IAES Journal of Electrical and Electronics Engineering
Vol. 8, No. 2, December 2021, pp. 30~34
ISSN: 2338-7432, DOI: 10.11591/jeee.v8i2.pp30-34

Electronic parking management systems for multi-storey buildings: architecture, vehicle detection, space allocation, and intelligent parking guidance—a review

Faris[1], Tri Wahono[2]
[1]Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2]Embedded Systems and Power Electronics Research Group, Yogyakarta, Indonesia

Article Info

Article history:

Received Nov 25, 2019
Revised Apr 6, 2020
Accepted Jul 31, 2020

Keywords:

Electronic parking management
IoT
Multi-storey parking
Parking guidance
Smart parking
Vehicle detection

ABSTRACT

The increasing number of private vehicles and limited urban land availability have intensified the demand for efficient parking facilities, particularly in multi-storey buildings. Conventional parking management often relies on manual supervision and static indicators, making it difficult for drivers to identify vacant spaces across different floors. This review examines electronic parking management systems for multi-storey buildings, focusing on vehicle detection, occupancy monitoring, access control, parking guidance, resource allocation, and information management. The discussion integrates research on wireless sensor networks, ultrasonic and infrared detection, camera-based monitoring, internet of things (IoT) architectures, and intelligent parking applications. Particular attention is given to the coordination of entrance systems, floor-level indicators, central databases, and user interfaces, since inconsistent occupancy information can reduce system effectiveness. The review also considers operational challenges associated with sensor accuracy, communication reliability, power consumption, cybersecurity, and driver behavior. Existing studies demonstrate that electronic monitoring and guidance can improve parking-space utilization and reduce unnecessary searching, although performance depends on appropriate system design and building characteristics. Future development should emphasize integrated sensing, reliable communication, scalable management software, and practical evaluation in operational multi-storey facilities.

This is an open access article under the CC BY-SA license.

1. INTRODUCTION

Parking management has become an important concern in urban areas where vehicle ownership continues to increase while available land remains limited. Multi-storey parking buildings provide a practical way to expand parking capacity vertically, particularly in commercial centers, hospitals, offices, universities, and transportation facilities. However, increasing the number of parking floors also creates operational difficulties because drivers must identify available spaces across several levels and navigate internal ramps and circulation routes. Without reliable information, vehicles may circulate unnecessarily, increasing waiting time, fuel consumption, and congestion around parking entrances [1], [2].

Conventional parking facilities commonly use manual attendants, paper tickets, mechanical barriers, and static capacity indicators. Although these methods can support basic operations, they provide limited information about individual parking-space availability and may require considerable human supervision. Electronic parking management systems offer an alternative by integrating vehicle detection, automatic access control, occupancy monitoring, and digital information displays. Research on smart parking has demonstrated the potential of combining sensing technologies and information systems to improve the management of parking resources [3]–[6].

The main research problem is how to coordinate parking-space information and vehicle movement throughout a multi-level facility. A system that detects vacant spaces but cannot guide drivers to their locations provides only partial assistance. Similarly, a guidance system becomes unreliable when sensors fail to update occupancy information or when vehicles occupy spaces without being registered. This review therefore examines the architecture, technologies, operational functions, and implementation challenges of electronic parking management in multi-storey buildings.

2. REVIEW SCOPE AND SYSTEM REQUIREMENTS

This review adopts an integrative approach that combines studies on smart parking infrastructure, vehicle detection, parking guidance, sensor networks, and automated multi-storey parking facilities. Research directly addressing parking structures is used to explain building-level requirements, while broader smart parking studies provide supporting evidence about sensing and information technologies. This distinction is necessary because not all smart parking research has been conducted inside multi-storey buildings. The review focuses on electronic systems that monitor and manage parking occupancy rather than purely mechanical parking structures.

