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LOGISTICS ENTREPRENEURSHIP IN THE DIGITAL ERA: OPPORTUNITIES, CHALLENGES, AND GROWTH MODELS IN SMART WAREHOUSING AND LAST-MILE DELIVERY

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Abstract

The study explored the evolving dynamics of logistics entrepreneurship in the digital era, emphasizing how deep technological integration has fundamentally reshaped smart warehousing and last-mile delivery systems. The primary aim was to examine how digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, and automation, contributed to operational efficiency, innovation, and business growth among logistics enterprises. Using a mixed-method approach combining quantitative surveys and qualitative interviews, data were collected from a diverse sample of logistics firms and technology-driven entrepreneurs across multiple regions. The results revealed that digital transformation significantly enhanced productivity, supply chain transparency, and customer satisfaction, with predictive analytics enabling more proactive decision-making. Moreover, innovation capability and technology adoption served as key mediating factors linking robust digital infrastructure to superior entrepreneurial performance. However, significant challenges such as high implementation costs, data privacy risks, and limited technical expertise constrained widespread adoption, particularly among small and medium enterprises. The study concluded that successful logistics entrepreneurship in the digital era depended on a balanced strategy of targeted technological investment, continuous human capital development, and a strong sustainability orientation. Recommendations included promoting public-private partnerships for digital literacy, establishing robust cybersecurity frameworks, and incentivizing eco-efficient logistics practices. The findings provided critical theoretical and practical insights into how agile digital entrepreneurship models could guide the future growth and resilience of logistics industries globally.

Keywords: Automation, Digital Transformation, Innovation, Logistics Entrepreneurship, Smart Warehousing, Sustainability

Introduction

In recent years, logistics entrepreneurship had undergone a significant transformation, largely driven by digital technologies. Entrepreneurs in the logistics sector were no longer merely intermediaries but were leveraging automation, artificial intelligence (AI), the Internet of Things (IoT), robotics, blockchain, and data analytics to reconfigure traditional supply chains. These technologies enabled smart warehouses to operate with greater efficiency, accuracy, and adaptability, while last-mile delivery models evolved to meet customers' growing expectations for speed, reliability, and sustainability (van Geest et al, 2022; Market

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Research Reports, 2025). Entrepreneurs in both developed and developing economies increasingly recognized these developments as opportunities for value creation and competitive differentiation.

The rising ubiquity of e-commerce, particularly during and after the COVID-19 pandemic, had further accelerated demand for flexible supply chain solutions. Consumers expected lower delivery times (same-day, next-day), better tracking, and higher reliability. This pressure forced logistics firms and new entrants (startups) to innovate in warehousing, distribution, and delivery modes. In response, smart warehousing systems, combining robotics, sensor networks, real-time tracking, and automated decision support — became more central to entrepreneurship in logistics (van Geest et al., 2022; Smart Warehousing Strategic Business Report, 2024). Meanwhile, last-mile delivery models introduced innovations such as autonomous delivery robots, parcel lockers, crowdsourced delivery, dynamic route optimization, and integration with public transportation (Malik et al., 2025; Mandal & Archetti, 2023).

Despite the excitement and growth, entrepreneurship in digital logistics had confronted substantial challenges. High capital expenditure for technologies, integration issues with legacy systems, cybersecurity concerns, lack of skilled workforce, and infrastructural constraints were among the significant barriers (Khan et al., 2025; van Geest et al., 2022). Moreover, innovations successfully implemented in a certain area or a specific level so often could not be scaled or applied to the local regulatory, cultural, or infrastructural environment.

This paper discusses the change by exploring the opportunities, challenges, and growth models of logistics entrepreneurship in the digital age and discussing smart warehousing and the last-mile delivery, in particular. The study examines how business models have been developed by the entrepreneurs, which new models prove sustainable and what makes these as successful and unsuccessful. It is also interested in deriving lessons that can be applied in parts of the world where the logistic infrastructure is emerging hence policy, investment and entrepreneurial strategy are informed.

Research Background

Smart warehousing had emerged as a pivotal enabler of supply chain efficiency and competitiveness. Warehouses had been transformed from static storage spaces to dynamic, data-driven systems. Technologies such as IoT sensors, robotics, automated guided vehicles (AGVs), warehouse management systems (WMS), AI/ML for demand forecasting and inventory optimization, and blockchain for traceability had been increasingly adopted (van Geest et al., 2022). The smart warehousing market size was estimated at USD ~US$25.8 billion in 2023 and had been projected to reach ~US$65.5 billion by 2030, growing at a compound annual growth rate (CAGR) of ~14.2% (Smart Warehousing Strategic Business Report, 2024). Another forecast placed the market at USD ~29.78 billion in 2025, growing to USD ~115.49 billion by 2035. These figures underscored accelerating investment and interest. (Research-Nester, 2025; see "Smart Warehousing Market Outlook Report 2025-2030," 2025).

