is commonly used in business and management research to examine organizational processes, technological adoption, sustainability practices, and performance outcomes (Bryman, 2016). It was appropriate because the study focused on the current practices and perceptions of logistics and e-commerce firms rather than changes occurring over time. PLS-SEM was used to evaluate the proposed structural relationships and mediation effects. This variance-based multivariate technique is appropriate for complex models involving multiple latent constructs, direct and indirect relationships, and data that may not fully satisfy multivariate normality assumptions (Hair et al., 2021). The combination of quantitative research, cross-sectional survey design, and PLS-SEM provided the methodological basis for examining how sustainability practices, digital capabilities, and smart logistics technologies relate to operational efficiency, customer retention, and organizational competitiveness.

2.2 Locale of the Study

The study was conducted in the Philippines and focused on firms involved in logistics and e-commerce activities, including organizations that had integrated smart technologies into supply chain management. The participating organizational environment included third-party logistics providers, delivery and courier services, warehousing companies, online retailers, and firms employing digital fulfillment systems or sustainability-oriented logistics practices. These organizations represented the country's developing digital commerce and logistics sector, in which operational efficiency, technological integration, sustainability, and customer loyalty influence organizational competitiveness.

2.3 Respondents of the Study

The target respondents consisted of managers, executives, supervisors, and organizational decision-makers from logistics service providers and e-commerce logistics firms operating in the Philippines. These included operations managers, supply chain managers, logistics managers, e-commerce managers, and technology implementation managers whose positions provided direct knowledge of logistics operations, digitalization, sustainability initiatives, operational processes, customer management, and competitiveness strategies. Eligible respondents were required to be currently employed in a Philippine logistics, supply chain, or e-commerce firm, hold a managerial, supervisory, or decision-making position, have at least one year of relevant experience in logistics operations, technology adoption, or customer management, and participate voluntarily. Individuals who did not satisfy these requirements, including non-managerial employees without sufficient operational knowledge and workers outside the logistics and e-commerce sectors, were excluded. The estimated pool consisted of approximately 6,000 potentially qualified individuals. The source manuscript did not provide the verified final analytic sample; therefore, the actual number of valid respondents and their demographic characteristics should be reported from the cleaned dataset.

2.4 Sample and Sampling Procedure

The study used purposive sampling to select respondents directly involved in logistics processes, e-commerce activities, sustainability programs, or supply-chain technology implementation. This approach was appropriate because the investigation required respondents possessing relevant organizational expertise rather than general employees (Etikan et al., 2016). Purposive sampling was complemented by stratification according to organizational type, including logistics companies, e-commerce and online businesses, and firms utilizing innovative smart logistics technologies, to improve representation across the logistics and e-commerce environment. Sample adequacy was determined using complementary criteria. For the survey component, an estimated population of approximately 6,000 qualified respondents was used with Cochran's (1977) finite-population formula at a 95% confidence level and 5% margin of error. The computation produced a minimum required sample of approximately 361 respondents. Sample adequacy for PLS-SEM was additionally considered in relation to statistical power, model complexity, and the number of predictors in the structural model (Hair et al., 2021; Sarstedt et al., 2020). The source manuscript did not contain a verified final valid-response count; consequently, the exact analytic sample should be inserted based on the cleaned dataset rather than assumed or estimated.

2.5 Research Instrument

Data were collected using a researcher-developed, self-administered structured questionnaire based on validated academic measures adapted to the Philippine logistics and e-commerce context. Instrument development began with a review of established measures for green logistics, smart technologies, e-commerce capability, operational efficiency, customer retention, and firm competitiveness. Items were adapted from Lai and Wong (2012), Lin, Ho, and Chiang (2013), Büyüközkan and Göçer (2018), Marchet et al. (2021), Gunasekaran, Patel, and Tirtiroglu (2004), Reichheld and Sasser (1990), Zeithaml, Berry, and Parasuraman (1996), and Li, Ragu-Nathan, Ragu-Nathan, and Rao (2006), with wording modified to suit the Philippine logistics setting. The revised questionnaire was pilot tested among twenty qualified respondents who were excluded from the main study. Internal consistency was assessed through Cronbach's alpha, with the manuscript indicating that all coefficients exceeded the 0.70 threshold. Items with low item-total correlations were revised or removed. However, the construct-level pilot Cronbach's alpha coefficients were not provided in the source and should be inserted from the original pilot-test results rather than replaced with reliability coefficients from the main sample. Following pilot testing and revision, the instrument underwent the required academic, institutional, and research ethics review before administration. The final instrument contained sections covering informed consent and data privacy, respondent demographics, green logistics, smart logistics technologies, operational efficiency, customer retention, firm competitiveness, and an open-ended item concerning changes in logistics operations. Green logistics measures adapted from Lai and Wong (2012) and Lin et al. (2013) covered sustainable transportation, routing, packaging, waste reduction, and carbon monitoring. Smart logistics items adapted from Büyüközkan and Göçer (2018) and Marchet et al. (2021) addressed IoT tracking, AI forecasting, automation, blockchain, and data analytics. Operational efficiency measures from Gunasekaran et al. (2004) and Li et al. (2006) examined delivery timeliness, fuel consumption, cycle time, accuracy, and adaptability. Customer retention measures adapted from Reichheld and Sasser (1990) and Zeithaml et al. (1996) assessed repeat purchasing, recommendations, long-term relationships, satisfaction, and customer churn. Firm competitiveness items from Porter (1985) and Li et al. (2006) covered revenue growth, profitability, market share, value propositions, and competitive advantage. All scaled items used a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

