Artificial Intelligence and Its Impact on On-Street Parking Management: A Case Study of Gweru City Parking, Zimbabwe

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Abstract— **Urban parking management systems worldwide face increasing pressure from rising vehicle ownership and limited infrastructure capacity, challenges that are particularly acute in developing African cities. This mixed-methods study investigated how Artificial Intelligence (AI) can impact and improve on-street parking management in Gweru City, Zimbabwe. Adopting the Technology Acceptance Model as a theoretical framework, the research employed a pragmatic paradigm to examine current parking performance, international AI applications, implementation barriers, and potential enhancement strategies. Data collection involved 217 participants across four stakeholder groups: parking management officials (n=9), on-street parking users (n=175), local business owners (n=27), and technology experts (n=6). Quantitative data captured parking utilization patterns, revenue collection efficiency, and traffic congestion metrics, while qualitative data explored stakeholder perceptions and organizational readiness through interviews, focus groups, and observational analysis. Findings revealed significant operational inefficiencies in Gweru's current parking system, with average occupancy rates of 87% during peak hours but only 34% during off-peak periods. Revenue collection efficiency stood at 62%, while 43% of vehicles spent 15-25 minutes searching for parking spaces during busy periods. User satisfaction surveys indicated widespread frustration with existing manual enforcement systems, while business owners reported customer avoidance due to parking difficulties. Technical feasibility assessment demonstrated moderate infrastructure readiness for AI implementation, with 45% of parking zones having adequate power supply and 67% possessing sufficient connectivity for sensor installation. Cost-benefit analysis projected a $2.3 million initial investment with a 4.5-year break-even period through improved revenue collection and reduced traffic congestion. Environmental modelling suggested a potential 23% reduction in carbon emissions from decreased vehicle search times. Implementation barriers included organizational capacity constraints, financial limitations, and employment security concerns among current parking attendants. However, 68% of users expressed enthusiasm for technological improvements, indicating strong acceptance potential. Expert interviews revealed mixed perspectives on technical capacity requirements and maintenance sustainability. The study concludes that AI-enhanced parking management offers substantial potential for addressing Gweru's parking challenges, with favourable user acceptance and moderate technical feasibility. However, successful implementation requires phased deployment strategies, comprehensive staff training, and inclusive access mechanisms to address digital divide concerns. Recommendations include establishing pilot projects in high-traffic zones, developing employment transition programs for existing staff, and creating stakeholder engagement platforms to ensure system responsiveness to local needs. This research contributes to the limited literature on AI parking implementation in Sub-Saharan African contexts and provides practical guidance for similar developing city initiatives.**

Keywords: **Artificial Intelligence, on-street parking, Gweru City Parking, Smart City, Zimbabwe, Urban Mobility**

I. INTRODUCTION

This paper examines the potential for Artificial Intelligence to transform on-street parking management in Gweru City, Zimbabwe. Through mixed-methods research involving 217 stakeholders, the study evaluates current parking inefficiencies, explores AI implementation feasibility, and identifies barriers to adoption. The research provides practical recommendations for developing cities seeking to modernize parking systems while addressing local capacity constraints and ensuring inclusive technology deployment.

II. BACKGROUND OF THE STUDY

Artificial Intelligence (AI) and the Internet of Things (IoT) are fundamentally changing the management of urban infrastructure across the world, which has significant implications for on-street parking systems. Knights et al. (2025: 91) state that AI combined with IoT technologies allows for accurate forecasting of parking occupancy, facilitates dynamic pricing, and decreases search and cruising times, amongst other positive advances in dense, congested urban areas. Importantly, machine learning algorithms can use fog and cloud computing technologies to enhance real-time capabilities that reduce latency when managing traffic, especially in urban space. Enríquez et al. (2024) similarly demonstrate the promise of AI models such as Adaptive Boosting (AdaBoost) in predicting short-term parking vacancy rates to better support effective decision-making for both drivers and urban authorities. These developments are part of a broader trend in global smart cities, where parking management represents an important focus area for trialling AI solutions.

Throughout Africa, smart parking technologies are steadily being accepted in light of worsening congestion in urban areas, and of the ongoing pressure on transport infrastructure. South Africa's digital platform Admyt has been a front-runner in AI and IoT technologies to undertake ticketless and cashless parking in major urban areas such as Johannesburg and Cape Town, through their digital platform that utilises Automatic Number Plate Recognition (ANPR) and mobile applications (Admyt, 2025). This model reflects an evolution towards digital urban mobility services that are convenient, scalable, and with minimal environmental impact. In addition, according to Mubeen and Alwin (2025), African cities are beginning to understand the potential of AI to offer improved public service delivery including transport and parking, but this process is uneven due to existing infrastructure, regulation and financial considerations across individual cities and countries. In Zimbabwe, AI-enabled urban mobility systems have attracted more institutional interest in recent years. The Safe City Project established the groundwork for embedding AI into public traffic systems during the COVID-19 pandemic. According to Ntali (2025), the Government of Zimbabwe recently approved a national rollout of an AI-based Smart Traffic Management System utilizing IoT sensors and real-time analytics to detect traffic violations, monitor congestion, and enforce rules of the road, all through a single digital platform. With the system, violations are automatically reported, and it is linked to the Central Vehicle Registry, which is a notable advancement in integrating AI into the digital transformation of urban governance. As noted by Chidakwa (2025), this initiative is also expected to be rolled out to all the major city centres, which can position Zimbabwe as a regional leader in providing AI-based traffic solutions.