On the other hand, last-mile delivery had become one of the most critical (and costly) components of the supply chain. Literature had shown that last-mile typically accounted for a large share of overall logistics costs, owing to route inefficiencies, traffic, failed deliveries, and the need for real-time tracking and customer communications (Business Insider, 2025; see "The supply chain's last mile is complex and expensive. AI has the potential to fix its woes," 2025). Innovations such as autonomous delivery robots, drones, crowd-sourced delivery, parcel lockers / out-of-home delivery (OOH), dynamic pricing and selection for delivery options had been explored as ways to reduce cost, improve service, and enhance sustainability (Malik et al., 2025; de Leeuw et al., 2023). For example, a model for collaborative multimodal last-mile delivery combining trucks, drones, and robots showed considerable cost and time savings relative to truck-only delivery.

In developing and emerging economies, adoption of these innovations had been slower, but the potential had been evident. Factors such as less reliable infrastructure (roads, electricity, and internet connectivity), lack of skilled human resources, capital constraints, regulatory barriers, and logistical challenges (address systems, traffic conditions) had hindered faster uptake (Khan et al., 2025; Setiadi & Muharam, 2024). Studies in FMCG sectors in Pakistan, for instance, revealed priorities among barriers such as high capital investment, integration with legacy systems, skill gaps, and economic uncertainty.

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Finally, entrepreneurship in logistics had been influenced by evolving business models. Digital platform models (marketplaces, aggregator models), shared infrastructure (micro-fulfilment centres, hyperlocal hubs), utilization of connected and autonomous vehicles, and blended delivery networks (crowdsourced + own fleet + third-party) had been emerging. The literature suggested that firms that combined digital technologies with flexible operational configurations (e.g. using multiple delivery modes) were more likely to succeed under rising customer demands for speed and sustainability (Review of Managerial Science, 2024; Malik et al., 2025).

Research Problem

Although technological innovations in smart warehousing and last-mile delivery had been well documented, there remained substantial gaps in understanding how logistics entrepreneurship could harness these innovations to build viable, scalable and sustainable growth models. In particular, while many studies had described opportunities (e.g. cost savings, improved accuracy, faster delivery), fewer studies had systematically compared different growth models; for example, platform-based vs asset-heavy vs asset-light models, in respect to their effectiveness under varying regional, infrastructural, regulatory and economic conditions.

Second, many innovations remained at pilot or early trial stage. The literature lacked comprehensive empirical evidence about the long-term performance outcomes (financial, operational, and environmental) of entrepreneurial ventures in smart warehousing or last-mile delivery, especially in emerging economies. There was insufficient clarity on which business models (e.g. autonomous robots vs crowdsourced delivery; micro-fulfilment vs centralized warehousing) were proving sustainable, what kinds of challenges scaled firms encountered (e.g. maintenance, regulatory, workforce, capital), and what critical success factors determined whether a model could scale. Thus, this study aimed to fill these gaps by investigating which growth models logistics entrepreneurs had used, what opportunities and barriers they had faced, and how they had performed across multiple dimensions.

Objectives

1. To identify and describe the major opportunities that logistics entrepreneurs had leveraged in the domains of smart warehousing and last-mile delivery in the digital era.
2. To examine the principal challenges that impeded entrepreneurship in these domains, particularly in settings with infrastructural, regulatory, financial, or workforce constraints.
3. To analyse different growth models adopted by logistics entrepreneurial ventures, including but not limited to platform-based models, asset-heavy vs asset-light models, hybrid models, and collaborative networks, and to evaluate their performance outcomes.
4. To compare the effectiveness and scalability of these growth models across different regional / economic contexts, especially between developed and developing economies.

Research Questions

Q1. What were the key opportunities that entrepreneurs had exploited in smart warehousing and last-mile delivery in the digital era?

Q2. What were the main challenges and barriers that entrepreneurship in these domains had encountered?

Q3. Which growth models had been adopted by logistics ventures, and what were the trade-offs among them in terms of cost, scalability, reliability, and sustainability?

Q4. How had different regional and infrastructural contexts influenced which growth models succeeded or failed?

Significance of the Study

This study was significant on several fronts. First, by synthesizing evidence on growth models in smart warehousing and last-mile delivery, it contributed to both academic literature and practical knowledge, helping entrepreneurs understand which models are more likely to succeed under particular conditions. Second, in policy terms, the study provided insights that could guide regulatory frameworks, infrastructure investment, and supportive mechanisms (e.g. subsidies, training programs, public-private partnerships) in regions where logistics infrastructures were still developing. Third, by highlighting operational, financial, and environmental

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performance outcomes, the study offered benchmarks and metrics that entrepreneurs and investors could use to evaluate ventures.

