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Improving last mile distribution systems through the Internet of Things: a South African case

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Abstract: The study investigates the impact of the IoT on the cost and quality of last-mile logistics, the critical and often challenging final phase of the supply chain. With the relentless growth of e-commerce and the increasing demands for efficient and reliable delivery services, understanding how IoT affects last-mile logistics is increasingly becoming important. Through the integration of IoT technologies such as GPS tracking, RFID systems, and real-time data analytics, the study aimed to assess the extent to which the application of the IoT affects the cost and quality of last-mile distribution in South Africa. As a result, the study provides valuable insights into the potential cost savings or increases associated with IoT adoption, quality challenges and areas of improvement, customer satisfaction and the overall performance of last-mile distribution systems. The methodology involves the collection of primary data from selected distribution companies in South Africa. Statistical software was used to analyse the data to shed light on the tangible benefits and challenges associated with IoT adoption in last-mile logistics as they relate to cost and quality. The research findings indicate that implementing IoT in last-mile distribution systems in South Africa can significantly improve efficiency and effectiveness. The IoT integration with existing infrastructure enables seamless communication, proactive decision-making, and reduced delivery delays. Overall, by leveraging IoT technologies and real-time data analysis, organisations can optimise their distribution processes, reduce costs, improve quality, and enhance overall customer experience.

1 Introduction

Last-mile delivery is a critical component of the supply chain, but it faces numerous challenges, exacerbated by the complexities of the Covid-19 era [1]. While it is the most crucial link, [2] claims that it is also the least effective. Efforts to eliminate obstacles and enhance transportation quality have led to a focus on consumer-driven logistics, cost reduction, and innovative solutions like micro-hubs and crowd delivery [3]. [4] suggest 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 and during the covid 19 years, this growth doubled, causing a need for innovative solutions to the challenges associated with the increasing demand of home deliveries. South Africa, as a rapidly developing nation with a thriving digital economy, is not immune to the challenges associated with last-mile logistics [5]. This study assesses how IoT adoption affects the cost and quality of last-mile distribution in South Africa. It aims to uncover potential cost savings, quality enhancements, customer satisfaction improvements, and overall performance of the LMD sector. Leveraging IoT's capabilities can enhance efficiency, visibility, and responsiveness in deliveries, leading to satisfied customers and reduced operational costs. By addressing South Africa's unique logistics challenges, this research paves the way for more efficient and sustainable distribution operations, enabling businesses to deliver goods with improved quality and cost efficiently.

2 Literature review

2.1 Last-mile distribution systems

[6] define Last Mile Distribution Systems as the last leg of the supply chain, covering the transportation and delivery of goods to the final point of consumption. Last-Mile Distribution Systems are crucial for ensuring timely and efficient delivery, as well as customer satisfaction. [7] opine that this stage often involves complex logistical operations, including route optimisation, inventory management, and coordination with various stakeholders such as couriers, drivers, and customers. Efficiency and effectiveness in last-mile distribution are vital for customer satisfaction, cost optimisation, and overall business success. Customers are provided with a plethora of online purchasing options, which places greater pressure on last-mile providers to ensure their service delivery and offerings are optimal at all times [8]. It is imperative for last-mile service companies to maintain cost-effectiveness and superior quality of the service provided despite the increased demand for deliveries for them to flourish in the online market [9].

