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Research on Coordinated Development of Smart Parking and Charging Facilities

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Abstract: With the rapid development of the new energy vehicle industry and accelerated urbanization, cities face dual challenges of "parking difficulties" and "charging difficulties". This paper explores the theme of "coordinated development of smart parking and charging facilities", aiming to analyze how technological innovation and management optimization can transform these two systems from isolated layouts to deep integration. The chapter first outlines key supporting pathways centered on IoT, big data, AI technologies, and V2G (Vehicle-to-Grid) technology, while summarizing typical collaborative models such as "park-charging integration" and "photovoltaic-storage-charging-discharge integration". Finally, it proposes policy guidance, business model innovation, and technological innovation to promote efficient synergy between the two systems, enhancing the digitalization and sustainable development of urban transportation systems.

Keywords: Charging facilities; Coordinated development; Smart parking; Urban governance; Vehicle-network interaction

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1. Introduction

With China's accelerating urbanization and surging vehicle ownership, the city parking crisis has become increasingly severe. The rapid growth of new energy vehicles (NEVs) has posed fresh challenges to traditional parking systems. By the first half of 2025, China's total vehicle fleet reached 460 million, with NEVs accounting for 36 million units (10.27% of the total). The lagging development of supporting charging infrastructure has become a critical bottleneck constraining NEV industry growth [1]. Against this backdrop, the coordinated development of smart parking systems and charging infrastructure has emerged as a key solution to address these challenges.

As a cornerstone of smart city infrastructure, intelligent parking systems utilize IoT, big data, and AI technologies to achieve digital management and efficient utilization of parking resources. Charging facilities, serving as "energy refueling stations" for new energy vehicles, directly impact user experience and industry development through their strategic deployment and operational convenience. The Chinese government prioritizes

the coordinated development of smart parking and charging infrastructure. In September 2025, the National Development and Reform Commission and five other departments released the "Three-Year Doubling Action Plan for Electric Vehicle Charging Infrastructure (2025–2027)", which outlines a national target to establish 28 million charging facilities by 2027. These facilities will provide over 300 million kilowatts of public charging capacity, meeting the charging demands of more than 80 million electric vehicles nationwide.

Meanwhile, the action plan jointly issued by the Ministry of Housing and Urban-Rural Development and eight other departments has elevated the integrated development of smart parking and charging facilities to a city-level strategy. It proposes to "promote coordinated development between smart city infrastructure and intelligent connected vehicles, leveraging pilot projects like the 'vehicle-road-cloud integration' initiative to advance smart parking systems. Local governments are encouraged to establish city-wide smart parking service management platforms." Starting from the challenges brought by the explosive growth of new energy vehicles, this paper analyzes the key technical paths and typical models of the coordinated development of smart parking and charging facilities, discusses the challenges faced in the process of promotion, and puts forward targeted countermeasures and suggestions, aiming at providing decision-making reference for urban transportation planners and related enterprises.

2. Key technologies and typical models for coordinated development

2.1. Key technologies

2.1.1. Data fusion and platform construction technology

Big data and AI technologies form the foundational resources of smart parking-charging systems. By integrating parking space status data, charging facility usage patterns, vehicle locations, and battery levels, the system creates a multi-source data fusion network for real-time monitoring, enabling precise matching of parking spaces with charging resources [2]. Furthermore, AI algorithms predict user behavior, charging demands, and parking patterns to optimize resource allocation and scheduling strategies, thereby enhancing overall system efficiency. The unified platform architecture also supports cross-regional and cross-operator data interoperability within urban areas, providing robust support for government planning and enterprise precision construction.

