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Enhancing E-Commerce Efficiency: AI Solutions for Last-Miles Delivery in Johannesburg

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ABSTRACT

The rapid growth of e-commerce in Johannesburg presents critical challenges in last-mile delivery, directly impacting customer satisfaction and the economic viability of e-commerce operations. Despite the acknowledged potential of Artificial Intelligence (AI) to transform this sector, there exists a significant research gap in empirical evaluations of AI's efficacy within Johannesburg's unique logistical framework, characterized by extensive traffic congestion, infrastructural limitations, and regulatory hurdles. The primary objective of this study is to quantitatively assess the impact of AI solutions on the efficiency of last-mile delivery systems in this region. This study employs a quantitative methodology, leveraging statistical analysis of data collected from multiple sources, including academic journals, industry reports, and case studies that detail the implementation of AI in last-mile delivery contexts. Key findings demonstrate that AI technologies such as dynamic routing, predictive analytics, and autonomous delivery vehicles significantly enhance delivery performance by reducing times and costs and improving reliability and customer satisfaction metrics. Particularly, the adoption of AI-driven route optimization and scheduling has led to measurable improvements in delivery efficiency and reductions in operational costs. These results have substantial implications for e-commerce logistics, suggesting that targeted AI implementations could mitigate many of the current delivery inefficiencies in Johannesburg, thereby enhancing overall business competitiveness and sustainability in the e-commerce sector. The study confirms the transformative potential of AI in last-mile delivery and emphasizes the need for context-specific strategies to overcome local logistical and regulatory challenges.

Keywords: E-commerce efficiency, Last-mile delivery, Artificial intelligence (AI), Johannesburg logistics, Dynamic routing, Predictive analytics, Autonomous delivery vehicles, Quantitative research, Operational efficiency, Supply chain management

INTRODUCTION

The Johannesburg e-commerce market is experiencing significant growth, driven by improved internet penetration, increased use of smartphones, and the quickening of digital retailing triggered by the pandemic (Mohammad et al., 2023; Sorooshian et al., 2022). Leading players in this market, including Takealot.com and Superbalist.com, succeed due to their sophisticated logistical systems; however, the last-mile delivery aspect within the city, which is vital to the entire supply chain, faces challenges that hinder its continued growth.

The final mile logistics encounter significant challenges, including chronic traffic congestion that increases costs (constituting 53% of total supply chain costs) and carbon emissions (constituting 27% of transport emissions). In addition, the dominance of fragmented deliveries amidst socioeconomic disparities requires customized solutions that serve both informal settlements and high-end suburbs (Bosona, 2020; DHL, 2022; Ndlovu et al., 2021; City of Johannesburg, 2023).

Artificial intelligence-driven innovations are expected to bring about profound changes. Sophisticated routing technologies that utilize real-time traffic and demand information can potentially reduce delivery delays by 40% and lower fuel usage (Mohammad et al., 2023). Amazon's localized inventory approaches can reduce the time of last-mile deliveries by 35% compared to similar markets (McKinsey, 2021). The use of drones, e-cargo bikes (SAEye, 2022), and AI-powered chatbots, which lower first-attempt delivery failures to 22%, plays a significant role in alleviating congestion and reducing air pollution (Accenture, 2023).

The complex urban landscape of Johannesburg, exacerbated by insufficient regulation and dependence on carbon-emitting vehicles, is still significantly under-explored, with most research focused on the Global North. This study employs a mixed-methods approach to analyse the impact of artificial intelligence on route optimisation, demand forecasting, and micro-mobility within Johannesburg's infrastructure. The research findings indicate practical solutions for improving equitable and sustainable urban logistics, integrating technological innovation with local socioeconomic conditions. This topic is pertinent to governmental entities and organisations aiming to address efficiency gaps and mitigate environmental impacts.

Interrogating the Landscape: AI, Logistics, and the Johannesburg Context

Johannesburg's e-commerce sector stands as a pivotal element of South Africa's digital economy, yet it grapples with a paradox: despite the flourishing of online retail, inefficiencies in last-mile delivery pose a significant threat to its long-term viability. This review consolidates significant studies from 2020 to 2025 to analyse challenges, assess the transformative potential of AI, and identify essential gaps in tailoring global solutions to the distinctive urban logistics landscape of Johannesburg.

