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Considerations for Planning Charging Stations on College Campuses: A Focus on Safety and Economy

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Abstract: As intelligent networked cars become increasingly integrated into people's lives, the charging infrastructure of new energy vehicles is becoming a significant factor in the development of the new energy vehicle market. In light of the rapid growth of this market, the problem of charging stations is gradually becoming apparent. This paper puts forward a charging station planning idea. Firstly, a forecast of the charging demand must be made. Subsequently, the economic viability, safety, ease of use for faculty and staff, and the rapid development of new automotive technology must be taken into account. Finally, research and analysis of the actual data must be carried out following the requirements of the different college campuses.

Keywords: New energy vehicles; Charging station; Safety; Economy

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1. Research background

In light of the current global situation and socio-economic context, it has become imperative for China to develop and promote the growth of new energy vehicles. The introduction of incentive policies by the Chinese government and the sizeable consumer market have contributed to the growing popularity of new energy vehicles among users. New energy vehicles can effectively reduce consumer costs, while intelligent configurations enhance user experience. As a result, more users are accepting and purchasing new energy vehicles [1].

In the period between January and May 2024, the production and sales of new energy vehicles reached a total of 3.926 million units and 3.895 million units, respectively. This represents a year-on-year growth of 30.7% and 32.5%, respectively [2]. The expansion of new energy vehicle sales is accompanied by an increase in supplementary power infrastructure. According to the website of China's National Development and Reform Commission, as of the end of May 2024, China's national charging infrastructure totaled 9.92 million units, representing an increase of 56% year-on-year. Among these, public and private charging facilities reached 3.05 million units and 6.87 million units, respectively, representing an increase of 46% and 61%, with the vehicle-to-pile ratio reaching 2.45:1. China has built the world's largest number of charging infrastructure systems, the widest range of services, and the most complete types of charging infrastructure systems [3].

The provision of extensive and accessible charging facilities can facilitate the advancement of the emerging

electric vehicle industry. This is evidenced by the April 2024 sales figures for new energy passenger cars, as reported by the Passenger Vehicle Market Information Joint Branch of the China Association of Automobile Distribution. These figures indicate a notable increase in pure electric sales, with approximately 408,000 units sold, representing a 23% growth. The year-on-year change was 1% (down 1.6% from a year earlier), while the year-on-year change for plug-in hybrid sales was 64.3% (up 6.5% from a year earlier). The volume of plug-in hybrid sales was approximately 265,000 units, representing a 64.3% increase compared to the previous year and a 6.5% decline in comparison to the preceding quarter. An increasing number of consumers are opting for plug-in hybrid electric vehicles (PHEVs) due to the vehicle-to-power ratio not being sufficiently high, coupled with concerns about range [15].

According to an article published by China CCTV International Network Limited, the fire incidence rate of China's new energy vehicles in 2023 was 0. The article of China CCTV International Network Limited indicates that the fire rate of new energy vehicles in China in 2023 is 0.96 per 10,000. Furthermore, the new energy vehicle ownership in 2023 is estimated to result in approximately 1,960 new energy vehicle fires. This is of particular importance concerning the fire safety of new energy vehicle parking and charging facilities in densely populated college and university campuses.

The integration of automated driving technology in new energy vehicles offers the potential for a "vehicle-to-road-network" synergy. The planning of power supply infrastructure should be considered holistically within the context of the wider transport and energy network system. This necessitates the integration of key elements such as new energy vehicles, road networks, charging facilities, and energy, which should be planned with a degree of foresight. In their study on the network design of dedicated lanes for self-driving cars, Han and other scholars noted that the presence of manned cars in shared lanes with self-driving cars introduces uncertainty into the traffic system and diminishes the potential of self-driving cars to enhance road capacity. Consequently, they proposed that certain sections of lanes be selected to establish dedicated lanes for self-driving cars within the existing road network [4].

