LEVERAGING THE INTERNET OF THINGS IN THE LAST-MILE COMPLEXITY DISTRIBUTION SYSTEM

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ABSTRACT

The complexity of the last-mile supply chain logistics network fails to align with the unprecedented growth of electronic commerce (e-commerce) for Durban courier companies. Integrated IoT technologies, such as Global Positioning System (GPS) tracking, Radio Frequency Identification (RFID) systems, and real-time data analytics, can optimise distribution processes, reduce costs, improve quality, and enhance the overall customer experience. The objectives are to establish the extent of the organisational complex last-mile distribution system. Furthermore, to examine the effective and efficient use of IoTs in the last mile Durban courier industry. This method employs quantitative techniques, and purposive and snowball sampling were used to select representatives from Durban courier companies who possess skilful and well-informed knowledge concerning the phenomenon of interest. The main findings suggest that the integration of IoTs in the complex last-mile logistics industry has the potential to optimise routing, eliminate in-process collisions, enhance cost efficiency, and enable organisations to exercise agile operations, responding to quasi-real-time visibility of inventory levels in stores, in transit, and warehouses. The research findings contribute to the development of industry best practices and guidelines. These insights can be shared with industry professionals, policymakers, and stakeholders to facilitate informed decision-making, encourage collaboration, and accelerate the adoption of IoT solutions in the LMD sector.

Keywords: Last-Mile Distribution, Iot, Logistics, Complexity System.

JEL: R12, O33

1. INTRODUCTION

With the relentless growth of e-commerce and the increasing demand for efficient and reliable delivery services, understanding how IoT affects last-mile logistics is increasingly becoming important both for companies and consumers alike. Seemingly, the implementation of IoTs in the complex last-mile distribution system in the Durban region has the propensity to improve efficiency and effectiveness. The study focuses on the complexity of the last-mile distribution system and the role of IoTs as a focal technology to establish innovative technological impact, organisational challenges and interoperability. The study provides a brief background, research objectives, theoretical framework, research methodology, data analysis, and recommendations, along with managerial implications.

2. BACKGROUND OF THE STUDY

Last-mile delivery is a critical component of supply chain logistics, but it faces compounding challenges, exacerbated by the complexities of infrastructure, sustainability, and fragmented supply chain structures. Supply chain logistics complexity epitomises the degree to which the individual views logistics innovation and technology as being difficult, stemming from lagging structural, infrastructural, and developmental adaptability. While it is the most crucial link, it is also the least effective logistics distribution system to cope with the scalability of e-commerce economic activities. Efforts to eliminate challenges and enhance transportation quality have led to a focus on consumer-driven logistics, cost reduction, and innovative solutions, such as micro-hubs and crowd delivery (Weber

& Badenhorst-Weiss, 2018). Yang et al. (2022) underpin that in recent years, the global demand for efficient and reliable last-mile distribution systems has been on the rise, driven by the rapid growth of e-commerce and the need to reach geographically dispersed customers. Ignat & Chankov (2020) define e-commerce as the selling and buying of items using the internet or an online platform, with a substantial increase in interest over the recent past, particularly for domestic e-commerce (such as household consumables, clothing, food items, and electronics). It is a crucial process step in online shopping as it is the only interaction between the customer and the courier service (Jiang et al., 2021). South Africa, as a rapidly developing nation with a thriving digital economy, is not immune to the challenges associated with last-mile logistics (Ajayi & Laseinde, 2023). The last-mile logistics companies in Durban serve as the focal sample frame to establish the magnitude of the complex challenges associated with adopting IoT and further examine the influence of efficient and effective organisational strategies on the use of IoT in the last-mile South African logistics industry. The research paper focuses on the complex last-mile logistics system and vehicle-based alternatives for last-mile distribution in urban freight (Oliveira et al., 2017; Zhong, 2020).

