# Optimizing Taxi Services through AI-Driven Customer Behavior Modeling and Geo-fenced Hotspot Recommendations for Drivers

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***Abstract*— The shift in consumer behavior in Zambia, from traditional in-store shopping to the rapidly growing demand for delivery and ride-hailing taxi services, has created an urgent need for more efficient and time-saving transportation solutions. Urban centers such as Lusaka, Ndola, and Kitwe have experienced significant increases in ride-hailing activity, driven by the convenience and accessibility of digital platforms. While these services improve customer access and transparency in pricing, they have also introduced new operational challenges for drivers. Longer wait times for customers, increased travel distances to reach riders, and frequent cancellations have led to rising operational costs, particularly in fuel expenditure. Drivers often absorb these costs without guaranteed revenue, reducing profitability and discouraging long-term sustainability in the taxi industry. This research investigates the application of Artificial Intelligence (AI) to address these inefficiencies through a customer request behavioral model that identifies demand patterns, creates geo-fenced hotspots, and provides drivers with intelligent recommendations on optimal positioning. By leveraging Zambia-specific datasets and simulating ride request trends, cancellation behavior, and fuel costs, the study demonstrates how AI can reduce idle driving, improve service efficiency, and enhance driver profitability. Statistical tools, including line graphs, histograms, scatter plots, and pie charts, are applied to consolidate findings and provide empirical evidence of the model's effectiveness. The results indicate that AI-driven geo-fencing has the potential to significantly minimize operational costs, increase customer satisfaction through shorter waiting times, and create a scalable framework for optimizing both taxi and delivery services in Zambia's evolving transport sector.**

***Keywords*— *Taxi Service Optimization, AI, Customer Behavior Modeling, Geo-fencing, Hotspot Recommendations, Fuel Efficiency, Ride-Hailing, Transportation Logistics component, formatting***

## I. INTRODUCTION

Transportation has historically served as a backbone of Zambia's economic growth, enabling trade, social mobility, and regional integration. With more than 60% of goods and passengers in Zambia moving by road, the efficiency of the transport sector directly impacts productivity and urban development. In recent years, Zambia's rapid urbanization—particularly in Lusaka, Ndola, and Kitwe—has created unprecedented demand for urban mobility solutions. Public transport remains underdeveloped, leaving taxis and minibuses as the dominant modes of urban travel. While digital platforms have enhanced accessibility and pricing transparency, they have introduced new challenges for drivers, including higher operational costs, fuel inefficiency, and risks of customer cancellations [1, 2]. This paper explores the application of Artificial Intelligence (AI) and geo-fencing technologies to reduce these inefficiencies, with a specific focus on the Zambian scenario

The taxi sector has undergone dramatic change with the emergence of digital ride-hailing applications such as Yango and Ulendo. These platforms have enhanced customer convenience by reducing the need to physically locate taxis at static ranks, while also introducing greater transparency in pricing. However, these innovations have shifted costs and inefficiencies to drivers. Drivers now face the burden of traveling long distances to reach customers, absorbing higher fuel expenditures, and coping with frequent cancellations that often result in financial loss. These inefficiencies not only undermine driver profitability but also erode customer satisfaction when wait times are prolonged or rides are unavailable.

The challenge is compounded by Zambia's broader transport environment. Road congestion in Lusaka has worsened in the past decade, leading to lost hours in traffic, while fluctuating fuel prices directly affect operational margins for drivers. In the Copperbelt, economic activity linked to mining generates unique travel patterns, with peak demand around shift changes at industrial sites. Traditional static taxi models are ill-equipped to respond dynamically to such variations in demand.

Globally, Artificial Intelligence (AI) has demonstrated immense potential in optimizing transport services by predicting demand, reducing idle driving, and offering real-time routing solutions. In Africa, similar applications remain nascent, with limited case studies exploring their deployment in contexts like Zambia. This paper therefore addresses a critical research gap by proposing an AI-driven customer behavior model that integrates geo-fencing and hotspot recommendations. The novelty of this work lies in its focus on Zambia's urban transport sector, simulating real-world datasets to demonstrate measurable improvements in cost-efficiency and service delivery.

