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Dilemmas in Developing Electric Vehicle Charging Infrastructure in Qujing: Causes and Solutions

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Abstract: *As a demonstration province for plateau green energy, Yunnan has seen a rapid rise in new energy vehicle (NEV) penetration. However, the contradiction between supply and demand of charging infrastructure and efficiency bottlenecks urgently need to be addressed. Taking the Economic Development Zone of Qujing City as a typical case, this study establishes a "space-time-technology" three-dimensional evaluation system, integrates intelligent dispatching and green energy technologies, and proposes an optimized plan for charging facilities with plateau characteristics. The research reveals that the distribution of charging piles in Qujing features "concentration in urban areas, shortage along highways, and absence in scenic spots", and charging efficiency is significantly affected by power grid load and equipment aging. By means of GIS-based data collection APPs, AI image recognition for automatic statistics on the type and status of charging piles, and questionnaires, an analysis of the usage, space, time, and technology of NEV charging facilities in Qujing shows that: the number of charging piles in the Economic Development Zone of Qujing currently lags far behind the growth rate of NEVs, with an imbalanced vehicle-to-pile ratio and uneven distribution. To address the problems of NEV charging piles in the Economic Development Zone of Qujing, this paper puts forward the following planning suggestions: optimize the spatial layout of charging piles, focus on filling the gaps of charging facilities along highways and in scenic spots, and promote the construction of "wind-solar-storage-charging integrated" stations; implement an intelligent dispatching system and time-of-use electricity pricing strategy to guide off-peak charging and narrow the peak-valley difference of the power grid; strengthen the standardized management of charging facilities and regulate platform operation and construction access conditions; promote high-power charging piles, IoT-based intelligent regulation, and vehicle-grid integration technologies; ensure the stability of power supply, promote regional coordinated planning, and build a new energy travel ecosystem in the central Yunnan urban agglomeration, so as to provide a systematic solution for the efficient development of charging infrastructure in Qujing. After the overall implementation of the plan, the carbon emission intensity in the transportation sector of the Economic Development Zone is expected to decrease by 23%, contributing to the achievement of the "14th Five-Year Plan" target of reducing energy consumption per unit of GDP.*

Keywords: *Electric Vehicle; Charging Station; Energy Conservation and Emission Reduction; Intelligent Dispatching*

1. Introduction

Against the global tide of actively addressing climate change and vigorously promoting energy conservation and emission reduction, the development of electric vehicles (EVs) has emerged as a pivotal measure to achieve sustainable development in the transportation sector. Boasting remarkable advantages in energy conservation and emission reduction, EVs are regarded as an ideal alternative to traditional fuel-powered vehicles, bearing far-reaching significance for reducing carbon emissions, improving air quality, and alleviating the energy crisis. As a major city in Yunnan Province, Qujing has actively responded to this wave of green development. In recent years, the number of motor vehicles in Qujing has been on a steady rise, ranking among the top in the province. This trend has not only brought about traffic pressure but also provided broad space for the popularization of EVs. Therefore, conducting in-depth research on the quantity and charging speed of EV charging piles in Qujing, and analyzing the current layout and functional matching of charging piles from multiple dimensions, are of crucial practical significance for improving the local EV charging service network, advancing the practice of energy conservation and emission reduction, and achieving the goal of green transportation

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development[1]-[2].

2. Research Object

This paper selects Qujing Economic and Technological Development Zone as the research object, and conducts an investigation on the distribution of charging pile infrastructure, usage efficiency, user demands, and other related aspects within the zone.

There are regional differences in the distribution and charging speed of electric vehicle (EV) charging piles in Qujing City: the density of charging piles in urban areas is 4.2 units/km², with fast-charging piles accounting for 65%; the density of charging piles on expressways is relatively low at 0.8 units/km², but the proportion of fast-charging piles is as high as 90%; the density of charging piles in tourist attractions is 1.5 units/km², while the proportion of fast-charging piles is only 40%. This results in an excessively high ratio of slow-charging piles, which makes it difficult to meet tourists' demand for short-term rapid charging. The charging piles in Qujing Economic and Technological Development Zone (QETDZ) exhibit a distribution characteristic of "high density in the central area and low density in the peripheral areas": the density of charging piles in the commercial center of the main urban area reaches 4.5 units per square kilometer, while that in industrial parks and urban-rural fringe areas is less than 0.8 units per square kilometer. In terms of usage, the utilization rate of charging piles in core commercial districts such as Wanda Business Circle exceeds 85% during peak hours, with frequent queuing; in contrast, the average daily utilization rate of charging piles in suburban areas is only 30-40%, indicating a significant resource mismatch. Analysis of charging data reveals that the nighttime utilization rate (19:00-23:00) of charging piles in residential areas peaks at 75%, while those in business districts achieve a utilization rate of over 80% during daytime working hours (9:00-17:00). Such temporal and spatial distribution differences reflect that the current layout of charging facilities has not yet achieved precise matching with the travel and charging needs of citizens.