The key challenges for the last-mile distribution system align with the increased complexity of demand for speedy delivery, reliability, agility in adapting, and responsiveness in delivering quality logistics services. The complexity of IoT implementation in last-mile distribution systems in the Durban region underscores the elusive goal of improved efficiency and effectiveness. The middle mile, with its complexities and scale, has a significant impact on the overall efficiency of the supply chain. The objectives are to establish the extent of the organisational complex last-mile distribution system. Furthermore, to examine the effective and efficient use of IoTs in the last mile Durban courier industry. The IoT integration enables seamless communication to create in-sync operations across the first-mile, mid-mile, and last-mile, as well as interconnected logistics systems and large-scale networks.

Theoretical framework

The emerging doughty trend in retail electronic commerce and online shopping requires coordinated processes and connected technologies across supply and sales channels, one everything (Saghiri et al., 2017). The Internet of Things (IoT) enables interdependence and interaction through real-time information and continuous material and product flows. Those interactions change over time and face many uncertainties from the lenses of complex adaptive theory (Miller & Page, 2009; Pathak et al., 2007). The growth of electronic commerce is recognised as a complex adaptive system. Complexity refers to the degree to which an individual perceives the innovation as being difficult to understand and use (Rogers, 2010). The last-mile sector, as a catalyst of the supply chain logistics network, epitomises an integral part of electronic commerce (e-commerce) to mitigate fluctuating consumer demands (Mbhele, 2023). Last-mile deliveries in urban areas introduce additional complexity to the electronic fulfilment process due to the specific constraints of this operating environment (Mbhele & Rambaran, 2024), including high levels of congestion, increasingly strict regulations, and a lack of dedicated logistics infrastructure. The retailing, operations, technology and supply chain logistics characterise complex adaptive systems with some core elements and features, which can be summarised (Choi et al., 2001; McCarthy, 2003; Nilsson & Darley, 2006; Wollin & Perry, 2004): agents, connectivity, emergence, and autonomy/control. Complex adaptive systems consist of agents (or entities) which are interdependent and interconnected, such as retailers, manufacturers, technology agents, and delivery companies, which are agents of the complex system. Last-mile deliveries in urban areas introduce additional complexity to the e-fulfilment process due to the specific constraints of this operating environment (Kitukutha & Oláh, 2018), including high levels of congestion, increasingly stringent regulations, and a lack of dedicated logistics infrastructure. The complex system of e-commerce engenders questions about the sustainability of home delivery services for online purchases.

3. LITERATURE REVIEW

Last-Mile Logistics

The efficiency of the courier company and the condition in which the package is delivered determine the overall quality of the service, despite all subsequent processes administered by an automated system designed to achieve optimal production (Tumino et al., 2019). The first mile deals with individual producers or manufacturers, the last mile focuses on individual customers, and the middle mile concerns itself with bulk transportation (Mbhele, 2023). The last mile signifies the final leg of the logistics journey, bringing goods from the local distribution centre to the consumer's doorstep (Jamous, Kerbache & Omari, 2022; Kafile & Mbhele, 2023), and it remains the final touchpoint where the supply chain interacts directly with the customer (Jing & Hu, 2023). The Durban last-mile delivery involves land-based methods, such as cars, vans, bikes, or lorries, and still restricts the use of drone air transport. The coordinated miles (first, middle, and last) heavily rely on emerging technologies for development and deployment to enhance the efficiency of last-mile delivery, making it easier for consumers to receive their desired products with speed and precision (Mbhele & Rambaran, 2024). The main hurdles in the first mile stage involve ensuring the accurate picking of goods, efficient packaging, and practical information systems for tracking and documentation (Zhang & Huang, 2020; Jing & Hu, 2023).

Dimensions of the last-mile logistics

Urban Logistics: The Urban Logistics Opportunities-Last-Mile Innovation report (Wang et al., 2020) predicted that in 2025, the cost associated with logistics globally would increase by up to 10.6 trillion. The need for optimisation in last-mile distribution (LMD) emerges in relation to a set of issues that include the growing complexity of metropolitan areas of eThekwini Municipality, greater pressure for reduced delivery times with hindrances from mini-buses' operations, and operational costs that are at a minimum for logistics companies (Mbhele, 2023). The evolving delivery methods ensued from relying on truck fleets, soon reaching bottlenecks due to congestion in the Durban city centre, while environmental regulations to develop smart cities through decarbonisation, and escalating fuel prices affect the seamless operations and efficient last-mile logistics networks (Mo et al., 2023; Gunay-Sezer et al., 2023). Due to ecological concerns, the global drive for greener logistics has motivated the growing deployment of electric cars and electric cargo bikes (Nando's SA), although few countries have legalised the use of drones to assist LMD (Muñoz-Villamizar et al., 2024). The hub-based delivery strategy by Engen Garages, Pep Stores and Postnet partly employs the use of electric cargo bikes greatly reduces emissions and traffic congestion in urban cities (Mbhele & Rambaran, 2024), proving it to be a potentially better approach in achieving efficiency compared to the conventional modes of delivery (Ballano et al., 2023).