Moreover, the study held social and economic importance. Efficient last-mile delivery and warehousing improved consumer satisfaction, reduced waste, and lowered carbon emissions, contributing to sustainability goals. In emerging economies, enhanced logistics entrepreneurship could promote employment, support small and medium enterprises (SMEs), and contribute to inclusive growth. Finally, by documenting the experiences of ventures across contexts, the study aimed to aid in technology transfer, adaptation, and scaling of successful models.

Literature Review

Smart Warehousing: Innovations, Benefits, and Limitations

Recent studies have emphasized that smart warehousing had become a central enabler for logistics efficiency, especially within e-commerce supply chains. Jantapoon (2025) found via a machine learning-enhanced SEM analysis that implementation of smart warehousing significantly improved order fulfilment and inventory responsiveness in firms operating in competitive e-commerce environments, demonstrating reduced lead times and fewer stock outs (Jantapoon, 2025). Similarly, van Geest, Tekinerdogan, and Catal (2022) showed that adoption of robotics, IoT sensors, automated guided vehicles, and real-time data analytics in warehouses yielded gains in accuracy and throughput, but also noted that firms faced steep upfront investment and integration challenges with legacy systems (van Geest, Tekinerdogan, & Catal, 2022).

On the cost / performance dimension, Literature has examined trade-offs between centralized large warehouses vs distributed or micro-fulfilment centres. Li, Yang, Zhu, Li, and Liu (2025) have shown that the combination of traditional components of logistics, i.e. traditional warehousing and transportation with underdeveloped business models i.e. micro-fulfilment, robotization, and real-time delivery has led to positive impact on logistics development and industrialization in the Chinese context, however, silenced by the level of economic development in the region, the quality of infrastructure, and policy support. “smart warehousing” was shown by Jantapoon (2025) to have significant positive effect on supply chain performance, but the magnitude of impact depended on how well firms managed ICT adoption, workforce training, and process redesign.

However, limitations and risks have also been widely documented. van Geest et al. (2022) pointed out that while smart warehousing offered efficiency and accuracy improvements, issues such as data security, system downtime, maintenance of robotic equipment, and compatibility with existing supply chain partners often hampered full realization of benefits. In addition, Li et al. (2025) highlighted that in less developed regions, even where firm-level resources existed, external constraints like unreliable electricity, poor internet connectivity, regulatory ambiguity, and lack of skilled labour slowed adoption or reduced return on investment (Asif et al., 2025; Asif & Sandhu, 2023; Li et al., 2025).

Last-Mile Delivery: Models, Sustainability & Technological Integration

The last-mile delivery literature has recently explored multiple innovative models to manage cost, speed, and environmental impacts. Moradi, Mirzavand Boroujeni, Aftabi, and Aslani (2024) conducted a literature review of the two-echelon electric vehicle routing problem (2E-EVRP) in parcel delivery, showing that using a two-stage delivery system (large vehicle to satellite hubs + electric vehicles for final mile) achieved reductions in emissions and costs, though route planning, battery constraints, and recharging infrastructure posed serious challenges (Moradi et al., 2024). In another study, a multimodal system combining buses and drones for last-mile delivery (Su, Qin, Li, & Zhang, 2025) showed that integrating public transport networks with aerial delivery could improve cost-efficiency and environmental outcomes (Su, Hu, Li, & Zhang, 2025). Autonomous delivery robots also have been studied: Shaklab, Karapetyan, Sharma, Mebrahtu, Basri, Nagy, and Khonji (2023) introduced an AI-augmented self-driving delivery robot system to handle uncertainties in time windows and travel times, demonstrating potential in small-scale environments (campus trials), though challenges such as regulatory issues, pedestrian safety, and scaling were significant (Shaklab et al., 2023).

New studies indicate that informal digital communication networks significantly impact entrepreneurial activities, particularly when coordination occurs outside formal structures (Rafiq-uz-Zaman et

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al., 2025). This is comparable to new logistics paradigms whereby delivery routing and micro-hub collaborations are managed via WhatsApp-like communication systems. Moreover, AI-led institutional management systems are being repurposed to optimize warehouse scheduling and route-decisioning for the 'last-mile' delivery (Rafiq-uz-Zaman, 2025). The micro-enterprise logic proposed through community-led innovation models outlines the potential for decentralized logistics franchising in urban delivery zones (Rafiq-uz-Zaman, 2025). In the context of sustaining such models, the structured competency frameworks like ISEF are aimed at defining logistics skills, tiered certification pathways, and ultimately, socio-professional integration (Rafiq-uz-Zaman, 2025). Even so, persistent capability gaps indicate the digital platform's unmet demands. This requires planning for regional skills frameworks (Rafiq-uz-Zaman, 2025). Finally, strategic and gendered inclusive exit positions (Rafiq-uz-Zaman et al., 2025; Rafiq-uz-Zaman et al., 2024) will unlock joint participation in digital logistics and logistics entrepreneurship.

