Comprehensive Review of Smart Parking Occupancy Prediction Models in Nairobi City: Strengths, Weaknesses, and Research Gaps

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Abstract. An in-depth analysis of smart parking occupancy prediction models in contemporary cities is presented in this research. The paper identifies key research gaps while methodically analyzing the strengths, flaws, and resilience of existing models. Priority was given to the models' precision and efficacy in addressing the city's growing parking issues. An extensive analysis of these models demonstrated that they help to manage to park effectively because of their properties including real-time data integration and great forecast accuracy. On the other hand, several restrictions and flaws have been found, including issues with data accessibility, a lack of generalizability, and the complexity of certain advanced models. These findings emphasized the value of creative and situation-specific responses. The findings demonstrated the urgent need for further study, notably in the fields of data integration, scalability, interpretability, cost-effectiveness, and user-centered methods for smart parking models. These flaws are now being addressed to build a comprehensive smart parking system that is tailored to the particular urban dynamics of Nairobi. They also provide a framework for future study. Our project's ultimate goal is to significantly improve Nairobi's urban mobility and parking management, and machine learning will be a key instrument in this transformation process.

Keywords: Literature Review · Nairobi City · Occupancy Prediction · Parking Management · Smart Parking · Traffic Management · Urban Mobility · Urban Planning

1 Introduction

While cities continue to grow and car ownership becomes more common, the task of managing parking spaces becomes more difficult. Inadequate parking management can result in air pollution, traffic congestion, and lost time [1]. However, parking space utilization can be optimized with the help of smart parking systems that use cutting-edge technology, resulting in a superior parking experience. Accurate parking occupancy predictions are critical for intelligent parking system efficiency, allowing proactive management and effective resource allocation [2].

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Smart parking systems can simplify the process of locating vacant parking spaces and enhance the productivity of parking enforcement officers. These systems operate by precisely forecasting parking occupancy in real-time, resulting in more efficient utilization of resources and well-informed choices for drivers and parking operators [2]. Although there are several approaches to predicting parking occupancy, each technique has its unique advantages and limitations.

1.1 Smart Parking Occupancy Prediction

Accurate forecasting of parking space occupancy is essential for efficient parking space management. To optimize resources and make proactive decisions, park managers must have this information [3]. Additionally, this helps reduce traffic congestion, enhance the parking experience, and allocate resources effectively. The use of intelligent parking systems has created a significant demand for intelligent prediction of parking space occupancy in cities.

A lot of research papers have delved into diverse modeling strategies, data collection techniques, and predictive factors to augment the accuracy and dependability of occupancy estimates [4]. Smart parking occupancy prediction systems can now be expanded with technological breakthroughs such as the Internet of Things, data analytics, and cloud computing. Nevertheless, forecasting parking lot occupancy is a complex task that relies on multiple factors, including the day and time of the week, weather conditions, and parking lot location [5].

1.2 Multivariate Logistic Regression

The statistical model of multivariate logistic regression has gained widespread popularity for its effectiveness and interpretability in predicting binary outcomes [6]. This technique involves studying the relationship between multiple predictor variables and a binary outcome, thereby offering valuable insights into the factors that influence park occupancy. By accurately estimating the probability of occupancy, logistic regression enables parking managers to plan and allocate resources more efficiently [7, 8].

In smart parking, multivariate logistic regression is frequently used to forecast parking occupancy and enhance parking management techniques [9]. The logarithmic chance of park occupancy and the predictor variables, however, are assumed to be linearly related [10]. The predictor variables are therefore considered to be independent of one another [5].

1.3 Ordinary Least-Squares Regression

Ordinary least squares regression (OLS) is a well-established technique for parameter estimation and inference in linear regression [11]. Although OLS regression was originally developed for continuous outcome variables, it can be adapted for binary outcomes within the framework of logistic regression. The use of OLS in the context of multivariate logistic regression enables robust parameter estimation and model interpretation using the theoretical foundations and statistical properties of OLS regression [12]. Although

OLS regression is a widely used technique, it has some limitations when applied to smart parking occupancy prediction [13], which assumes a linear relationship between the predictor variables and the outcome variable [14].