Township logistics: Township last-mile logistics also assist customers in receiving orders from the convenience of their workplace or doorstep, with quick turnaround times, often offering same-day or next-day delivery (Woody et al., 2022). However, Rajendran and Wahab (2022) suggest that it is a costly service, with the expected date of delivery not guaranteed, and complications associated with locating the delivery address in townships and informal settlements, as well as the possibility that the recipient may not be available to receive the delivery. The level of crime hinders the operation of using a digital key through a one-time allocation to customers, which is used to open the deposit box and place the parcel in the townships. However, the digital township economy has been empowered by the complementary integration of multiple IoT technologies, and communities are being tentatively digitally transformed for e-commerce transition. The impending factors prevent the township communities from absorbing and benefiting from the digital economy.

Rural Logistics: Integrating Rural LMD is particularly challenging due to the dispersed nature of populations, longer delivery distances, and limited infrastructure (Mbhele, 2023). Although integrating drones or Unmanned Aerial Vehicles (UAVs) provides encouraging opportunities for bridging last-mile gaps, their practicality is impacted by energy limitations, environmental issues (Chen & Wang, 2024), and legal considerations by Aviation Regulations in South Africa. In rural logistics, hybrid strategies that combine UAVs and conventional transportation methods, such as van vehicles and scooters, can increase accessibility and efficiency. IoT-enabled tracking and AI-powered route optimisation can also improve delivery performance, bringing reliable and affordable LMD services to disadvantaged communities. Infrastructural limitations in the more rural provinces, such as KwaZulu-Natal, the Eastern Cape, Limpopo, and Mpumalanga (Mbhele, 2024), including charging outlets for electric vehicle fleets and access to telecommunication networks in remote areas, also hinder large-scale integration in this industry (Li et al., 2024). The number of individuals requesting faster and more flexible delivery options is increasing rapidly, driven by the ongoing surge in online transactions. The IoT empowers and entrenches rural communities through logistical connectivity, tracking, tracing, visibility and transparency, while infrastructure deters the growth of the digital rural economy. It further contravenes the UN Sustainable Development Goal 9: (Industry, Innovation and Infrastructure) - Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation (UN-SDG, 2030).

Last Mile for Sustainability: Sustainability has emerged as one of the most important issues in last-mile logistics. The broader society is increasingly pressurising motorists and fleet companies worldwide to improve their environmental, social and governance (ESG) performance for continuous improvement in decarbonising from the first to last-mile operations, including the use of electricity to power their entire value chains (de Bruyn, 2025). The expectations from the UN Climate Change and the 2015 Paris Agreement targets to decrease greenhouse gas (GHG) emissions by 43% by 2030 (United Nations, 2015) ensure sustainable fleet decarbonization and accelerate the deployment of net-zero emissions (South African Government, 2021). Goal 9 - Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation, and Goal 11 - Make cities and human settlements inclusive, safe, resilient and sustainable. The increasing volume of urban deliveries has led to a rise in carbon pollution and traffic congestion, especially in metropolitan cities (Castillo Campo & Alvarez Fernandez, 2023). This has led governments and environmental bodies to call for companies to reduce their carbon footprint, in addition to developing greener logistics models. Gupta et al. (2022) state that providing efficient service to ensure success is based on research, where a company conducts studies to anticipate potential stakeholders, possible retailers, client markets, as well as other last-mile service providers.