2.1 Internet of Things (IoT) in supply chain management

2.1.1 Overview of the Internet of Things (IoT) technology

The IoTs is not a single technology, but rather a creative alliance of numerous complementary technologies working together to close the gap between the digital and physical worlds [10] and [11]. The phrase "Internet of Things" was first used in 1999 by the Massachusetts Institute of Technology's (MIT) Auto-ID Center for SCM to describe a method of tracking items via the Internet using radio-frequency identification (RFID) linking to an Electronic Product Code (EPC) serving as a unique identifier for each individual item [12]. Since then, the definition of a "Thing" has expanded to cover a variety of digital gadgets that can be uniquely identified, read, sensed, addressed, and operated autonomously through the Internet. Examples include RFID, sensors, actuators, cell phones, and smart products [13]. By utilising the Internet as a communication infrastructure, a means of data storage, and a platform for data processing and synthesis, these authors further contend that the capabilities of IoT devices are hypothesized to surpass the inherent functionality of any item. Today, social networks, cloud computing, big data analytics, and GPS telematics all contribute to the IoT platform's expansion [14]. Self-awareness, individuality, control, interconnection, adaptability, transformability, synergy, self-decisiveness, and strategic behaviour are important IoT features [15].

2.1.2 Applications of the IoT in Supply Chain Management

[16] reported that SCM has seen a transition that takes the form of a basic RFID-based tag for product recognition, then adopts sensor technology and then communicates devices to a smarter supply chain. The authors found that technical advances have opened the way not only to track the goods but also to predict situations for avoiding losses for the company and safeguarding the goods properly for the right individual to collect information and convey them to the right person at the right time for the early delivery of the goods. [17] showed that tools like RFID followed by wireless sensor networks and then middleware, web platforms and cloud computing play a significant role in integrating the supply chain information digitally. Adopting technologies such as the IoT in SCM also decreases the times required to purchase or buy products and services and offers improved communication using items that in effect speed up the efficiency of companies [18]. The study also showed that the Internet of Things is strong in terms of visibility, auto-capture and sharing of information. This in turn provides a positive effect on costs, followed by quality and supply chain flexibility in integrated supply chain businesses.

[19] the IoT in the supply chain management sector is not just for big, resourceful companies and their SCs. It is a widely used and widely accessible technology for a variety of SCM functions, such as information linking with vendors, gathering real-time progress data from vendors, producing real-time quality/maintenance data, inventory tracking, and information sharing. Enhancing reverse logistics, enabling quality monitoring and quality-controlled logistics, collecting product data while in use, and cooperative ordering are all ways to increase operational efficiencies and income prospects [20]. Making better operational decisions and improving strategic outcomes at the SC and firm levels is ultimately made possible by the availability and analysis of IoT-enabled real-time data [21]. For instance, [22] describes how IoT and big data analytics are used in a logistics company to enhance driver safety, operational effectiveness, and environmental sustainability. Cost implications play a crucial role in the adoption of IoT-enabled last-mile distribution systems. Implementing IoT technologies in the context of last-mile logistics involves significant upfront and ongoing costs, including device procurement, network infrastructure, data storage, and maintenance. For organisations operating on tight budgets or with limited resources, the financial burden of IoT implementation can pose a significant challenge [23]. For this reason, careful assessment of the return on investment is essential, along with considering the long-term cost benefits when planning the integration of IoT solutions [24]. Moreover, the scalability of IoT adoption becomes a complex task due to the heterogeneity of products and underlying technologies. Building an infrastructure capable of supporting thousands of connected products requires substantial investment. Therefore, addressing cost-related concerns and finding cost-effective solutions is vital for successfully improving last-mile distribution systems through the Internet of Things [25]. Although there is a definite need for IoT application in the last mile distribution of goods processes [26] further report that due to how fast technology is moving, there is a reluctance from top management to invest in any form of technology. This resulted in a fear that it would be deemed obsolete within a few years [27].

3 Methodology

3.1 The research approach and data collection methods

This study follows a quantitative research approach. The quantitative analysis of the impact of IoT on the cost and quality of LMD companies helped to evaluate the potential benefits of integrating IoT technologies in improving last-mile distribution in South Africa. A structured survey questionnaire was designed to collect data from six last-mile distribution companies within the Durban region of south Africa, using a purposive sampling technique, two hundred and ten (210) participants were selected for the study as the sample derived from the population including logistics managers, delivery personnel, and administrators. Consequently, only one hundred and seventy-nine (179) questionnaires were useable. The survey was designed to gather information on the challenges faced, the potential benefits of IoT adoption,

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and the critical factors influencing cost and quality while ensuring the anonymity and confidentiality of the participants. The questionnaires were then coded into Excel and exported into the Statistical Package for Social Sciences (SPSS), version 27.0. Frequency distribution and descriptive statistics were employed in the analysis of the quantitative data.