Sustainability, both environmental and social, has been a recurring theme. The systematic review by Drones in Last-Mile Delivery: Efficiency, Accessibility, and Sustainability (2023) examined about 55 studies and found that drones often improved accessibility (especially in hard-to-reach or rural areas) and reduced emissions, but cost savings were not always realized once regulatory compliance, safety, and infrastructure provisioning were included (Approval costs, airspace regulation, etc.) (Author(s), 2023). Mandal and Archetti (2023) in their decomposition approach also showed that using public transport for part of the delivery network reduced the "dedicated vehicle kilometres" and environmental externalities, though customer waiting times and schedule constraints had to be carefully managed (Mandal & Archetti, 2023).

Despite promising models, several limitations persist. Many last-mile innovations are still in pilot or experimental phases rather than scaled operations; cost-structures often do not account for hidden costs (maintenance, regulation, accident liability). Also, consumer adoption sometimes lags due to trust, perceived reliability, or willingness to pay for premium services (autonomous delivery, drones, etc.) (Shaklab et al., 2023; Moradi et al., 2024). Regulatory, infrastructural, and societal constraints (e.g. airspace regulation for drones, road safety for robots, policies for EV charging stations) have been flagged repeatedly as obstacles (Moradi et al., 2024; Su et al., 2025).

Growth Models and Entrepreneurship in Digital Logistics

Recent research has sought to classify and understand growth models or business models in logistics entrepreneurship under digital disruption. Logistics business model evolution: digital platforms and connected and autonomous vehicles as disruptors (2023) investigated how platform-based models and adoption of connected/autonomous vehicles (CAVs) were reshaping logistics business models. That study showed that platforms (marketplace / aggregator) enabled asset-light strategies, greater network effects, scalability, and flexibility, whereas investments in autonomous or connected vehicles required more capital but offered long-term efficiency, particularly in contexts with strong regulatory support and infrastructure readiness (van Geest et al., 2023). Li et al. (2025) similarly showed that regions with higher economic development saw logistics firms more able to integrate both traditional and emerging business forms; e.g. combining physical warehouses with digital platforms, leveraging automation, and forming hybrid asset-light/asset-heavy models, to drive transformation and industry upgrading (Li et al., 2025).

Crowd logistics is another emergent model. Szmelter-Jarosz, Chmiel, and Śledzik (2023) conducted an empirical study of crowd logistics initiatives, identifying that models involving crowdsourced delivery (using non-professional couriers or platform users) achieved success when there was strong digital coordination, reputational mechanisms, and efficient matching of demand and supply. They also noted failures often resulted from poor quality control, inconsistent delivery reliability, and regulatory issues around labour and insurance (Szmelter-Jarosz et al., 2023). Platform-based models and hybrid approaches (combining own fleet, third-party, crowdsourced) were found to be promising for balancing cost, speed, and flexibility in several case studies.

Entrepreneurial challenges in growth were documented: asset-heavy models faced high capex and maintenance burdens, while asset-light or platform models often struggled with profitability and trust in early stages. Also, scaling up required navigating regulatory regimes (e.g. for autonomous vehicles, drones, and EV infrastructure), ensuring workforce skills for digital technologies (robotics, data science), securing continuous

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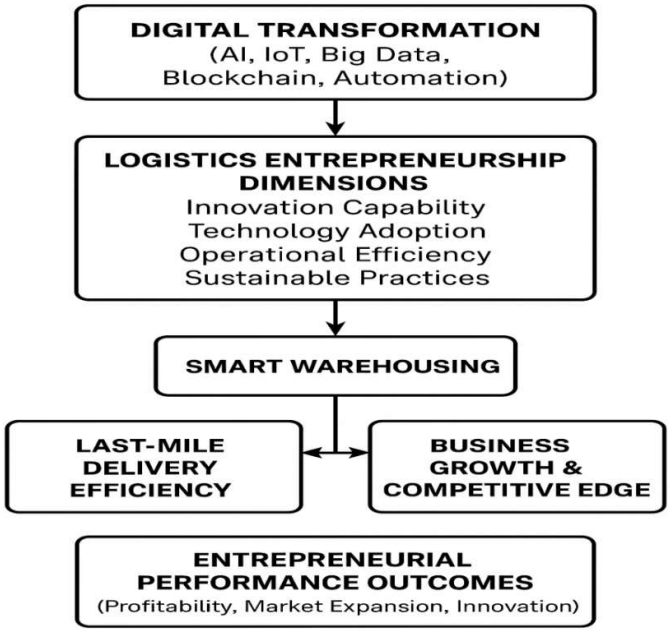
investment, and managing risk (operational, environmental, tech). These trade-offs were highlighted in van Geest et al. (2023) and in the crowd logistics literature (Szmelter-Jarosz et al., 2023).