In summary, in densely populated and student-heavy college and university campuses, the planning of charging facilities should not only consider the economic implications but also the safety of the students and staff. It is recommended that the impact of new energy vehicle recharging infrastructure in colleges and universities be moderately considered in light of the rapid development of emerging technologies such as Telematics and smart unmanned charging. This will facilitate the recharging infrastructure to play a maximum role in its lifecycle, reduce economic costs, and help car owners to enjoy convenient charging facilities.

2. Classification of replenishment infrastructure

The current state of the art in the field of electric vehicle (EV) refueling infrastructure can be broadly categorized into three main types: slow charging, fast charging, and power exchange stations. In **Figure 1**, the charging method is divided into alternating current (AC) charging and direct current (DC) charging [5].

Conventional charging, also known as slow charging, is a method of charging that involves the use of portable charging equipment carried with the vehicle for charging. This method can utilize both household power and charging piles. Fast charging is a method of directly charging the battery through a high-power DC charging pile, with the battery being charged to approximately 80% in a relatively short period [5]. Nevertheless, slow charging can facilitate a more profound charge of the battery and consequently extend its lifespan [6].

The power exchange method is a process whereby the power battery of a new energy vehicle is replaced at a service station site, thereby replenishing the vehicle's power. On 4 July 2024, NIO POWER announced the data of power refilling services in June and the charging and exchange cooperation with other enterprises (**Table 1**), of which 23.79% were completed through home charging piles, 4.07% used NIO's public charging piles, and 18% relied on third-party public charging facilities. As much as 54.14% of the refilling service was done through the

NIO's power exchange station [7]. Comparison of the number of NIO POWER supercharging stations and other major new energy vehicle manufacturers as of 15 May 2024 **(Figure 1)**.

Table 1. NIO charging and switching co-operation as of May 2024

Co-operation time	Charging and switching enterprises	Cooperation content
2024.05.08	GAC Group	The objective of this initiative is to facilitate strategic collaboration on the topics of charging and switching.
2024.04.25	Lotus Cars	The objective of this initiative is to facilitate strategic collaboration on the topics of charging and switching.
2024.04.23	Deepal	The process of establishing a connection between two or more charging networks.
2024.04.18	SAIC-GM	The process of establishing a connection between two or more charging networks.
2024.04.03	Jiyue Automobile	The process of establishing a connection between two or more charging networks.
2024.03.22	Zhong'an Energy	Co-operation to promote the construction of 1,000 storage, charging and body-switching stations
2024.03.14	CATL	Based on the needs of the new coming power exchange scenario, co-operate in the development of long-life battery
2024.02.27	China Southern Power Grid Co., Ltd.	Will co-operate in battery banking, recycling, switching stations, virtual care power plants, equity investment, etc.
2024.01.11	Chery Automobile Co., Ltd.	Strategic co-operation on power switching
2024.01.11	JAC Group	Strategic co-operation on power switching
2023.12.14	Rwe Group	Co-operation in the supply of electricity
2023.11.29	Geely Group	Strategic co-operation on power switching, charging network interconnection co-operation opened in March the following year
2023.11.21	Changan AUTO	Co-operation in power exchange business