3.2 Population, sampling and sample size

A population can be 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 [28]. The population in the context of this research was selected using purposive sampling and included 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 [29] 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". Alternatively put, sampling is the procedure used to gather data about a population's overall makeup through examination of a subset of it. 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. Using Yamane's statistical formula to determine the adequate sample size of a population of 440 under study. This would hence be (1):

$$n = \frac{N}{(1+N(e)^2)} \quad (1)$$

Where:
n - signifies the required sample size
N - signifies the population under study
E - signifies the margin of error. It sets the accuracy of the sample proportions. With an accuracy of plus or minus 5%, then e is usually set at 0.05.

The study illustrates with the above formula to determine the sample size from a given population size of 440 (N) with a margin of error (e) of 0.05 by substituting the given variables as follows (2):

$$n = \frac{440}{(1+440(0.05)^2)} \quad (2)$$

$$n = \frac{440}{2.1}$$

$$n=210$$

Therefore, a sample size of 210 respondents out of a population of 440 would be an acceptable number of responses to maintain a 95% confidence level.

4 Results and discussion

Based on the overall aim of the study, this section presents the results and analysis of the collected data, which serve as the foundation for interpretation and the discussion of the results.

4.1 The influence of the IoT in the LMD industry in South Africa

In asking the respondents about their perceived or experienced influence of IoT in the LMD industry in South Africa, the researchers aimed to ascertain the specific areas in which IoT had a discernible impact on both cost and quality. This information can assist organisations in directing their focus towards the most promising IoT applications within the LMD sector. Evaluating the advantages of IoT in LMD not only facilitates the assessment of returns on investment (ROI) but also provides a clearer understanding of the value proposition associated with the implementation of IoT solutions. Through the systematic collection of data on positive outcomes, this study aimed to quantitatively measure the influence of IoT across various dimensions, including cost savings, increased productivity, error reduction, quality enhancement, heightened customer satisfaction, and the attainment of competitive advantage. The resultant research findings are poised to make substantial contributions to the establishment of industry best practices and guidelines. These insights can be shared among industry professionals, policymakers, and stakeholders to enable well-informed decision-making, promote collaborative efforts, and accelerate the adoption of IoT solutions in the LMD sector.

4.1.1 Use of the IoT in last-mile logistics in South Africa

The researcher asked this question to understand adoption rates and gain insight into the extent to which IoT technologies have been adopted in the industry. This information can assist in identifying trends and assessing the current level of implementation as well as in understanding the current landscape, challenges, and opportunities in this field.

Table 1 Use of IoT technologies in organisational operations

	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 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 descriptive 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, smart technology impacted the order fulfilment point. This suggests potential improvements in inventory management and order processing efficiency, which can positively affect both cost control and the accuracy and timeliness of deliveries, directly impacting quality. Furthermore, in 70.4% of instances, smart technology was linked to improved deliveries. This improvement may encompass various aspects, including on-time deliveries, reduced errors, and enhanced customer experiences.

To further explore the integration of IoT within the LMD sector, respondents were asked about the prevailing IoT technologies employed within their organisation. The findings showed that out of 399 cases of technologies that are currently most used, 99.4% (n=178) were linked to End-to-End tracking, revealing its prominent role. Furthermore, 97.2% of these cases were credited to the Global Positioning System (GPS), underscoring its wide adoption. In contrast, a mere 5.0% (n=9) of the cases were associated with sensors, signifying their limited usage, while 6.1% of the cases were attributed to Radio Frequency Identification (RFID). These results hold significant implications for both cost-effectiveness and quality enhancement within the LMD industry.