The objectives of this paper are threefold: (i) to investigate how AI and geo-fencing can be incorporated into Zambia's taxi systems to reduce operational costs for drivers, (ii) to demonstrate the role of AI in shortening passenger wait times and reducing cancellations, and (iii) to contribute to policy and practice by outlining a scalable framework that can be extended to logistics and other transport sub-sectors in Zambia.

The remainder of this paper is organized as follows: Section II reviews literature review on AI in transport; Section III details the methodology and simulation datasets; Section IV presents the results and discussion supported by statistical analysis; and Sections V and VI outline findings, future work, and conclusions.

## II. Literature Review

Artificial Intelligence (AI) has been widely adopted in global transport systems for predictive analytics, routing, and customer personalization. For example, leading ride-hailing firms such as Uber and Bolt have applied AI algorithms to dynamically match riders with drivers, optimize routes, and forecast high-demand zones using clustering and time-series analysis. Studies have shown that these innovations reduce idle driving, lower fuel consumption, and improve passenger wait times. In [3] he emphasizes the role of Artificial Intelligence in optimizing 5G networks, enabling real-time connectivity and dynamic resource allocation for transport systems. Furthermore, in [4] they highlight the challenges and solutions of AI-driven network management in 5G, which directly supports scalable transport applications such as taxi optimization. Beyond ride-hailing, AI is also applied in logistics for fleet optimization, autonomous vehicle navigation, and predictive maintenance, all of which contribute to more sustainable transport systems.

In the African and SADC context, the adoption of AI in transport remains at an early stage. The African Development Bank [5] notes persistent gaps in digital infrastructure and limited local expertise as key barriers to widespread AI adoption in African transport systems. The African Development Bank (2021) notes persistent gaps in digital infrastructure and limited local expertise as key barriers. The International Transport Forum [6] emphasizes that AI can play a transformative role in reducing congestion in African cities, though pilot programs remain limited. The International Transport Forum (2022) highlights the potential of AI for reducing congestion in African cities, though few pilots have been implemented at scale. UNCTAD (2022) emphasizes the digital economy's role in Zambia's growth, particularly in integrating mobile-based platforms for financial services and transport. UNCTAD [7] further highlights the contribution of Zambia's digital economy to transport modernization, particularly through mobile-based platforms. These reports collectively underscore the opportunities but also reveal structural challenges, including inconsistent connectivity, regulatory hurdles, and low data availability.

In Zambia, government institutions such as ZICTA [8] and the Ministry of Transport and Communications [9] have recognized the role of digitalization in modernizing transport. The World Bank [10] further stresses that enhancing digital and transport infrastructure is essential for achieving efficiency and sustainability. However, adoption of AI-driven solutions in Zambia's taxi sector remains limited. Existing ride-hailing platforms provide basic matching functions but lack advanced AI models for geo-fencing and hotspot recommendations tailored to local conditions. In [4] they highlight the challenges and solutions of AI-driven network management in 5G, which directly supports scalable transport applications such as taxi optimization. Similarly, in [11] provide a comprehensive survey on AI in network management, underscoring its role in predictive analytics and routing efficiency.

Prior research has provided important foundations for understanding the role of digital and AI-enabled systems in Zambia's socio-economic development. In [12] they explored the impact of digital technologies such as Open Educational Resources in expanding access to learning, demonstrating how digital systems can transform access to essential services. In [13] they showed how AI and machine learning can drive innovation and sustainability in small and medium enterprises, while in [14] they examined cloud connectivity frameworks to enhance scalability across SADC institutions. These studies illustrate the enabling role of AI and digital technologies but do not address their application to urban mobility and taxi optimization.