Intelligent Supply Chain Management (SCM)

The strategic mitigation of modern global business challenges is embedded in responsive, agile, and resilient supply chain management, facilitating productive and continuous improvements. Supply chain management (SCM) is a systematic approach to integrating flows in managing a series of consumer cycles, replenishment cycles, distribution cycles, operations cycles, procurement cycles, and design cycles, all embedded with capable self-correction resilience and underpinned by the infusion of innovative supply chain technology to achieve responsiveness, agility, and efficiency. Phase and Mhetre (2018) reported that SCM has undergone a transition that enables the integration of customer needs into the various horizontally integrated supply chain cycles across the entire value creation network, thereby creating a cyber-physical system. Therefore, smart supply chain management (SSCM) can be interpreted as an integrated application of advanced technologies from emerging information, communication, and technology, as well as analytics, to configure and link the supply chain process cycles across different supply chain partners, thereby developing an intelligent, connected, and resilient system. An intelligent supply chain enables an effective and efficient system, allowing for the infusion of various emerging technologies, such as IoTs, big data analytics, and blockchain, to drive impactful supply chains. Zhang, Yang and Yang (2023, p.1078) define a smart supply chain as "a supply chain that integrates partners that can self-organise and automatically adapt to environmental changes, and makes the intelligent decision that best achieves business goals. The characteristics include being integrated, intelligent, adaptive, and self-optimising. SSC is a dynamic, evolving process that extends vertically and horizontally in terms of integration, along with the technology development and business innovation".

Internet of Things Technology

Technology is frequently embedded in machines to facilitate the operation of procedures, often even without detailed or specific knowledge of their inner workings, thereby rendering tasks less costly and more efficient. According to Madlamini (2018), technology encompasses the accumulation of methods, techniques, processes, and skills in the distribution and delivery of goods or services to achieve business plans and objectives for first-mile and last-mile logistics. According to Kuang (2018), supply chain managers can certainly improve the effective performance of last-mile distribution by applying recent technology in supply chain management. Rodrigues, Ruivo, and Oliveira (2021) and Alhaimer (2021) suggest that relative advantage plays a crucial role in the adoption of IoT in last-mile logistics, enabling the continuous improvement of operations cycles, logistics cycles, and process cycles. The relative advantages of applying Internet of Things technologies in the last-mile distribution industry in South Africa include benefits such as collaboration, competitiveness, effectiveness, and efficiency, as Abed (2020) discovered that relative advantage is a significant influence on the adoption of technology. Chatterjee (2021) adds that compatibility resonates with the advantage of IoT technologies; it focuses on the rate of technological innovation, propensity for adoption by organisations, and the dependability on the current standard of operations, beliefs, values, previous experiences, and needs of the organisation.

Artificial Intelligence (AI) in last-mile logistics: for logistics firms, the integration of AI and sophisticated algorithms has become increasingly crucial, as it reduces operating expenses without compromising service quality. AI is among the important tools in the optimisation of LMD due to its simplicity in implementation. Key methods in AI that are particularly useful for solving complex problems, such as those related to vehicle routing or real-time adjustments in delivery routines, include Machine Learning and reinforcement learning. There are AI-based multi-agent systems (Alyassi et al., 2023; Bentley et al., 2023) developed for route optimisation. These systems update routes dynamically based on real-time traffic and customer availability, such as Checkers 60 Sixty delivery, Pick n Pay, ASAP delivery, and more. Deep reinforcement learning models have demonstrated efficiency in parcel consolidation and matching processes (Silva, Pedroso, & Viana, 2023). Additionally, AI can maximise revenues and enhance courier performances (Russo & Comi, 2023). The integration of AI into LMD enhances its sustainability and improves customer satisfaction by analysing previous demand patterns and optimising fleet operations in real-time, ensuring a fair distribution of workload among couriers (Shuaibu, Mahmoud, & Sheltami, 2025).