Table 2 Commonly used IoT technologies

	Responses (N)	**Percent**	**Percent of cases**
End-to-end tracking	178	44.6%	99.4%
Security cameras	27	6.8%	15.1%
Sensors	9	2.3%	5.0%
Radio Frequency Identification (RFID)	11	2.8%	6.1%
Global Positioning System (GPS)	174	43.6%	97.2%
Total	**399**	**100.0%**	**222.9%**

Table 3 Business processes affected by IoT

	Responses (N)	**Percent**	**Percent of cases**
Reporting and decision making	178	33.5%	99.4%
Order fulfilment	176	33.1%	98.3%
Fleet management	177	33.3%	98.9%
Total	**531**	**100.0%**	**296.6%**

Furthermore, respondents were asked what business processes are affected by IoT in the organisation. the descriptive analysis revealed that among the 531 cases of business processes influenced by IoT, the majority (n=178; 99.4 %) were attributed to reporting and decision-making, indicating that IoT technology plays a crucial role in enhancing data-driven decision-making processes. Additionally, 98.9% of the cases were linked to fleet management, revealing how IoT contributes to cost optimisation in this area as IoT devices can provide real-time tracking and monitoring of vehicles, leading to more efficient route planning, reduced fuel consumption, and maintenance cost savings, all of which positively impact the organisation's overall cost structure. While 98.3% of the cases were associated with order fulfilment, 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.

Table 4 Challenges of the IoT

Challenges	**Responses (N)**	**Percent**	**Percent of cases**
Connectivity	33	7.20%	18.40%
Data collection and processing	169	36.90%	94.40%
Limited bandwidth	23	5.00%	12.80%
Cybersecurity	175	38.20%	97.80%
Lack of regulation	58	12.70%	32.40%
Total	**458**	**100.00%**	**255.90%**

The descriptive analysis of the challenges faced by the IoT in the LMD industry indicates that cybersecurity is the most prominent concern, with 97.8% of respondents identifying it as a challenge. This has significant implications for both cost and quality. Investing in robust cybersecurity measures can be costly, but it is essential to protect sensitive data and ensure the quality of IoT systems by preventing breaches and data loss. Similarly, (94.4%) of respondents highlighted data collection and processing as a challenge. Efficient data collection and processing are vital for delivering high-quality services and products in the LMD industry. However, implementing the necessary infrastructure and technologies for data management can be costly. Furthermore, if data collection and processing are not done accurately, it can lead to errors and lower the quality of insights and decisions made using IoT data. The challenges related to lack of regulation (32.4%) connectivity (18.4%) and limited bandwidth (12.8%) also have cost and quality implications. The absence of clear regulations can create uncertainty and compliance costs for businesses, impacting their cost structure. Additionally, poor connectivity and limited bandwidth can hinder the real-time functionality and effectiveness of IoT systems, potentially compromising the quality of services and data analysis.

In summary, the identified challenges in the IoT LMD industry, including cybersecurity, data collection and processing, lack of regulation, connectivity, and limited bandwidth, all have varying degrees of impact on both cost and quality. Addressing these challenges effectively is crucial for LMD businesses to maintain high-quality services and products while managing their costs efficiently.

5 Conclusion

This section contains the study's concluding remarks in relation to the research objectives, recommendations and summary of findings and implications for the study.

5.1 Summary of findings

The study found a strong correlation between cost and quality efficiency in LMD businesses that have integrated IoT technologies. Key factors influencing cost efficiency and quality management include accurate and timeless collection of data through IoT sensors which equips businesses to make informed decision making, optimises resource allocation and minimises waste all enhancing both cost and quality efficiency. 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 [30].

