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DEVELOPMENT OF A SMART PARKING SYSTEM USING AUTOMATIC DEBIT AND OPTICAL CHARACTER RECOGNITION

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Abstract— *The current parking infrastructure predominantly relies on traditional or semi-automatic mechanisms, leading to significant inefficiencies during peak hours. This study proposes the development of a fully automated smart parking system utilizing locally sourced Indonesian components to reduce dependence on imported parts. The proposed Auto-Debit Smart Parking System incorporates Optical Character Recognition (OCR) for vehicle identification and automated payment, improving both accuracy and operational efficiency. The system consists of two primary modules: server software for gate control and an image-processing host application. Space Vector Pulse Width Modulation (SVPWM) is employed for switching control, and communication is facilitated via wired or wireless channels using the RS232C standard. Vehicle entry and exit are detected by sensors that transmit signals to the Command TX module. To evaluate real world applicability, the system was implemented and tested in various public and commercial environments, including office buildings, shopping malls, and open parking areas.These testing sites represent common urban parking conditions with varying lighting, network connectivity, and traffic density, allowing the system's adaptability and reliability to be analyzed comprehensively. An experimental research method is adopted, encompassing prototype development, testing, data acquisition, and performance evaluation. The results indicate reduced operational costs and enhanced user convenience, validating the system's effectiveness in supporting modern, efficient parking management.*

Keywords: *efficiency, OCR, prototype, sensors, smart parking.*

Intisari— *Sistem parkir yang ada saat ini umumnya masih menggunakan mekanisme tradisional atau semi otomatis yang sering menimbulkan ketidakefisienan pada jam sibuk. Penelitian ini bertujuan untuk mengubah sistem tersebut menjadi sistem parkir cerdas otomatis penuh dengan memanfaatkan sumber daya lokal Indonesia guna mengurangi ketergantungan pada komponen impor. Sistem Auto Debit Smart Parking yang diusulkan mengintegrasikan teknologi Optical Character Recognition (OCR) untuk identifikasi kendaraan dan pembayaran otomatis, sehingga meningkatkan presisi dan efisiensi. Sistem ini terdiri atas dua komponen utama: perangkat lunak server untuk kontrol gerbang dan aplikasi pemrosesan citra sebagai host. Space Vector Pulse Width Modulation (SVPWM) digunakan untuk pengaturan pensaklaran, sedangkan komunikasi dilakukan melalui saluran kabel atau nirkabel dengan standar RS232C. Kendaraan yang masuk dan keluar terdeteksi oleh sensor yang mengirimkan sinyal ke modul Command TX. Untuk menilai kesiapan implementasinya sistem ini diuji di berbagai lingkungan publik dan komersial.termasuk gedung perkantoran,pusat perbelanjaan, serta area parkir terbuka. Lokasi pengujian tersebut mewakili kondisi parkir perkotaan dengan variasi pencahayaan,kestabilan jaringan dan kepadatan lalu lintas sehingga memungkinkan analisis menyeluruh terhadap adaptabilitas dan keandalan sistem. Dengan pendekatan eksperimental, penelitian ini meliputi pengembangan prototipe, pengujian, pengumpulan data, dan analisis kinerja. Hasil penelitian menunjukkan penurunan biaya operasional dan peningkatan kenyamanan pengguna, membuktikan efektivitas sistem dalam mendukung manajemen parkir modern yang efisien*.

Kata Kunci: efisiensi, OCR (pengenalan karakter optik), prototipe, sensor, parkir pintar.

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INTRODUCTION

The rapid advancement of the transportation sector has significantly impacted the demand for adequate parking facilities. Currently, many parking systems still operate using conventional or semi-automatic methods. In semi-automatic systems, the parking gate opens only when the vehicle owner presents a registered parking ID card at the designated position. If the ID card is unregistered or unavailable, the gate remains closed, requiring the vehicle owner to register as a user and obtain an ID card to access the parking area. Consequently, parking managers must issue cards or tickets daily and manually record vehicle policy numbers, resulting in an inefficient process. Under these circumstances, transitioning from conventional and semi-automatic systems to fully automated parking solutions has become both essential and urgent.