Research approach and design

This study employed a quantitative research approach to investigate the integration of IoT technologies in enhancing complexity in the last-mile distribution system. An exploratory study is a valuable means of asking open-ended questions to discover what is happening and gain insights about a topic of interest for inferring (Sekaran, 2020; Creswell, 2021; Saunders et al., 2020). This section provides an understanding of how ontology corresponds to epistemology and, in turn, corresponds to the methodology to which the study subscribed and the tools that were employed. It is therefore vital that researchers emphasise the study's perspective in terms of the different philosophical perspectives, such as ontology (what constitutes knowledge), epistemology (how we know it), and axiology (what values are involved in it). With this epistemological stance, positivists seek to establish relationships between constructs, generally by comparing groups or responses using quantitative methodologies, such as surveys. A structured survey questionnaire was designed to collect data from the six last-mile distribution companies within the Durban region of South Africa, including logistics managers, delivery personnel, and administrators. The survey was designed to gather deductive information on the IoT diffusion and the critical factors influencing the complexity of last-mile logistics. The survey was administered electronically using online survey platforms, ensuring the anonymity and confidentiality of the participants. The collected data were then analysed using appropriate statistical techniques.

Population, sampling and sample size

A population is defined as the total number of units, elements, or cases, such as individuals, organisations, items, or events, from which a sample can be drawn for study purposes (Saunders et al., 2018). The population in the context of this research was selected using purposive sampling, including six last-mile distribution companies in Durban. The practical reason for excluding other LMD companies in South Africa is that Durban is one of the three biggest cities in South Africa with an effective and sustainable logistics sector; therefore, this population was a good representation of the entire country. According to Sekaran & Bougie (2016, p.203), sampling is "the process of selecting a sufficient number of the right elements from the population so that a study of the sample and an understanding of its properties allow for generalisation to the population elements". Based on the formula for sample size with the margin of error set at 5%, the sample size for this study was 210, with a response rate of 179.

4. DISCUSSION OF RESULTS

This section presents the results and analysis of the collected data, providing a basis for discussion and interpretation of the findings. The research objective was to establish the extent of the organisational complex last-mile distribution system by leveraging IoT for cost efficiency, better quality, and responsive business processes. The influence of the IoT in the LMD industry facilitates the assessment of the returns on investment (ROI) and value proposition for implementing IoT solutions. By gathering data on the positive outcomes, its impact can be quantified in various aspects such as cost savings, productivity gains, fleet optimisation, quality, improved customer satisfaction, and competitive advantage.

Table 1
COMPLEX LAST-MILE BUSINESS PROCESSES AFFECTED BY IOT

Variable	**Responses(N)**	**Percentage**
Reporting and decision-making	**178**	**34%**
Order fulfilment	**176**	**33%**
Fleet management	**177**	**33%**
Total		**100%**

The extent of influence was indicated by respondents on which complex last-mile business processes are affected by IoT in the organisation (Table 1). The descriptive analysis revealed that among the business processes influenced by IoT, 178 (34%) were attributed to reporting and decision-making. This indicates that IoT technology is crucial in enhancing data-driven decision-making processes. Additionally, 33% of the respondents were linked to fleet management. It is an inference that IoT contributes to cost optimisation routing in designated areas. IoT devices enable real-time tracking and monitoring of vehicles, resulting in more efficient route planning, reduced fuel consumption, and maintenance cost savings, all of which positively impact the organisation's overall cost structure. The other critical contribution by the respondents is associated with order fulfilment (33%), underscoring the importance of IoT in streamlining supply chain operations. Improved visibility and tracking of inventory and orders can result in faster and more accurate order processing. These results highlight that IoT significantly affects both cost and quality in various business processes, emphasising its potential to drive efficiency, reduce expenses, and enhance decision-making within the organisation. Figures 1 and 2 explore the impact of IoT technology on cost and quality in the LMD industry.