1.4 Robustness and Challenge

Developing a robust occupancy prediction model requires addressing potential challenges arising from real-world parking datasets [15]. Outliers, influential observations, and violations of model assumptions can affect the accuracy and reliability of the model. To overcome these challenges, robust regression techniques and data transformations can be used, increasing the robustness of the model and ensuring accurate predictions [16].

Concerns include user adoption and behavior, integration and interoperability, integration and data security, privacy and data security, and dynamic parking situations [17]. For the implementation and operation of smart parking systems to be effective, it is essential to address these resiliency and obstacles. To guarantee the system's dependability, accuracy, and user happiness, a mix of technological advancements, good planning, collaboration amongst stakeholders, and continuous monitoring and development is needed.

2 Statement of the Problem

Nairobi, Kenya is a thriving metropolis that faces an ongoing urban challenge related to transportation congestion. Residents and visitors in general increasingly experience this issue daily, and it poses a significant barrier to efficient urban mobility. The struggle to find a parking spot in the congested city streets is at the core of this problem. Accurately estimating parking availability in Nairobi is the major difficulty of this work. This is a challenging computational problem with significant effects on urban transportation. It is crucial to find a solution in a city that is expanding quickly since every minute spent seeking parking causes traffic to back up.

Technology- and data-driven smart parking systems are developing as viable answers to Nairobi's urban transportation issues. These solutions promise to ease traffic, lower pollution, and enhance urban life in general. They serve as the watchdogs of effective municipal transportation by directing drivers to open parking places in real-time. Implementing intelligent parking systems is a fundamentally computational difficulty. It is difficult to anticipate parking occupancy accurately because of several dynamic and interconnected elements. This covers the hour of the day, the day of the week, the location, and any outside activities.

The complexity of these factors requires a sophisticated computational approach. In this computational snafu, machine learning emerges as our promising solution. Robust Multivariate Logistic Regression, in particular, takes center stage, providing a sophisticated tool for calculating parking space availability. Its ability to manage nonlinearity and multivariate interactions is perfectly suited to the complexities of city mobility. The benefits of using machine learning to anticipate parking occupancy are threefold.

First, it saves drivers time by directing them to available parking spaces rather than circling and looking. Second, it has the potential to cut traffic congestion and emissions

dramatically, contributing to a more sustainable urban transportation ecosystem. Predicting parking occupancy accurately in Nairobi is a significant computational issue. It is at the crossroads of technology and urban design, presenting a viable answer to the city's traffic problems. Utilizing the power of machine learning, specifically logistic regression, we aim to address this difficulty and contribute to the growth of Nairobi's urban mobility, paving the way for a more efficient, sustainable, and livable city.

3 Objectives

The primary objectives of this study are; to conduct a thorough literature review of smart parking occupancy prediction models in Nairobi City, to evaluate the strengths and weaknesses of these models, and to identify research gaps that warrant further investigation in future studies.

4 Related Studies

Related studies of proposed and developed models is as described in Table 1 below.

Table. 1. Proposed models and their methodologies.

No	Title Model	Algorithm Used	Description	Year
1	Blockchain-Based Parking Solutions	Blockchain technology for secure transactions	Blockchain is explored for secure and transparent payment and booking systems in smart parking	(2010)
2	Machine Learning-Based Time Series Analysis	Time series analysis with machine learning (e.g., LSTM, ARIMA)	Time series analysis models with machine learning components are used to forecast parking space availability	(2010)
3	Reinforcement Learning for Parking Space Allocation	Reinforcement Learning	Uses reinforcement learning techniques to optimize parking space allocation and reduce congestion	(2016)
4	Fuzzy Logic-Based Smart Parking System	Fuzzy Logic	Implements fuzzy logic for decision-making in a smart parking system, considering factors like occupancy and vehicle arrival rates	(2017)

(*continued*)

Table. 1. (*continued*)

No	Title Model	Algorithm Used	Description	Year
5	Edge Computing for Smart Parking	Edge Computing and Machine Learning	Implements edge computing with on-site data processing and machine learning for real-time parking predictions and management	(2021)
6	Blockchain-Enabled Parking Management	Blockchain (for data security and transparency)	Utilizes blockchain technology for secure and transparent parking transactions and data management	(2022)

4.1 Parking Solutions

Parking solutions refer to a variety of tactics and tools used to address parking-related problems including a lack of parking, traffic, and the effective use of parking spots. Citations are formal notifications or fines delivered to car owners who breach parking restrictions and are one component of parking solutions [19]. Based on a variety of variables, parking solutions may be divided into numerous different categories. These groups reflect diverse strategies for addressing parking-related issues to enhance convenience, effectiveness, and sustainability in urban settings.

