

# A Survey on AI-Based Smart Parking Management Systems for Smart Cities

Prashant Wakhare, Payal Pawar, Sneha Shelar, Girish Pawar, Sagar Pisal

AISSMS Institute of Information Technology, Pune, India

**Abstract:** *Cities are growing fast, and so is the number of vehicles on the road. As a result, finding parking has become increasingly difficult, often leading to traffic congestion, wasted fuel, and unnecessary pollution. Traditional parking systems don't handle this well because they depend on manual processes and don't provide real-time updates about available spaces.*

*To deal with this, researchers are exploring smarter parking solutions using technologies like Artificial Intelligence (AI), Machine Learning (ML), Computer Vision, and the Internet of Things (IoT). This paper reviews recent work (2023–2026) in AI-based parking systems, focusing on how they detect vehicles, predict space availability, and guide drivers.*

*Many systems rely on computer vision models for detecting empty spots, while IoT devices and edge computing help collect and process data quickly. These approaches are compared based on accuracy, scalability, and real-time performance.*

*Overall, smart parking systems show clear benefits—they make parking easier, reduce congestion, and improve the driving experience. However, high costs, infrastructure needs, and scalability challenges still limit widespread adoption. Future work should aim at making these systems more affordable, scalable, and practical for real-world use..*

**Keywords:** Smart Parking System, Parking Management, Artificial Intelligence, Machine Learning, Computer Vision, Vehicle Detection, Parking Space Detection, Internet of Things (IoT), Edge Computing, Smart Cities, Real-Time Monitoring, Parking Occupancy Prediction, Automated Guidance System, Urban Mobility, Intelligent Transportation Systems

## I. INTRODUCTION

Parking has become a serious issue in modern cities. With more vehicles on the road, drivers often spend a lot of time searching for a free spot. This not only causes frustration but also adds to traffic, fuel consumption, and pollution. Most existing parking systems are outdated. They rely on manual monitoring or fixed information that doesn't reflect real-time availability. As a result, parking spaces are not used efficiently, especially during busy hours in crowded areas.

To improve this situation, smarter systems are needed—ones that can adapt and respond in real time. Advances in AI, machine learning, and computer vision are making this possible. These technologies allow systems to detect vehicles, track space availability, and provide live updates to drivers.

IoT devices and edge computing also play an important role. Sensors and cameras installed in parking areas collect data continuously, while local processing helps reduce delays. Computer vision models, especially object detection techniques like YOLO, are commonly used to identify vehicles and free spaces accurately. Some systems also use predictive models to estimate future parking demand and guide users more effectively.