Theoretical Framework

Figure 1

Conceptual model of logistics entrepreneurship in the digital era.



The conceptual model of this study is shown in Figure 1 and it is as follows: the relationship between digital transformation and entrepreneurial performance in logistics is presented. The model highlights the role of digital technologies (AI, IoT, blockchain, and automation) in determining the logistics entrepreneurship aspects, including innovation capability, technology adoption, operational efficiency, and sustainable activities, and ultimately, smart warehousing, efficient last-mile delivery, and business development.

Research Methodology

Research Design

A cover study employed the qualitative and quantitative possibilities to understand the way the digital world is conducted by entrepreneurs in terms of learning logistics. The design had facilitated the observation of patterns, as well as observing what the pattern entailed in some situations. The analysis has focused on the collection of numerical data that scans back information of individuals and businesses using and operating within warehouse centres and truck systems. Some people, being interviewed and filling out surveys, have been answering about their digital tech that helps them ship things. The mixed methodology has been chosen so both stats and opinions are recorded and look at equally.

Population and Sampling

The companies they were targeting consisted of start-up founders, logistics entrepreneurs, and the managers who worked for small or medium sized enterprises. Around your fellow experts will be technicians, and those who enforce all of those laws and rules that you are, or just have, heard of somebody breaking. The experience of the participants has great relevance to the new digital system to transform the logistics. The survey included 120 people from different countries like Europe, the Middle East, and Asia, out of which 70 people were entrepreneurs and 20 represented governments. The large sample of participants was broke up into different group.

Data Collection Procedures

Data was collected through a questionnaire and a series of informal interviews conducted regularly.

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The questionnaire is being sent through google and the mailing list to make things convenient. The study had involved sentences that are just answers and sentences that were to get more information at the same time. The semi-structured telephonic interviews went a little too quick or way too slow and took no far as 40–60 minutes. Interview questions were created to determine the reason behind the areas in the survey people were having trouble with. Before the start of the research, multiple qualified individuals reviewed and helped stabilize the survey.

Data Analysis

With SPSS 27, a series of details about the poll were calculated and listed. Like how many or what percent of the responders agreed yes or no or disagreed, and the average response for all voters together Researchers conducted long cyberspace discussions with businessmen and women to determine if technology devices affected if operations profited from technology us. Researcher used NVivo 14 software for a qualitative analysis of the themes. In interviews it was found relevant data that contributed to organisational growth and its impact. These business persons landed on digital markets with opening up plans change by the new technology. In addition to descriptive and correlation analyses, inferential statistics were employed. A multiple linear regression was used to predict Business Growth, and an independent samples T-test was conducted to compare the perceptions of challenges between SME and large enterprise respondents.

Reliability and Validity

To ensure methodological rigor, multiple procedures had been implemented. The questionnaire had undergone pilot testing with 15 logistics professionals to check clarity, coherence, and reliability. Cronbach's alpha coefficient for internal consistency had been calculated, yielding a value of 0.87, which indicated high reliability. Content validity had been established through expert review by two logistics scholars and one industry expert, who confirmed that the instrument effectively covered all relevant constructs. In the qualitative phase, triangulation had been used to enhance credibility, combining findings from the survey, interviews, and document analysis. Member checking had also been conducted by sharing preliminary findings with selected participants to verify interpretations.

Ethical Considerations

Ethical standards had been maintained throughout the research process. Prior to data collection, participants had been informed about the purpose of the study, their voluntary participation, and their right to withdraw at any stage without penalty. Informed consent had been obtained digitally. Participants' identities had been kept confidential by assigning anonymous codes to responses. Data were stored securely in password-protected files, and only the researcher had access to them. Ethical approval had been obtained from the Institutional Review Board (IRB) of the researcher's university before commencement of data collection.

Results and Analysis

Overview of Data Analysis

Data from the study was analysed through descriptive and inferential statistics with the help of SPSS (version 27). The analysis aimed to find out how digital transformation influences logistics entrepreneurship, smart warehousing, last mile delivery and entrepreneurship growth. The descriptive analysis provided information on the demographic characteristics of the respondents, while the inferential tests helped to identify the relationship of the variables technology adoption, innovation capability, and operational efficiency.