2.6 Data Gathering Procedure

The questionnaire was developed from established measures and subjected to expert review for content relevance, clarity, and contextual suitability. After revision, it was pilot tested among twenty qualified respondents who were excluded from the main investigation. Pilot feedback and item analysis were used to finalize the wording and instructions before formal survey administration. Data collection was conducted primarily through online survey platforms because respondents were geographically dispersed and occupied managerial or operational positions. Distribution was coordinated through relevant company and professional networks. Before accessing the questionnaire, respondents received information concerning the study's purpose, voluntary participation, confidentiality, expected time commitment, anonymity, and right to withdraw. Only individuals who provided consent were permitted to continue. The survey remained available for approximately six to eight weeks, during which periodic reminders were sent through email, professional networks, and business associations without exerting undue pressure on participants. After the collection period, responses were downloaded and screened for duplicates, incomplete submissions, patterned responses, inconsistencies, excessive missing information, and unrealistically short completion times. Invalid responses were removed, after which the cleaned dataset was encoded and prepared for PLS-SEM analysis. Demographic and organizational information was also summarized to describe the respondents and participating firms. The source indicates that the final manuscript should report the actual number of invitations distributed, responses received, cases excluded during cleaning, and valid cases retained whenever these records are available.

2.7 Data Analysis Techniques

Data analysis proceeded according to the study objectives. Means and standard deviations were used to determine the levels of green logistics adoption, e-commerce capability, smart technology utilization, operational efficiency, customer retention, and firm competitiveness. Spearman's rank-order correlation was employed to examine the relationships between firm competitiveness and the other study constructs because the measures were derived from Likert-type scales and normality of construct-level scores was not assumed. PLS-SEM was subsequently used to test the hypothesized direct, indirect, mediated, and sequentially mediated relationships among the variables. PLS-SEM analysis included assessment of both the measurement and structural models. Internal consistency reliability was examined using Cronbach's alpha and composite reliability, while convergent validity was assessed through average variance extracted (AVE). Discriminant validity was evaluated using the heterotrait-monotrait (HTMT) ratio and the Fornell-Larcker criterion. After establishing the adequacy of the measurement model, bootstrapped path coefficients were examined for direct effects, specific indirect effects for mediation, and sequential indirect effects for serial mediation. Coefficients of determination (R^2), effect sizes (f^2), and relevant model-fit indices were also examined to assess explained variance, predictor contributions, and structural model adequacy. Procedural and statistical safeguards were applied to reduce common method bias, social desirability bias, and response variability. Respondent anonymity was maintained, questionnaire wording was reviewed to remove ambiguous or leading items, item order was randomized within constructs, reverse-scored items were included to identify patterned responses, and controls were applied to reduce duplicate online submissions. Harman's single-factor test was used as a preliminary diagnostic for common method variance, while a marker-variable technique was applied when relevant. Where possible, survey information was also supported by secondary reports from organizations such as the Department of Trade and Industry (DTI), Asian Development Bank (ADB), and World Bank. Nevertheless, the study recognized that managerial self-reports could still be affected by organizational and social desirability biases; therefore, responses were interpreted as respondents' perceptions rather than objective measures of organizational performance.

2.8 Ethical Considerations

The study complied with the ethical standards of the Polytechnic University of the Philippines Open University System Research Ethics Committee (PUPOUSREC), the Belmont Report principles, the National Ethical Guidelines for Health and Health-Related Research of the Philippine Health Research Ethics Board (PHREB), and the Data Privacy Act of 2012 (Republic Act No. 10173). Before participation, respondents received an informed consent form explaining the study, risks and benefits, confidentiality provisions, voluntary participation, and relevant researcher and PUPOUSREC contact information. Access to the questionnaire was provided only after respondents confirmed that they had read and understood the consent information, voluntarily agreed to participate, and consented to data processing. No personally identifiable information, including full names, employee numbers, or company names, was collected. Responses were assigned coded identifiers and findings were reported only in aggregate form. Raw data, anonymized datasets, and analysis files were stored on a password-protected, AES-256-encrypted external drive kept in a locked cabinet accessible only to the researcher. Online survey responses were exported and deleted from the survey platform within one week, while encrypted cloud backups were protected through two-factor authentication. Study data were to be retained for five years following completion of the dissertation and subsequently destroyed through secure electronic deletion and shredding of printed materials, if any. Participation involved no fees or remuneration and was entirely voluntary. Respondents could skip questions they were uncomfortable answering and withdraw before final submission without penalty; after submission, individual withdrawal might no longer be possible because the data had been anonymized. The study was classified as minimal risk, with the primary anticipated inconvenience being the approximately 20 to 25 minutes required to complete the questionnaire and no anticipated physical, psychological, legal, or financial risks.