Building on the previously outlined context, this research focuses on designing an intelligent, precise, and efficient automatic parking system to alleviate vehicle congestion during peak hours. The primary goal is to develop and implement a Smart Parking System equipped with an Auto-Debit mechanism and integrated Optical Character Recognition (OCR) technology. This integration enables seamless and fully automated payment processing, thereby enhancing operational efficiency, minimizing human intervention, and improving the overall user experience in modern parking management.

Numerous current technologies employ sensors in every parking facility to address the issue of automated parking space identification. Nonetheless, the expense associated with the devices and their deployment is significantly elevated, particularly for certain expansive parking facilities. The paper proposes the creation of a more adaptive and cost-effective smart parking system utilizing distributed or smart cameras [1]. This study conducts a comprehensive performance evaluation of the online smart parking system implemented in Jakarta, focusing on three key dimensions: application quality, collaboration aspects, and financial feasibility.

The assessment of application quality includes usability, reliability, responsiveness, and user satisfaction with the digital platform[2][3]. This study designs a smart parking system utilizing an ESP32 microcontroller, infrared sensors, and an integrated camera module, in which real-time parking slot information is transmitted and displayed on a smartphone interface[4]. A prototype of a smart parking system utilizing RFID, NodeMCU, and Google Spreadsheets has been developed. The system integrates RFID-based automatic identification with NodeMCU control to operate the parking barrier, which opens only when the detected ID matches the entries stored in the online database[5].The system aims to improve accuracy in vehicle detection, enhance monitoring capabilities, and provide users with seamless access to parking availability data through a mobile application [6]. A research [7] smart parking systems have emerged as a promising solution to Indonesia's growing urban mobility challenges, driven by rapid motorization, limited parking capacity, and inefficient conventional management[8] [9].

Existing literature highlights that integrating IoT sensors, edge processing, wireless communication (such as Wi-Fi, NB-IoT, or LoRaWAN), and cloud-based analytics can significantly reduce cruising time, improve space utilization, and enhance revenue transparency. Typical architectures combine occupancy detection technologies (ultrasonic, infrared, magnetic, camera-based OCR), edge gateways for preliminary data processing, and mobile applications that provide real-time availability and digital payments. Smart Parking Technology for Vehicle Security Systems Based on Rotational Sensors [10].

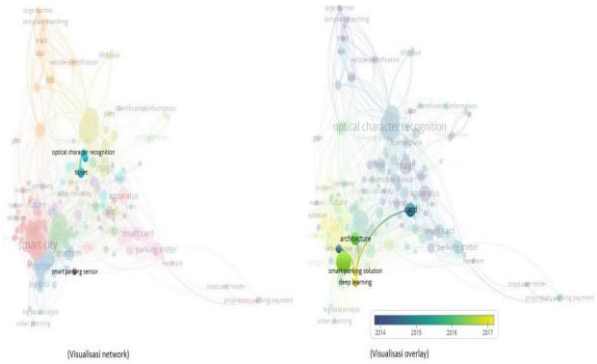
The main aim of this research is to investigate the security threats that specifically affect Internet of Things (IoT) technologies implemented within the public sector[11][12]. The study evaluates various prediction. Research exists on parking reservation systems that oversee multiple roadside parking spaces throughout the city center, aiming to reduce the overall social cost of parking or to direct vehicles to available spaces[13]. Additionally, intelligent camera systems with wireless communication are employed for monitoring vehicular traffic [14].