4.2 Predictive Modelling for Smart Parking Occupancy

The development and implementation of data-driven strategies to anticipate and estimate parking space availability in real-time are components of predictive modeling for smart parking occupancy [11, 20]. To predict smart parking occupancy, several predictive modeling techniques have been investigated. Based on historical data, real-time sensor data, and other pertinent variables including weather, events, and time of day, these models seek to anticipate parking occupancy.

4.3 Parking and Parking System in Nairobi City

The development and implementation of data-driven strategies to anticipate and estimate parking space availability in real-time are components of predictive modeling for smart parking occupancy [11, 20]. To predict smart parking occupancy, several predictive modeling techniques have been investigated. Based on historical data, real-time sensor data, and other pertinent variables including weather, events, and time of day, these models seek to anticipate parking occupancy. To create prediction models for smart parking occupancy, regression approaches, machine learning algorithms, and statistical techniques have all been extensively used [11].

5 Nairobi County Transport Management

The county government of Nairobi does not have an extensive park management system. However, it has established several rules that are occasionally disregarded by users, which has an impact on the effectiveness and efficient movement of traffic in urban regions, particularly during busy periods when the central business district is crowded [17]. Nairobi, like many other cities across the world, looked at a range of smart parking solutions to address the difficulties related to parking congestion. Smart parking concepts and technologies have been tested and implemented to improve parking management and the quality of urban mobility in general.

Attempts have been made to address parking management issues all across the world throughout the years. A parking management system was suggested as a solution to Nairobi's parking issues, and it is a crucial component of the county's economy that directly affects productivity. As a result, it contributes significantly to profitability, productivity, and overall performance. The parking regulations as listed in [17]. It is also illegal to park on private property without the owner's or another person with legal access to the property's consent. Trailers cannot be parked on public roadways unless they are connected to a vehicle that can push or pull them.

5.1 Nairobi County Government Traffic and Transport Management

Since 1980, both the quality of road traffic and public transportation have decreased [9]. This is due to a lack of discipline among drivers and pedestrians, insufficient public transit due to the large population, an increase in the number of automobiles, insufficiently enforced laws, and an increase in the number of cars [19]. The district's congestion is anticipated to be decreased via the construction of highways and bypasses. Roundabout elimination and other vehicle parking choices outside the primary business district are other suggested strategies to reduce traffic congestion [18]. Table 2 below lists some of the parking lots in Nairobi's central business district that are managed by the two primary agencies, along with their capacities.

Table 2. Showing Nairobi parking lots

Location	Capacity	Authority in Charge
Sunken Car Park	243	County Government
Nairobi Law Courts	220	County Government of Nairobi
Gichamu Lane	80	Private
KICC Grounds	300	Private
Kenyatta Avenue near Laico Regency	180	Private

(*continued*)

Table 2. (*continued*)

Location	Capacity	Authority in Charge
Utalii Street	70	Private
Intercontinental Hotel open-air parking	70	Private

The modern underground structure is a creative way of providing motorists with additional, convenient, and secure parking spaces within the city center such as an innovative parking facility at the Holy Family Minor Basilica.

5.2 Aspects of Urban Logistics and Parking in Nairobi City

Parking and urban logistics are essential elements of urban planning and management. They contribute significantly to the smooth running of cities and the improvement of urban residents' quality of life. Nairobi, like many other African towns that are developing quickly, presents specific challenges and possibilities related to parking and urban logistics. Drivers utilize a variety of applications, like Google Maps, to find parking spaces and navigate to their destinations, among other things. The essential aspects of Nairobi's parking and urban logistics are listed in Table 3 below.