2.1.2. Vehicle-to-Grid (V2G) technology

Vehicle-to-Grid (V2G) technology serves as the core mechanism enabling bidirectional energy flow between new energy vehicles and power grids. By transforming electric vehicles into mobile distributed energy storage units, V2G technology allows charging during off-peak hours and discharging during peak hours, thereby participating in power system regulation to enhance grid stability. This innovation not only optimizes energy allocation efficiency but also effectively reduces user charging costs while boosting grid integration of renewable energy. The "Three-Year Doubling Action Plan for Electric Vehicle Charging Infrastructure Service Capacity (2025–2027)" explicitly proposes accelerating V2G pilot applications to establish market-oriented charging mechanisms based on time-of-use pricing and vehicle-grid interaction. By the end of 2027, over 5,000 new bidirectional charging and discharging (V2G) facilities are expected to be added, with reverse discharge capacity exceeding 20 million kWh [3].

2.2. Typical patterns

2.2.1. "Intergrated Parking-Charging" construction model

The "Integrated Parking-Charging" model refers to a comprehensive approach that coordinates parking and

charging needs during the planning phase of parking facilities. This strategy involves strategically arranging charging infrastructure, encouraging businesses and enterprises to invest in construction and share operational revenue, while promoting efficient land use and shared infrastructure. This model avoids resource waste and construction disruptions caused by later modifications, and has been widely adopted in large commercial complexes and public transportation hubs.

For instance, the Nanchang Minyuan Road Green Smart Parking Lot, built under the "Integrated Parking-Charging" concept, features 330 parking spaces and 170 fast/slow charging stations. Drivers can use an app to check availability, schedule charging, and plug in instantly. When leaving, they can seamlessly combine parking fees with charging costs, significantly enhancing user convenience and facility utilization. Additionally, under the "Three-Year Doubling" initiative, newly built residential areas must install charging facilities in all designated parking spaces or reserve installation conditions, meeting requirements for direct meter installation and electrical safety. Existing neighborhoods are gradually upgrading their charging infrastructure to accommodate the extended charging and parking needs of new energy vehicles.

2.2.2 "Photovoltaic storage charging and discharging" integrated mode

The "photovoltaic-storage-charging-discharging" integrated model synergistically combines renewable energy, energy storage systems, and bidirectional charging infrastructure to enable localized energy production, storage, and consumption. The Nanchang Honggutan Vehicle-Grid Interaction Super Charging Demonstration Station embodies this integrated approach, featuring approximately 5,818 square meters of photovoltaic building-integrated carports in parking areas, complemented by energy storage facilities and 36 charging-discharging parking spaces. The vehicle-grid interaction demonstration zone is equipped with four 300-kilowatt 1-to-6 host units, each equipped with 6 charging guns supporting bidirectional DC output across 200V to 750V voltage ranges.

The new-generation charging demonstration zone offers 8 supercharging stations capable of delivering 80% battery capacity in 10 minutes, significantly reducing user charging wait times. Participants who engage in charging and discharging activities at the demonstration station can earn electricity-saving credits and access value-added services like residential electricity discount coupons [4]. This model not only resolves charging challenges but also promotes clean energy utilization, serving as a crucial pathway toward achieving carbon neutrality in the transportation sector.

3. Major challenges in promoting coordinated development

3.1. Policy and standard barriers

Insufficient policy coordination is the primary obstacle to the development of smart charging systems. Currently, urban parking management policies and new energy vehicle promotion policies are often formulated by different departments, lacking coordination and consistency. For example, the construction of civilian charging facilities involves approval requirements in multiple fields, such as land conversion, power grid laying, and fire safety review, resulting in complex procedures, long cycles, and usage limitations. Although the three-year doubling plan requires provinces and cities to "simplify the approval process for installation and power connection while strengthening safety management and improving service guarantees" to address this issue, overall, policy barriers remain significant.

Additionally, the lack of unified charging facility standards is another major obstacle. There are differences in battery design voltages, interface standards, and data platform compatibility among domestic and foreign electric vehicle manufacturers, making system interoperability difficult and hindering the formation of scale effects. Taking charging interfaces as an example, domestic charging interfaces use the GB/T Chinese national standard, while the North American market predominantly uses Tesla's NACS standard, and Europe generally adopts the CCS2 standard. Imported electric vehicles (non-designed for Chinese market) require interface conversion at domestic charging stations to charge normally.