The proposed device incorporates key image-processing techniques, including binarization, detection of potential plate characters, identification of plate boundaries, perspective correction, character segmentation, optical character recognition (OCR), and subsequent post-processing procedures [15]. This study seeks to design an IoT-based smart parking solution that integrates a QR code activated parking lock and employs IR obstacle sensors to reliably determine the availability of parking spaces[16].

In this study, an E-Parking information system is designed to support the implementation of smart government in Pontianak City [17]. The advancement of smart city technologies has steadily grown to enhance human quality of life, particularly in the area of urban mobility [18]. Parking remains

a significant challenge, as drivers often struggle to locate available spaces across numerous parking areas, leading to wasted time, unnecessary fuel consumption, and increased environmental pollution [19]. An Analysis of the User Interface Design in a Car Parking Finder Application [20]. Traffic congestion and the shortage of parking spaces in the tourist district of Jalan Braga, Bandung, have emerged as major challenges that demand innovative approaches. This research focuses on developing and deploying an IoT-based Smart Parking System, supported by a mobile application, to improve efficiency, transparency, and user convenience in parking management. [21].

This study presents an innovative integration of auto-debit payment functionality, enabled by Optical Character Recognition (OCR), into an intelligent parking system utilizing the Space Vector Pulse Width Modulation (SVPWM) technique. The system's performance and data processing are further enhanced through the application of Artificial Neural Networks (ANN) and Particle Swarm Optimization (PSO) within an artificial intelligence framework. Figure 1 provides a gap analysis to underscore the originality and research contribution of this work.



Source: (Research Results, 2024)

Figure 1. Gap Analysis

MATERIALS AND METHODS

This study adopts an experimental methodology to develop a prototype intelligent parking system integrating Optical Character Recognition (OCR) and Internet of Things (IoT) technology. The development process includes prototype design, fabrication, testing, data collection, and quantitative causal analysis enhanced by an Artificial Neural Network (ANN) framework. Space Vector Pulse Width Modulation (SVPWM) is applied for process control and switching duration. System performance is verified by ensuring that host-transmitted signals conform to the required format, enabling the DC-geared servo motor to operate as instructed. Camera sensor input generates transmission (Tx) commands each time a vehicle enters or exits, with corresponding data stored and later compared to calculate parking fees. The prototype employs readily available components, including the CodeVision software package, an OCR control module, two geared DC servo actuators, a barrier mechanism, and an Atmega 8535 microcontroller, which is widely accessible in the local market.

The primary purpose of this research is to design and implement a fully automated smart parking system that integrates Optical Character Recognition (OCR) for vehicle identification with an auto-debit payment mechanism. Beyond improving operational efficiency and reducing congestion during peak hours, this study highlights the strategic use of locally sourced Indonesian components, which distinguishes it from many existing solutions that rely heavily on imported hardware. By demonstrating that advanced parking automation can be achieved using affordable, domestically available resources, this work contributes to reducing system development costs, increasing accessibility, and fostering technological self-reliance in Indonesia. The research not only delivers a functional prototype but also provides a scalable reference model for smart parking systems that can be replicated in other developing regions facing similar economic and infrastructure challenges. In doing so, this study addresses both technical innovation—through OCR, auto-debit integration, and SVPWM-based control—and socio-economic impact, by supporting the local manufacturing ecosystem and minimizing dependence on foreign supply chains.

According to the flowchart depicting the study completion process in Figure 2, the subsequent sequence of tasks is outlined below:

1. Developing an application program using Visual Studio 2010 with C#
2. Developing a video streaming design that includes buttons for start, stop, screen streaming, picture capture, image monitoring, and image saving.
3. Developing video streaming, camera capture, and parking entry and exit controls
4. Incorporating time elapse labels, recognition result labels, and zoom camera captures of vehicle license plates.
5. Incorporating black and white radio buttons as alternatives for optical identification, hourly rupiah text, duration, and Rp label.
6. Incorporating save labels, file labels, and two storage directory texts.
7. Incorporating temporal text, incrementing counter text, and loading picture button