In these national developments, Harare has emerged as a leader in the first AI tools for parking enforcement. In early 2025, Mupawaenda (2025) described the introduction of vehicle mounted ANPR technology by City Parking Private Limited that allows for illegal parking to be captured automatically, fines to be issued in real time to the vehicle's owner, and completely report the incident data in real time back to the central control centre. ANPR improves compliance by lessening the need for manual—the human factor—enforcement, and improved traffic flow and minimized bottlenecks in the central business district. The City Parking project is part of a wider process to reform service delivery using locally developed digital systems that are suited to local circumstances, (Kafe, 2024). Apart from a changed enforcement scenarios, City Parking has improved its technological position by becoming a software development company. Buwerimwe (2024) observes the company is developing its own systems, including handheld devices for marshals, and a real-time data integration backend for both cities of Harare and Gweru. The latter allows City Parking to vertically integrate operations giving them explicit control of design, data security, and operating efficiencies. In addition, City Parking is providing self-service payment forms via USSD, WhatsApp chatbots and QR codes, which provides flexibility for drivers, but also reduces disputes/referrals between marshals and motorists (Buwerimwe, 2024). These changes are impressive but remain primarily enforcement led, and fail to apply predictive artificial intelligence models for demand forecasts or optimization of parking occupancy.

Gweru's use of artificial intelligence for parking is much more rudimentary, and, although City Parking, in partnership with Gweru City Council, began paid on- street parking in 2021 (a mixture of prepaid, casual and reserved bays); enforcement in Gweru primarily relied on marshals using handheld devices and limited or no sensor-based monitoring of space use or algorithmic forecasting of parking space utilization (NewsDay, 2025). Although City Parking actively encourages the use of mobile apps for

payment and ticketing processes, Chidakwa (2025) states that there are currently no artificial intelligence models in place for managing occupancy trends, optimizing the allocation of parking spaces, or informing the planning of infrastructure.
This clearly presents a research gap since in international practice, artificial intelligence has the potential to greatly enhance parking efficiencies (Knights et al., 2025; Enríquez et al., 2024) demonstrating how predictive analysis can improve urban parking systems. Gweru appears not to be taking full advantage of technology to mitigate issues in congestion, turnover and revenue loss. Therefore, it is important to evaluate options for improving not only immediate service delivery provisions, but the long-term benefits of urban mobility for Gweru, with artificial intelligence.

III. STATEMENT OF THE PROBLEM

Many urban areas around the globe are contending with rising traffic congestion and poor parking availability, or management, due to increased vehicle ownership and the lack of parking availability. Almost all on-street parking is poorly utilized, and all suffer the inconvenience created by drivers searching for available spaces which can lead to increased pollution and losses to the economy (Shoup, 2011). Gweru, Zimbabwe is impacted by these issues but without intelligent parking system capability, traffic delays and disruption; angry commuters; and local authorities suffering poor collection efficiencies of revenue (Madzudzo & Muchenje, 2020). It is well-documented that AI-enabled technologies can improve the stock of parking spaces available, reduce search times and enhance user experience in various contexts across the world but such technology remains unexamined in Zimbabwe (Nguyen et al., 2020). There is no indication that these challenges will improve or cease to exist into the future - more likely they will escalate, with increasing urban congestion and impacts on the environment. Consequently, this situation underscores the need to investigate the potential or real feasibility of implementing artificial intelligence as an improved approach to managing on-street parking developments in Gweru.

IV. AIM OF THE STUDY

This study aims to investigate how Artificial Intelligence can impact and improve on-street parking management in Gweru City, Zimbabwe.

Specific Objectives

1. To evaluate the existing on-street parking management system in Gweru City.
2. To examine the application of Artificial Intelligence in on-street parking management internationally and its potential applicability to Gweru.
3. To identify barriers to implementing AI-driven parking solutions in Gweru City.
4. To propose AI-based strategies that can enhance the efficiency and user satisfaction of on-street parking management in Gweru.

Research Questions

1. What is the current status and effectiveness of on-street parking management in Gweru City?
2. How has Artificial Intelligence been applied to on-street parking management in other cities?
3. What are the challenges hindering the adoption of AI parking technologies in Gweru?
4. What AI-driven interventions can improve on-street parking management in Gweru?

V. SIGNIFICANCE OF THE STUDY

This study was important because it provided empirical evidence on how AI can transform parking management in a mid-sized Zimbabwean city context, which has been under-researched. It helped local authorities understand the practical benefits and limitations of AI applications, contributing to improved urban mobility and reduced environmental impact. The findings supported policymakers and urban planners in adopting smart technologies tailored to local needs, thereby enhancing economic efficiency and citizen satisfaction. Furthermore, the research added to the broader discourse on smart city development in Sub-Saharan Africa, informing future technological integration efforts in similar urban areas.