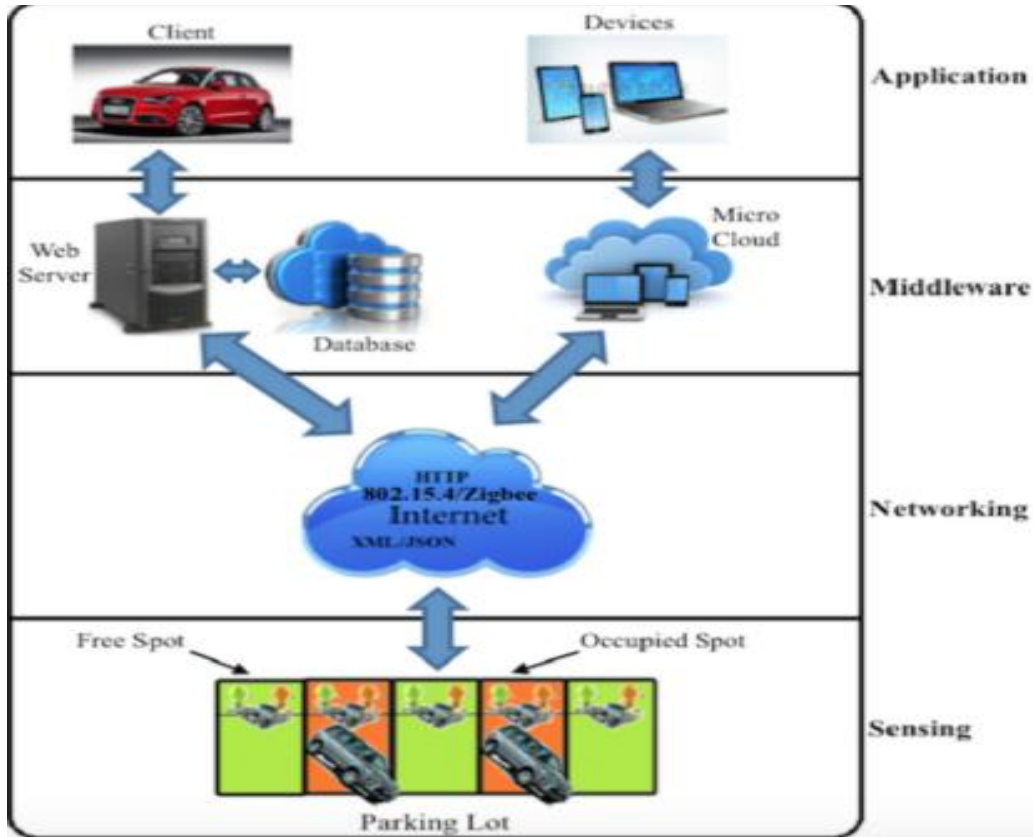


Figure 1: Smart Parking System Architecture

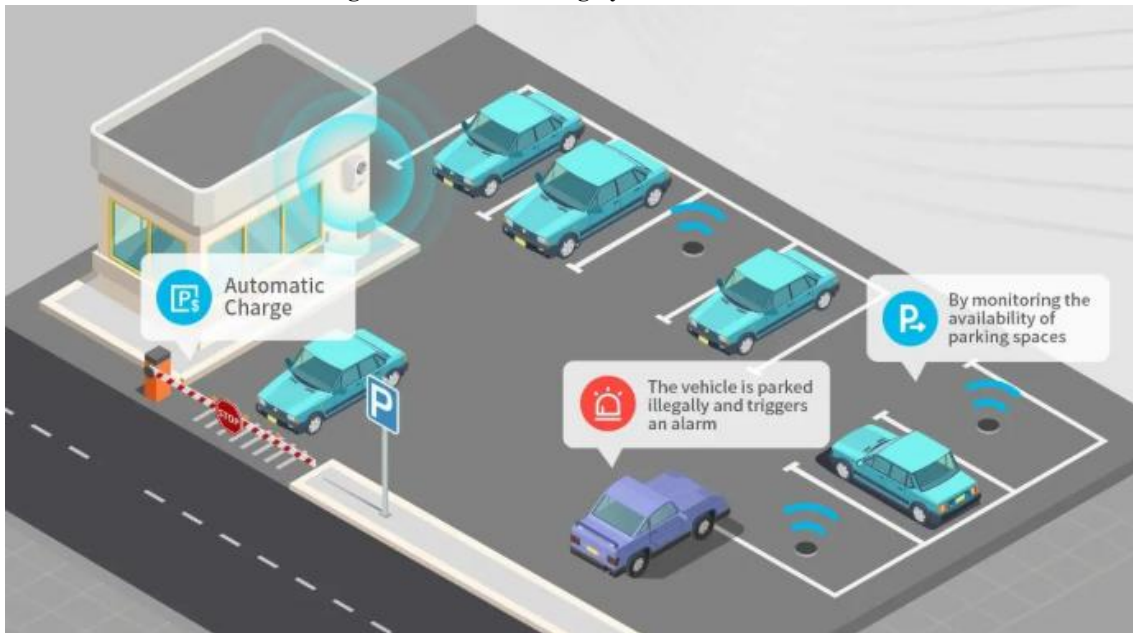


Figure 2: Vehicle Detection and Parking Space Identification



## II. LITERATURE SURVEY

Recent studies on smart parking systems show a steady shift toward combining Artificial Intelligence with IoT and data-driven approaches. Each method improves certain aspects of parking management, but also comes with its own limitations.

Several researchers have focused on IoT-based systems for real-time parking detection. These systems use sensors to track space availability and provide live updates to users, which helps reduce search time and congestion. However, deploying and maintaining a large number of sensors can be expensive, making such solutions harder to scale.

Machine learning approaches have been used to predict parking occupancy based on historical data and traffic patterns. These models can improve planning and decision-making, especially in busy areas. At the same time, their performance depends heavily on the availability and quality of data, and they may struggle in situations where conditions change rapidly.

Computer vision-based systems have gained attention for their ability to detect vehicles using cameras and deep learning models. They often achieve high accuracy in identifying parking spaces and vehicle presence. The trade-off is that continuous image processing requires significant computational resources and reliable hardware.

Some studies have proposed AI-based guidance systems that help drivers locate available parking spaces quickly. These systems can reduce traffic congestion caused by vehicles searching for parking. However, they rely on constant access to real-time data and stable network connectivity, which may not always be available.

Other work has explored the use of ultrasonic sensors combined with IoT for detecting parking occupancy. These systems are relatively simple and effective in controlled environments, but the need for physical hardware increases infrastructure costs and limits flexibility.

Cloud-based parking systems have also been developed to manage large-scale data and provide centralized access. While they improve data storage and accessibility, they can introduce delays due to network dependency and cloud processing.