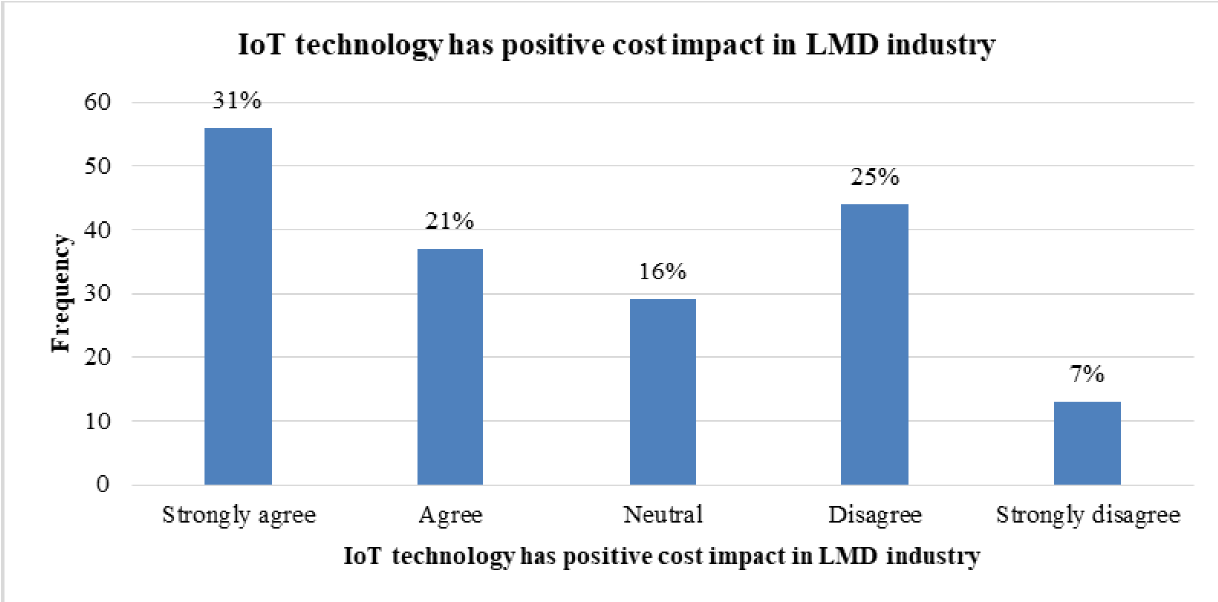

FIGURE 1
IOT TECHNOLOGY HAS A POSITIVE COST IMPACT ON THE LMD INDUSTRY

Figure 1 has an overall mean (M) score of 2.56 and an overall standard deviation (SD) of 1.345. The descriptive results show an overwhelming majority of agreement, with 52% of respondents agreeing that IoT technologies have a positive cost impact in the LMD industry. However, 32% of the respondents are in disagreement that IoT technologies have a positive cost impact on the LMD industry. Lastly, 16% of the respondents remained neutral about this statement.

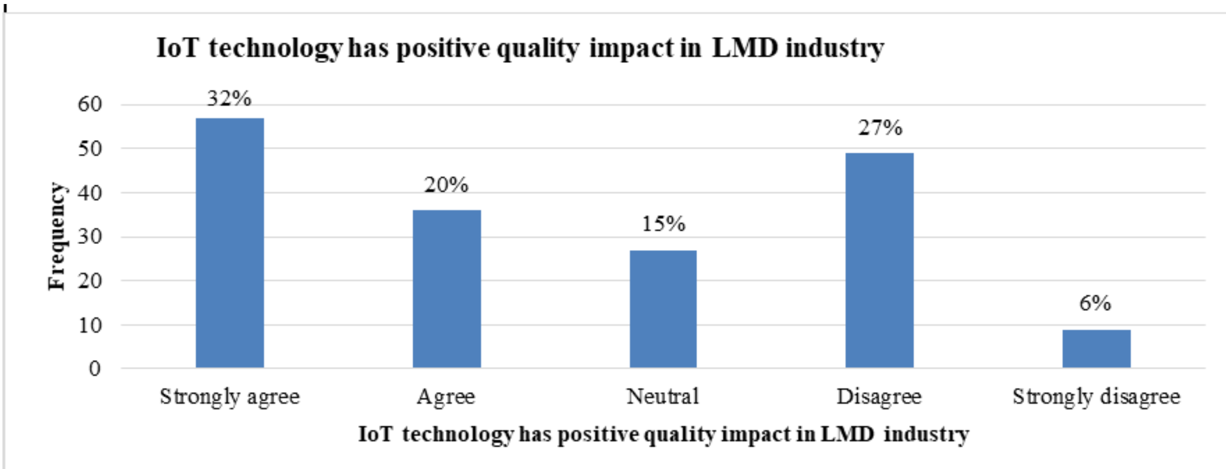

FIGURE 2
IOT TECHNOLOGY HAS A POSITIVE QUALITY IMPACT ON THE LMD INDUSTRY

Figure 2 similarly has a mean (M) score of 2.53 and a standard deviation (SD) of 1.324; the descriptive statistics indicate that overall, 52% of the respondents agreed that IoT technologies have a positive quality impact in the LMD industry, while 33% disagreed with the statement, respectively. A further 15% of the respondents remained neutral on this issue.