Source: Compiled by WAYS

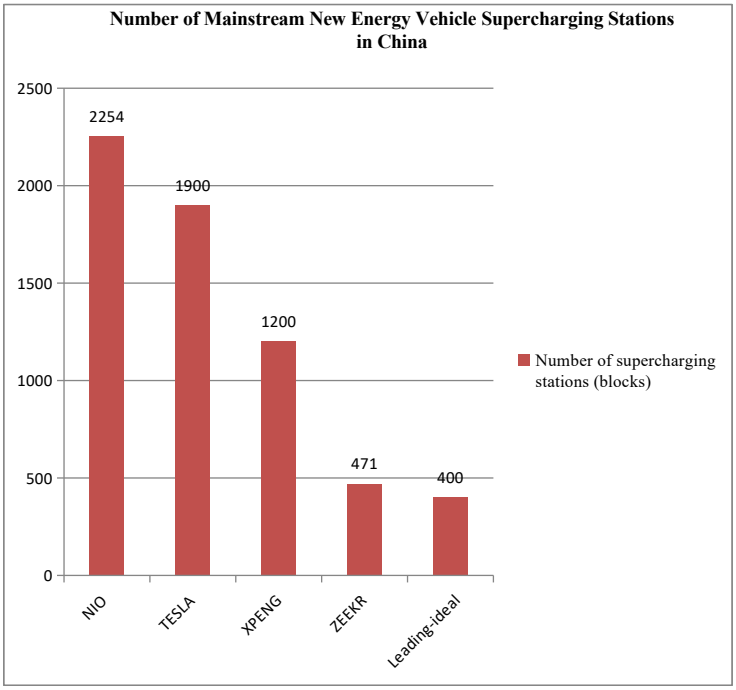

Figure 1. Number of Mainstream New Energy Vehicle Supercharging Stations in China as of May 15, 2024 (Source: Compiled by WAYS)

3. Main influencing factors for planning new energy vehicle charging facilities on college campuses

3.1. Economic aspects

The primary factor to be considered when planning new energy vehicle charging infrastructure on college campuses is the economy. This is driven by the desire of college campus administrators to spend less money and derive the greatest benefit from it. Concurrently, in the current market situation in China, the investment required to construct a small charging station with more than 10 fast-charging piles can be as high as millions of yuan [7]. According to data from the network, the cost of NIO's first-generation charging station is estimated at 3 million RMB, while the cost of the third-generation charging station is estimated at 1.5 million RMB. The high construction cost is likely to dissuade college campus managers from pursuing this option. Furthermore, the subsequent operational phase of the replenishment infrastructure necessitates the incurrence of considerable operational and maintenance costs, including those associated with electricity, personnel, and the upkeep of the charging piles and batteries [7]. If there is a significant discrepancy between the planned charging infrastructure and the actual demand, the siting planning for the charging stations is deemed to be unreasonable. Moreover, if the number of charging piles constructed does not align with the actual charging demand, it can result in a shortage of charging piles or a surplus of idle piles. This can present additional challenges for university campus managers [8].

Following an investigation into the construction companies specializing in the manufacture of electric vehicle charging stations in China, it was found that they offer a variety of collaboration models. One such model involves the purchase of the company's charging equipment by the university, with the university then responsible for the construction, maintenance, and planning of the charging station. This model carries a significant financial burden. An alternative option is to enter into a collaborative agreement with a private enterprise, which would assume responsibility for the planning, construction, and maintenance of the charging station. In return, the university would grant the enterprise the right to use the land for a specified period, with the profits from the charging station being divided between the two parties in a pre-agreed ratio.

Regardless of the approach, the overarching objective is to account for the cost. This entails determining whether the charging station's life cycle can be completed in a manner that optimizes the benefits of the charging station. In China, the construction of charging stations is largely subsidized by the government. However, it is important to note that there is still a certain amount of subsidy. Consequently, when planning for charging stations, it is also necessary to consider the impact of policy factors and the potential for policy changes to affect the economic costs.

3.2. Security aspects

Both charging stations and power exchange stations are susceptible to the risk of fire. According to the Chinese national standard GB 50067-2014, "The Design and Fire Prevention Code for Automobile Garages, Garages, and Car Parks," Article 5.1.1 and 5.1.2, the underground automobile garage fire-resistance level for the first and second levels is 2,000 m^2. When the installation of an automatic fire-extinguishing system is considered, the maximum permissible area should not exceed 4,000 m^2. However, for the installation of charging facilities, the code lacks clear requirements [9]. In other words, there is no explicit requirement for fire protection of charging stations or power exchange stations. However, there is a more general requirement for fire protection of buildings. This implies a more extensive requirement for the construction of the charging infrastructure. The builder may choose to install fire facilities or not, but in a densely populated college campus, this point should not be overlooked. The charging facilities on the college campus must have fire safety regulations in place to ensure the safety of teachers and students [14].