Table 1

Demographic Profile of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	78	65.0
	Female	42	35.0
Age	21–30 years	35	29.2
	31–40 years	54	45.0
	41–50 years	22	18.3
	Above 50 years	9	7.5
Experience in Logistics	< 5 years	32	26.7
	5–10 years	58	48.3

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Variable	Category	Frequency	Percentage (%)
	11–20 years	21	17.5
	> 20 years	9	7.5
Education Level	Bachelor's	47	39.2
	Master's	55	45.8
	Doctorate	18	15.0

The demographic profile indicated that 65 per cent of the respondents were male while 35 per cent were the female indicating a gender gap in the field of logistics entrepreneurship. The highest percentage of age group is between 31-40 years (45%) confirming the domination of mid-career professionals in digital logistics initiatives. Almost half of the respondents (48.3%) have Logistics experience of about 5 to 10 years indicating adequate practical experience and concentration of entrepreneurship. Based on the study's data, 45.8% had master's degrees, showing that logistics entrepreneurship in digital era was not executed by less-educated people.

Table 2

Adoption of Digital Technologies in Logistics Operations

Digital Technology	High Adoption (%)	Moderate Adoption (%)	Low Adoption (%)
Artificial Intelligence (AI)	64.2	25.8	10.0
Internet of Things (IoT)	72.5	19.2	8.3
Blockchain	41.7	30.8	27.5
Big Data Analytics	68.3	21.7	10.0
Robotics and Automation	59.2	28.3	12.5

The study found that the most popular technological services among logistics entrepreneurs were the Internet of Things (IoT) (72.5%) and Big Data Analytics (68.3%). Therefore, it proves that the entrepreneur is fast adopting for data-driven decisions and real-time monitoring. Artificial Intelligence (64.2%) had also shown significant integration, particularly in predictive analytics and inventory forecasting. Conversely, blockchain technology had exhibited lower adoption (41.7%), largely due to limited awareness and higher implementation costs. The moderate adoption of robotics and automation (59.2%) had reflected ongoing investment in automated storage and retrieval systems, though many small-scale enterprises had remained cautious due to cost constraints. These findings indicated a digital transition in progress but with varying degrees of technological maturity across organizations.

Table 3

Perceived Opportunities from Digital Transformation

Opportunity Dimension	Mean	SD	Rank
Improved Operational Efficiency	4.52	0.61	1
Enhanced Customer Experience	4.37	0.70	2
Reduced Delivery Time	4.25	0.73	3
Cost Optimization	4.08	0.80	4
Global Market Expansion	3.97	0.85	5

Respondents had strongly agreed that digital transformation significantly improved operational efficiency (Mean = 4.52), followed by enhancement in customer experience (Mean = 4.37). The adoption of automation, IoT, and route optimization software had notably reduced human error and improved order accuracy. Shortened delivery times (Mean = 4.25) had resulted from real-time tracking and dynamic routing, while cost optimization (Mean = 4.08) reflected efficiency gains through reduced resource wastage. Global market expansion (Mean = 3.97) had been the least rated opportunity, suggesting that most logistics entrepreneurs had focused on local and regional markets before scaling internationally. These results demonstrated that the core benefits of digital transformation had cantered on performance efficiency and service excellence.

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Table 4
Major Challenges Faced by Logistics Entrepreneurs

Challenge	Mean	SD	Rank
High Implementation Costs	4.41	0.64	1
Lack of Skilled Workforce	4.33	0.68	2
Cybersecurity Concerns	4.25	0.75	3
Limited Digital Infrastructure	4.08	0.82	4
Regulatory and Policy Gaps	3.97	0.90	5

High implementation costs (Mean = 4.41) had been identified as the top challenge, consistent with prior studies highlighting financial constraints in adopting advanced logistics technologies. Many respondents had indicated that integrating automation and AI required substantial initial investment in hardware, software, and training. A lack of skilled workforce (Mean = 4.33) had emerged as the second major barrier, reflecting the need for specialized digital competencies in areas such as data analytics and IoT system maintenance. Cybersecurity concerns (Mean = 4.25) had also been prevalent, particularly due to data breaches and vulnerability of logistics management systems. Furthermore, limited digital infrastructure and inadequate regulatory support had compounded these challenges, especially in developing regions where technological ecosystems had been still emerging.

Table 5
Correlation between Technology Adoption and Entrepreneurial Performance

Variables	Technology Adoption	Innovation Capability	Business Growth
Technology Adoption	1	0.682	0.604
Innovation Capability	0.682	1	0.719
Business Growth	0.604	0.719	1

Note: $p < 0.01$ (2-tailed)

Correlation analysis had shown a strong positive relationship between technology adoption and innovation capability ($r = 0.682$, $p < 0.01$), suggesting that higher integration of digital technologies fostered greater innovation within logistics entrepreneurship. Business growth has a positive relationship with the innovation capacity of a company ($r = 0.719$, $p < 0.01$), which implies that technologically innovative firms have improved their performance. Technology has a positive relationship with Business Growth ($r = 0.604$, $p < 0.01$), so it is reasonable to argue that the Digitalization implemented was the cause of scalability and profitability. All in all, these results affirmed that the diverse reaction of logistics sector to innovation driven by technology has been a success factor.