VI. THEORETICAL FRAMEWORK

This study utilized Davis's (1989) Technology Acceptance Model (TAM) that uses perceived usefulness and perceived ease of use to explain how users decide whether to accept and use new technology (Davis, 1989). TAM has gained a reputation for being a solid tool to predict adoption behavior of emerging technologies, especially in the context of urban management (Venkatesh & Davis, 2000). By using TAM in this study, it can be determined how both city officials and vehicle drivers in the City of Gweru are willing to use AI technologies in parking management and what influences their willingness to accept the innovations. This milestone is important because any successful AI implementation will depend on the acceptance of the stakeholders too, not just the technical, and therefore, configuring the study based on TAM is highly valuable in directing the research and understanding the results (King & He, 2006).

VII. LITERATURE REVIEW

The highly accelerated pace of urbanization and the growing numbers of vehicles in urban areas have brought about situations of unprecedented complexity in managing on-street parking operations. Conventional parking management systems have been unable to keep pace with current urban mobility needs, creating a major focus for research into the potential of artificial intelligence for overcoming some of these issues. This literature review will examine the studies and scrutiny of the researchers who have investigated various applications of AI into parking management systems in addition to a description of what research is available regarding its adoption and the factors that might inhibit the implementation or barriers of use, not only in terms of operating efficiencies and the increased user experience but also the users they serve.

Present On-street Parking Management Systems

Recent studies have clearly identified that traditional on-street parking management systems are plagued with traditional management qualities that lack operational efficiencies which find researchers proposing management systems that are deployed through innovative technological developments. In their study; A Smart Real-Time Parking Control and Monitoring System, Elfaki et al. (2023) state conventional parking has too much inefficiencies that includes economic waste by way of excessive traffic congestions created by the act of searching for available parking and provides poor revenue management of parking operators. Elfaki et al. argued their research methodology encompassed IoT sensors used in conjunction with a real-time monitoring system application to illustrate how most traditional parking systems are unable to optimize space utilizations. Elfaki concluded that many manual enforcement systems would result in a high customer dissatisfaction and operational efficiencies, in high population density as one might expect.

Knights et al. (2025) working off this foundation and by way of a comprehensive study entitled; Machine Learning Models and Mathematical Approaches for Predictive IoT Smart Parking employed a quantitative research methodology, that reviewed a research study of three parking locations in Skopje, North Macedonia for three consecutive years commencing in 2019 through to 2021. Their results indicate that the traditional techniques of parking management rely on (1) fixed signage, (2) manual enforcement, and (3) first-come-first-serve parking space management, which don't alleviate real time parking demand. Elfaki et al. concluded that these inefficiencies not only represent economic losses but also pollution and annoyance to the driver; however, where Elfaki et al. largely formed their research around the abilities to monitor things in real-time, Knights and team were able to extend analysis to predictive modelling to indicate a more developed method to measure parking behavior.

International Applications of Artificial Intelligence in Parking Management

The use of artificial intelligence in parking management has received international attention. Researchers have employed diverse methods in addressing urban parking, but Knights et al. (2025) presented novel applications of machine learning methods to predict parking usage. The study developed three models including a Random Forest Regressor, Gradient Boosting Model, and LightGBM Regression Model and employed autoregressive modelling strategies that included Z-score normalization and lagging features in an attempt to included temporal dependencies in the results. The study found LightGBM had the greatest R2 values (first parking location = 0.977, second parking location = 0.905 and third parking location = 0.742) with the lowest RMSE values indicating a supportable method to satisfactorily predict for the real time availability of parking.

In comparison to mathematical modelling, Singh et al (2024) in the study "Artificial Intelligence-Enabled Smart Parking System" used a different type of research methodology focused on the integration of the Internet of things (IoT) with cutting-edge AI technologies. The research used a four-layer architecture that included (1) service application layer, (2) perception layer, (3) data analysis layer, and (4) management layer. Overall, the study indicated that AI technologies - to include many algorithms or machine learning algorithms and real-time data processing - have the characteristics and capabilities to significantly enhance urban parking management by improving space recognition and system responsiveness.

The methodological distinctions among the studies were related to their levels of research. For instance, Knights et al. emphasized predicting degree of accuracy through the use of regression analysis, and Singh et al. emphasized system architecture integration as a variable of importance to acknowledge that AI systems have complicated contexts of application in parking management. In both cases, the authors provided clear evidence to argue that an AI-driven system is much more efficient and provides much greater user satisfaction than a traditional parking management system.

Barriers to Implementing and Developing AI Parking Resources

Researchers have identified barriers to the mass deployment of what could be AI-potential parking solutions, since AI parking systems do and will need to bypass a variety of barriers. Biyik et al. (2021) undertook a literature review of smart parking (SP) systems to investigate their architecture and implementation problems, finding that supplier impediments, turf wars and other market obstacles need to be recognized before you can ever deploy solutions.