IoT innovations, such as real-time predictive analytics, offer new opportunities for both traditional and online retailers to enhance customer experiences, optimise inventory management, and improve supply chain operations. By adopting these IoT advancements, retailers can stay competitive and deliver seamless experiences to customers [31-35]. The study also revealed that IoT technologies positively influence the responsiveness and performance of last-mile logistics companies. Elements such as security cameras, IoT-enabled vehicles, sensors, RFID, and GPS contribute to increased productivity, efficiency, and customer satisfaction by reducing lead times, defects, and information inaccuracies. Additionally, end-to-end supply chain visibility provided by these elements enables partners to enhance market responsiveness and mitigate supply chain disruptions.

5.2 Recommendations

Based on the study findings, the key recommendations for last-mile logistics businesses and other stakeholders in the industry are to prioritize 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 improve data collection and processing capabilities, focusing on data accuracy and real-time analysis, which will enable better decision-making and resource optimisation, ultimately reducing wastage and improving both cost and quality efficiency. Furthermore, it is crucial for businesses to invest in security cameras, IoT-enabled vehicles, sensors, RFID, and GPS to boost productivity, efficiency, and customer satisfaction in the last-mile delivery process. Collaboration with regulatory bodies and industry stakeholders to establish comprehensive guidelines and standards for IoT application in the LMD sector, ensuring compliance and accountability, is also advisable. Additionally, the study recommends the use of alternative connectivity solutions, such as edge computing and 5G networks, to mitigate connectivity issues and enhance data transmission efficiency. Lastly, stakeholders across industries should recognise the value of IoT technologies and consider their adoption in day-to-day operations and future planning, as the digital revolution continues to reshape the e-commerce landscape. This proactive approach will help last-mile logistics businesses maintain high-quality services while efficiently managing costs, fostering innovation, and sustaining their competitive edge in the face of evolving challenges and opportunities in the sector.

5.3 Contribution and practical implications of the study

5.3.1 Contribution to the body of knowledge

This research addresses the lack of empirical studies on the application of IoT technologies in the LMD industry in Durban, South Africa. By studying the factors influencing cost and quality efficiency, the research provides valuable insights for logistics companies in South Africa to develop strategies for adopting innovative technologies to improve cost and quality management. This not only helps them become innovation-based logistics service providers but also promotes sustainability. The study contributes to the logistics industry and the broader field of Supply Chain Management. Additionally, it extends knowledge and understanding of the application of IoT technologies in LMD companies, providing more literature on IoT technologies and business performance in the LMD sector of the Supply Chain. This work advances understanding in an under-researched context and provides a detailed framework for applying IoT technologies in the LMD sector in Durban, South Africa, and other developing economies worldwide.

5.4 Implications of the study

5.4.1 Managerial implications

To survive and succeed, LMD companies must embrace cutting-edge technologies to effectively reach the market and meet customer demands. Strategies promoting the use of advanced technologies, like IoT, are essential for success. In South Africa's reduced consumer spending power, a viable option for businesses is adopting a low-cost leadership strategy without compromising quality. The adoption of contemporary perspectives in strategy formulation, with IoT technologies as a driver for agility holds promise for helping last-mile businesses achieve competitiveness and sustainability.

5.4.2 Policy implications

The study recommends that the South African government should adopt policies that support technology use in logistics companies through strategic management and financial backing. Moreover, allocating resources to address other critical needs, such as infrastructure development (roads, electricity, and internet bandwidth), is vital, as these challenges often hinder progress. To enhance the SME sector, the government should prioritise providing managerial and technical skills to SMEs.

5.5 Future research

This study offers valuable insights into IoT's potential to improve last-mile distribution systems in South Africa, with a specific focus on the influence of IoT on the cost and quality of the LMD sector. However, there are opportunities for future research to explore additional dimensions and aspects of IoT integration in last-mile logistics, including risk management, environmental impact and sustainability, Regulatory and legal implications, customer experience and comparative studies. By addressing these areas of research scholars would expand the knowledge and understanding of how IoT technologies can transform and optimise last-mile logistics, ultimately leading to more efficient and customer-centric delivery systems.

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