

Research on the Spatial Layout of New Energy Vehicle Charging Stations under the Background of "Dual Carbon": Taking Hangzhou City, Zhejiang Province as an Example

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ABSTRACT

Electric vehicles are an important measure to achieve China's goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. But with the rapid development of Hangzhou, the traffic congestion situation in Hangzhou has become increasingly serious. The introduction of license plate and travel restrictions has also led to the development of new energy vehicles that is inevitably in line with the trend of the times. In order to follow up with the government's "dual carbon" goals, the layout of new energy vehicle charging piles in Hangzhou has become a key issue. We will take Hangzhou as an example to analyze the layout of new energy vehicle charging piles in the context of "dual carbon", We have also proposed a layout plan to make the charging piles of new energy vehicles in Hangzhou more in line with reality, using scientific methods to analyze them more reasonably and bring better energy utilization effects to the city. This will enable the better development of new energy vehicles in Hangzhou and enable the "dual carbon" plan to be achieved as soon as possible.

KEYWORDS

New energy electric vehicles; Charging facilities; Distribution research; Hangzhou City.

1. INTRODUCTION

In 2020, China proposed carbon reduction targets of "peak carbon emissions" and "carbon neutrality". Under the dual carbon goals, electric vehicles, as an effective way to achieve energy conservation and emission reduction, have been elevated to a strategic level by the country and highly valued by governments at all levels in China. As an important guarantee for green travel of electric vehicle users, the scientific and reasonable layout and capacity of charging stations not only affect the service quality, operational efficiency, and operational safety of charging stations, but also directly affect the convenience of electric vehicle users' travel and the effectiveness of resource allocation. The rapid development of new energy vehicles in Hangzhou, Zhejiang Province, has led to the gradual introduction of subsidy policies for new energy charging piles. The utilization and development of new energy vehicle charging piles is a trend of the times, and the trend of new energy trams becoming the mainstream mode of transportation in China is emerging. The convenient and efficient layout of new energy vehicle charging networks is the cornerstone for the good development and popularization of electric vehicles.

The use of new energy vehicles is one of the ways to build healthy cities, and the layout of charging stations directly affects the promotion and application of new energy vehicles. Optimize the spatial layout of new energy charging stations in order to further promote the promotion of new energy

vehicles and promote the construction and development of healthy cities. The spatial layout of new energy vehicle charging stations directly affects the utilization rate of resources.

In 2023, scholars conducted an in-depth analysis of the economic feasibility of the distribution pattern of electric vehicle charging stations, focusing on the distribution pattern, economy, and actual data of charging stations. Based on the current situation of charging stations in first tier cities, suggestions for optimizing the layout of electric vehicle charging stations are proposed to avoid resource waste and excessive construction while meeting charging needs. In 2023, scholars conducted a dual layer layout optimization model for electric vehicle charging stations based on multi-source data such as interest point locations, user generated charging demand locations, and demand preferences. The upper level model optimizes the location and capacity of electric vehicle charging stations with the objective function of total social cost. The lower level model constructs the user's best choice model based on three indicators: addressing distance, addressing time, and congestion level. In 2024, leading new energy vehicle companies such as Jike, Huawei, Ideal Automobile, and Xiaopeng Automobile are expected to gradually set clear goals in the construction of high-power supercharging piles. Propose the construction of a two-level charging facility system consisting of backbone charging stations and satellite charging stations, with the principle of charging facility layout, and carry out the spatial layout of public charging facilities according to the three levels of "point, line, and surface". In 2024, scholars constructed a collaborative optimization model for the replacement of electric bus fleets and the layout of charging facilities based on time and space dimensions. The various research methods have played a leading role in the spatial layout of charging piles in Hangzhou, Zhejiang Province, and have important reference significance for the subsequent layout and construction of charging piles.