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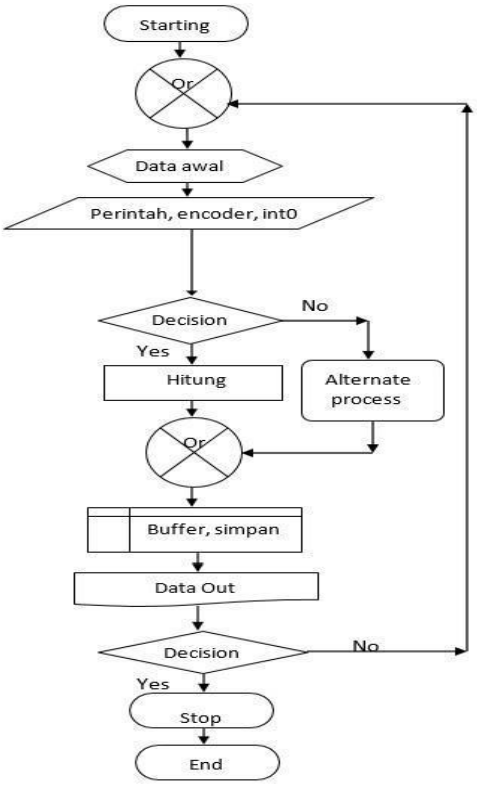
8. Compilation and execution of the initial year of Smart Parking System Development software featuring Auto Debit, which exhibits the monetary amount and time via a button. In the subsequent year, this button is replaced by a proximity switch that triggers an interrupt to the microcontroller, facilitating communication with the host to automatically deduct credit from the auto debit card.



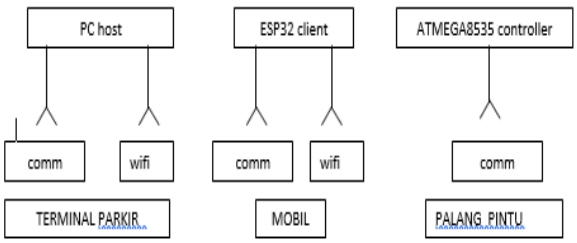
Source: (Research Results, 2024)
Figure 2. Signal Processing Flowchart

RESULTS AND DISCUSSION

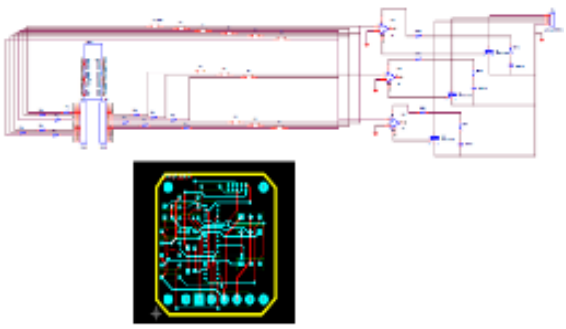
The prototype requires each vehicle to be equipped with an e-money transceiver, enabling seamless gate passage without stopping. The application was developed using Visual Studio 2010 with the C# programming language. Development began with defining functional requirements and system architecture, followed by designing an intuitive user interface, implementing Optical Character Recognition (OCR) algorithms for license plate detection and automated debit processing, and configuring server–host communication using the RS232C standard via wired or wireless connections. Gate control modules were integrated using Space Vector Pulse Width Modulation (SVPWM) for precise switching and timing. The program underwent iterative testing to evaluate performance, verify data accuracy, and ensure compatibility with sensor devices that detect vehicle entry and exit. Findings from these tests were used to refine the prototype prior to final implementation.

The reader transceiver is required to remain active for approximately 30 seconds as the vehicle passes through the entrance or exit gate, thereby ensuring automatic detection by the system. The final prototype testing of the Smart Parking System software, featuring Auto-Debit and Optical Character Recognition (OCR), was conducted during its inaugural year.