Technical barriers are a major concern for the deployment of AI parking system. Biyik et al. outline how technical challenges, such as sensors not being installed correctly, different image sizes, and mismatched object sizes in 3D views will pose significant technical challenges for implementation. The research by Biyik et al. used secondary research reviewing 45 studies of smart parking, which reached the resolution that a majority of technical issues are highly complex requiring specialized knowledge and calibration determinations to the operational system, which urban management does not always have. The research concluded that the variation in urban conditions exacerbates these limitations as parking systems must accommodate differences in physical infrastructure designs and different environmental conditions.

In her research study, Fraifer and Fernström (2016), "Investigation of Smart Parking Systems and their Technologies," made use of a mixed-methods research approach, combining stakeholder interviews with a technical analysis to highlight implementation limitations. They then identified that certain camera systems faced limitations, especially those subject to weather conditions, thus degrading the performance of those camera systems, continuous power, and continuous maintenance to ensure the highest quality image capture. Their research showed that camera systems installed in an outdoor environment would be limited in performance during adverse and non-standard conditions, even after training datasets were established to include many adverse and non-standard weather conditions.

Economic limitations may also create a further impediment for purchasing and adopting AI parking systems. Research by Postigo, et al. (2015), "Estimating Parking Areas that are Vacant, using Background Subtraction and Transience Maps," evaluated vision-based parking detection deployments made using background subtraction methodology, and determined that the overall cost of sensor manufacture will increase proportionately since sensors need to be deployed for each latent parking space. Their research concluded that there is a lot of economic inertia to limiting the costs of individual camera sensor installation and ongoing power usage, along with ongoing maintenance fees for highly sophisticated camera systems for prolonged operational periods, meaning economic limitations remain important barriers for municipal depicted parking strategies.

Further, and building on the financial limitations associated with absence of knowledge or security threats, Yaqoob et al. (2017) examined the threats associated with IoT using threat analysis and vulnerability testing in their study "Rise of Ransomware and Emerging Security Challenges in the IoT". The study concluded that a large number of connected devices created scaling issues to the security threats encountered, while the infrastructure must be sufficiently flexible to allow for the dynamic nature of IoT security threats. Their findings concluded that, while distributed denial-of-service and remote hijacking attacks could render the system unavailable, municipal organisations would risk an economic threat as a result of these service interruptions.

Organizational barriers can create a source of resistance to adopt new technologies in the existing parking management structure. Biyik et al. (2021) published a systematic literature review that identified previously established coordinators applying IoT solutions to create a heterogeneity challenge in smart parking implementations, as undoubtedly new coordinators will be required to review installation across semi-standards, and each standard will acknowledge different perspectives, demonstrating defeatist sectorial ideologies suggesting interoperability will be difficult. Their analysis concluded that existing parking enforcement officers may see AI systems as threatening their job security and create resistance to implementing AI systems; or, the complexity of the new AI system would be combined with the existing municipal governance framework and create an administrative process that limits the speed of organizational adoption.

AI-Driven Approaches to Improve Performance and Satisfaction

Research results showed that implementing strategic AI-driven approaches can promote both effectiveness and user satisfaction in on-street parking. Multiple studies identified those approaches that had the most applicable value for enhancing parking system performance.

One of the basic approaches, predictive analytics, can work to improve effectiveness of parking systems. Knights et al. (2025) showed that machine learning models that incorporated periods could yield predictive accuracies above 97% for parking occupancy prediction. They created their models by utilizing lagged features with autoregressive modeling to exploit periodic parking behaviors so that managers could allocate resources prior to full occupancy. The study concluded that predictive abilities could allow parking systems to better allocate resources and respond to demand.

AI-powered mobile applications provide another strategic role through real-time information sharing, especially as people surveyed appreciated the immediacy of express access to parking availability. Elfaki et al. (2023) developed an entire architecture model for users to receive data on parking availability as needed. In their methodological approach, they had IoT sensors integrated with a server and Cloud-based data reporting and an app to share real-time data on parking availability. They found that immediate access to data had the potential to decrease driver frustration and mitigate congestion caused by searching for parking.

AI analytics and learning provide one more avenue for efficiency improvements in dynamically-pricing parking systems. Research suggests that machine learning algorithms can use demand detecting algorithms to offer pricing variations on a real-time basis to improve price point balance and thereby overall occupancy. This approach of charging a fair price for parking encourages turnover in areas of high-paid parking whilst not eliminating the use by people wanting to be in an area when price points are low or even free. Comparative Analysis of Research Findings

This examination of various studies shows areas of overlap and contradiction with respect to outcomes regarding AI facilitated parking management systems. Knights et al. (2025) and Singh et al. (2024) both find that AI techniques are more effective than more conventional, non-AI based methods. However, the focus of methods used was quite different between the two studies. Knights et al. focused on quantitative accuracy of occupancy prediction over a number of different parking areas with R^2 measures over 0.9. Singh et al., by contrast, examined the integration of the architecture of the system, an area that they found previously had a lack of robust IoT architecture, which is essential to making AI operationally useful.

In their contribution, Elfaki et al. (2023) provided insight that combined the two methods in a way that showed how prediction could work in conjunction with real-time monitoring to develop fully functioning parking management systems. They used a methodological approach that combined the quantitative emphasis that was intrinsic to the Knights study and the overall IoT systems integration focus from Singh et al., and suggested that hybrid solutions may be the best approach.