2. OVERVIEW OF THE RESEARCH AREA

In Hangzhou, Zhejiang Province, it is the provincial capital and sub provincial city, as well as the largest city in the province. As one of the sub central cities and economic centers in the Yangtze River Delta region, the city has experienced rapid development in new energy vehicles in recent years. As of the end of 2021, the total output value of the new energy vehicle industry, including vehicles, components, and power batteries, was approximately 8 billion yuan. The Hangzhou Municipal Bureau of Economy and Information Technology stated that the data has increased by more than 1 billion yuan compared to 2020. Multiple goals and requirements have been put forward for the infrastructure of new energy vehicles in Zhejiang Province, including the cumulative construction of over 2.3 million charging stations and no less than 900000 rural areas by 2025, including 120000 public charging stations and no less than 20000 rural areas, to meet the charging needs of over 4 million new energy vehicles; In 2025, the annual sales of new energy vehicles will reach over 1 million units, and over 500 new energy vehicle maintenance service outlets will be established. In recent years, the number of electric vehicles in Hangzhou has experienced explosive growth. Currently, the number of new energy vehicles in Hangzhou has reached 728000, accounting for approximately 18% of the total number of motor vehicles in the city. Especially in the past two years, Hangzhou has added over 200000 electric vehicles annually, accounting for over 60% of the total annual growth. In 2023, Hangzhou incorporated the construction of public charging facilities into people's livelihood for the first time, with a plan to complete 2000 public field charging piles. As of the end of November, Hangzhou has built 2403 new public field charging piles, with a completion rate of 120.15%, exceeding the annual target ahead of schedule.

3. ANALYSIS OF SPATIAL LAYOUT FACTORS FOR NEW ENERGY VEHICLE CHARGING STATIONS

The planning of the spatial layout of charging stations should consider the demand of new energy vehicle users for charging stations, the maximization of utilization efficiency of charging stations, and the convenience of users. The demand for charging stations by new energy vehicle users will affect the number and location of charging station layouts. When arranging the space of the charging station, it is also necessary to consider whether the traffic near the charging station is accessible and the time to reach the charging station, in order to avoid charging difficulties and low efficiency and inconvenience in the utilization of the charging station. The spatial layout of charging stations also needs to be planned reasonably according to policies.

3.1. Impact of charging demand in different regions

(1) Differences in the ownership of new energy vehicles in different regions

The number of new energy vehicles in a region usually refers to the number of new energy vehicles in a certain area. The more new energy vehicles there are in a certain area, the more demand there is for charging stations. On the contrary, the less new energy vehicles there are in a certain area, the less demand there is for charging stations. The ownership of new energy vehicles is an important factor affecting the spatial layout of charging stations. If the difference in the number of new energy vehicles in different regions is not considered, but the spatial layout of charging stations is carried out with the same charging service radius, it will cause some areas to have difficulty charging, while others will have idle charging stations, low utilization rate, and low resource allocation efficiency.

(2) The average range of new energy vehicles

The range of different types of new energy vehicles varies. The average range of new energy vehicles is also an important factor affecting the demand for charging stations. The average range of new energy vehicles can determine the daily charging frequency of new energy vehicles, and determine the charging cycle of new energy vehicles in different regions. New energy vehicles with longer range have longer charging cycles than those with shorter range, and the daily charging frequency is relatively small. That is to say, under the same number of new energy vehicles, the demand for charging stations is relatively small, This will ultimately affect the spatial layout of new energy vehicle charging stations in different regions in terms of quantity.

(3) The daily use of new energy vehicles

The daily use of new energy vehicles is mainly divided into three categories: private passenger use, ride hailing, and public transportation, which are important factors affecting the spatial layout of charging stations.

Private passenger cars in new energy vehicles are often used as commuting tools for users to work, and are generally charged in residential and work areas. Therefore, the charging demand near residential and work areas is higher than in other areas, and charging stations should be reasonably arranged near the two areas. When private passenger cars are used for daily life, they are often charged in areas such as shopping malls, parks, and tourist attractions. In areas with high traffic, it is necessary to plan the spatial layout and quantity of charging stations reasonably.

Online ride hailing users are generally used to pick up and drop off customers. They have a long driving time, multiple charges, a long driving distance, and a random and complex driving route. This requires a reasonable layout of charging stations near the road, and also requires a high coverage of the spatial layout of charging stations. Public transportation generally has a fixed origin and destination, a fixed charging location, and a fixed route. Charging stations near major transportation routes are generally used for emergency charging.