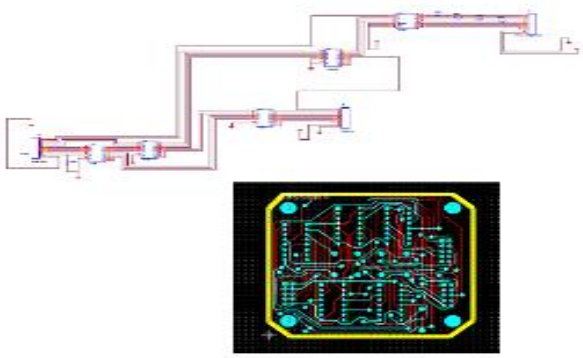
The application is initialized by launching the software, activating the camera module, and pressing the vehicle entry button, which temporarily replaces the proximity switch planned for implementation in the second year. During entry, the system records the vehicle's license plate, a close-up image, entry time, e-money ID, and balance. Upon exit, the vehicle exit button is pressed (also substituting for the proximity switch), after which the software automatically calculates the parking duration, determines the corresponding fee, deducts the amount from the e-money balance, and authorizes gate opening. Test results confirm that the software performs as designed, meeting both functional specifications and the planned implementation timeline. Figure 3 shows the layout of the development of a smart parking system.



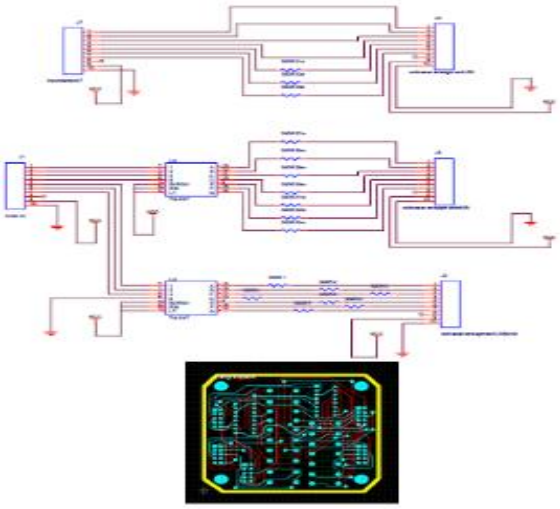
Source: (Research Results, 2024)
Figure 3. Parking terminal layout, cars, barriers



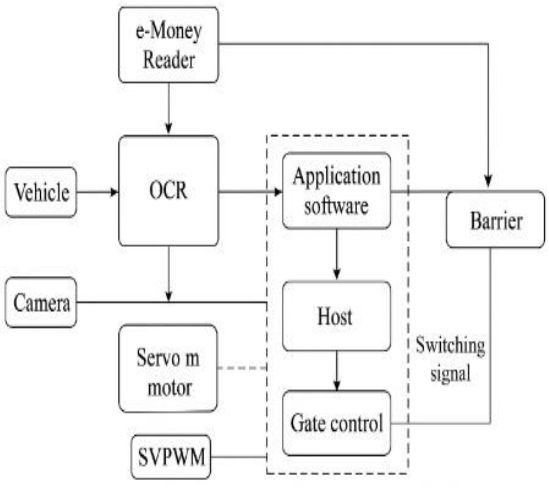
Source: (Research Results, 2024)
Figure 4. Schematic & PCB



Source: (Research Results, 2024)
Figure 5. Schematic & PCB 3-digit decimal input convert to BCD



Source: (Research Results, 2024)
Figure 6. Schematic & PCB BCD convert to Seventh segment Led 3 digit display



Source: (Research Results, 2024)
Figure 7. Block diagram of the smart parking system prototype with auto debit and OCR