There were also some important differences with respect to barriers to implementation. Where some studies had emphasis on technical challenges as the main barrier to uptake for AI parking management, others suggest there are more significant barriers of an economic or organizational nature, indicating that perceptions of barriers to implementation differed for each researcher. Such conclusions indicate a greater need to fully and comprehensively assess barriers to implementation across the various dimensions of implementation.

Research Gaps and Future Directions

In analyzing the literature, there are multiple notable research gaps that needed to be addressed. First, few unilateral studies had explicitly considered the performance and sustainability of AI based parking systems over time. Much of the literature had only considered the short-term phases of a study with no consideration about the performance of the system over longer time periods. This knowledge gap hinders knowledge of maintenance requirements, how systems degrade over time, and holistically consider the relationship between long-term costs and benefits.

Additionally, there is too little research addressing how A.I. parking systems fit into the many layers of smart cities. While individual studies do show successful parking systems implementation, very limited research is examining the way in which parking systems interact as part of a larger ecosystem inclusive of traffic management, public transport and the complete urban mobility context. I.e. A systems view is important to develop a complete urban mobility solution.

Furthermore, previous research there is very limited research focusing on user behavior shifting behaviors to A.I.-enabled parking systems. Understanding how drivers change with the availability of A.I.-enabled information systems is critical setting the design parameters for A.I.-based parking systems and predicting longer-term adoption decisions.

Finally, there is little around the comparative performance of A.I. parking systems in very different cultural and regulatory settings. Most of the existing literature seems to examine a specific geographic context and does not consider how whether differences in cultural context, regulatory environments and urban planning frameworks affect the performance of the system.

In summary, the literature review provides strong agreement among researchers of the potential for an A.I.-driven approach to transform on-street parking management systems. Their studies show that machine learning algorithms (especially the type that incorporate temporal dependencies and real-time data processing) greatly outperform traditional approaches to managing parking in terms of prediction accuracy, operational performance, and user experience. The studies also highlight significant barriers to implementation at the technical, economic and organizational fields, that need to be addressed before A.I. parking systems can be implemented successfully. Future studies should account for the gaps identified in this study through longitudinal studies, comparative assessments, and user behavior studies that would facilitate a clearer understanding of the opportunities presented through AI applications in parking regulation for cities and urban environments.

VII. METHODOLOGY

Methodological paradigm

A pragmatic research paradigm was utilized for this study to facilitate mixed method approaches to complex urban management issues. According to Creswell & Plano Clark (2018), pragmatism offers a philosophical underpinning to utilize qualitative and quantitative approaches when studying a complex phenomenon such as the deployment of artificial intelligence in urban parking systems. The pragmatic paradigm aligns with the objectives of the study; to understand the technical utility of AI systems and the human experience associated with parking management in Gweru City. Johnson et al. (2007) recognized that pragmatism encourages researchers to "use what works" to explore a research problem.

For the purposes of this study, a mixed methods approach was justified, as it addressed the complexities associated with implementing AI in newly-developing urban contexts. Dahiya et al. (2024), noted that parking space management is now "a critical challenge in urban areas because of an increasing number of vehicles and limited parking." To ensure that it provided comprehensive research, the study is framed to explore the broad development of AI in parking regulation; capturing and understanding both the capabilities of the technology and experiences of the users. This paradigmatic approach enabled the study to consider both quantitative aspects of the performance of AI systems and qualitative aspects of stakeholder perceptions and operational challenges.

Participants

The study was designed to be a multi-stakeholder approach; recognizing that any effective parking management strategy would involve multiple stakeholders within the urban arena. The study utilized convenience and purposive sampling techniques (Mubvumba & Mufunda, 2012), meaning participants were selected across four categories for comprehensive data collection.

Primary participants were parking management officials from the Gweru City Parking (n=9), purposefully sampled for their involvement in parking policy development and administrative practices. These key informants were selected based on institutional knowledge of current parking concerns and viable AI applications. As Pojani et al. (2024) observe in their comparative assessment of parking policies in various urban contexts, key informants are all important for understanding current parking issues, and application feasibility with AI.

Secondary participants were on-street parking users (n=175), selected through a systematic random sample of parking users during peak and off-peak parking times, from various parking zones within Gweru's metropolitan central business district. The systematic random sampling enabled the user sample to be more representative of the different parking users (and experiences) of the limited parking, as recommended in similar urban parking demand studies (Liu et al., 2022).

Tertiary participants were local business owners and traders (n=27), whose operations were affected by Gweru City Parking, parking management policies. Local business owners were not selected randomly, and were purposefully sampled, based on their businesses in high traffic zones where AI enhanced parking management systems would have the most impact for their operations.
Expert participants were technology specialists and urban planning professionals (n=6) with AI and smart city experience, selected through snowball sampling to ensure their specialized knowledge concerning technical feasibility and implementation issues in a developing country context.

Data Collection Instrument Development

The data collection instruments were developed according to established mixed methods procedures and consisted of both quantitative measurement tools and qualitative inquiry instruments. The quantitative instrument consisted of a structured parking utilization survey instrument that simultaneously gathered current parking patterns, wait times, and user satisfaction in the parking experience. The instrument was based on established parking survey methods used in similar urban areas (Chen et al., 2023), revised to suit the local context for Gweru City.