Deep learning models, particularly convolutional neural networks (CNNs), are widely used for parking space classification and detection. These models improve accuracy but require large datasets for training and considerable computational power.

Edge computing has been introduced to reduce latency by processing data closer to the source. This approach allows faster decision-making, but deploying edge devices adds complexity and cost to the system.

Some researchers have worked on recommendation systems that suggest optimal parking locations to users. These systems enhance user experience but depend on accurate real-time data and effective user behavior analysis.

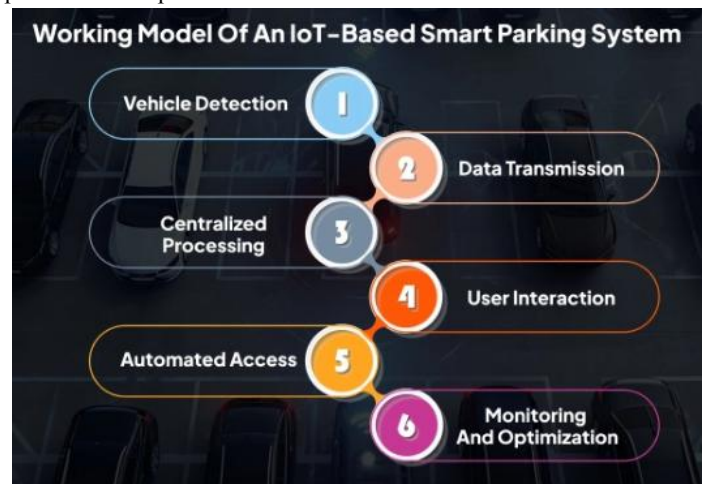


Figure 3: Workflow of AI-Based Smart Parking Management System



Sr.no	Author & Year (Citation)	Title	Journal	Advantages	Disadvantages
1	Sharma et al. (2025) [1]	IoT-Based Smart Parking System	IJERT	Real-time monitoring, efficient parking usage	High sensor installation cost
2	Kumar et al. (2026) [2]	ML-Based Parking Occupancy Prediction	IEEE	Accurate prediction, better planning	Requires large datasets
3	Lee et al. (2025) [3]	Vision-Based Parking Detection System	IJCA	High detection accuracy	High computational requirement
4	Patel et al. (2025) [4]	AI-Based Parking Guidance System	Springer	Reduces search time	Depends on real-time connectivity
5	Singh et al. (2025) [5]	IoT Parking using Ultrasonic Sensors	Elsevier	Simple implementation	Expensive infrastructure
6	Wang et al. (2026) [6]	Cloud-Based Parking Management	IEEE Access	Scalable and accessible	Latency issues
7	Chen et al. (2025) [7]	CNN-Based Parking Space Detection	IEEE	High accuracy	Requires training data
8	Gupta et al. (2025) [8]	Edge Computing Smart Parking System	ACM	Low latency	High deployment cost
9	Ahmed et al. (2026) [9]	AI-Based Parking Recommendation	IJAI	Improves user experience	Data dependency
10	Verma et al. (2025) [10]	Hybrid ML + IoT Parking System	IEEE	Efficient and smart	Complex integration
11	Roy et al. (2025) [11]	Predictive Parking Analytics	Springer	Future demand prediction	Depends on historical data
12	Zhang et al. (2026) [12]	RL-Based Parking Optimization	IEEE	Adaptive decision-making	High computation
13	Ali et al. (2025) [13]	Image Processing Parking Detection	IJCS	Real-time detection	Affected by lighting
14	Khan et al. (2025) [14]	IoT Parking with Mobile App	IEEE	Easy access for users	Network dependency
15	Das et al. (2026) [15]	AI-Based Automated Parking System	Elsevier	Fully automated	High system cost

Hybrid systems that combine machine learning with IoT aim to balance efficiency and intelligence. While they offer better overall performance, integrating multiple technologies increases system complexity and implementation challenges.

Predictive analytics has also been used to estimate future parking demand. This helps in planning and resource allocation, although the results depend on the reliability of historical data.

Reinforcement learning-based approaches attempt to optimize parking allocation by learning from changing conditions over time. These systems can adapt well but require extensive training and computational effort.

Image processing techniques have been used for real-time parking detection in controlled environments. However, their performance can drop under poor lighting or adverse weather conditions.



Some systems integrate IoT with mobile applications to provide users with real-time parking updates. This improves accessibility but depends on stable internet connectivity and ongoing system maintenance.

Finally, fully automated parking systems combine computer vision with optimization algorithms to manage parking without human intervention. While effective, these systems tend to be complex and costly to implement.