A suitable system should provide accurate vehicle detection, real-time occupancy updates, and clear information about available spaces. It should also support controlled entry and exit, parking-space allocation, payment or ticket management, and operational reporting. In multi-storey facilities, the system must distinguish occupancy by floor and parking zone rather than presenting only the total number of vacant spaces. These requirements establish the relationship between electronic hardware, communication infrastructure, management software, and driver guidance [4]–[7].

3. ARCHITECTURE OF ELECTRONIC PARKING MANAGEMENT SYSTEMS

An electronic parking management system generally consists of vehicle identification devices, entrance and exit controllers, parking-space sensors, local communication units, a central processing platform, and user information interfaces. At the entrance, an RFID card, QR code, ticket dispenser, or license-plate recognition device can identify a vehicle and authorize access. Sensors installed at individual spaces or designated zones determine whether parking capacity is available. The collected information is transmitted to a local controller or central server, where occupancy data are processed and distributed to displays and management applications [2], [3], [7].

The central controller maintains the relationship between vehicle access records and parking-space availability. When a vehicle enters, the system updates the available capacity and may assign a suitable floor or zone. When the vehicle leaves, the corresponding parking record is closed and the available capacity is recalculated. Geng and Cassandras [2] demonstrated a smart parking infrastructure that integrates parking detection, reservation, allocation, and communication, including a pilot implementation in a parking garage. Such work illustrates the importance of coordinating operational functions rather than treating parking detection as an isolated activity.

The architecture can be implemented through centralized, distributed, or hybrid configurations. A centralized system stores occupancy information in a common server and manages the overall facility through a single control platform. A distributed system allows floor-level controllers to process sensor information locally before sending summarized data to the central server. A hybrid architecture combines local decision-making with centralized monitoring, which may improve responsiveness when a building contains many parking spaces. Wireless sensor networks and IoT platforms provide possible communication foundations for these configurations [7], [8].

4. VEHICLE DETECTION AND OCCUPANCY MONITORING

Vehicle detection is a fundamental function because every subsequent management decision depends on the accuracy of occupancy information. Ultrasonic sensors estimate the distance between the sensor and an object, allowing the controller to identify whether a vehicle is present in a parking space. Infrared and proximity sensors detect changes in the surrounding environment, while magnetic sensors identify disturbances in the local magnetic field caused by vehicles. Camera-based systems use image processing to identify occupied spaces and may monitor several parking spaces from a single installation [9]–[12].

Each detection method has different installation and operational characteristics. Ultrasonic sensors can provide direct space-level information but may require a sensor for every parking bay, increasing installation and maintenance costs. Camera-based monitoring can cover multiple spaces, although lighting conditions, occlusion, image quality, and privacy considerations affect its reliability. Wireless sensor

networks reduce the need for extensive signal cabling, but battery life, radio interference, and network coverage must be considered. Perković *et al.* [8] reviewed smart parking sensor technologies and emphasized the importance of balancing detection performance with energy consumption.

For multi-storey buildings, sensor placement must reflect the physical characteristics of each floor. Ceiling-mounted sensors may be appropriate where the ceiling height and structural layout permit reliable measurements, while floor-level or wall-mounted devices may be more suitable in other configurations. Ramps, pillars, narrow parking bays, and ventilation equipment can affect sensor coverage and communication quality. A robust installation should therefore be tested under actual building conditions rather than relying exclusively on laboratory measurements.

5. PARKING GUIDANCE, ALLOCATION, AND INFORMATION MANAGEMENT

Parking guidance transforms occupancy data into practical instructions for drivers. Entrance displays can indicate the number of available spaces on each floor, while floor-level indicators direct vehicles toward available zones or individual parking bays. LED indicators positioned above parking spaces can provide immediate visual confirmation of availability. These functions are particularly valuable in multi-storey facilities because drivers need information that is both accurate and spatially specific [10], [13].