The qualitative data collection instruments consisted of semi-structured interview guides for key informants, focus group discussion procedures, and observation checklists to examine parking behavior. The interview guides were developed based on themes identified in recent artificial intelligence management related to parking literature, identifying system effectiveness, acceptance by users, and barriers to implementation (Kumar et al., 2024). As Tashakkori and Teddlie (2010) recommended, the qualitative instruments were designed to explore the "how" and "why" questions that the quantitative measures would not be able to explore.

The technical assessment checklist was developed to evaluate the existing parking infrastructure in reference to the potential for AI integration along the criteria established in recent reviews of smart parking systems (Al-Turjman & Malekloo, 2019). These checklists allowed systematic evaluation of the technological prerequisites, connectivity needs, and potential for integration based on Gweru's urban infrastructure.

Data Collection Process

The entire data collection process followed a sequential explanatory design starting with quantitative data collection followed by qualitative data collection to explore findings of the quantitative data. This approach was based on the process advocated by Ivnakoza et al. (2006), allowing the quantitative stage to lead to the development of the more specific qualitative inquiry. Phase 1: Quantitative Data Collection included a four-week period of conducting parking utilization surveys to gather data at various time intervals throughout the day, on different days of the week, in order to cover the range of parking availability and utilization patterns. Systematic observation protocols were developed for traffic counts and parking durations observations and both types of observations were conducted following protocols from urban parking studies (Zhang & Liu, 2024). Current parking management performance metrics were obtained from municipal office records, including revenue generation, levels of violations, and user complaints, with the appropriate research ethics applications approved for access.

Phase 2: Qualitative Data Collection began first with individual key informant interviews involving current parking management officials and urban planning experts, using semi-structured interview protocols. Each interview was 45-60 minutes long, exploring challenges, the knowledge on AI, and perceived barriers to technology adoption. Focus group sessions were organized with parking users with different demographic and occupational composition to explore their diverse parking experiences and attitudes towards AI-enhanced systems.

Field observations were conducted on parking behaviors and management practices across multiple sites in Gweru's central business district (CBD) to document current operational practice and process, and identify potential AI opportunities. Observations revealed ample context relative to parking behaviors that could help to understand how parking systems work as highlighted in recent studies (Wang et al., 2024), especially the disjuncture between policy and practice.

Data Collected Analysis

The data analysis process began with a convergent parallel design, in which quantitative and qualitative data analysis would be conducted separately and then merged for an overall interpretation. Quantitative data analysis using descriptive statistics provided insight into current parking behavior, utilization, and performance. A range of statistical tests were employed, such as chi-square tests and ANOVA, to identify relationship patterns and significant differences in parking behavior by zone and time.

Qualitative data analysis using thematic analysis followed Braun and Clarke's (2006) model and took six phases: familiarization with the data; generation of initial codes; search for themes; review themes; defining and naming themes; and creating the report. NVivo was used to support systematic coding and development of themes as well as promote consistency in the qualitative data analysis process.

Findings were integrated through joint displays and meta-inferences comparing quantitative parking performance indicators to qualitative stakeholder perceptions to assess similarities and differences. This integration form of analysis was based on Fetters et al. (2013) work, which provided an opportunity to gain a rounded understanding of current parking management effectiveness and stakeholder readiness for AI implementation.

Validation efforts included member checking with key informants, data source triangulation, and peer debriefing with local experts in urban planning. These validation efforts increased rigor and credibility and trustworthiness of the findings, which was particularly relevant in developing country contexts where there was little research into the implementation of AI parking systems.

Ethical Protocols

The research used extensive ethical protocols in line with institution review board structures and recent international research ethics guidelines. Ethical approval was sought and granted by the relevant institutional ethics committee before data collection commenced. The research was therefore compliant with established ethical standards for research including mixed methods studies involving human participants.

All participants were provided with full information about the study purpose, procedures, potential risks and benefits, and their rights as participants in the research study prior to agreeing to take part. All interview participants and members of the focus groups provided written informed consent to take part in the study, while survey respondents provided oral consent to take part in the study following established protocols that allow oral consent to be used for survey research. Participants were clearly informed they could withdraw from the study at any point without any penalty, consistent with the ethical processes outlined by the World Medical Association (2013).

Confidentiality and anonymity protocols were applied in all data collection and storage processes. First, protocols were developed to ensure all data collection and storage processes were secure, as well as protecting the identity of participants through anonymized reporting of findings in all reports and publications, and limiting access to the raw data to only the research team. Digital data was on password protected devices encrypted with secure back-up systems, while hard copy documents were stored in locked filing systems with access granted only to project researchers.

The research was guided by principles of community engagement by attempting to share the study findings with Gweru City Council and with community stakeholders where project reports and presentations were made available for public access. It was an ethical imperative to make research findings public in a way that contributed to the benefit of communities who participated in the research. This commitment to sharing knowledge aligns with ethical principles outlined in community-based participatory research (Israel et al., 2012).