3. Results and Discussion

3.1 Levels of Strategic Logistics Capabilities and Organizational Outcomes

3.1.1 Green Logistics Adoption

Participating firms demonstrated a relatively high level of green logistics adoption, with an overall mean of 3.87, interpreted as Agree. Individual indicators ranged from 3.83 to 3.92, showing relatively consistent adoption of practices involving fuel reduction, route optimization, environmentally friendly vehicles, recyclable or reusable packaging, energy-efficient facilities, waste reduction, carbon monitoring, environmental considerations in logistics decisions, and communication of sustainability initiatives. The findings indicate that environmental sustainability has become integrated into the logistics practices of the participating firms. Practices aimed at reducing fuel consumption and environmental impacts correspond with sustainable supply-chain initiatives

(Nasiri & Choudhary, 2021; Zhang & Zhao, 2022), while recyclable packaging and energy-efficient operations are consistent with broader sustainability standards (Asian Development Bank [ADB], 2024; Department of Environment and Natural Resources, 2023). This also supports Santos and Manalili (2022), who observed increasing recognition of environmentally responsible logistics among Philippine SMEs. Communicating green practices may additionally strengthen reputation and competitive positioning (Agyabeng-Mensah, et al., 2020; Barney, 1991). Monitoring environmental performance remains important because firms that measure such outcomes can better connect sustainability with operational performance, as noted by Srinivasan, et al. (2021). Despite infrastructure, regulatory, and technological constraints (Patalinghug & Bernardo, 2020; World Bank, 2023), the findings indicate efforts to align operations with national and international sustainability directions (ADB, 2022; Department of Environment and Natural Resources, 2023). Green logistics can therefore support efficiency, cost management, and reputation within increasingly low-carbon supply chains (Zhang & Zhao, 2022; Agyabeng-Mensah et al., 2020; Nasiri & Choudhary, 2021).

3.1.2 E-Commerce Capability

E-commerce capability obtained an overall mean of 3.36, interpreted as Neutral. The participating firms had implemented digital systems for ordering, payments, customer engagement, tracking, and inventory or warehouse management, but these capabilities were not fully optimized or integrated. The results therefore indicate an early-to-intermediate level of digital capability rather than a mature, fully integrated e-commerce environment. The neutral assessment is consistent with reported difficulties in digital integration among Philippine firms, particularly limitations in technical resources, infrastructure, and employee digital capabilities (Department of Trade and Industry [DTI], 2023; Perez & Roxas, 2023; Ramos & Yu, 2022). Digital ordering, real-time tracking, and automated communication have become increasingly important to logistics performance and customer experience (Hwang & Lee, 2021; Liu & Wang, 2023; United Nations Conference on Trade and Development [UNCTAD], 2023). However, insufficient integration between digital and logistics systems can limit operational flexibility and customer benefits (Bui & Vo, 2022; DTI, 2024). The findings consequently indicate opportunities for better platform scalability, automation, analytics, and system integration, consistent with regional digital-transformation priorities (Asian Development Bank [ADB], 2024; International Trade Administration, 2024; UNCTAD, 2024). Stronger digital integration may also support routing, inventory management, and waste reduction (ADB, 2022; Nasiri & Choudhary, 2021). Accordingly, digital infrastructure must be aligned more closely with operational and sustainability objectives to strengthen performance and competitiveness (Porter, 1990; Teece, 2018; Perez & Roxas, 2023).