As shown in Figure 7, the prototype integrates an automatic debit system with Optical Character Recognition (OCR) for license plate detection. The system architecture comprises the following components:

a. Input Module, equipped with OCR cameras and an e-money reader transceiver installed in vehicles, enabling seamless identification and access without requiring vehicles to stop.
b. Processing Unit, developed using Visual Studio 2010 with C#, incorporating algorithms for license plate recognition, parking fee computation, and real-time data processing.
c. Communication Interface, implements RS232C standards via both wired and wireless connections to ensure stable and accurate data transmission between the host application and the central server.
d. Gate Control System. utilizes Space Vector Pulse Width Modulation (SVPWM) to precisely control switching and timing mechanisms for automated gate operation.
e. Database and Server, responsible for storing license plate records, parking timestamps, e-money ID and balance data, as well as transaction histories to facilitate automated debit processing.
f. User Interface,designed for operational simplicity, providing monitoring features for operators during testing and deployment phases.

This prototype allows vehicles to enter and exit parking facilities automatically while deducting parking fees directly from the driver's e-money account. Furthermore, the modular structure facilitates iterative refinement and supports scalability, including replacing manual vehicle entry and exit buttons with proximity switches in subsequent development stages.

The compilation and execution of the Smart Parking System Development software with Auto Debit demonstrated a display feature showing the amount in Rupiah (Rp) and the corresponding parking time via a dedicated button. This button was later replaced by a proximity switch, functioning as an interrupt to the microcontroller and enabling communication with the host system to automatically deduct credit from the auto-debit card, thereby supporting a barrier-free parking system. The first-year prototype testing of the Smart Parking System, incorporating Auto Debit and Optical Character Recognition (OCR), was conducted to evaluate the system's functionality,

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accuracy, and overall reliability. The application software was implemented using Visual Studio 2010 with the C# programming language. The testing procedures were carried out as follows:

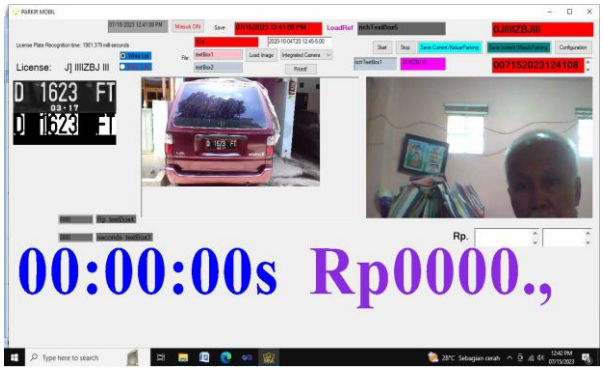
a. Vehicle Entry Simulation, The camera button was activated to capture both the license plate image and a close-up photograph of the vehicle. The vehicle entry button was then pressed to simulate the function of a proximity switch (which will be replaced by an actual proximity switch in the second year). The system successfully recorded the vehicle's license plate number, captured vehicle images, logged the entry time, and stored the vehicle's e-money ID along with its balance in the database.
b. Vehicle Exit Simulation, the *vehicle exit* button was pressed to simulate the function of a proximity switch for vehicle departure. The software automatically calculated the parking duration and corresponding fees. The required amount was deducted from the vehicle's e-money balance, and the vehicle exit was authorized without any manual intervention.
c. System Performance, the software consistently operated in accordance with the planned design and implementation schedule. All recorded data—including license plate numbers, images, entry and exit times, e-money IDs, and balance changes—were stored with complete accuracy. No operational failures were observed during testing, confirming seamless integration among OCR-based license plate recognition, e-money processing, and gate control simulation.

The prototype testing results, as summarized in the table, demonstrate that the Smart Parking System with Auto Debit and OCR functions as intended. During the vehicle entry simulation, the system successfully captured license plate images, vehicle photos, and recorded entry time, e-money ID, and balance information with no errors, confirming the proper operation of the simulated proximity switch. In the vehicle exit simulation, the software accurately calculated parking duration and fees, automatically deducted the corresponding amount from the stored e-money balance, and authorized vehicle departure without manual intervention, supporting the barrier-free parking concept. Furthermore, system performance testing verified that all recorded data including license plate numbers, images, timestamps, and balance changes were stored precisely, and no operational failures occurred. These results confirm that the integration between OCR-based license plate recognition, e-money processing, and gate control simulation is reliable and consistent with the system's planned design.