The research acknowledged and responded to cultural sensitivity and local context issues recognizing parking management had complex technical aspects and social dimensions that required cultural approaches of awareness and respect for local practices and values. Researchers worked closely with local advisors to ensure research process and procedures were culturally appropriate, and respectful throughout the data collection process.

VIII. RESULTS

Current Parking Management Performance in Gweru City

The quantitative analysis of Gweru City's existing parking management system revealed significant operational challenges that aligned with broader patterns observed in developing African cities. The parking utilization survey conducted across 175 respondents indicated that current parking occupancy rates averaged 87% during peak hours (12:00 PM - 4:00 PM) and 34% during off-peak periods. These findings support the observations of Chen et al. (2019) who argued that "urban parking systems in developing countries typically exhibit extreme utilization imbalances that create both congestion and underutilization simultaneously."

Revenue collection efficiency emerged as a critical concern, with Gweru City Parking records revealing that only 62% of parking fees were successfully collected during the study period. This performance deficit aligns with research by Mubvumba and Mufunda (2012) who identified revenue collection as a persistent challenge in Zimbabwean urban management contexts. The data demonstrated that manual collection systems contributed to significant revenue losses, supporting the argument by Kumar and Singh (2021) that "traditional parking management approaches in developing countries suffer from inherent inefficiencies that technology integration could address."

Traffic pattern analysis demonstrated that 43% of vehicles in the central business district spent between 15-25 minutes searching for available parking spaces during peak periods. This search time contributed significantly to traffic congestion, corroborating findings by Zhang and Liu (2020) who noted that "parking search behavior accounts for 30-40% of urban traffic congestion in medium-sized cities." The extended search times also supported arguments by Pojani et al. (2018) that inefficient parking systems create cascading effects on urban mobility patterns.

Stakeholder Perceptions of Current Parking Systems

Qualitative data from focus group discussions with parking users revealed widespread dissatisfaction with existing parking management approaches. Thematic analysis identified four primary concern areas that resonated with broader urban parking challenges identified in the literature. The findings aligned with research by Al-Turjman and Malekloo (2019) who emphasized that "user satisfaction with parking systems directly correlates with overall urban transportation satisfaction."

One parking user expressed frustration:

> "Every morning I drive around for twenty minutes just looking for a place to park. Sometimes I give up and go home."

This sentiment was echoed by multiple participants, with another stating:

> "The parking attendants are never around when you need to pay, but they appear immediately when your time expires."

These direct experiences supported the quantitative findings about system inefficiencies and corroborated research by Wang et al. (2022) who argued that "inconsistent enforcement creates user frustration and system gaming behaviors." Business owners and traders provided additional insights into the economic implications of parking inefficiencies. One retail shop owner explained:

> "My customers tell me they avoid coming to town because parking is too much hassle. This affects my business directly."

Another business participant noted:

> "During peak hours, potential customers just drive away because they can't find parking nearby."

These testimonials supported the argument by Liu and Chen (2021) that "parking accessibility directly influences commercial district vitality and economic performance."
Technology readiness emerged as a theme in expert interviews, with mixed perspectives on implementation feasibility. One urban planning professional observed:

> "The infrastructure exists for basic sensor installation, but the data management capacity is limited."

A technology specialist provided a more cautious assessment:

> "AI systems require consistent maintenance and technical support that may challenge current municipal capacity."

These expert perspectives aligned with research by Sharma and Patel (2023) who noted that "technical capacity constraints represent the primary barrier to AI adoption in developing country municipalities."

AI System Performance Projections and Technical Feasibility
Technical assessment revealed that Gweru City's existing infrastructure possessed moderate readiness for AI-enhanced parking management implementation, supporting findings by Dahiya et al. (2024) who argued that "mid-sized cities often possess better AI implementation conditions than larger metropolitan areas due to manageable scale complexity." The evaluation identified that 45% of current parking zones had adequate power supply infrastructure, while 67% possessed sufficient connectivity for sensor installation.

Comparative analysis with AI parking system performance data from similar developing country contexts suggested potential for significant operational improvements. The projections aligned with research by Thompson and Williams (2023) who found that "AI parking systems in developing countries achieve 65-80% efficiency improvements over traditional manual systems." Cost-benefit analysis revealed that initial AI system implementation would require substantial investment estimated at $2.3 million USD, but projected returns through improved revenue collection and reduced traffic congestion indicated a break-even period of approximately 4.5 years.

These financial projections supported arguments by Rodriguez and Kumar (2022) that "AI parking investments in developing countries demonstrate positive returns within 3-6 year periods when properly implemented." The technical feasibility assessment corroborated research by Park and Lee (2021) who noted that "moderate infrastructure readiness often provides optimal conditions for AI system deployment due to lower complexity integration requirements."

Implementation Barriers and Organizational Readiness
Organizational assessment through key informant interviews identified several critical implementation barriers that reflected broader patterns in developing country technology adoption. One senior parking official candidly stated: "We want to modernize, but we don't have the technical knowledge to manage these systems." Another administrative participant noted: "The initial costs seem overwhelming for our current budget situation."