Table 3. Showing key features of Nairobi's urban logistics and parking in Nairobi City

Key Aspects	Finding/Challenge/Measures	Source
Parking Scarcity	Nairobi faces a shortage of parking spaces, especially in the central business district (CBD). This leads to illegal parking and traffic congestion	[24]
Smart Parking Solutions	Nairobi has started implementing smart parking solutions that use technology, such as sensors and mobile apps, to help drivers find available parking spaces and make payments	[18]
Accessibility and Safety	Ensuring that parking facilities are accessible to all, including people with disabilities, and providing adequate security are essential considerations	[24]
Urban Planning	Urban planners must carefully consider the impact of parking on the city's landscape and overall urban development, aiming for sustainable and efficient use of space	[14]
Informal Parking	Informal parking attendants are common in Nairobi. Formalizing and regulating this sector is important for both parking management and employment	[17]

(*continued*)

Table 3. (*continued*)

Key Aspects	Finding/Challenge/Measures	Source
Parking Fees and Regulations:	Parking fees and regulations, including metered parking and time limits, are used to manage parking demand. These policies need to be enforced effectively	[17]
Mixed-Use Parking Facilities	Due to space constraints, Nairobi is exploring mixed-use parking facilities that incorporate commercial or residential spaces along with parking infrastructure	[25]

5.3 Parking Lots in Nairobi City

Urban transportation difficulties must be addressed, thus technology advancements that move cities toward sustainable smart cities are essential. Offering effective parking services to its citizens is a huge problem for Nairobi County [14]. Lack of knowledge of available parking lots and the easiest ways to get there are some of these difficulties.

The average time spent by vehicles looking for parking is 32 min, according to a 2011 IBM parking survey. About 9,500 parking spots are managed by the Nairobi County Council in the city's commercial hub. On an average peak day, nearly 10,000 automobiles use this parking lot, which is located on Taifa Road, Sunken Car Park (243 spaces), Law Courts Park (220 spaces), and street parking [19].

In comparison to the number of vehicles, each of the county's two off-street parking areas has a capacity of just 700 autos each day. Despite district administrations' advice that people park at their own risk, city drivers complain of additional payments of Kshs 250 to 450 for parking boys who park every day for safety reasons [19] (Fig. 1).

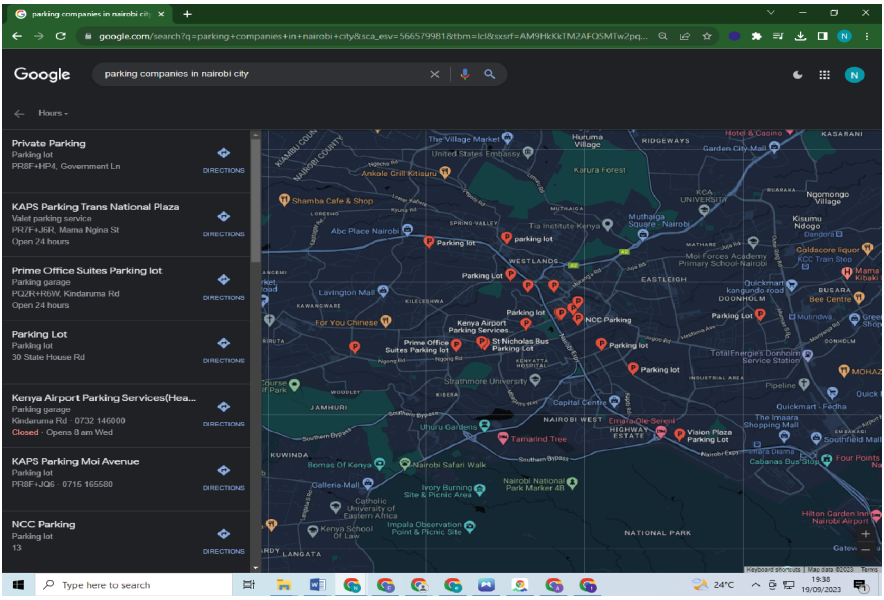

Fig. 1. Showing the Google Map location for some of the Parking Lots within Nairobi CBD

6 Parking Solutions in Nairobi City

On-street, off-street, or buildings—which may be private or public—are all options for parking. Parking is quite dynamic; a parking lot may be engaged and in the next 10 min the lot is unoccupied. According to the IBM worldwide parking study conducted in 2011 [20], finding a parking place, particularly in densely populated metropolitan areas, has become a daily struggle for many drivers. According to a 2010 IBM poll, more than a quarter of drivers got into a parking lot-related argument with another driver, and nearly six out of ten drivers gave up looking for one.