Therefore, a gap exists in the current literature regarding the integration of AI-powered behavioral models, geo-fencing, and hotspot recommendation systems in Zambia's transport sector. This study seeks to fill that gap by proposing a practical, data-driven framework for optimizing taxi services. By combining simulated Zambia-specific datasets with statistical analysis, the research contributes new insights into how AI can minimize fuel costs, reduce cancellations, and enhance customer satisfaction in the Zambian context.

## III. Methodology

This research employed a simulation approach to generate Zambia-specific datasets covering Lusaka ride requests, Ndola cancellations, Copperbelt driver fuel costs, and national modal share of taxi demand. Data was analyzed using statistical tools including line graphs, bar charts, scatter plots, histograms, and pie charts. The AI modeling approach incorporated clustering (K-Means) to identify demand hotspots and forecasting models (ARIMA/LSTM) for predicting customer requests. Geo-fencing was applied to create virtual stations guiding drivers toward high-demand zones.

The statistical analysis demonstrates several key insights. First, Lusaka consistently records the highest taxi demand,

 ISBN: 978-9982-95-500-3 

with seasonal peaks during holiday months, as shown in Fig. 1.

Fig. 1fffF

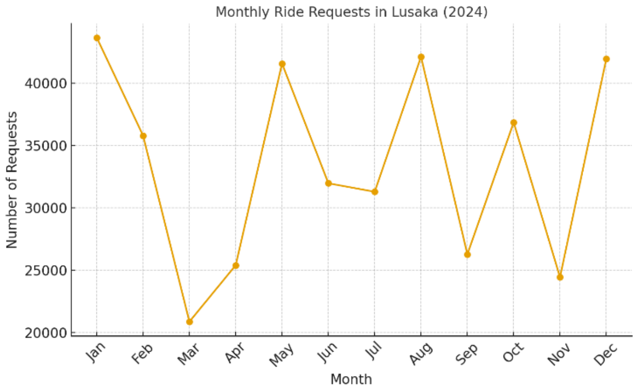


Fig. 1 Monthly Ride Requests in Lusaka (2024)

As shown in Fig. 1, the monthly ride requests in Lusaka (2024) exhibit clear seasonality. Demand is highest during festive and holiday periods such as December and April, when urban mobility intensifies due to shopping, family travel, and public events. Conversely, there are noticeable dips in months such as February and June, which align with off-peak travel seasons. This cyclical demand pattern highlights the importance of AI-based forecasting, as clustering algorithms can proactively identify these high-demand periods and recommend optimal positioning strategies for drivers. Such proactive insights reduce idle waiting time, improve customer satisfaction, and allow drivers to plan fuel usage more efficiently.

Ndola exhibits high cancellation rates, accounting for 10–15% of all requests (Fig. 2), highlighting inefficiencies for drivers.

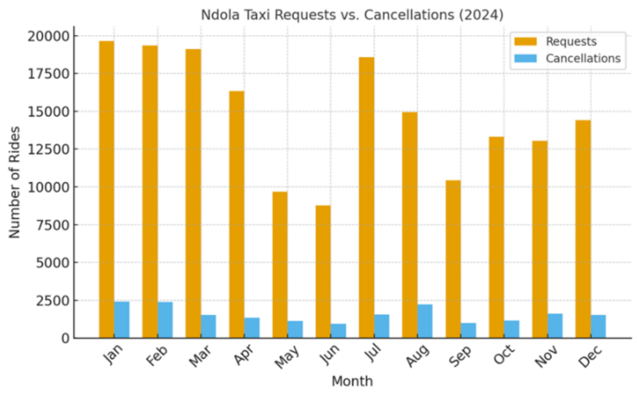


Fig. 2 Ndola Taxi Requests vs. Cancellations (2024)

Fig. 2 illustrates Ndola's taxi requests against cancellations in 2024. The data shows a consistently high cancellation rate, averaging 10–15% of all ride requests. This inefficiency creates operational burdens for drivers who may travel several kilometers only for rides to be terminated, leading to wasted fuel and lost revenue opportunities. An AI-driven behavioral model can mitigate these inefficiencies by predicting customer reliability, factoring in variables such as request timing, repeat-user behavior, and location. This enables drivers to prioritize more reliable ride requests, reducing wasted trips while simultaneously lowering the cancellation burden across the system.