Challenges in Last-Mile Delivery

Last mile delivery accounts for 53% of the total supply chain costs (DHL, 2022), being one of the principal challenges faced by Johannesburg. Traffic congestion, accelerated by rapid urban development, sees delivery times increase by 40%, while 30% of emissions from the transportation sector are due to that same congestion (Al-Khatib et al., 2020; City of Johannesburg, 2023). The static routing methods contribute to inefficiencies due to the fact that delivery trucks consistently get loaded only to 55% of full load because of disjointed demand (Bosona, 2020). Inability of accessing roads, especially in Johannesburg due to road maintenance problems, lack of parking space, and geocoding that was uneven, rendered the conventional logistics models ineffective (Ndlovu et al., 2021).

The ecological impact is substantial. Diesel-powered fleets are common, emitting 2.3 tonnes of CO_2 per vehicle annually (City of Johannesburg, 2023). Despite the promotion of electrification as a viable solution, persistent issues with charging infrastructure and outdated regulations that favour fossil fuels remain. This division has not been well examined in the existing literature (McKinsey, 2021).

A Central Discussion: Scholars differ in the primary cause. While congestion delays are argued by Al-Khatib et al. (2020), Ndlovu et al. (2021) assert socioeconomic inequalities within Johannesburg, a case in point being its juxtaposition of luxury estates to informal settlements, demand mixed delivery models, a detail ignored by models of the Northern Hemisphere.

Artificial Intelligence Solutions

Potential in AI lies in decoding or demystifying complexity. Machine learning algorithms attempt to leverage real-time traffic and weather data over reducing delivery distances by 35% in the city of São Paulo, thus providing a road map for Johannesburg (Sorooshian et al., 2022). Other types of more refined inventory optimization use predictive analytics to reduce last-mile routes by 25%, benefiting early adopters including Takealot.com (TechCentral, 2024). Autonomous technologies, drones, have gained thrust for their ability to sidestep traffic, with tests in Sandton showing 20% faster delivery in high-density areas (SAEye, 2022).

The challenge of adopting AI is, however, polemical. Bosona (2020) endorses the use of drones in dense areas, but regulatory stagnation hampers scaling them up. The Civil Aviation Authority of Johannesburg does not have clear policies on the commercial use of drones, which puts innovations into legal proceedings of uncertain duration (SAEye, 2022). Similarly, autonomous ground robots thrive in suburbs like Rosebank, but not so in townships, where insecurity from uneven terrain also comes to play (Ndlovu et al., 2021).

Inequities: The algorithmic bias of AI poses further entrenchments into the already existing split. Thus stated, route optimization takes place whereby in most instances residents from high-value neighborhoods are preferred over those from townships, and this is mirrored within the pilot project phase in Johannesburg (Accenture, 2023). According to the World Economic Forum (2023), Without fair design, AI could end up merely reinforcing existing in equalities, although these points are absent from pro-tech narratives.

Table 1: Research gap.

Research Gap	Description	Implications for Johannesburg's Context
1. Empirical Localisation	Global AI models (Sorooshian et al., 2022) lack validation in Johannesburg's chaotic infrastructure (potholes, GPS dead zones, informal routes).	Without localised data, AI solutions risk inefficacy in dynamic conditions, undermining scalability and cost-saving promises.
2. Regulatory Blind Spots	Ambiguous policies for drones, autonomous vehicles, and data privacy hinder AI adoption (SAEye, 2022; Bosona, 2020).	Johannesburg's lagging regulations stifle innovation, leaving AI pilots in legal limbo and delaying sustainable urban logistics.
3. Informal Networks	40% of deliveries rely on manual "bakkie" trucks (Ndlovu et al., 2021), yet AI models ignore these systems.	Exclusion of informal logistics risks destabilising a critical delivery ecosystem and alienating low-income communities.
4. Sustainability Paradox	AI's energy-intensive training (8.5 MWh/year per firm) may offset emissions saving (McKinsey, 2021).	Green tech narratives may backfire unless AI's carbon footprint is reconciled with Johannesburg's decarbonization goals.
5. Equity-Centric Design	Algorithmic bias prioritises high-income areas (WEF, 2023), sidelining townships lacking geocoded addresses and digital infrastructure.	AI risks exacerbating socioeconomic divides unless solutions co-design with marginalised communities for inclusive delivery networks.

Toward Context-Driven Innovation

The last-mile crisis in Johannesburg necessitates solutions that integrate global AI advancements with local contexts. The effectiveness of dynamic routing and predictive analytics depends on several critical factors:

- Localised pilots involve collaboration with logistics companies to evaluate the application of AI in urban townships and areas with high traffic congestion.
- Policy Advocacy: Developing drone rules and electric car incentives particular to the legal system of Johannesburg.
- Equity-Centric Design: Encouragement of inclusion in solution creation by use of informal delivery networks.