According to this study, almost 30% of a city's traffic is caused by automobiles that circle the neighborhood seeking for an empty parking space. Driving about while seeking parking took on average between 31 and 40 min globally, while drivers in Nairobi took an average of 31 min to find a parking space. Different Parking Guidance Information Systems (PGIS) have been developed to address the difficulties associated with finding parking spaces, but they frequently function as standalone systems in designated areas and, as a result, only disseminate information to a small number of users or selected users, potentially missing out on potential new users. Due to erroneous or outdated information given, these systems' utilization is still low after their installation [21].

6.1 Smart Parking Management System

This technique makes use of several different technologies, most notably the deployment of wireless parking meters installed on sturdy platforms with sensing and communication capabilities, reducing parking conflicts and enabling drivers to get real-time parking information at their destinations [22]. Many systems are not clever enough to assist drivers in finding a desired parking place in congested regions, and can occasionally make the issue worse if they give the wrong information to the drivers [23].

Detailed information on parking availability and utilization would allow drivers to make better real-time decisions on the use of parking lots and roadside parking [23]. To make these systems smarter, Rashid, [23], proposed a Reservation-based Smart Parking System (RSPS) that not only broadcasts real-time parking prices based on parking availability but also provides reservation service as part of a user-targeted service.

6.2 Intelligent Transport Systems (ITS)

ITS aims to provide innovative solutions to the transport sector by application of various technologies such as car navigation, traffic signal control, automatic number recognition, and speed cameras. In the car parking industry, ITS objective is to extract and recognize vehicle registration numbers from car images using various machine learning algorithms, process the image data, and utilize the information for parking lot access records [23]. Using this technology, information regarding parking-free spaces can be relayed to users in real-time.

ITS would be categorized in the line of image acquisition and processing to determine whether parking lots have objects on them and if there are objects, the image processing can judge whether it is a vehicle or not. Collating this data, the number of parking spaces available is relayed to the control center. The ITS and the smart parking management

system may have a drawback called multiple-user-chasing-single-space [23]. This is a phenomenon whereby a parking lot has very few parking spaces available during busy hours and more drivers struggle for fewer parking spaces causing severe congestion.

6.3 ZKTeco Smart Parking Systems

ZKTeco Smart Parking Systems is the perfect solution for the growing need for safe parking spaces in Kenya's cities and towns. As the economy and living standards improve, more vehicles are hitting the roads, making the Automatic Number-Plate Recognition (ANPR) device the ideal solution for a convenient and safe user experience from the entrance to the parking space [23]. The ZKTeco Parking Solution offers a range of License Plate Recognition Products (LPR), Ultra-High Frequency (UHF) Products, Parking Barrier Products, and Parking Guidance Products, perfect for busy and high-volume parking.

Installed LPR Cameras detect when vehicle license plates enter the designated area, and customers can easily follow indications to the available parking bays with the help of indicating lights, guidance displays, and the vehicle search kiosk. With the Zkteco Car Park Solution, drivers can search for their vehicles via the vehicle search kiosk, which integrates with the car park system and can detect where and when cars are parked in real-time. Customers can simply enter their car plate number to see their vehicle on the 2D map and the shortest path to it.

7 Establishing the Gap

The parking management system currently in use in Nairobi County has made strides in digitization, specifically in e-payment. However, these efforts have primarily focused on increasing revenue and reducing industry corruption, rather than addressing the issue of finding convenient parking spaces. Implementing a similar system in the Central Business District, which is a bustling business hub, would be an ideal testing ground for its success. If proven effective, this system could be replicated in other areas with high amounts of daily vehicle traffic and parking demands.