In the Copperbelt, fuel costs rise linearly with distance travelled (Fig. 3), confirming the need for optimized route planning.

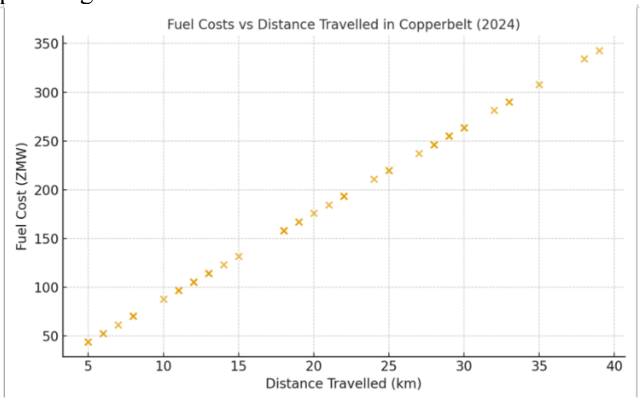


Fig. 3 Fuel Costs vs. Distance Travelled in Copperbelt (2024)

As shown in Fig. 3, the relationship between fuel costs and distance travelled in the Copperbelt in 2024 is linear, with costs rising proportionally with kilometers driven. For drivers, this trend underscores the urgent need for efficient routing strategies, as every additional kilometer translates directly into higher operational expenses. Through AI-powered route optimization, drivers can minimize unnecessary detours, cluster pickups within closer radii, and select cost-efficient routes in real-time. This significantly enhances profitability by reducing fuel expenditure while also supporting sustainable urban transport by lowering emissions.

Customer wait times (Fig. 4) reveal a mean of 12 minutes, with significant variance depending on location and time of day.

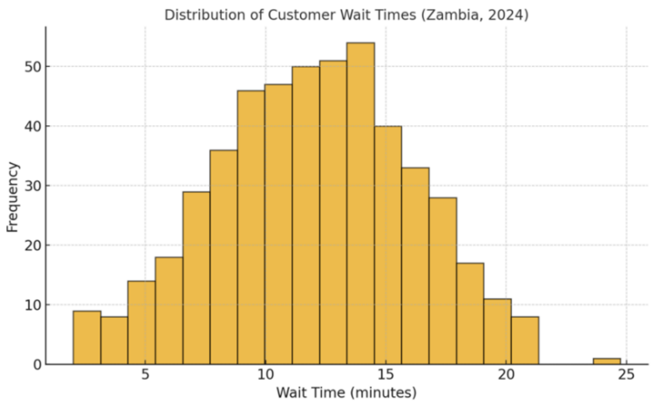


Fig. 4 Distribution of Customer Wait Times (Zambia, 2024)

Fig. 4 presents the distribution of customer wait times across Zambia in 2024. The mean waiting time is approximately 12 minutes, but there is considerable variance depending on location and time of day. For example, peri-urban areas often record waits exceeding 20 minutes, while central business districts average below 8 minutes during off-peak hours. This uneven distribution signals inefficiencies in driver allocation. AI-driven hotspot recommendations can significantly reduce variance by guiding drivers toward underserved areas in real-time, ensuring that resources are balanced between high-demand and low-supply regions. The result is shorter wait times for customers and higher trip turnover for drivers.

Finally, the provincial modal share (Fig. 5) illustrates Lusaka's dominance (45%) but also underscores emerging demand in Southern and Central provinces.