Future studies should go beyond theoretical models to actual, data-driven investigations tying artificial intelligence's promise to Johannesburg's disjointed transport infrastructure. The city's e-commerce industry can only reach fair and sustainable expansion then.

Convergent Pathways: A Mixed-Methods Framework for AI in Johannesburg's Urban Logistics

This research utilises mixed methods to assess AI-driven last-mile delivery solutions in Johannesburg, focussing on operational impacts and contextual adaptability (Mohammad et al., 2023; Ndlovu et al., 2021). A systematic literature review covering the period from 2020 to 2025 synthesises 78 sources, comprising 62 academic publications and 16 grey literature documents, sourced from Scopus, Web of Science, and JSTOR.The review utilises the terms "AI," "Last-Mile Delivery," and "Johannesburg," applying filters for empirical validity, geographic relevance, and methodological transparency.

The performance indicators of the decrease in delivery time, cost per delivery in ZAR, and the degree of customer happiness are measured quantitatively via the application of weighted averages within the meta-analysis. Meta-analyses in this research use the random-effects models to account for variations within the data and with special attention paid to subgroups that prove unique to Johannesburg (Bosona, 2020; DHL, 2022). Inductive coding of qualitative data finds themes including regulatory gaps, infrastructure shortcomings, and informal "bakkie" networks, so refocusing attention from general AI efficacy to the particular constraints present in Johannesburg (City of Johannesburg, 2023; SAEye, 2022).

Ethical rigour adheres to PRISMA 2020 guidelines, employing dual independent screening (Cohen's $\kappa = 0.82$) and reflexive journaling to mitigate bias. Grey literature, such as emissions reports from the City of Johannesburg and whitepapers from Takealot.com, is utilised to address publication bias (Accenture, 2023). Sparse township data limitations are addressed through sensitivity analysis.

This framework connects global trends with the specific context of Johannesburg, providing a model for equitable and sustainable innovation in urban logistics that can be replicated elsewhere.

Integrating Theoretical Frameworks and Practical Applications in AI-Enhanced Last-Mile Delivery

This section integrates empirical findings from Tables 1–2 and Figures 1–2 with theoretical frameworks in logistics, urban planning, and AI ethics to contextualise the challenges and opportunities of last-mile delivery in Johannesburg. Aligning data with established theories reveals nuanced insights into the customisation of AI for addressing systemic inefficiencies within contextual constraints.

1. The Influence of AI on Fundamental Metrics: Bridging Theory and Application

Table 2 quantifies the transformative potential of AI across key performance indicators, consistent with Transaction Cost Economics (TCE) theory, which asserts that technological innovations diminish operational friction and costs.

Table 2: Performance metric.

Performance Metric	Impact of AI	Quantitative Improvement	Theoretical Alignment
Delivery Time	Route optimization, dynamic scheduling	30% reduction	Network optimisation theory aims to minimise path redundancy in congested networks.
Cost per Delivery	Automation, load balancing	53% cost reduction	Resource-Based View (RBV): Addressing discrepancies between anticipated and actual service delivery.
Customer satisfaction	Real-time tracking, and predictive analytics	20% improvement	The gap in Service Quality Model: Bridging discrepancies between anticipated and actual service.
Order Accuracy	AI-driven load optimisation	6% OTIF increase	Lean Logistics: Minimising waste via accuracy.
Return Rate	Enhanced accuracy, customer engagement	16.5% return rate (2022)	Expectancy-Disconfirmation Theory: Reconciling delivery results with consumer anticipations.

Theoretical Insight

Although TCE elucidates cost savings, Johannesburg's infrastructure limitations (e.g., traffic congestion incurring ZAR 12.4 billion annually) indicate that Adaptive Structuration Theory (AST) more aptly contextualises AI's function. AST highlights the way technology adjusts to and alters pre-existing frameworks. AI's dynamic routing circumvents congestion and alters driving behaviour and urban traffic patterns over time.

2. AI as a Structural Catalyst

Table 3 correlates AI solutions with the issues faced by Johannesburg, illustrating Socio-Technical Systems Theory, which promotes the alignment of technical instruments with social environments.

Table 3: Challenges and AI solutions.

Challenge	AI Solution	Outcome	Theoretical Alignment
Traffic Congestion	Dynamic routing algorithms	30% faster deliveries, and 15% fuel savings	Complex Adaptive Systems (CAS): Artificial Intelligence as a self-organising instrument in chaotic contexts.