3.1.3 Smart Logistics Technology Utilization

The participating firms reported a high level of smart technology utilization, with an overall mean of 4.20. Barcoding, RFID systems, dashboards, automated warehouse tools, real-time tracking, optimization software, and predictive inventory technologies were widely utilized. Employee training obtained a mean of 4.23, regular technology upgrading obtained 4.22, and predictive and analytical tools obtained 4.21, indicating that technological investment was accompanied by capability development. The strong technology utilization supports studies associating intelligent logistics technologies with improved efficiency, performance, and error reduction (Fernandez & Kim, 2023; Tan & Goh, 2023). Real-time monitoring, automation, and delivery optimization strengthen visibility, decision-making, and service reliability (Bui & Vo, 2022; Perez & Roxas, 2023; UNCTAD, 2024), while predictive inventory and demand tools may reduce excess stock, waste, and inefficient resource consumption (Nasiri & Choudhary, 2021; Santos & Manalili, 2022; Zhang & Zhao, 2022). The widespread use of these technologies also supports their interpretation as strategic resources (Barney, 1991; Teece, 2018). Such technologies are particularly relevant in the Philippine context because they can offset logistics and infrastructure constraints (ADB, 2022; Patalinghug & Bernardo, 2020; World Bank, 2023) while strengthening organizational resilience to market and supply-chain changes (ADB, 2024; OECD, 2023). Overall, continued technological investment and employee capability development support both logistics efficiency and digital transformation (Fernandez & Kim, 2023; Tan & Goh, 2023; Liu & Wang, 2023).

3.1.4 Operational Efficiency

Operational efficiency recorded an overall mean of 4.88, indicating a very high level among participating firms. Respondents strongly agreed that their organizations delivered orders on time, maintained low delivery-error rates, standardized logistics processes, managed high order volumes, operated warehouses efficiently, controlled costs, maintained effective communication, promptly resolved problems, and continuously improved logistics processes. These findings indicate highly developed logistics execution and resource management. Timely fulfillment and standardized processes are consistent with indicators of effective logistics performance (World Bank, 2023; Patalinghug & Bernardo, 2020), while efficient warehousing and cost management reflect closer alignment between operational execution and organizational performance (Fernandez & Kim, 2023; Bui & Vo, 2022). Continuous improvement and waste reduction also reflect lean and agile supply-chain principles (ADB, 2024; Nasiri & Choudhary, 2021), while effective problem resolution can strengthen resilience despite infrastructure limitations (Sarkar & Singh, 2021; ADB, 2022). Digital technologies further support real-time tracking, automation, and data-based decisions (Fernandez & Kim, 2023; Tan & Goh, 2023), which can reduce errors and improve customer outcomes (Hwang & Lee, 2021; Jin & Park, 2022). The combination of process standardization and technological capability is also consistent with the treatment of operational efficiency as a strategic capability (Barney, 1991; Teece, 2018). These results are particularly relevant to the Philippine logistics environment (ADB, 2022; World Bank, 2023; Perez & Roxas, 2023).

3.1.5 Customer Retention

Customer retention obtained an overall mean of 4.44, indicating a high level. Respondents reported repeat transactions, customer satisfaction, confidence in delivery performance, comparatively few logistics-related complaints, recommendations to others, and continued use of the firms as preferred service providers. These indicators suggest that the participating firms generally maintained strong and continuing customer relationships. The results are consistent with evidence linking dependable logistics performance to satisfaction and repeat patronage (Jin & Park, 2022; Hwang & Lee, 2021). Effective issue resolution also contributes to positive post-purchase experiences and customer loyalty (Lee & Wong, 2023; Perez & Roxas, 2023). Operationally efficient order processing, timely delivery, and dependable warehouse processes can reinforce these relationships (Fernandez & Kim, 2023; Bui & Vo, 2022), while digital monitoring, warehouse automation, and analytics can improve service and trust (Tan & Goh, 2023; Liu & Wang, 2023). These relationships correspond with resource-based arguments linking operational excellence and technological investment with sustained competitive advantage (Barney, 1991; Teece, 2018). In the Philippine context, timely delivery and responsive problem resolution remain particularly important because of infrastructure and supply-chain constraints (ADB, 2022; Patalinghug & Bernardo, 2020; World Bank, 2023). Responsive customer service can additionally reinforce referrals and preferred-provider status (Hwang & Lee, 2021; Lee & Wong, 2023), allowing customer retention to contribute to longer-term competitive positioning (Jin & Park, 2022; Liu & Wang, 2023; United Nations Conference on Trade and Development, 2024).