After conducting a thorough literature review, it has become clear that a research gap exists in the development of a robust Ordinary Least-Squares (OLS) based Multi-variate Logistic Regression Model for predicting smart parking occupancy in Nairobi city. This gap is due to the unique challenges associated with predicting smart parking occupancy, including limited data availability and data sparsity.

8 Methodology

Within this research, we provide a detailed account of the methods used to thoroughly investigate the Smart Parking Occupancy Prediction Models (SPOPM) concept. Our study employed specific inclusion criteria to gather pertinent information on SPOPM. These criteria required that the reviewed studies were focused on peer-reviewed articles or conference papers, published in English, and specifically pertained to the development

or evaluation of smart parking occupancy prediction models in Nairobi city. The analysis incorporated reputable publishers such as Routledge Taylor & Francis Group, IEEE Xplore, ScienceDirect, Springer Link, ACM Digital Library, Hindawi, Nairobi County, KEBS, UoN Digital Repository, JKUAT Digital Repository, KU Digital Repository, and MOI University Digital Repository, among others.

The methodology employed in this paper is rooted in the research method detailed in reference [21]. The paper review process was broken down into three distinct phases, namely planning, review, and results. During the planning phase, guidelines were established to facilitate the effective search of review materials. The review phase was dedicated to developing rigorous guidelines for constructing search strings aimed at identifying relevant review materials from various repositories. This phase yielded initial results, garnered pertinent research papers, and sifted through possible contributions. Subsequently, the chosen documents were subjected to thorough scrutiny during the results phase. A snapshot of the methodology utilized in this study is depicted in Fig. 2 below.

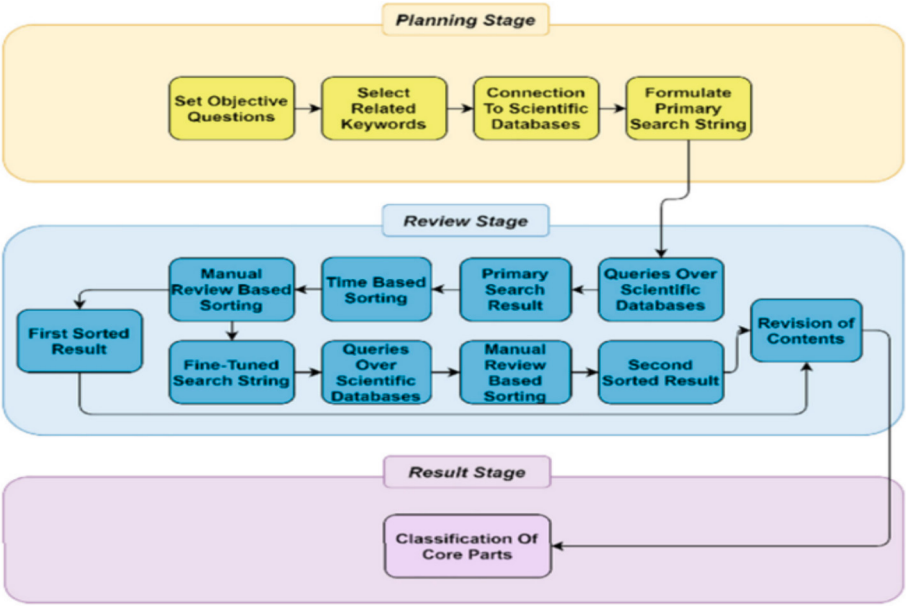

Fig. 2. Showing the Research method in detail

8.1 Data Collection

A systematic literature search was performed using reputable databases, focusing on publications from the year 2008 to the year 2023. The search utilized keywords search strings such as “Urban Mobility, Smart Parking”, “Parking Management”, “Occupancy Prediction”, “Nairobi City Traffic”, “Urban Planning”, Traffic Management and related

terms. A table of query results from different formulated strings over various scientific databases was drawn.