The research objective two aims to examine the effective and efficient use and implementation of IoTs in the last mile of the Durban courier industry. The IoT integration enables seamless communication to create in-sync operations in the first-mile, mid-mile, and last-mile, as interconnected logistics systems and large-scale networks. Leveraging IoT's capabilities can enhance efficiency, effectiveness, visibility, and responsiveness, leading to faster, reliable delivery and ultimately satisfied customers, as well as reduced operational costs. By addressing South Africa's unique logistics challenges, this research lays the groundwork for more efficient and sustainable distribution operations, enabling businesses to deliver goods with improved quality and cost-effectiveness.

Table 2
CHALLENGES OF THE IOT ON THE COMPLEXITY OF LMD SYSTEM

Challenges	Responses (N)	Percent	Percentage Accumulation
Cybersecurity	175	38%	38%%
Data collection and processing	169	37%	75%
Lack of regulation	58	13%	88%%
Connectivity	33	7%	95%%
Limited bandwidth	23	5%	100%
Total	**458**	**100.00%**	

The descriptive analysis revealed that, among the challenges of the IoT in the complex LMD industry, most respondents (38%) identified cybersecurity, followed by 37% who opted for data collection and processing. Moreover, 13% pointed to a lack of regulation, 7% cited connectivity issues, and 5% mentioned limited bandwidth.

Table 3
IOT IMPLEMENTATION

Implementation	Responses (N)	Percent	Percent of Cases
Tracked vehicles	177	23.70%	98.90%
Expanded delivery routes	160	21.40%	89.40%
Expansion and use of drones	10	1.30%	5.60%
Improved deliveries	126	16.90%	70.40%
Order fulfilment point	137	18.40%	76.50%
Packaging and labelling	51	6.80%	28.50%
Defects management	38	5.10%	21.20%
Reverse logistics	47	6.30%	26.30%
Total	**746**	**100.00%**	**416.80%**

The researchers inquired about the IoT technologies currently in use and implemented within the organisations to evaluate their impact on cost and quality aspects of operations. The descriptive analysis revealed that out of a total of 746 instances where smart technology influenced operations, a significant 98.9% of these cases were related to tracked vehicles. This indicates a pronounced reliance on IoT for monitoring and managing transportation logistics, which can have direct implications on cost efficiency, route optimisation, and overall quality of service. Moreover, the findings revealed that in 89.4% of cases where smart technology played a role in the respondents' organisations, it was associated with expanded delivery routes. This expansion might signify potential cost savings through efficient route planning and quality of service, as it can impact delivery times and customer satisfaction. Additionally, in 76.5% of cases, complementary smart IoT technology impacted the order fulfilment point. This suggests potential improvements in inventory management and order processing efficiency, which can positively impact both cost control and the accuracy and timeliness of deliveries, ultimately affecting quality. Furthermore, in 70.4% of instances, smart IoT technology was linked to improved deliveries (faster-reliable-responsive). This improvement may encompass various aspects, including on-time deliveries, reduced errors, and enhanced customer experiences. In the integration of IoT within the LMD sector, IoT technologies are linked to End-to-End tracking, credited to the Global Positioning System (GPS), and enhanced by Radio Frequency Identification (RFID) for both cost-effectiveness and quality improvement within the LMD industry.