The allocation module determines how available spaces should be assigned to incoming vehicles. A simple system may direct drivers to the nearest available space, whereas a more advanced system can consider vehicle dimensions, reserved spaces, accessibility requirements, and expected parking duration. Geng and Cassandras [2] demonstrated the use of optimization for assigning and reserving parking spaces based on user preferences and resource availability. Serpen and Debnath [14] examined a management system for automated multi-storey robotic parking, integrating path planning, elevator scheduling, and resource allocation to reduce customer waiting time and improve space utilization.

A central database can support parking records, payment processing, reservation management, and operational reporting. The database should maintain consistent records of vehicle entry, assigned space, parking duration, payment status, and exit. Mobile or web applications can provide users with availability information and reservation services, while management dashboards allow operators to monitor occupancy across floors. Research on smart parking architectures emphasizes the value of integrating sensing, networking, cloud platforms, and user-facing applications [4]–[8], [15].

Table 1 summarizes the main technologies and functions involved in electronic parking management for multi-storey buildings. The comparison indicates that the selection of a detection method should depend on building structure, installation cost, maintenance requirements, and required information accuracy. It also demonstrates that a complete system needs more than vehicle sensors because access control, communication, guidance, and database management must operate together.

Table 1. Technologies and functions in electronic multi-storey parking management

System component	Main function	Advantages	Main considerations
RFID, QR code, or license-plate recognition	Vehicle identification and access authorization	Automated entry and exit records	Identification accuracy and data security
Ultrasonic sensors	Detect vehicle presence in individual spaces	Direct occupancy measurement	Sensor placement and installation quantity
Infrared or proximity sensors	Detect vehicles near parking bays	Simple electronic integration	Environmental interference and detection range
Magnetic sensors	Detect vehicle-induced magnetic changes	Low-profile installation	Calibration and magnetic interference
Camera-based monitoring	Identify occupied and vacant spaces	Multiple spaces can be monitored	Lighting, occlusion, privacy, and processing
Floor-level controller	Collects and processes local sensor data	Supports distributed operation	Network synchronization and fault recovery
Central server and database	Stores occupancy, access, and payment records	Centralized monitoring and reporting	Cybersecurity and data consistency
Digital guidance displays	Directs drivers to floors and available spaces	Reduces unnecessary circulation	Display visibility and information accuracy
Mobile or web application	Provides availability and reservation information	Convenient user access	Connectivity and user accessibility

6. OPERATIONAL CHALLENGES AND PERFORMANCE EVALUATION

The effectiveness of an electronic parking system depends on the accuracy and timeliness of its information. A false vacant-space indication may direct a driver toward an already occupied bay, while a false occupied indication can reduce the usable capacity of the building. Communication delays can also create inconsistencies between the actual parking condition and the information displayed at the entrance. These problems require continuous monitoring, sensor calibration, and procedures for correcting incorrect occupancy records [8], [9], [11].

Multi-storey facilities introduce additional operational challenges because vehicle movement is constrained by ramps, floor transitions, turning areas, and limited circulation space. A guidance system should avoid directing too many vehicles toward the same floor or zone, particularly when congestion develops near ramps and access points. The allocation algorithm should consider not only vacant-space availability but also the ease of reaching the assigned location. Studies of parking guidance and intelligent parking technologies highlight the importance of providing drivers with useful information throughout the parking process [13], [16].

System evaluation should include technical, operational, and user-oriented indicators. Technical measurements may include vehicle-detection accuracy, communication delay, system availability, and the frequency of incorrect occupancy updates. Operational measurements should include average parking-search time, entrance and exit processing time, space utilization, vehicle throughput, and queue length. User-oriented evaluation can examine navigation clarity, perceived convenience, reservation usability, and satisfaction. A combination of these indicators provides a more complete assessment than simply counting the number of sensors or displaying the number of vacant spaces.