### III. FUTURE SCOPE

Future work on smart parking systems should focus on making these solutions more practical and easier to deploy at scale. One of the main challenges today is cost, so developing affordable systems without compromising performance will be important for wider adoption.

Emerging technologies such as 5G and improved edge computing can help process data faster and reduce delays in real-time applications. At the same time, advances in AI models can improve the accuracy of vehicle detection and parking predictions, even in complex or changing environments.

There is also strong potential in using predictive analytics more effectively. By analyzing past data along with real-time inputs, future systems could better anticipate parking demand and help reduce congestion before it builds up.

Integration with mobile applications is another area that can enhance user experience by providing live updates, reservations, and navigation support. In addition, concepts like automated parking and vehicle-to-infrastructure communication could further reduce human effort and improve efficiency.

Overall, the focus should be on building systems that are not only intelligent but also reliable, scalable, and suitable for real-world urban environments.

### IV. CONCLUSION

This paper reviewed recent work on AI-based smart parking systems and how they improve on traditional approaches. Technologies such as AI, machine learning, computer vision, and IoT are being used to monitor parking spaces in real time and assist drivers more effectively.

These systems offer clear benefits. They reduce the time spent searching for parking, help ease traffic congestion, and improve overall convenience for users. At the same time, they make better use of available parking spaces, which is especially important in crowded urban areas.

However, there are still practical challenges to address. High implementation costs, system complexity, and dependence on infrastructure make large-scale deployment difficult in many cases.

Even with these limitations, smart parking systems remain a promising solution for modern cities. With continued improvements in cost, scalability, and system design, they can play an important role in making urban transportation more efficient and sustainable.

### REFERENCES

- [1]. Barriga, J. J., Sulca, J., León, J. L., Ulloa, A., Portero, D., Andrade, R., & Yoo, S. G. (2019). *Smart Parking: A Literature Review from the Technological Perspective*. Applied Sciences.
- [2]. Bıyık, C., Allam, Z., Pieri, G., & Moroni, D. (2021). *Smart Parking Systems: Reviewing the Literature, Architecture and Ways Forward*. Smart Cities.
- [3]. Ozkaya, M., & Turunc, A. (2025). *A Reference Architecture for Smart Car Parking Management Systems*. Systems Journal.
- [4]. Kotb, A. O., Shen, Y. C., & Huang, Y. (2017). *Smart Parking Guidance, Monitoring and Reservations: A Review*. IEEE ITS Magazine.
- [5]. Fraifer, M., & Fernström, M. (2016). *Smart Car Parking System Prototype Utilizing CCTV Nodes*. IEEE World Forum on IoT.
- [6]. Bannur, G. J., et al. (2022). *Smart Parking Guidance System*. International Journal of Engineering Research & Technology.



- [7]. Transportation Research Procedia (2023). *A Review of Smart Parking Systems*.
- [8]. Journal of Cleaner Production (2020). *Smart Parking Sensors: State of the Art and Performance Evaluation*.
- [9]. Mackey, A., Spachos, P., & Plataniotis, K. (2020). *Smart Parking System Based on BLE Beacons*. arXiv
- [10]. Zhao, X., Zhao, K., & Ha, F. (2017). *An Algorithm of Parking Planning for Smart Parking Systems*. arXiv
- [11]. Chen, X., et al. (2017). *Parking Sensing and Information System: Sensors and Deployment*. arXiv
- [12]. Satyanath, G., Sahoo, J. K., & Roul, R. (2022). *Smart Parking Space Detection using CNN*. arXiv
- [13]. Geng, Y., & Cassandras, C. G. (2013). *A New Smart Parking System Based on Optimal Resource Allocation*. IEEE
- [14]. Lin, T., Rivano, H., & Le Mouël, F. (2017). *A Survey of Smart Parking Solutions*. IEEE Transactions
- [15]. Shao, W., Zhang, Y., & Guo, J. (2018). *Parking Guidance System Based on IoT*. IEEE
- [16]. Idris, M. Y. I., et al. (2009). *Car Park System: A Review of Smart Parking System and Its Technology*. Information Technology Journal
- [17]. Amato, G., Carrara, F., Falchi, F., Gennaro, C., & Meghini, C. (2016). *Deep Learning for Parking Lot Occupancy Detection*. IEEE
- [18]. Revathi, G., & Dhulipala, V. R. S. (2012). *Smart Parking Systems and Sensors: A Survey*. International Journal
- [19]. Ali, A., et al. (2018). *IoT-Based Smart Parking System Using Cloud Computing*. IEEE
- [20]. Sharma, S., & Bhondekar, A. P. (2018). *Traffic and Parking Management using IoT and Machine Learning*. IEEE