Table 1. Prototype Testing Result

Test Case	Input	Actual Output	Result
Vehicle Entry	Press "Camera" and "Vehicle Entry" button	All data recorded successfully	Pass
Vehicle Exit	Press "Vehicle Exit" button	Correct duration and fee deduction	Pass
Data Storage	Entry/exit logs with timestamps	All logs stored accurately	Pass
System Response	Repeated entry/exit cycles	No errors observed	Pass

Source: (Research Results, 2024)



Source: (Research Results, 2024)

Figure 8. Results of compiling, execution of software

To evaluate real world applicability, the system was implemented and tested in various public and commercial environments,including office buildings, shopping malls, and open parkir areas.These testing sites represent common urban parking conditions with varying lighting, network connectivity, and traffic density, allowing the system's adaptability and reliability to be analyzed comprehensively.

Real Impact (Qualitative and Quantitative) on the Target Sector and Society

1) Qualitative Impact

a. User convenience and efficiency
The implementation of Optical Character Recognition (OCR) enables automatic vehicle identification through license plate

recognition, significantly accelerating entry and exit processes without requiring physical parking cards or tickets. Additionally, the Auto-Debit mechanism facilitates cashless transactions, minimizing payment time and queue length, thereby enhancing overall user convenience and system efficiency.

b. Transparency and accuracy improvement
All parking transactions are recorded digitally, ensuring higher levels of transparency and accountability in financial reporting and auditing processes. Users can access detailed transaction data through an integrated application, increasing trust and accuracy in payment verification.

c. Enhanced security
OCR-based vehicle identification allows for secure digital recording and archiving, enabling faster vehicle tracking in cases of emergencies or security incidents. Furthermore, system integration with authorized databases can assist in detecting stolen or law-violating vehicles, contributing to a safer parking environment.

d. Integration within the smart city ecosystem
The proposed smart parking system can be integrated with other smart city infrastructures, such as traffic management systems, public transportation, and digital payment networks. This interoperability supports urban digital transformation and contributes to the realization of intelligent and interconnected cities.

2) Quantitative Impact

a. Operational cost reduction
The automated system reduces the need for manual labor by approximately 30–50% compared to conventional parking systems. Additionally, the elimination of physical tickets and reduced manual processes contribute to operational cost savings of 20–40%.

b. Transaction time reduction
Vehicle entry and exit durations decrease by 50–70% relative to manual systems. Through OCR identification and automatic payment, the average transaction time per vehicle is reduced from 30–60 seconds to 5–10 seconds, significantly improving traffic flow within parking areas.

c. Increased parking capacity and utilization
By reducing transaction duration and vehicle queues, the overall parking capacity increases by 15–25%, as vehicles circulate more efficiently. Consequently, the utilization rate per parking slot per hour also improves, optimizing facility performance and user throughput.

CONCLUSION

This study successfully developed a Smart Parking System prototype integrating auto-debit payment and optical character recognition (OCR) for license plate detection. Experimental results demonstrate its ability to reduce operational costs, shorten transaction times, optimize parking facility utilization, and enhance user convenience, transparency, and security. The system evolved from a button-controlled fee display to a proximity switch interrupt, enabling seamless automatic credit deduction and supporting a fully automated, barrier-free parking solution. To advance this prototype toward commercial implementation, future work should incorporate industrial-grade hardware, conduct large-scale field evaluations, enhance transaction security protocols, integrate cloud-based data management for scalability, and develop user-centric features such as mobile balance monitoring and digital receipts. These improvements will strengthen system reliability, expand usability, and support widespread adoption.

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