Cybersecurity and privacy are also important because electronic parking systems may store license-plate information, payment records, user identities, and movement histories. Unauthorized access to these records could expose sensitive information or allow manipulation of parking availability. Secure communication, role-based access, encrypted data storage, and appropriate data-retention policies should therefore be included in the system design. These requirements become increasingly important when parking facilities are connected to cloud platforms or wider smart-building infrastructure [4], [15].

7. FUTURE RESEARCH DIRECTIONS

Future development should focus on integrating multiple sensing technologies to improve detection reliability in complex building environments. A hybrid approach combining ultrasonic sensors and camera-based verification may reduce the weaknesses of individual detection methods. Edge processing could also reduce communication loads by analyzing sensor data near the point of collection before transmitting occupancy updates to the central server. Further research should evaluate these architectures under different lighting conditions, vehicle types, and parking layouts.

Intelligent allocation and prediction offer another direction for improving multi-storey parking operations. Historical occupancy data can help estimate demand by floor, time of day, and day of the week. The management system could then distribute incoming vehicles more evenly, reserve suitable spaces, and provide more accurate availability information. Research on shared parking and multi-criteria parking recommendation demonstrates the potential of optimization methods to improve resource utilization while considering user preferences [17]–[20]. However, these approaches require field validation to establish their practical benefits.

8. CONCLUSION

Electronic parking management systems can improve the operation of multi-storey buildings by integrating vehicle identification, occupancy detection, access control, parking allocation, and digital guidance. The reviewed literature demonstrates that ultrasonic, infrared, magnetic, camera-based, and wireless sensor technologies provide different options for monitoring parking availability. Centralized and distributed architectures can coordinate these devices with databases, displays, and user applications. The effectiveness of the system depends on maintaining accurate and timely information throughout the complete parking process. A reliable multi-storey parking system must consider building geometry, sensor placement, communication performance, vehicle circulation, and the needs of different users. Parking guidance should be connected to allocation and access-control functions so that information displayed to drivers reflects actual conditions. Future systems should emphasize hybrid detection, secure data management, predictive allocation, and operational evaluation in real facilities. With these considerations, electronic parking management can support more efficient space utilization, improved driver convenience, and better management of multi-storey parking infrastructure.

REFERENCES

[1] D. C. Shoup, "Cruising for parking," *Transport Policy*, vol. 13, no. 6, pp. 479–486, Nov. 2006, doi: 10.1016/j.tranpol.2006.05.005.

[2] Y. Geng and C. G. Cassandras, "A new 'Smart Parking' System Infrastructure and Implementation," *Procedia - Social and Behavioral Sciences*, vol. 54, pp. 1278–1287, Oct. 2012, doi: 10.1016/j.sbspro.2012.09.842.

[3] R. E. Barone, T. Giuffrè, S. M. Siniscalchi, M. A. Morgano, and G. Tesoriere, "Architecture for parking management in smart cities," *IET Intelligent Transport Systems*, vol. 8, no. 5, pp. 445–452, Aug. 2014, doi: 10.1049/iet-its.2013.0045.

[4] F. Al-Turjman and A. Malekloo, "Smart parking in IoT-enabled cities: A survey," *Sustainable Cities and Society*, vol. 49, p. 101608, Aug. 2019, doi: 10.1016/j.scs.2019.101608.

[5] J. J. Barriga *et al.*, "Smart parking: A literature review from the technological perspective," *Applied Sciences (Switzerland)*, vol. 9, no. 21, p. 4569, Oct. 2019, doi: 10.3390/app9214569.

[6] M. G. D. Ogás, R. Fabregat, and S. Aciar, "Survey of smart parking systems," *Applied Sciences (Switzerland)*, vol. 10, no. 11, p. 3872, Jun. 2020, doi: 10.3390/app10113872.

[7] A. Hilmani, A. Maizate, and L. Hassouni, "Designing and managing a smart parking system using wireless sensor networks," *Journal of Sensor and Actuator Networks*, vol. 7, no. 2, p. 24, Jun. 2018, doi: 10.3390/jsan7020024.