Table 4. Query results from different formulated strings over various scientific databases

Scientific Database	Primary Search String	Primary Search String Result	Modified Search String	Modified Search String Result
Routledge Taylor & Francis Group	"Smart" AND "Parking" AND "Solutions" AND "Sensors" AND "Method"	97	(((smart parking) OR autonomous parking) AND IoT)	185
IEEE Xplore	((((smart parking) AND systems) AND methods) AND networks)	167	(((smart parking) OR autonomous parking) AND intelligent sensors)	294
ScienceDirect	Smart Parking System/Solutions	153	(((smart parking) OR autonomous parking) AND intelligent sensors)	389
Springer Link	Smart Parking System/Solutions	200	(((smart parking) OR autonomous parking) AND IoT)	977
ACM Digital Library	"Smart" AND "Parking" AND "Solutions" AND "Sensors" AND "Method"	121	(((smart parking) OR autonomous parking) AND IoT)	169
Hindawi	Smart Parking System	416	(((smart parking) OR autonomous parking) AND IoT)	0
Nairobi County	Smart Parking System/Solutions	12	Smart Parking AND IoT AND intelligent sensors	2
KBS	Smart Parking System/Solutions	3	Smart Parking AND IoT AND intelligent sensors	0
UoN Digital Repository	Smart Parking System/Solutions	7	Smart Parking AND IoT AND intelligent sensors	6

(*continued*)

Table 4. (*continued*)

Scientific Database	Primary Search String	Primary Search String Result	Modified Search String	Modified Search String Result
JKUAT Digital Repository	Smart Parking System/Solutions	9	Smart Parking AND IoT AND intelligent sensors	4
KU Digital Repository	Smart Parking System/ Solutions	4	Smart Parking AND IoT AND intelligent sensors	3
MOI University Digital Repository	Smart Parking System/ Solutions	5	Smart Parking AND IoT AND intelligent sensors	1

To compile information regarding smart parking systems and solutions, we carefully selected reputable journal publishers and conducted a comprehensive analysis of both global and local research as shown in Table 4 above. The resulting insights were pivotal in shaping the fundamental components of this paper and identifying the latest technological advancements in the realm of smart parking systems. The scarcity of parking spots during peak hours is a widespread concern for large cities, causing individuals to waste precious time searching for a spot or sitting in long queues, ultimately leading to traffic congestion. To tackle this issue, a multitude of researchers have proposed innovative smart parking solutions and systems, utilizing various technologies to alleviate this challenge.

9 Analysis of the Findings

Quantitative and qualitative data analysis methods were employed. Statistical metrics, including publication trends, model types, and performance metrics, were collected and analyzed.

9.1 Publication Trends

From Table 5 below, the analysis revealed a steady increase in the number of publications related to smart parking prediction models in Nairobi City over the past decade. A total of seventy-nine (79) relevant studies were identified and included in this review (Fig. 3).

Table 5. Year-Wise Literature Frequency in Kenya

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Freq	0	0	0	0	0	1	3	4	7	9	6	11	8	16	12	2

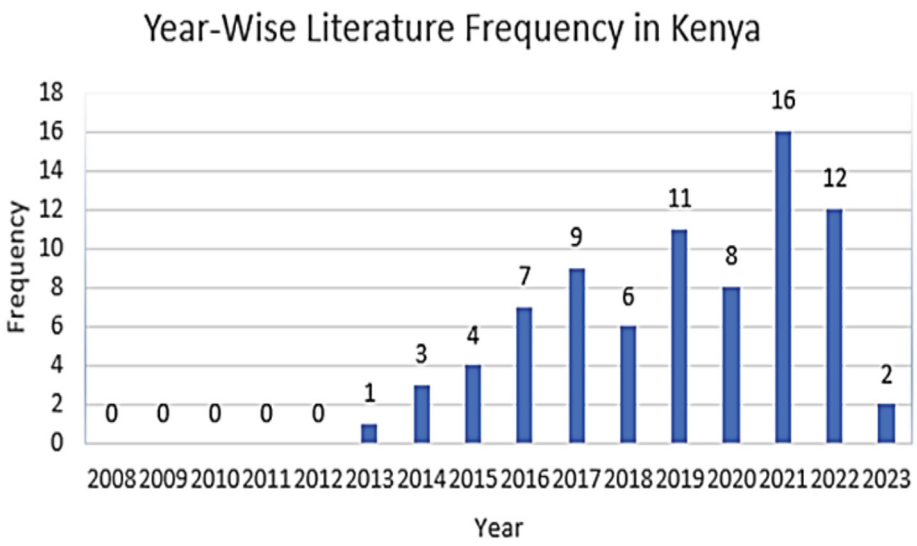

Fig. 3. Showing a Bar graph for the Year-Wise Literature Frequency in Kenya

9.2 Model Types

Related studies of proposed and developed models identified in the reviews are summarized in Table 6 below.