Research Methods: Field positioning and recording were conducted using a GIS data collection APP; AI image recognition technology was applied to automatically count the quantity and type of charging piles; in addition, online questionnaires were used to collect user feedback, and on-site interviews and surveys were carried out[3].The current situation is detailed in Figure 1.

Figure 1: Field Positioning and Recording of GIS Data Collection

3. Analysis of Survey Data

3.1. Three-Dimensional Analysis of Charging Piles in Qujing Economic and Technological Development Zone

Spatial Dimension: Combined with the analysis of Baidu's pedestrian flow heatmap, significant population mobility is observed around key areas in QETDZ, including the Central Business District (CBD: Wanda, The Bund), medical centers, sci-tech innovation hubs, as well as educational, commercial, and industrial centers. The initial effect of the Qilin-Zhanjiang-Maluo (Qizhanma) urban integration is evident. Within the region, there are 18 existing charging stations with a total of 649 charging guns, mainly distributed along Sanjiang Avenue, Xuefu Road, Cuifeng East Road, and Cuifeng West Road. In terms of facility scale, medium-sized, small-sized, and smaller charging stations account for approximately 81%. Regarding service radius—analyzed based on a 1-kilometer coverage

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standard—the total service area of all 18 charging stations (facilities) is about 23 square kilometers, accounting for 31.9% of the research scope. In terms of service attributes, there are 15 public charging stations (including 4 built alongside commercial outlets and 11 social public charging stations), 1 dedicated charging station (at the medical center), and 2 private charging piles. The current Distribution Map of Charging Facilities is detailed in Figure 2.

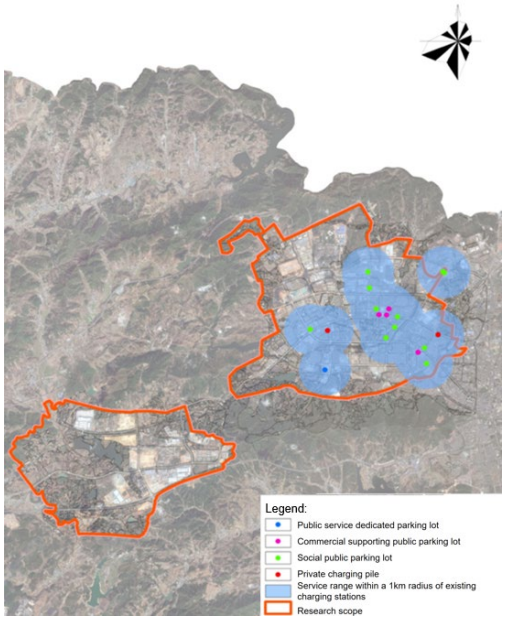

Figure 2: Current Distribution Map of Charging Facilities in the Economic and Technological Development Zone (ETDZ)

Temporal Dimension: An analysis of the matching degree between charging demand and supply across different time periods reveals that significant population mobility exists around the educational, commercial, and industrial centers of QETDZ. With the initial manifestation of the Qilin-Zhanjiang-Maluo (Qizhanma) urban integration effect, QETDZ has witnessed a population agglomeration phenomenon, leading to strong demands for vehicle travel and parking. According to Baidu' s pedestrian flow heatmap data, the daily population mobility in QETDZ is concentrated along Sanjiang Avenue (around Qujing Normal University and Wanda Plaza) and Nanhaizi Avenue (around Sanyuan Delong and Yangguang Energy). The Heat Map of Pedestrian Flow in the Economic and Technological Development Zone is detailed in Figure 3.

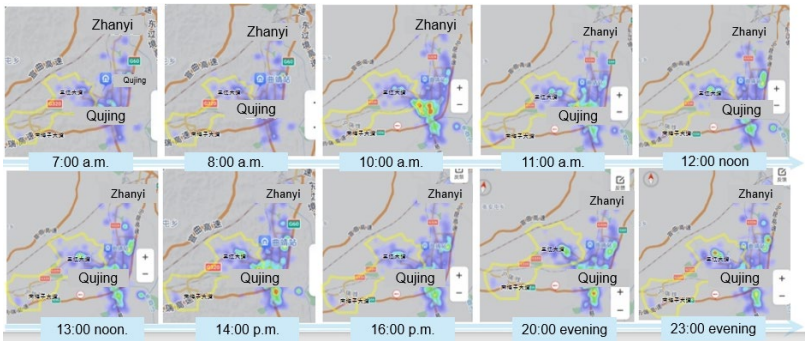

Figure 3: Heat Map of Pedestrian Flow in the Economic and Technological Development Zone (ETDZ)