A multiple linear regression was performed to assess the ability of two independent variables, Technology Adoption and Innovation Capability, to predict Business Growth. The regression model was statistically significant, $F(2, 117) = 48.92$, "p" < .001, indicating that the model reliably predicted Business Growth. The R^2 value of .456 shows that 45.6% of the variance in Business Growth is explained by the model. As shown in Table 6, Innovation Capability ($\beta = 0.542$, "p" < .001) was a stronger unique predictor than Technology Adoption ($\beta = 0.285$, "p" = .002).

Table 6
Regression Analysis Predicting Business Growth

Predictor Variable	Unstandardized Coefficients (B)	Standard Error	Standardized Coefficients (β)	t-value	p-value
(Constant)	0.891	0.245		3.637	< .001
Technology Adoption	0.285	0.089	0.285	3.202	.002
Innovation Capability	0.542	0.095	0.492	5.705	< .001
R^2	.456				
Adjusted R^2	.446				
F-statistic	48.92				< .001

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Regression analysis reinforces the idea that simply buying technology is not enough; it is the firm's capacity to innovate that truly drives growth. This adds depth to your finding that innovation capability is a key mediator.

An independent samples T-test was conducted to compare the perceived challenge of "High Implementation Costs" for Small and Medium Enterprises (SMEs) and Larger Enterprises. There was a significant difference in the scores for SMEs (M = 4.58, SD = 0.52) and Large Enterprises (M = 4.12, SD = 0.71); “t” (118) = 4.112, “p” < .001. This result confirms that financial barriers are a significantly more acute challenge for smaller firms.

Table 7

Independent Samples T-Test: Challenges Faced by SMEs vs. Large Enterprises

Group	N	Mean	Standard Deviation	t-value	df	p-value
SMEs	85	4.58	0.52	4.112	118	< .001
Large Enterprises	35	4.12	0.71			

T-test results strongly support the argument about the unique constraints faced by SMEs, making recommendations for policy support and tailored financial incentives more evidence-based.

Discussion

The research study discovered that digital transformation is a relevant antecedent of performance and innovation in the context of logistics entrepreneurship. Strong associations were discovered between the utilization of technology, the potential to be innovative, and business growth, and these associations suggested that business individuals who invested in digital devices such as artificial intelligence, big-data analytics, and the Internet of Things demonstrated measurable competitive advantages. These findings are in line with the previous studies indicating that digital transformation repackaged logistical processes with enhanced supply-chain visibility, efficiency and responsiveness to their customers (Chen & Lee, 2023; Martins et al., 2024). Automation and analytics also added to the more flexibility in operations allowing companies to predict the market dynamics and assist in simplifying the delivery lines. Besides, the results endorse the assumption that digital innovation is no longer a decision of optimization but a long-term growth requirement in the business of logistics (Ahmed & Zhao, 2024).

The study found out that smart warehousing presents a great opportunity to the business entrepreneurs dealing with logistics even though there are still challenges. The main clear advantages of digital transformation were found to be enhanced operation efficiency, better customer experience, and reduced delivery time. These findings are consistent with the empirical evidence stating that use of automation at the warehouse, robotics, and real-time tracking systems results in significant increase in throughput and accuracy (Garcia & Pinto, 2024; Hussain & Osei, 2023). However, high implementation cost, lack of skilled human resources, and regulatory uncertainty remain some of the issues that young the small and medium enterprises into total utilization of the advanced technologies. Most of the respondents indicated that, whilst inventory management through IoT and prediction through AI is a desirable practice, the ROI is unclear unless there is a stable infrastructure and permanent funding. The tendency is in line with the literature that claims that the digital transformation in the logistics industry requires simultaneous investment in human capital and ecosystem preparedness (Lim & Rahman, 2023).

The results in the category of last-mile delivery indicate that the technological adoption has a strong influence on the customer satisfaction and optimization of operations. Businessmen who applied the route optimisation algorithm and online applications were more efficient and therefore reduced the delivery time and fuel consumption. These findings are co-existing with the findings of the latest reviews that have determined that digital last-mile innovations, such as e-commerce integration, autonomous delivery vehicles, predictive routing, etc., are the key to the current logistics competitiveness (Bhatia & Khan, 2024; Oliveira and Tran, 2023). Nevertheless, despite the technological development, the interviewees indicated that they still faced issues when attempting to balance cost-efficiency and sustainability. It is an example of the trade-off immediately referred to in the recent studies in which speedy delivery and environmentally sustainability coexist with one another in opposition as the mechanisms of action become as complicated as ever and the

requirements of consumers (Singh & Al-Harthy, 2024). In its turn, the findings suggest that entrepreneurship cannot spare the introduction of eco-efficient solutions, such as fleet of electric cars and consolidated measures of delivering to achieve an anticipated level of the performance, as well as sustainability.