The current market offers two main types of new energy vehicles: pure electric vehicles and plug-in hybrid

vehicles [10]. These vehicles share several characteristics, including a high battery combustion temperature, fast fire spread, combustion of carbon monoxide, benzene, hydrogen, and other harmful gases, the risk of electrical fires, and a long fire extinguishing time [11]. The majority of electric vehicle charging stations are equipped with indoor fire hydrant boxes, trolley-type or portable water-based or dry powder fire extinguishers, fire blankets, and firefighting sand, among other safety measures [11]. According to various sources, there are several ways to extinguish a power battery fire and combustion. One method is the use of fire blankets and fire sand, which can extinguish the fire but cannot cool it down. These materials must be thrown into the pool after extinguishing the fire. Another method is the use of a substantial quantity of continuous firefighting water to reduce the temperature of the battery combustion, slow down the spread of the fire, and reduce the economic losses due to the combustion of new energy vehicles. Depending on the specific requirements, charging facilities on college campuses can select the most appropriate firefighting facilities.

3.3. Over-planning aspects

The planning of charging facilities involves two aspects. Firstly, the penetration rate of new energy vehicles on college campuses must be estimated to ascertain the cost of constructing the charging facilities. The penetration rate is a key factor in determining whether the charging station can meet the charging demand over its entire life cycle, while also reducing the average cost of the entire charging station life cycle. For instance, Zhou and Wu analyzed the characteristics of electric vehicle parking demand on college campuses to predict the growth rate of motor vehicle ownership in the region and the penetration rate of electric vehicles on college campuses. Based on this analysis, they established different mathematical models for solving the problem and found the optimal solution to determine the number of charging facilities on college campuses [12,13].

Additionally, the development of emerging technologies for new energy vehicles should be considered. Neither the planning nor the use of charging stations is an isolated process, rather, it is part of a larger transport and energy network system, which includes key elements such as electric vehicles, road networks, power grids, and energy sources. As the field of vehicle-to-grid (V2G) technology continues to develop and mature, the potential for synergistic interactions between the various elements of the transport and energy system will become increasingly evident. This will necessitate the integration of synergistic planning into the research agenda for the future development of the transport and energy system, to enhance its overall efficiency [8]. The collaborative planning of future transport and energy system efficiency improvement will become an important research direction [8].

4. Recommendations for planning charging facilities on university campuses

4.1. Demand forecast

The initial step in the planning of charging facilities on college campuses should be to predict the charging demand. A visit to the university campus is necessary to ascertain the number and characteristics of new energy vehicles, as well as to investigate the daily habits of new energy vehicle owners. In addition, it is important to consider the potential impact of the construction of a charging station on the university campus, in terms of the penetration rate of new energy vehicles. Subsequently, the overall demand for charging stations on college campuses must be determined, so that the requisite number of charging stations can be constructed to meet the demand for charging new energy vehicles on college campuses. This will help to avoid the phenomenon of a pile of hard-to-find and idle charging piles.

Subsequently, research the regulations about the parking of new energy vehicles on college campuses. Some campuses are expansive, necessitating the layout of charging stations to consider the existing situation of staff parking needs, the parking of staff vehicles, and the proximity of staff offices to the research of new energy vehicle

parking location characteristics on college campuses. This approach is conducive to improving the efficiency of the charging station and enhancing the satisfaction of staff.