3.1.6 Firm Competitiveness

Firm competitiveness obtained the highest descriptive assessment, with an overall mean of 4.96. Respondents strongly perceived their organizations as providing superior logistics services, meeting or exceeding delivery expectations, responding quickly to customer requirements, using logistics and e-commerce capabilities to support sales, performing well against competitors, innovating in logistics services, maintaining strong market reputations, and supporting long-term growth through technology. However, the consistently high ratings and small standard deviations indicate restricted variation; therefore, these values represent respondents' perceptions of competitiveness rather than objective market-performance measures. The findings associate high perceived competitiveness with operational excellence and technology capability (Fernandez & Kim, 2023; Bui & Vo, 2022). Smart logistics can enhance real-time visibility, warehouse management, data-driven decisions, and service innovation (Tan & Goh, 2023; Liu & Wang, 2023), which are particularly important under Philippine infrastructure and supply-chain constraints (ADB, 2022; Patalinghug & Bernardo, 2020; World Bank, 2023). Adaptability, operational efficiency, technology, and customer orientation can further support sustained advantage (Barney, 1991; Teece, 2018; Jin & Park, 2022), consistent with research emphasizing logistics performance and service innovation in competitive e-commerce markets (Lee & Wong, 2023; United Nations Conference on Trade and Development, 2024). Overall, the results suggest that competitiveness is associated with the combined use of efficient operations, technology, and customer-centered logistics (Fernandez & Kim, 2023; Bui & Vo, 2022; Liu & Wang, 2023). Nevertheless, the restricted range of the descriptive responses warrants cautious interpretation and supports future validation through objective indicators such as market share, revenue growth, and customer churn.

3.2 Relationships and Structural Effects Among the Study Variables

3.2.1 Association of the Strategic Capabilities and Mediators with Firm Competitiveness

Spearman correlation analysis revealed positive and statistically significant, although modest, associations between firm competitiveness and all five other constructs. Operational efficiency had the strongest correlation with competitiveness ($\rho = 0.184$, $p < 0.001$), followed by customer retention ($\rho= 0.171$, $p < 0.001$), e-commerce capability ($\rho = 0.145$, $p < 0.001$), smart technology ($\rho = 0.138$, $p < 0.001$), and green logistics ($\rho = 0.129$, $p < 0.001$). These coefficients represent bivariate associations and do not establish independent structural effects because they do not simultaneously control for the other constructs. The strong relative position of operational efficiency supports its importance to logistics competitiveness. Customer retention likewise reinforces the role of reliable service, prompt delivery, and effective problem resolution in sustaining customer relationships (Jin & Park, 2022; Lee & Wong, 2023; Liu & Wang, 2023). E-commerce capability reflects the importance of digital systems in responding to market requirements (Perez & Roxas, 2023; Department of Trade and Industry, 2024), while smart technology and green logistics also show positive relationships with competitiveness through operational transparency, efficiency, sustainability, and reputation (Tan & Goh, 2023; Agyabeng-Mensah et al., 2020; Zhang & Zhao, 2022). These combined relationships are consistent with the resource-based interpretation of competitive advantage (Barney, 1991; Teece, 2018) and with the growing importance of integrated digital and sustainable logistics strategies (ADB, 2022; United Nations Conference on Trade and Development, 2024; World Bank, 2023). The significant correlations are not inconsistent with later non-significant direct PLS-SEM paths because structural coefficients represent unique relationships after the other predictors and mediating mechanisms are considered simultaneously.

3.2.2 Direct Structural Effects

The structural model showed that operational efficiency had the strongest significant direct effect on firm competitiveness ($\beta = 0.5235$, $t = 6.243$, $p < 0.001$). Customer retention also significantly predicted competitiveness ($\beta = 0.1722$, $t = 2.661$, $p = 0.008$) and operational efficiency ($\beta = 0.3223$, $t = 7.020$, $p < 0.001$). Smart technologies ($\beta = 0.2626$, $t = 5.932$, $p < 0.001$), e-commerce capabilities ($\beta = 0.2372$, $t = 5.309$, $p < 0.001$), and green logistics practices ($\beta = 0.1574$, $t = 3.657$, $p = 0.0003$) significantly predicted customer retention. In contrast, e-commerce capabilities did not significantly predict firm competitiveness directly ($\beta = 0.0198$, $t = 0.632$, $p = 0.527$), and neither did green logistics ($\beta = -0.0570$, $t = 1.689$, $p = 0.091$). The direct effect of smart technologies on competitiveness was positive but remained at borderline significance ($\beta = 0.0722$, $t = 1.926$, $p = 0.054$). The dominant direct effect of operational efficiency supports previous findings identifying quality, reliability, responsiveness, and effective logistics execution as immediate sources of competitive performance (Fernandez & Kim, 2023; Bui & Vo, 2022). This interpretation is further supported by studies identifying supply-chain execution as a proximate competitive capability (Li et al., 2006; Gunasekaran, Subramanian, & Papadopoulos, 2017; Huang, Singh, & Ghobadian, 2020) and by the view that advantage depends on how efficiently organizational activities are performed (Porter, 1985). The significant effects involving customer retention suggest that loyalty is connected with operational, technological, and sustainable strategies rather than functioning independently (Jin & Park, 2022; Lee & Wong, 2023; Liu & Wang, 2023; Agyabeng-Mensah et al., 2020). The non-significant direct effects of green logistics and e-commerce capability and the borderline direct effect of smart technology imply that these upstream capabilities may contribute primarily through operational and relational mechanisms (Fernandez & Kim, 2023; Tan & Goh, 2023). This is consistent with the resource-based perspective that value emerges from effectively integrated combinations of resources (Barney, 1991; Teece, 2018) and supports integrated technological, sustainability, and customer strategies in Philippine logistics (Asian Development Bank [ADB], 2022; United Nations Conference on Trade and Development [UNCTAD], 2024; World Bank, 2023).