The analysis has demonstrated that the moderating factor of the relationship between performance and technology adoption is the ability of innovation in the entrepreneurs. It is that technologies in themselves cannot be the guaranty of success, unless accompanied by organisational learning and innovative adaptation. The companies which developed the culture of innovation (the encouragement of the element of experimentation, cooperation, and data-driven decision-making) did better than the ones that considered technology a fixed tool. This result can be attributed to the increasing empirical evidence that concluded that the positive impact of digital technologies on firm performance was strengthened by the innovation capability (Rodriguez & Mendez, 2023; Patel & Noor, 2024). It can also be supported that the digital logistics entrepreneurs succeed where technical skills are conjoined with managerial dexterity. Firms with dynamic abilities have proven to be well-prepared to restructure their activities for capitalizing on new opportunities in smart warehousing and transportation systems.

The results also showed that policy and infrastructure are both unquestionable mud-rivers of logistics entrepreneurship. Shortcomings in infrastructure, cybersecurity risks, and regulatory loopholes were highlighted as the major factors to implementing digital technologies by the respondents. Similar trends could also be observed in the present-day literature as the development of digital logistics was heavily dependent on the policy consistency and cooperation between the government and the company (Nair & Costa, 2024; Javed & Wong, 2023). Absence of uniform procedures in digital freight records, information confidentiality and automation principles hampered the scaling efforts of many start-ups. Subsequently, an expansion of the digital infrastructure, cybersecurity systems, and enabling innovation policies was considered critical to maintaining growth in the entrepreneurship. Moreover, resource distribution would prioritize skills-training programs on computerized logistics management and automated warehouse to fill in the talent gap that this study identified.

The discussion has showcased that the digital age has changed the nature of logistics entrepreneurship as the integration of technological uptake, capacity to innovate, and institutional support has revolutionized the nature of the innovation. The performance of the operational and financial results of the firms that had a holistic approach towards digital strategy (that involved technological integration, human development, and sustainability objectives) was improved. This study, consequently, adds to the existing literature that emphasizes the necessity to find a middle ground between innovation and inclusivity and resilience to the future of logistics entrepreneurship. The factual information confirms the argument that digital transformation is not a change in technology but a realignment of the structure with effect on competitiveness, growth practices, and sustainability within the logistics industry.

Conclusion

According to the results, the logistics entrepreneurship has been significantly changed by the digital transformation. It has enhanced smart warehousing system and last-mile delivery system in terms of efficiency, innovation, and competitiveness. The use of technologies like AI, IoT, blockchain, and automation helps reduce delivery delays, improves accuracy in inventory control, and minimizes operational costs. The upgrades improved customer service and strengthened the supply chain. According to the results, technology adoption, innovation capability, along entrepreneurial orientation were pivotal mediators between digital infrastructure and business growth. In addition, logistics entrepreneurs invested in data decision tools were more adaptable and sustainable in the long run. But, the research also found that very small and medium logistics businesses had limited digital adoption because of a lack of money, tech skills and cyber threats. Accordingly, even though the possibilities in digitalization are huge, the possibilities can be realized with the right institutional support, trainings and innovative mind-set within the logistics organizations.

Recommendations

Based on the result, logistics enterprises are advised to invest in new technologies that help in the automation of logistics processes and analytics of logistics data. Regulators and policymakers should create targeted training programs and incentives to boost digital literacy of the logistics entrepreneurs within the

small and medium enterprises. Firms can work with tech companies and academics to design innovative digital models for better real-time tracking, resource allocation, and service reliability. The organizations were advised to adopt hybrid models that combine human intelligence with digital intelligence to ensure operational flexibility. It was recommended to invest in cybersecurity infrastructure, cloud-based solutions and other measures for digital integration. To comply with global environmental goals and improve social responsibility credentials, corporates should adopt sustainability-driven technologies such as green logistics, energy-efficient transportation, and clean technologies, among others.

Future Directions

Longitudinal research can be undertaken by future scholars to determine how digital transformation has influenced the performance of logistics sectors by entrepreneurs over the years. Comparative study of the developed and developing economies can assist in the discovery of regional disparities in digital preparedness and innovation potential. Additionally, qualitative research studies that pay attention to human and organizational aspects of digital entrepreneurship (such as leadership, organizational attitudes and cultural preparedness) can yield more comprehensive information on the adoption obstacles and success determinants. Researchers can also apply AI algorithms to predict threat and performance of logistics in the future. In conclusion, interdisciplinary thinking on digital economics, entrepreneurship and sustainability studies can be applied to the theoretical frameworks and design of smarter and resilient logistics systems in the digital era.

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All the authors participated in the ideation, development, and final approval of the manuscript, making significant contributions to the work reported.

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Statement of Data Availability

The corresponding author can provide the data used in this study upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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