4.2. Selection of charging facilities

To meet the charging demand on the college campus, the most appropriate charging facilities must be selected. Charging facilities are divided into two categories: the first is the charging station, which must consider the number of slow-charging piles, fast-charging piles, or even super-charging piles. The second type is the power exchange station, which can be disregarded in the current situation, given that the batteries of major car companies are not compatible. To ascertain whether or not a vehicle requires charging on a college campus, it is necessary to consider several factors. These include the length of time that the vehicle is likely to be parked on campus, the owner's demand for information regarding the battery charging status, the vehicle's travel characteristics (travel time and distance), and so forth. Once these factors have been taken into account, it will be possible to determine whether the vehicle in question requires charging on campus and, if so, whether this should be done quickly or slowly. Subsequently, different charging equipment must be selected. For example, a charging enterprise offers a range of products, including 7 kW AC charging piles; 120 kW, 160 kW, 240 kW, 320 kW, and 360 kW single guns; 240 kW and 480 kW split systems with four and six guns, respectively; and 480 kW split flexible equipment with eight guns. The 480 kW split flexible equipment with eight guns (one supercharging and seven fast charging) is also available. Similarly, the 720 kW split flexible equipment with eight guns (one supercharging and seven fast charging) is available. The 720kW split flexible equipment comprises 12 guns, the 800kW split flexible equipment comprises 14 guns, and the 960kW split flexible equipment comprises 16 guns. Each product is priced differently, reflecting the varying demand for these products on the university campus.

4.3. Charging facilities location environment selection

Once the charging facilities have been selected, the next step is to consider the location of the charging facilities on the college campus. In this context, it is important to note that the priority should be the safety of the charging station. Therefore, it is advisable to avoid placing the charging station in areas where there is a high density of students and teachers, such as student dormitories, teaching buildings, experimental buildings, and other areas where there is a high concentration of people. This is to ensure that in the event of a fire, the new energy vehicle can be safely charged or parked, thus reducing the risk of casualties and economic losses. Furthermore, the location should be able to guarantee the construction of firefighting facilities. These facilities should include a fire extinguishing system, an automatic alarm system, and smoke evacuation facilities (such as those found in underground car parks) [12]. Following the specific characteristics of the site, the design and installation of automatic drenching systems, wet automatic sprinkler systems, water spray systems, and high-pressure water mist systems, as well as other automated firefighting devices, may be undertaken, with the option of also setting up a certain amount of fire blankets and fire sand.

Furthermore, the location of the charging station should be selected to ensure the greatest convenience for the user population. As previously stated, the faculty and staff typically park their vehicles in locations that are closer to their respective offices. This allows for an improved utilization rate of the charging station, which is convenient for the faculty and staff to access their vehicles. This also enhances their satisfaction and happiness.

In light of the ongoing advancement of intelligent networked vehicles, it is imperative to consider the integration of automated driving technology in the planning of charging stations. Two potential avenues emerge in this regard. Firstly, the institution may choose to implement regulations that safeguard the operational framework of automated driving. Secondly, the college campus may designate a specific route from the entrance to the

charging station, with due consideration for the integration of automated driving. This approach aims to balance convenience and safety for all users of the campus.

4.4. Life cycle cost estimation of charging facilities

The final stage of the charging station planning process on the university campus is the estimation of the cost of the charging facility's life cycle. This encompasses the cost of the land, the charging equipment, the charging station building renovation and construction, the charging station operation and maintenance, the charging station construction and grid upgrading, the fire safety facilities, and the cost of the construction of the special road for automated driving. A mathematical model is then constructed based on the charging equipment life cycle and the charging station life cycle. This is followed by the solution of the optimal planning for the construction of charging stations on college campuses.

5. Conclusion

This paper is based on the analysis of new energy vehicle charging demand on college campuses, college campus security and the characteristics of the future development of technology, the planning of new energy vehicle charging stations on college campuses, site selection planning, and the idea that each college campus's requirements are not the same. In the charging station's actual planning on the college campus, the characteristics of the program and the choice of data research and modeling are considered, and then the optimal planning scheme is found.

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Disclosure statement

The authors declare no conflict of interest.

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