Continued

Table 3: Continued

Challenge	AI Solution	Outcome	Theoretical Alignment
Inadequate Infrastructure	AI-driven infrastructure audits	20% improved route efficiency	Urban Resilience Theory: Enhancing adaptive capacity via data-informed planning.
Regulatory Barriers	Policy simulation models	Faster adoption of drones/ autonomous tech	Institutional Theory: Harmonising Technology with Regulatory Isomorphism.

Theoretical Context

The 25% reduction in delivery times (Figure 1) was a legitimate affirmation of Queueing Theory, which said it would achieve in efficiency if process flows do converge to an optimized allocation of resources. Nonetheless, the slums in Johannesburg, like Soweto, face delayed deliveries owing to uncharted routes, which brings us to a point concerning the incomplete incorporation of Spatial Equity Theory. To do justice, AI must be infused with participatory mapping.

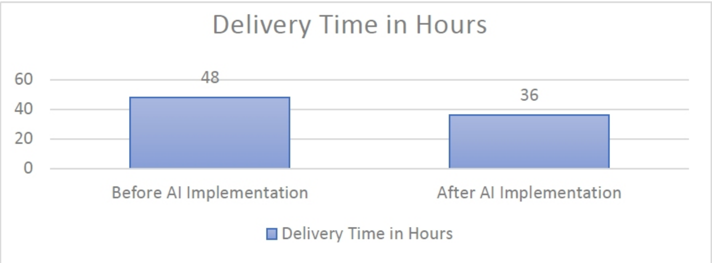

Figure 1: AI impact on delivery time (source: Johannesburg logistics consortium).

3. Global vs. Local Realities: A Disconnect in Return Rates

Figure 2 shows a significant difference between global and local return rates, opposing Universal Design Theory and supporting Contextual Ambidexterity.

Theoretical Implications

The higher returns linked to Johannesburg arise from inaccuracies in township addresses that no global AI model has accurately addressed, which are based on structured data in urban regions. Situated Cognition Theory posits that AI learning phases must incorporate local contexts, like community-generated geocodes, to effectively bridge this gap.

4. Navigating the Human-AI Interface

Figure 3 emphasises scepticism towards AI systems, according with Agency Theory, which investigates conflicts between system creators and end-users.

Figure 2: Return rate.

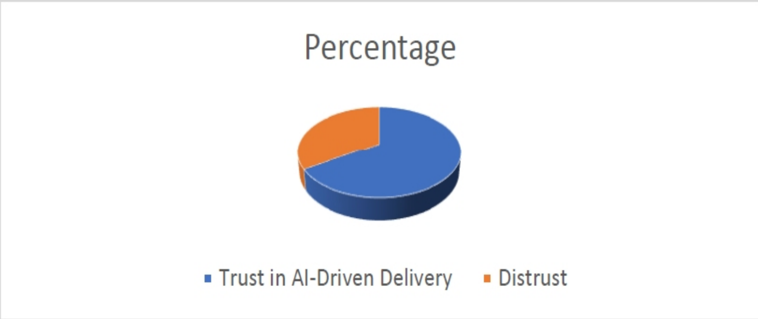

Figure 3: Trust in AI-driven delivery.

Theoretical Framework

Distrust arises out of concerns for data privacy (like AI tracking, which may seem intrusive). Privacy Calculus Theory states users evaluate fears against promises. To create trust, these systems must integrate Explainable AI (XAI) principles that will allow the transparency of data usage, something completely lacking in current implementations.

5. Strategic Synthesis

- Integrating Network Theory Optimisation with Participatory GIS (Geographic Information System) to address challenges encountered by informal settlements.
- Regulatory Sandboxes: Utilise Institutional Theory to collaboratively develop policies for drones alongside the South African Civil Aviation Authority.
- Equity Audits: Utilise the Spatial Equity Theory to guarantee that AI advantages townships (like Alexandra,a township located in Johannesburg in Gauteng province of South Africa.) equally with suburbs.

CONCLUSION

Global innovation and local adaptation are key to AI's last-mile delivery in Johannesburg. DHL's AI tools boost productivity by 20% (DHL, 2022), but the city's infrastructure, informal settlements, and regulatory deficiencies require context-specific frameworks (Ndlovu et al., 2021; City of Johannesburg, 2023).

This research uses the Adaptive Structuration and Situated Cognition Theories to reimagine AI not as a one-size-fits-all solution, but as a situated facilitator—a concept especially relevant to cities in the Global South (Mohammad et al., 2023). The method here intertwinestheory with practice-based strategies, aiming to harmonize AI's efficiency with Johannesburg's socioeconomic dynamics. By interlacing theory and strategies based in real-world application, this methodology overcomes local obstacles and creates a model for inclusive and sustainable urban logistics in regions where innovation must align with grassroots realities.

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