Internationally, Predominantly, machine learning techniques were used out of the seven selected models, including regression (14.29%), fuzzy logic (14.29%), Reinforcement Learning (14.29%), and blockchain (28.57%). Data collection primarily relied on IoT devices, and sensors as buzzing technologies of the current era, where all devices are interconnected with one another through the internet. On the local scene, these technologies are yet to be fully adopted and implemented.

Table 6. Proposed models and their methodologies.

No	Title Model	Algorithm Used	Description	Year
1	Blockchain-Based Parking Solutions	Blockchain technology for secure transactions	Blockchain is explored for secure and transparent payment and booking systems in smart parking	(2010)
2	Machine Learning-Based Time Series Analysis	Time series analysis with machine learning (e.g., LSTM, ARIMA)	Time series analysis models with machine learning components are used to forecast parking space availability	(2010)
3	Reinforcement Learning for Parking Space Allocation	Reinforcement Learning	Uses reinforcement learning techniques to optimize parking space allocation and reduce congestion	(2016)
4	Fuzzy Logic-Based Smart Parking System	Fuzzy Logic	Implements fuzzy logic for decision-making in a smart parking system, considering factors like occupancy and vehicle arrival rates	(2017)
5	Edge Computing for Smart Parking	Edge Computing and Machine Learning	Implements edge computing with on-site data processing and machine learning for real-time parking predictions and management	(2021)
6	Blockchain-Enabled Parking Management	Blockchain (for data security and transparency)	Utilizes blockchain technology for secure and transparent parking transactions and data management	(2022)
7	Regression Models	OLS	Use of mathematical formula to interpret parking spaces	(2022)

9.3 Strengths

The review found several strengths in the existing models, including effective use of historical parking data as indicated in Table 2 above, incorporation of weather conditions, and successful implementation of machine learning algorithms as indicated in Table 6 above.

9.4 Weaknesses

Considering the data provided in Table 4, it is evident that almost all of the reviewed papers chose only ML approaches that employ linear models. Weaknesses identified include limited consideration of real-time traffic data, inadequate attention to urban planning factors, and an over-reliance on linear models especially for technologies in Table 6 above. In Nairobi city, these technologies are still at an infant stage.

10 Conclusion

Nairobi city serves not only as the Kenya nation's capital but also as a significant trade and business hub in the East Africa region. Nonetheless, challenges related to inefficient road utilization, encompassing illegal on-street parking, limited public transportation options, and low parking rates within the central business district, often impede the smooth operation of the Nairobi Metropolitan Region as a central business hub. Previous research and parking surveys have consistently emphasized the critical importance of implementing efficient parking solutions to meet future parking demands. Thus, involving end-users in both the design and evaluation processes becomes paramount as this approach ensures that smart parking solutions can be tailored precisely to meet the unique needs and preferences of the target demographic, aligning the solutions closely with the group's specific requirements.

11 Recommendations

To enhance the smart parking system in Nairobi, these recommendations must be implemented:

- Conduct a real-world test of the system in collaboration with local officials, parking managers, and technology suppliers to ensure its success.
- Invest in enhancing data quality to improve parking availability predictions. This requires improved sensor technology, data validation methods, and maintenance procedures.
- Continuously update and refine machine learning models to ensure their accuracy. Regular updates based on fresh data and evolving urban conditions are essential.
- Explore potential connections between the smart parking system and other smart city initiatives, such as public transportation and traffic control.
- Integrate sustainability measures, such as solar-powered sensors or electric car charging stations, to support environmental objectives.
- Work with local authorities to create legislation and incentives that encourage the use of smart parking solutions. Clear policies are essential to expanding these systems in Nairobi and beyond.

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