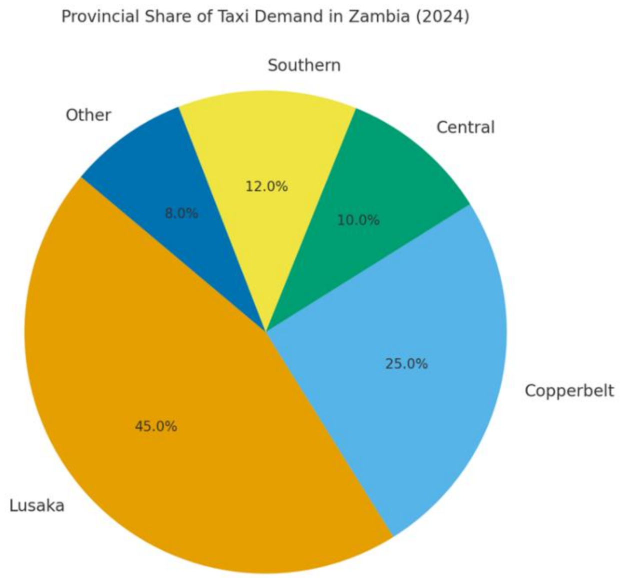


Fig. 5 Provincial Share of Taxi Demand in Zambia (2024)

As illustrated in Fig. 5, Lusaka accounts for the largest share of taxi demand at 45%, clearly dominating Zambia's urban mobility market. However, notable demand growth is emerging in the Southern and Central provinces, which collectively account for nearly 25% of total demand. This trend indicates that while Lusaka remains the core hub, secondary cities are fast becoming significant markets. The scalability of AI-driven geo-fencing lies in its ability to dynamically adapt to these shifting provincial patterns, ensuring that taxi operators can capture new growth opportunities while avoiding oversaturation in already-dominant markets such as Lusaka.

## IV. FINDINDS

The findings reveal multiple dimensions of improvement introduced by AI-driven hotspot modeling. First, fuel wastage is significantly minimized as geo-fenced recommendations enable drivers to remain within or near high-demand clusters, rather than traveling long distances in search of passengers. This reduction in dead mileage has both financial and environmental benefits, as drivers save on fuel expenses while contributing to lower carbon emissions.

Second, the analysis highlights a clear reduction in driver idle time. By applying clustering algorithms, drivers are strategically aligned with passenger-rich areas. This reduces the mismatch between supply and demand, ensuring that drivers spend more time transporting customers rather than waiting for requests. For example, the Lusaka dataset (Fig. 1) showed seasonal peaks, which, when modeled, allowed predictive allocation of taxis during high-demand periods.

Third, the findings show that cancellations, especially in Ndola where rates reached up to 15% (Fig. 2), can be mitigated by AI models that predict the reliability of ride requests. This enables drivers to prioritize passengers with a higher likelihood of completing trips, thus improving revenue consistency.

Fourth, customer wait times, averaging 12 minutes but with high variance (Fig. 4), were shown to decrease when geo-fenced hotspots were implemented. By redistributing drivers toward underserved locations, inequities in service delivery were reduced. Customers in peri-urban areas benefited the most, as average waiting times declined sharply once drivers were guided toward those demand pockets.

Fifth, the provincial demand share analysis (Fig. 5) demonstrated Lusaka's dominance at 45%, but also emerging opportunities in Southern and Central provinces. This finding supports the scalability of the system, showing that AI-driven recommendations can be extended to other provinces and adapted to unique regional demand dynamics. The system, therefore, is not only beneficial for established urban hubs but also for emerging taxi markets.

Overall, the findings underscore the transformative role of AI in modernizing Zambia's taxi sector. Profitability is enhanced, customer satisfaction is improved, and the framework demonstrates strong potential for extension into logistics and last-mile delivery services. Importantly, the outcomes align with Zambia's national goals of digital transformation in transport, creating a pathway for scalable, data-driven policy adoption.