3.2.3 Mediating Effects of Customer Retention and Operational Efficiency

The mediation analysis identified significant indirect pathways connecting the strategic capabilities with firm competitiveness. E-commerce capability indirectly influenced competitiveness through customer retention ($\beta = 0.0409$, $t = 2.418$, $p = 0.016$). Smart logistics technologies showed a significant indirect effect through operational efficiency and firm competitiveness ($\beta = 0.1135$, $t = 3.651$, $p = 0.0003$), and a significant sequential indirect effect through customer retention and operational efficiency ($\beta = 0.0443$, $t = 3.679$, $p = 0.0002$). Green logistics also demonstrated significant pathways through customer retention ($\beta = 0.0271$, $t = 2.150$, $p = 0.032$) and through customer retention and operational efficiency ($\beta = 0.0266$, $t = 2.754$, $p = 0.006$). E-commerce capability additionally demonstrated a sequential indirect effect through customer retention and operational efficiency ($\beta = 0.0400$, $t = 3.355$, $p = 0.001$). These results indicate that customer retention and operational efficiency function as important conversion mechanisms between organizational capabilities and competitiveness. The e-commerce pathway supports literature linking digital logistics service quality with customer loyalty (Hwang & Lee, 2021; Jin & Park, 2022; Perez & Roxas, 2023). Smart logistics appears to generate competitive value when technological resources improve operational performance and customer outcomes, consistent with Fernandez and Kim (2023), Tan and Goh (2023), and Liu and Wang (2023). This supports the Resource-Based View, in which competitive value depends on how effectively organizational resources are developed and utilized (Barney, 1991; Teece, 2018). For green logistics, the significant indirect effects are consistent with research linking sustainable logistics practices with operational and financial outcomes (Agyabeng-Mensah et al., 2020; Santos & Manalili, 2022; Zhang & Zhao, 2022; Nasiri & Choudhary, 2021). Its lack of a significant direct effect may reflect sustainability adoption driven partly by regulation, institutional pressure, or customer requirements rather than direct competitive positioning (Wu, Dunn, & Forman, 2011; Lin, Ho, & Chiang, 2013; Abbasi & Nilsson, 2016). When green practices are integrated into routing, packaging, energy management, and customer communication, their operational and relational value becomes more evident (Lai & Wong, 2012; Agyabeng-Mensah et al., 2020). Similarly, the sequential e-commerce pathway supports research connecting digital and service improvements with better logistics performance (Bui & Vo, 2022; Perez & Roxas, 2023). Overall, the mediation results indicate that sustainable and technological capabilities become competitively valuable when translated into operational efficiency and customer loyalty, consistent with a dynamic capability perspective (Teece, 2018; ADB, 2024; World Bank, 2023).

3.3 Explanatory Power and Relative Effects of the Structural Model

3.3.1 Variance Explained by the Model

The structural model explained 29.8% of the variance in customer retention ($R^2 = 0.298$; adjusted $R^2 = 0.294$), 36.6% of the variance in operational efficiency ($R^2 = 0.366$; adjusted $R^2 = 0.362$), and 40.7% of the variance in perceived firm competitiveness ($R^2 = 0.407$; adjusted $R^2 = 0.402$). These values indicate meaningful to moderate explanatory power while also showing that substantial variance remains attributable to organizational, market, and contextual factors outside the model. The findings suggest that the combined digital, technological, sustainability, operational, and relational constructs explain an important portion of organizational outcomes, but the R^2 values should not be interpreted as evidence that every individual path is strong or significant. The results are consistent with regional assessments emphasizing digital transformation, operational efficiency, and sustainable logistics as contributors to organizational performance and supply-chain resilience (Asian Development Bank [ADB], 2022; ADB, 2024; World Bank, 2023).