3.2. Economic and business model challenges

The development of public smart charging systems faces severe financial constraints. A complete smart charging system requires substantial investment, encompassing hardware components (such as charging stations, sensors, and electronic payment systems), software platforms, and communication infrastructure. This is particularly true for comprehensive facilities like photovoltaic supercharging stations, which demand even greater upfront capital. The lack of clear profit models further discourages private sector participation. Limited revenue streams, including charging service fees and value-added parking fee allocations, make rapid investment recovery challenging. Moreover, electricity pricing policies significantly impact operational economics. The differential between peak and off-peak electricity rates necessitates meticulous planning of charging operations to ensure financial viability.

3.3. Technical and operational barriers

From a technical standpoint, the primary challenge lies in system integration complexity. The smart parking-charging system requires deep integration of charging infrastructure, parking management systems, payment platforms, and energy management systems, presenting significant technical difficulties and demanding advanced algorithmic and AI computational capabilities. Operationally, cross-platform collaboration poses substantial challenges. The integration of parking and charging services involves multiple stakeholders, including parking facility operators, charging infrastructure providers, mobile payment platforms, and energy suppliers (State Grid Corporation of China). The complex distribution of interests and responsibilities among these parties makes coordination particularly difficult.

4. Suggestions for promoting the coordinated development of smart parking and charging facilities

4.1. Strengthening policy guidance and standard formulation

The government should play a guiding role by formulating comprehensive development plans. Smart parking and charging infrastructure should be incorporated into urban master plans and smart city frameworks, with clear development goals and implementation pathways. Drawing on Chengdu's experience, policies like the "Chengdu Electric Vehicle Charging and Battery Swap Infrastructure Development Plan" should incorporate integrated parking-charging projects into digital city development strategies. Simultaneously, efforts should accelerate the establishment of unified standards. Technical specifications for smart parking-charging systems, including data interfaces, payment settlements, and safety supervision, should be developed to ensure system interoperability and device compatibility. Approval procedures should also be streamlined through a one-stop approval mechanism, creating a fast-track process for smart parking-charging project implementation [5].

4.2. Innovative business model and investment and financing mechanism

The government and private investors may explore innovative business models to broaden revenue streams. For example, integrated service models that combine "parking + charging + value-added services" can be promoted to generate additional income through advertising, vehicle maintenance, entertainment services, and other complementary offerings. In line with the concept of "co-construction and sharing," Public-Private Partnership (PPP) models may be adopted to encourage the participation of parking facility owners, charging operators, internet platforms, and private investors in project development and operation through equity cooperation or franchise arrangements. Such approaches can help reduce investment risks, increase operational sustainability, and accelerate the deployment of charging infrastructure. Moreover, implementing time-sharing mechanisms for charging resources can improve equipment utilization and contribute to greater overall profitability.

4.3. Promoting technological innovation and data sharing

The government should enhance R&D support for core technologies, encouraging collaboration among enterprises, universities, and research institutions to tackle key challenges such as intelligent dispatching algorithms, high-power charging, and V2G technology. It should also promote the development of AI-powered smart management systems and facilitate data openness and sharing. By establishing city-level big data platforms for parking and charging, the government can ensure secure and privacy-preserving data flow while enabling orderly sharing. Additionally, improving user experience should be prioritized through optimized integrated applications that combine functions like charging station status queries, parking space searches, reservations, navigation, and payments, ultimately delivering a "one-click parking and charging" convenience.

5. Conclusion

The coordinated development of smart parking systems and charging infrastructure represents a crucial solution to address urban "parking difficulties" and "charging challenges." This initiative not only drives the intelligent and digital transformation of urban transportation systems but also promotes energy conservation, emission reduction, and sustainable development. With continuous advancements in vehicle-network interaction technologies, big data, IoT, and AI, coupled with innovative integrated operation models for smart parking and charging facilities, these systems will play a pivotal role in future smart city development and transportation energy transition. Simultaneously, they will contribute to achieving carbon peaking and carbon neutrality goals while enhancing urban governance capabilities and improving residents' quality of life.

Disclosure statement

The authors declare no conflict of interest.

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