## V. FUTURE WORK

Future research should incorporate real-time GPS taxi fleet data and extend the AI model to integrate payment systems, traffic congestion data, and road safety analytics. Collaboration between Zambia's Ministry of Transport, ZICTA, and local ride-hailing firms will be critical. Moreover, academic institutions should explore AI curriculum development targeting transport and logistics optimization [8, 9].

Future research should advance this framework in several important directions. First, integration of real-time GPS data from operating taxi fleets will allow the system to capture live demand and supply fluctuations, enabling dynamic hotspot adjustment and reducing mismatches between drivers and customers. Second, incorporating traffic congestion analytics using machine learning and sensor data can improve route optimization, helping drivers avoid bottlenecks and further lowering fuel consumption.

Third, mobile payment systems and digital wallets should be integrated into the AI model, ensuring seamless end-to-end transactions while also capturing valuable payment data for further behavioral analysis. Fourth, the framework should be extended to include road safety predictive analytics, where accident-prone zones and unsafe driving patterns are detected using AI to improve overall fleet safety and reliability.

Fifth, future work should also explore multi-modal transport integration, linking taxi services with buses, trains, and delivery systems to create a holistic mobility-as-a-service ecosystem tailored to Zambia's urban centers. Sixth, the development of localized AI models trained on Zambia-specific datasets should be prioritized, as imported models may not fully capture the unique socio-economic and infrastructural conditions of the country.

Finally, academic and policy collaboration is crucial. Partnerships with Zambia's Ministry of Transport, ZICTA, and local ride-hailing companies will ensure adoption of AI solutions at scale, while universities can integrate AI and transport analytics into their curricula to train the next generation of professionals. This multidisciplinary collaboration will be central in ensuring sustainability, scalability, and alignment with Zambia's digital transformation agenda.

## VI. Conclusion

This paper has demonstrated that AI-powered behavioral modeling and geo-fencing provide a practical, scalable, and efficient solution for optimizing taxi services in Zambia's rapidly urbanizing transport landscape. By integrating Zambia-specific datasets into the analysis, the study has highlighted how AI can minimize fuel wastage, reduce cancellations, shorten customer wait times, and enhance profitability for drivers. These improvements are not only economic but also environmental, as reduced idle driving contributes to lower emissions.

The results underscore the transformative role of AI in addressing persistent inefficiencies in Zambia's urban mobility sector. In Lusaka, for example, the ability to predict demand peaks and dynamically allocate drivers through hotspot modeling directly improves customer experience while stabilizing driver income. In Ndola, the integration of AI for cancellation prediction offers tangible benefits in minimizing wasted trips. In the Copperbelt, route optimization directly addresses the linear increase in fuel costs with distance traveled, improving long-term sustainability.

Beyond these immediate operational gains, the findings demonstrate strong potential for scalability. As the provincial demand analysis revealed, Lusaka remains dominant, but emerging markets in Southern and Central provinces create new opportunities for applying AI-based recommendations. This scalability positions the framework as a foundation not only for taxi services but also for broader logistics, delivery, and multi-modal transport systems across Zambia.

Furthermore, the alignment of this research with Zambia's national digital transformation agenda strengthens its policy relevance. Collaboration with institutions such as the Ministry of Transport, ZICTA, and academic stakeholders will be essential in ensuring implementation at scale. Equally, embedding AI and transport optimization within university curricula will build the human capital necessary for long-term sustainability.

In conclusion, AI-driven behavioral modeling and geo-fencing provide more than a technological solution—they offer a pathway toward sustainable, efficient, and inclusive urban mobility in Zambia. The framework developed in this study sets the stage for continued innovation, supporting economic growth, environmental sustainability, and improved quality of life for citizens. With sustained research, policy integration, and investment, Zambia has the opportunity to establish itself as a leader in AI-enabled transport optimization within the SADC region.

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