[8] T. Perković, P. Šolić, H. Zargariasl, D. Čoko, and J. J. P. C. Rodrigues, "Smart Parking Sensors: State of the Art and Performance Evaluation," *Journal of Cleaner Production*, vol. 262, p. 121181, Jul. 2020, doi: 10.1016/j.jclepro.2020.121181.

[9] S. S. Adhatarao, O. Alfandi, A. Bochem, and D. Hogrefe, "Smart parking system for vehicles," in *IEEE Vehicular Networking Conference, VNC*, Dec. 2015, vol. 2015-January, no. January, pp. 189–190. doi: 10.1109/VNC.2014.7013341.

[10] X. Chen *et al.*, "Parking sensing and information system: Sensors, deployment, and evaluation," *Transportation Research Record*, vol. 2559, no. 1, pp. 81–89, Jan. 2016, doi: 10.3141/2559-10.

[11] M. Bachani, U. M. Qureshi, and F. K. Shaikh, "Performance Analysis of Proximity and Light Sensors for Smart Parking," *Procedia Computer Science*, vol. 83, pp. 385–392, 2016, doi: 10.1016/j.procs.2016.04.200.

[12] J. K. Suhr and H. G. Jung, "A universal vacant parking slot recognition system using sensors mounted on off-the-shelf vehicles," *Sensors (Switzerland)*, vol. 18, no. 4, p. 1213, Apr. 2018, doi: 10.3390/s18041213.

[13] J. Hanzl, "Parking Information Guidance Systems and Smart Technologies Application Used in Urban Areas and Multi-storey Car Parks," *Transportation Research Procedia*, vol. 44, pp. 361–368, 2020, doi: 10.1016/j.trpro.2020.02.030.

[14] G. Serpen and J. Debnath, "Design and performance evaluation of a parking management system for automated, multi-story and robotic parking structure," *International Journal of Intelligent Computing and Cybernetics*, vol. 12, no. 4, pp. 444–465, Nov. 2019, doi: 10.1108/IJICC-02-2019-0017.

[15] A. Shahzad, J. Y. Choi, N. Xiong, Y. G. Kim, and M. Lee, "Centralized Connectivity for Multiwireless Edge Computing and Cellular Platform: A Smart Vehicle Parking System," *Wireless Communications and Mobile Computing*, vol. 2018, no. 1, Jan. 2018, doi: 10.1155/2018/7243875.

[16] S. Das, "A novel parking management system, for smart cities, to save fuel, time, and money," in *2019 IEEE 9th Annual Computing and Communication Workshop and Conference, CCWC 2019*, Jan. 2019, pp. 950–954. doi: 10.1109/CCWC.2019.8666537.

[17] P. Zhao, H. Guan, and P. Wang, "Data-driven robust optimal allocation of shared parking spaces strategy considering uncertainty of public users' and owners' arrival and departure: An agent-based approach," *IEEE Access*, vol. 8, pp. 24182–24195, 2020, doi: 10.1109/ACCESS.2020.2969987.

[18] G. Baranwal, D. Kumar, and D. P. Vidyarthi, "A Multi-Criteria Framework for Smart Parking Recommender System," in *2020 IEEE International Smart Cities Conference, ISC2 2020*, Sep. 2020, pp. 1–8. doi: 10.1109/ISC251055.2020.9239098.

[19] J. Yang, J. Portilla, and T. Riesgo, "Smart parking service based on Wireless Sensor Networks," in *IECON Proceedings (Industrial Electronics Conference)*, Oct. 2012, pp. 6029–6034. doi: 10.1109/IECON.2012.6389096.

[20] V. Paidi, H. Fleyeh, J. Håkansson, and R. G. Nyberg, "Smart parking sensors, technologies and applications for open parking lots: A review," *IET Intelligent Transport Systems*, vol. 12, no. 8, pp. 735–741, Oct. 2018, doi: 10.1049/iet-its.2017.0406.