Technical Dimension:

(1)Deployment of High-Power Charging Stacks: The charging station at Xinzhuang Service Area in Qujing Economic and Technological Development Zone (QETDZ) is equipped with 2 sets of 480kW DC fast-charging stacks, paired with 6 charging piles and 12 ultra-fast charging guns. Each gun has a maximum output power of 240kW, enabling efficient rapid energy replenishment services for large trucks and buses. Through high-power output, this technology shortens charging duration and significantly improves the service efficiency of the charging station. (2)Technology Adaptation and Scenario Coverage: The ultra-fast charging technology adopts the principle of "dynamic power

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distribution," which dynamically allocates power resources according to real-time vehicle demands. For instance, when the charging demand is low, a single charging gun can operate at full capacity; when multiple vehicles are charging simultaneously, the system automatically balances power distribution and prioritizes meeting the needs of fast-charging models, thereby maximizing resource utilization. (3)Internet of Things (IoT) and Intelligent Regulation: The intelligent charging piles deployed in Zefu Jiayuan Community, Qujing Economic and Technological Development Zone (QETDZ), are based on the "Internet of Things (IoT) + Internet" technology. They realize real-time collection of data such as charging current and power, as well as automatic power-off protection in case of abnormalities, with a charging safety response efficiency reaching the millisecond level.

3.2. Demand Forecasting and Analysis

Taking GDP as the primary indicator for the development of electric vehicles (EVs) in the city, the predicted development scale of EVs in Qujing City and Qujing Economic and Technological Development Zone (QETDZ) during the planning period is as follows in Table 1.

Table 1 Forecast Results of Electric Vehicle Scale

Indicator(s)	2025 (10,000 units)	2030 (30,000 units)
Vehicle Ownership	10.65	12.35
Proportion of Electric Vehicle (EV) Development Targets	20%	40%
Forecast of Electric Vehicle (EV) Ownership Scale	2.13	4.94

In Qujing Economic Development Zone, the scale prediction of electric vehicles shows the following figures. By 2025, the total number of vehicles in ownership is expected to reach 106,500, among which electric vehicles will account for 20%, with their ownership scale predicted to be 21,300. By 2030, the total vehicle ownership is projected to hit 123,500, while the proportion of electric vehicles will rise to 40%, and their ownership scale is forecasted to reach 49,400.

According to the requirements of superior documents such as the Guidelines for the Development of Electric Vehicle Charging Infrastructure (2015-2020) issued by the National Development and Reform Commission (NDRC) and Several Government Measures for Accelerating the Development and Promotion of New Energy Vehicle Industry in Yunnan Province [4], Qujing is designated as a city for the promotion and application of new energy vehicles. It is recommended that the ratio of public charging piles to electric vehicles (EVs) shall not be lower than 1:8, and the density of charging stations shall not be lower than 1.2 stations per square kilometer. Based on these requirements, the demand scale for charging piles in QETDZ is determined as follows: by 2025, the number of EV charging facilities required in QETDZ shall be no less than 2,663 guns; by 2035, the number of public charging stations in QETDZ shall be no less than 88, and the number of EV charging facilities shall be no less than 11,730 guns.

3.3. Analysis of Existing Problems

Platforms and Products: A large number of operational platforms exist without effective integration. Significant discrepancies in management standards and technical levels across different platforms have led to inconsistent quality of charging products available on the market. Some products perform poorly in key performance aspects such as charging stability and compatibility, causing considerable inconvenience to users.

Layout Orientation: Currently, the layout of charging stations is primarily profit-driven, with excessive focus on commercial interests. A large number of stations are concentrated in high-foot-traffic areas such as Wanda Plaza and Qujing Normal University. These areas already have heavy traffic flow, and the concentrated layout of charging stations attracts more vehicles, further exacerbating traffic congestion in local regions.

Number of Stations and Coverage: The number of charging stations is severely insufficient, with sparse distribution across the city. Given the current station density, it is difficult to meet the growing charging demand of electric vehicles (EVs). Meanwhile, the service coverage rate is low, and there are charging service blind spots in many areas—especially in urban fringe zones and around old residential communities.

Service Types: The types of charging services are relatively single, with most stations only providing conventional slow charging or fast charging services. There is a lack of differentiated services tailored to different vehicle types and user needs—such as the rapid charging demands of taxis

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and ride-hailing vehicles, and the off-peak night-time charging needs of private cars at lower electricity prices. As a result, they cannot adapt to the diverse usage scenarios and growth trends of electric vehicles (EVs).