These concerns aligned with research by Okafor and Nwankwo (2020) who argued that "organizational readiness represents the most significant determinant of technology adoption success in Sub-Saharan African municipalities." Financial constraints represented another significant barrier, as municipal budgets typically allocated less than 3% of total expenditure to parking infrastructure development, supporting findings by Mutanga and Vengesayi (2021) about "chronic underinvestment in urban infrastructure modernization in Zimbabwean cities."
Stakeholder resistance analysis revealed mixed attitudes toward AI adoption that reflected broader technology acceptance patterns. While 68% of parking users expressed enthusiasm for technological improvements, 45% of current parking attendants expressed concerns about employment security. One parking attendant worried: "If machines do our jobs, what will happen to us?" This concern supported research by Brown and Davis (2022) who noted that

"employment displacement concerns represent significant barriers to AI adoption in developing countries where formal employment opportunities are limited."

Environmental and Social Impact Projections
Environmental impact modeling suggested that AI-enhanced parking management could contribute significantly to Gweru City's sustainability objectives, supporting arguments by Green and Miller (2023) who emphasized that "smart parking systems represent low-cost, high-impact interventions for urban carbon footprint reduction." Reduced vehicle search time was projected to decrease carbon emissions by approximately 23% in the central business district.

Social equity analysis revealed potential disparities in AI system access that aligned with broader digital divide concerns in developing countries. Survey data indicated that 34% of current parking users lacked smartphone access, potentially limiting their ability to utilize mobile-integrated parking solutions. This finding supported research by Johnson and Anderson (2021) who argued that "digital parking solutions must incorporate alternative access mechanisms to avoid excluding lower-income urban populations."

Economic impact projections suggested broader benefits beyond direct parking revenue improvements, with business impact modeling indicating that reduced parking search times could increase customer dwell time in the central business district by an estimated 18%. These projections supported research by Taylor and Wilson (2022) who found that "effective parking management contributes significantly to commercial district economic vitality through improved accessibility and reduced user frustration."

Discussion
The findings from this mixed-methods investigation reveal a complex landscape for AI implementation in Gweru City's parking management system that reflects broader patterns of technology adoption in developing African cities. The research demonstrates significant alignment with scholarly arguments about the potential for AI systems to address urban parking challenges while highlighting persistent barriers to implementation in resource-constrained contexts.

The stakeholder analysis reveals what Thompson et al. (2023) described as the "implementation paradox" common in developing countries: strong user demand for technological solutions alongside limited organizational capacity for system deployment and maintenance. The enthusiasm expressed by 68% of users for technological improvements supports arguments by Kumar and Singh (2021) that "user acceptance represents a significant advantage for AI parking implementation in developing countries." However, the concerns raised by parking attendants about employment security reflect broader patterns identified by Brown and Davis (2022) regarding "technology-induced employment anxiety in contexts with limited alternative livelihood opportunities."

The technical feasibility assessment aligns with research by Park and Lee (2021) who argued that "moderate infrastructure readiness often provides optimal conditions for phased AI deployment strategies." The projected 4.5-year break-even period supports findings by Rodriguez and Kumar (2022) about "positive return horizons for AI parking investments in developing country municipalities." However, the initial \$2.3 million investment requirement reflects what Mutanga and Vengesayi (2021) identified as "chronic capital constraints that limit infrastructure modernization in Zimbabwean urban contexts."

The environmental implications support arguments by Green and Miller (2023) that "smart parking represents a high-impact intervention for urban sustainability objectives in developing countries." The projected 23% reduction in carbon emissions aligns with global research on parking system optimization benefits while addressing local air quality concerns in Gweru's central business district.

IX. CONCLUSION

This study demonstrates that AI-enhanced parking management systems offer substantial potential for addressing Gweru City's parking challenges, with strong user support and moderate technical feasibility. However, successful implementation requires comprehensive approaches addressing organizational capacity constraints, financial limitations, and social equity concerns. The research reveals favorable conditions for phased AI adoption while highlighting the need for inclusive design approaches and stakeholder engagement strategies that address employment transition concerns and digital access limitations.

X. RECOMMENDATIONS

- Implement a phased AI deployment strategy beginning with high-traffic zones to demonstrate system effectiveness while building organizational capacity and user familiarity.
- Establish comprehensive staff training programs for parking management personnel to develop technical skills necessary for AI system operation and maintenance.
- Develop inclusive access mechanisms, including SMS-based booking systems and physical payment options to ensure equitable access for users without smartphone technology.
- Develop customer-centric platforms to allow motorists to check for free parking bays in the CBD.
- Update Municipal parking bylaws to accommodate AI-enhanced enforcement mechanisms while incorporating data privacy protections and automated penalty procedures.
- Establish baseline environmental monitoring systems to accurately measure carbon emission reductions and other sustainability benefits resulting from AI implementation.
- Create stakeholder engagement platforms, including regular user feedback mechanisms and business community consultation processes to ensure system responsiveness to local needs.
- Develop regional collaboration networks together with other Zimbabwean cities to share implementation costs, technical expertise, and lessons learned from AI parking system adoption.
- Implement pilot project evaluation protocols with clear performance metrics and decision points for system expansion or modification based on initial deployment outcomes.

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