5. Conclusion, Remarks, and Summary of Findings

This section summarises the research findings, recommendations, implications for the study and the study's concluding remarks. The study found a strong correlation between cost and quality efficiency in LMD business processes using IoT technology. This means that reliance on IoT for monitoring and managing last-mile transportation logistics has direct implications for improving cost efficiency, route optimisation, on-time deliveries, and overall quality of service, thereby enhancing customer experiences. Key factors influencing cost and quality include the use of monitoring tools for fuel, lighting, and temperature management in fleets and facilities, which reduces unexpected downtime and provides prompt alerts (Ali et al., 2021; Ghadge et al., 2020; Choudhury et al., 2021). These findings align with previous research on Logistics 4.0 initiatives, which benefit the economy by lowering logistical expenses, increasing productivity, and improving customer satisfaction (Alabi et al., 2020; Nguyen & Petersen, 2017; Rodrigues, 2021; Armenia et al., 2021). The study also revealed that the LMD sector has not fully embraced IoT technologies due to infrastructure, compatibility, organisational culture, and a lack of skilled individuals. IoT presents opportunities for retailers to optimise ordering, minimise wastage, and enhance the customer experience. In last-mile logistics, IoT technologies have a positive impact on responsiveness and performance, with elements such as security cameras, IoT-enabled vehicles, sensors, RFID, and GPS enhancing productivity and supply chain visibility. Embracing IoT can enable seamless customer experiences for both physical and online retailers. As the e-commerce industry undergoes a digital revolution, businesses should adapt to succeed today and prepare for the future. These findings have implications for various stakeholders, including logistics service providers, retailers, technology service providers, policy makers and investors. The findings of this study also support those of other existing studies (Ghadge et al., 2020; Choudhury et al., 2021; and Bag et al., 2020).

Managerial Implications and Contributions

Logistics should enable meeting the demands of speed, economic efficiency, and effective business processes, while also extending to environmental sustainability through the integration of processes with complementary IoT-cutting-edge technologies, such as AI, algorithmic optimisation methods, autonomous systems, and blockchain technology. These technologies offer certain guarantees for enhancing optimal route planning, operational efficiency, and effectiveness, as well as customer experience (Silva et al., 2023), which will aid in resolving some of the inherent issues within contemporary logistics systems (Shuaibu et al., 2025). Optimisation algorithms form the basis for dealing with the complex issues of last-mile delivery, such as routing, task allocation, and efficiency (Chen et al., 2024), where the usage of machine learning Checkers 60 Sixty, Pick n Pay, Asap, Woolworths Dash for rapid, next-hour delivery, and traditional delivery for groceries, SPAR's online delivery service, SPAR2U, and Fastfood outlets using Uber Easts, Mr D, etc and these logistics provider could come up with scalable and flexible solutions that can handle dynamic market demands and environmental constraints.

Optimisation of complex LMD remains key to meeting the needs of urbanisation, e-commerce growth, a lack of robust logistics networks, and sustainability pressures. To further reach its full potential, fundamental legal regulations, financial constraints, and infrastructural barriers must be overcome for the digital economic growth of rural and township areas. The contributions of AI, IoT, and hybrid logistics models should earmark rural and township socio-economic development (Mbhele, 2024) towards enhancing routing efficiency, operational flexibility, and cost-effectiveness (Shuaibu et al., 2025). The research findings contribute to the development of industry best practices and guidelines. These insights can be shared with industry professionals, policymakers, and stakeholders to facilitate informed decision-making, encourage collaboration, and accelerate the adoption of IoT solutions in the LMD sector.

6. RECOMMENDATIONS AND FUTURE STUDY

Based on the study findings, the key recommendations for last-mile logistics businesses and other stakeholders in the industry are to prioritise the integration of IoT technologies into their operations for cost-efficiency, quality, and sustainability in the LMD sector. This includes investing in cybersecurity by implementing robust security measures and encryption protocols to safeguard sensitive data and IoT devices from potential threats. The second recommendation is to enhance data collection and processing capabilities, with a focus on data accuracy and real-time analysis, which will enable better decision-making and resource optimisation, ultimately reducing waste and improving both cost and quality efficiency. The future of LMD must develop robust logistics networks valuable for reliability, adaptability, and operational flexibility. Finally, to ensure the evolution of LMD, policymakers, industry, and academia must collaborate to address technology gaps, regulatory hurdles, and infrastructure constraints, enabling the logistics sector to establish a sustainable, resilient, and affordable last-mile delivery network.

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