3.3.2 Effect Sizes of Predictors

Operational efficiency produced the largest effect size for firm competitiveness ($f^2 = 0.2931$). Customer retention contributed to operational efficiency ($f^2 = 0.1150$) and had a smaller effect on firm competitiveness ($f^2 = 0.0315$). E-commerce capability showed effects of $f^2 = 0.0500$ on customer retention and $f^2 = 0.0200$ on operational efficiency. Smart logistics technologies showed $f^2 = 0.0610$ for customer retention and $f^2 = 0.0434$ for operational efficiency, while green logistics produced smaller effects across the tested paths ($f^2 \leq 0.0242$). The results reinforce operational efficiency as the most consequential immediate predictor of competitiveness in the estimated model. Smart technologies contribute to customer and operational outcomes through automation, tracking, and technology-enabled service processes (Fernandez & Kim, 2023; Tan & Goh, 2023), whereas the smaller effect sizes of green logistics may reflect its developing stage of adoption and infrastructure constraints in the Philippine setting (Santos & Manalili, 2022; Agyabeng-Mensah et al., 2020; Zhang & Zhao, 2022). Digital and technological capabilities therefore appear to contribute substantially through customer retention and operational efficiency rather than as isolated drivers of competitiveness (Liu & Wang, 2023; Perez & Roxas, 2023). This pattern is consistent with the growing emphasis on process optimization and digital transformation in Philippine logistics (Asian Development Bank [ADB], 2022; World Bank, 2023; ADB, 2024).

3.4 Measurement Model Reliability, Validity, and Structural Model Fit

3.4.1 Construct Reliability and Convergent Validity

All constructs obtained Cronbach's alpha values above 0.70, with customer retention ($\alpha = 0.9422$) and operational efficiency ($\alpha = 0.9367$) showing particularly high internal consistency. Composite reliability values also exceeded the conventional 0.70 criterion. Average Variance Extracted exceeded 0.50 for customer retention (0.6579), operational efficiency (0.6372), smart technologies (0.5982), e-commerce capabilities (0.5688), and firm competitiveness (0.5147). Green logistics obtained an AVE of 0.4489, slightly below the recommended threshold. The reliability coefficients indicate adequate internal consistency, consistent with established measurement-model criteria (Hair, Hult, Ringle, & Sarstedt, 2021). The composite reliability results further indicate that the indicators consistently represented their intended constructs, as discussed by Hair et al. (2021) and Teece (2018). The comparatively lower AVE of green logistics was interpreted within the manuscript in relation to variations in sustainability adoption among Philippine firms (Santos & Manalili, 2022; Agyabeng-Mensah, et al., 2020; Zhang & Zhao, 2022). The stronger reliability and convergent-validity results for customer retention, operational efficiency, and smart technologies are consistent with their importance in logistics digitalization and organizational performance (Fernandez & Kim, 2023; Tan & Goh, 2023; Bui & Vo, 2022). Differences in sustainability implementation may also reflect infrastructure, policy, and resource constraints (Santos & Manalili, 2022; Department of Environment and Natural Resources [DENR], 2023; ADB, 2024). Overall, the measurement results provide support for examining structural and mediating relationships among the constructs (World Bank, 2023; Asian Development Bank [ADB], 2022; Liu & Wang, 2023).

3.4.2 Discriminant Validity

The HTMT analysis supported discriminant validity because all ratios were below 0.85. The largest HTMT value was observed between operational efficiency and firm competitiveness at 0.6659. Smart technologies showed HTMT values of 0.6106 with e-commerce capability and 0.5204 with operational efficiency, while operational efficiency and customer retention had a value of 0.5535. Green logistics showed values of 0.5553 with e-commerce capability and 0.5584 with smart technologies. The Fornell-Larcker assessment similarly supported discriminant validity because the square root of each construct's AVE exceeded its correlations with other constructs. Customer retention had an AVE square root of 0.8111, e-commerce capability 0.7542, smart technologies 0.7734, operational efficiency 0.7983, and green logistics 0.6700. These results indicate that the constructs are empirically related but sufficiently distinct. The HTMT findings meet the criterion discussed by Hair, Hult, Ringle, & Sarstedt (2021). Moderate relationships involving smart technology, e-commerce capability, and operational efficiency are consistent with their complementary roles in digital logistics (Fernandez & Kim, 2023; Tan & Goh, 2023), while the relationship between operational efficiency and customer retention is consistent with literature linking logistics performance with loyalty (Jin & Park, 2022; Lee & Wong, 2023). Green logistics remains conceptually distinct despite its increasing integration with digital technologies (Santos & Manalili, 2022; AgyabengMensah, et al., 2020; Zhang & Zhao, 2022), supporting the complementary use of sustainability and digital capabilities (Nasiri & Choudhary, 2021; ADB, 2024). Overall, the HTMT findings allow the constructs to be examined separately in the structural model (World Bank, 2023; Liu & Wang, 2023; Perez & Roxas, 2023). The Fornell-Larcker results further support this interpretation (Hair, et al., 2021). Customer retention remained distinct from e-commerce capability and operational efficiency despite their relationships, consistent with prior customer-loyalty research (Jin & Park, 2022; Lee & Wong, 2023; Liu & Wang, 2023). E-commerce capability also remained distinct from green logistics and operational efficiency (Bui & Vo, 2022; Perez & Roxas, 2023; DTI, 2024), while smart technology and operational efficiency retained discriminant validity (Fernandez & Kim, 2023; Tan & Goh, 2023). Green logistics likewise remained a separate capability despite its relationship with digital practices (Agyabeng-Mensah, et al., 2020; Santos & Manalili, 2022; Zhang & Zhao, 2022). Together, the HTMT and Fornell-Larcker results support differentiation among the study constructs (World Bank, 2023; ADB, 2022, 2024).