4. Countermeasures and Suggestions

Through the scientific planning and layout of charging piles in Qujing Economic and Technological Development Zone (QETDZ), significant energy conservation and emission reduction effects are expected to be achieved: Based on the current 18% penetration rate of new energy vehicles (NEVs), the optimized charging network will promote the proportion of electric vehicles (EVs) to rise to 30%, reducing traditional fuel consumption by approximately 28,000 tons per year, which is equivalent to a reduction of 63,000 tons in carbon dioxide (CO_2) emissions. By deploying 12 integrated photovoltaic-storage-charging stations, the annual power generation from idle rooftop photovoltaic systems can reach 4.2 million kilowatt-hours (kWh), reducing indirect emissions from grid power procurement by 12,000 tons; combined with the off-peak charging strategy guided by time-of-use electricity prices, the peak-valley difference of grid load can be narrowed by 15%, and the proportion of clean energy consumption can be increased by about 8 percentage points. After the full implementation of the overall plan, the carbon emission intensity in the transportation sector of QETDZ is expected to decrease by 23%, helping to achieve the "15th Five-Year Plan" target of reducing energy consumption per unit of GDP [3].

4.1. Public Charging Station

Urban public charging stations are guided by the principle of "full openness and extensive service" to meet the demands of public parking and charging. They are laid out in conjunction with lands for park green spaces, gas-filling stations, substations, and public parking lots, while additional stations are supplemented across the area in combination with large-scale commercial outlets. This ensures a balanced distribution and enables coverage of a service radius of 2 stations per 3 square kilometers. In line with urban development, it is proposed to add a total of 110 new public charging stations with 11,938 charging piles. Specifically, 6 stations with 93 piles will be built in supporting facilities of park green spaces, 28 stations with 9,174 piles in those of commercial outlets, 6 stations with 144 piles in those of gas stations, 59 stations with 1,212 piles in those of public parking lots, 2 stations with 400 piles in integrated energy stations, and 9 stations with 162 piles in those of shantytown areas. The situation is as follows in Table 2.

Table 2 Construction Statistics of Charging Piles in Various Types of Public Charging Stations

Types of Charging Stations		Number of Stations (units)	Number of Charging Ports (Guns)	Proportion of the Number of Stations（%）
Public Charging Stations	Charging Facilities Supporting Park Green Spaces	6	93	5.5
	Charging Facilities Supporting Commercial Outlets	28	9174	25.5
	Charging Facilities Supporting Gas Stations	6	144	5.5
	Charging Facilities Supporting Public Parking Lots	59	1212	53.5
	Integrated Energy Station	2	400	1.8
	Charging Facilities Supporting Shantytown Renovation Areas	9	162	8.2
	Total	110	11938	100

4.2. Special-Purpose Charging Station

Special-Purpose Charging Stations serve urban parking spaces for specific vehicle types or those designated as "semi-open and specialized." They should be deployed in conjunction with land for public services, logistics and warehousing, industry, public transportation hubs, and environmental sanitation facilities to ensure that specialized spaces are equipped with independent charging capabilities. It is recommended to add new urban special-purpose charging stations based on the current status and planned land use of the aforementioned categories, with the following construction ratios of charging piles for different land types: Culture, Education, Sports, Medical, and Elderly Care Facilities: Charging piles shall be constructed in parking lots at a ratio of 1:8, with a certain number of additional

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piles reserved for public use. Government Departments and Institutional Units: Charging piles shall be constructed in parking lots at a ratio of 1:1, with a certain number of additional piles reserved for public use. Sanitation and Public Transportation Facilities: Charging piles shall be constructed for sanitation vehicles at a ratio of 1:1 to parking spaces. Parking Lots of Industrial and Logistics Facilities: Charging piles for industrial and logistics vehicles shall be installed at a ratio of 1:5 to the number of parking spaces.

5. Conclusion

Qujing Economic and Technological Development Zone' s charging pile planning integrates public, dedicated, and residential private charging networks, promising remarkable energy conservation and emission reduction effects. Optimized layout is expected to raise the new energy vehicle penetration rate to 30%, cutting annual fuel consumption by 28,000 tons and CO emissions by 63,000 tons. Supported by 12 photovoltaic-storage-charging integrated stations, time-of-use pricing for off-peak charging, and 4.2 million kWh of annual rooftop photovoltaic power generation, the plan will narrow grid peak-valley differences by 15%, increase clean energy absorption by 8 percentage points, and reduce transportation carbon intensity by 23%, aiding the "15th Five-Year Plan" GDP energy consumption targets. Public charging stations will expand from 18 to 110, covering key areas with a 3km service radius through multi-location integration. Dedicated stations will follow tailored allocation ratios for different land uses, while residential charging adopts demand prediction models and innovative modes—shared piles for old communities and pre-installed facilities for new ones—ensuring balanced, efficient, and user-friendly charging services across the zone.

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