3.4.3 Structural Model Fit

The structural model produced an SRMR of 0.0403, below the 0.08 criterion. The reported d_ULS and d_G values were 2.8717 and 1.0660, respectively, while the chi-square value was 3386.4976. The NFI was 0.8491, approaching the commonly referenced 0.90 threshold. These indicators were interpreted in the manuscript as supporting the adequacy of the structural model. The SRMR value indicates a small discrepancy between observed and predicted relationships, consistent with the model-fit criterion discussed by Hair, et al. (2021), while the NFI was interpreted as approaching acceptable fit (Hair et al., 2021). The model therefore provides an empirical basis for examining relationships among e-commerce capability, smart technologies, green logistics, operational efficiency, customer retention, and competitiveness. These relationships correspond with previous research on digital logistics and operational innovation (Bui & Vo, 2022; Fernandez & Kim, 2023; Perez & Roxas, 2023) and with the resource-based perspective that organizational capabilities can support competitive advantage (Barney, 1991; Teece, 2018; Agyabeng-Mensah, et al., 2020). Investments in digital infrastructure, automation, and sustainability may therefore contribute to operational and customer outcomes (Tan & Goh, 2023; Santos & Manalili, 2022; World Bank, 2023; ADB, 2022), consistent with Philippine initiatives promoting digital transformation and sustainable logistics (DTI, 2024; NEDA, 2023; ADB, 2024). Overall, the model-fit results support the use of the proposed framework for examining how digital, operational, relational, and environmental capabilities contribute to competitiveness within the Philippine logistics and e-commerce sector.

4. Conclusion & Recommendations

The study concluded that participating Philippine logistics and e-commerce firms generally demonstrated high levels of green logistics adoption, smart logistics technology utilization, operational efficiency, customer retention, and firm competitiveness, while e-commerce capability showed comparatively moderate digital integration. Although all study variables were significantly associated with firm competitiveness at the bivariate level, green logistics, e-commerce capability, and smart logistics technologies did not have statistically significant direct effects on competitiveness in the structural model. Instead, their competitive contributions were primarily realized through customer retention and operational efficiency. Green logistics significantly influenced customer retention, while smart logistics technologies and e-commerce capability significantly influenced both customer retention and operational efficiency. Customer retention significantly influenced operational efficiency and firm competitiveness, while operational efficiency emerged as the strongest immediate predictor of competitiveness. Overall, the findings support the proposed serial mediation model, indicating that strategic sustainability, digital, and technological capabilities contribute to competitiveness when they are effectively converted into stronger customer relationships and operational performance.

Logistics and e-commerce firms should prioritize operational efficiency by strengthening process reliability, inventory accuracy, warehouse productivity, transportation scheduling, order fulfillment, delivery performance, cost control, and continuous improvement, while treating customer retention as a core mechanism through improved service reliability, transparency, communication, and problem resolution. Green logistics initiatives should be maintained and evaluated according to measurable sustainability, customer, and operational outcomes, while e-commerce systems should be better integrated with customer relationship management, inventory, warehousing, payment, tracking, and fulfillment processes. Smart logistics technologies should be adopted strategically according to identified operational and customer-service needs and supported by employee capability development, process improvement, data governance, and performance measurement. Government agencies may support affordable digital infrastructure, workforce development, sustainable logistics, financing, and phased modernization, particularly for resource-constrained firms, while higher education institutions may strengthen instruction and industry collaboration in digital logistics, artificial intelligence, sustainability, Industry 4.0, and business analytics. Future studies should further validate the model using longitudinal, panel, experimental, comparative, or other research designs and examine additional organizational and contextual factors that may influence competitiveness.

The study is limited by its cross-sectional design, which captures organizational conditions at a single point in time and therefore does not establish definitive temporal or causal relationships among the variables. Its findings are also based largely on respondents' perceptions of their organizations, particularly regarding competitiveness, and should therefore not be interpreted as objective measures of organizational performance. Moreover, the model explained only part of the variance in customer retention, operational efficiency, and firm competitiveness, indicating that other organizational, market, and contextual factors not included in the study may also contribute to these outcomes.

5. Compliance with ethical standards

The study was conducted in accordance with established ethical principles governing voluntary participation, informed consent, confidentiality, data privacy, and responsible research practice. Appropriate measures were observed to protect respondents' identities, secure collected data, minimize potential risks, and ensure that participation remained voluntary throughout the research process. The study also adhered to the ethical standards and institutional requirements applicable to the conduct of the research.

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