3.2. Impact of traffic factors

The accessibility of regional transportation refers to the degree of accessibility to charging stations within the region. If charging stations are arranged on congested road sections, new energy vehicle users will take a long time to reach the charging stations for charging, have poor mobility, and have a high probability of long idle time and low utilization rate. Moreover, inconvenient transportation may lead to users reducing the number of charging stations used at this point and wasting resources. Therefore, when arranging the space of new energy vehicle charging stations, it is necessary to choose areas with convenient transportation nearby, so that users can enjoy more convenient charging services, reduce time costs, and improve the utilization rate of charging stations.

3.3. Policy and financial support and reward impact on charging stations

Policy planning is an important influencing factor on the spatial layout of new energy vehicle charging stations. The spatial layout and construction quantity of charging stations should comply with regional policy planning and be located within appropriate land areas.

Policy support and financial incentives will also affect the spatial layout of charging stations. At present, the new energy vehicle market is slowly starting, with a small proportion of total vehicle ownership in the region and a low investment return on charging piles. Unreasonable spatial layout can lead to high costs and low utilization rates. In the case of high risks and costs, the enthusiasm for charging pile construction in the region is not high, and the data volume of charging piles is small, resulting in incomplete layout. The imperfect construction of charging stations further exacerbates the difficulty of charging, which will lead to a decrease in the number of new energy vehicle users and form a vicious cycle. In this situation, the government should introduce a large number of policies related to the planning and construction of charging piles, provide certain financial support, provide assistance and encouragement, lead different regions to improve the spatial layout of charging piles, and further promote the construction of charging piles and the development of new energy vehicles.

4. CONSTRUCTION OF SPATIAL LAYOUT MODEL FOR NEW ENERGY VEHICLE CHARGING PILES

4.1. Determination of charging demand for new energy vehicles

(1) According to the total number Q of new energy vehicles in the research area and their usage, the number of new energy vehicles can be divided into private passenger cars Q_1 , public transportation Q_2 , and ride hailing Q_3 .

(2) Classify vehicles for different purposes and calculate the daily average mileage of new energy vehicle users. Divide the daily average mileage of new energy vehicles into private passenger cars s_1 , public transportation s_2 , and ride hailing services s_3

(3) The total daily driving distance S of various types of vehicles is calculated by multiplying the number of new energy vehicles with different uses and the daily average driving distance.

$$S=Q \times S$$

(4) Based on the total daily mileage of various new energy vehicles and combined with the range C of new energy vehicles for various purposes, determine the total daily charging times A for each type of new energy vehicle.

$$A=S/C$$

4.2. Determination of service radius for charging stations

Determine the service radius of the charging station using the central location theory. The central area theory is based on the regular hexagonal grid for spatial layout planning. It establishes a regular hexagonal grid layout based on the service radius, and each hexagonal center point is the construction point of the new energy vehicle charging pile. It can achieve full coverage of services in all areas, reduce the number of service facilities, minimize costs, and maximize services.

Based on the demand for various types of new energy vehicle charging piles determined in the previous text, combined with the proportion of new energy vehicle charging times in different areas, the number of charging piles constructed in different areas is determined. By calculating the land area in different areas, the service radius of each type of land charging pile is ultimately determined.

4.3. Cost Analysis Model

Build a cost analysis model to analyze the social total operating cost of the spatial layout of charging piles, determine the construction direction of the charging infrastructure with the lowest total operating cost in the area, and the number of charging piles to be constructed.

Social Total Operating Cost Model:

$$C = C1 + C2 + C3$$

$$C1 = P \text{ land} + P \text{ equipment} + P \text{ installation}$$

$$C2 = X \times Q \times P \text{ electrical} + P \text{ maintenance}$$

Where, C represents the total cost, C1 represents the construction cost of the charging station, C2 represents the usage cost of the charging station, and C3 represents the cost consumed by all users during charging at the charging station within one year. P land is the price of the land occupied during the construction of the charging pile, P equipment is the selling price of the charging pile, P installation is the installation cost of the charging pile, P maintenance is the maintenance cost of the charging pile, Q is the user's charging amount each time, P electricity is the price of charging the new energy vehicle charging pile, and X is the user's charging frequency within one year.

5. OPTIMIZATION STRATEGY FOR THE SPATIAL LAYOUT OF CHARGING STATIONS FOR NEW ENERGY VEHICLES

5.1. Distribution of the number of charging stations

The number of charging stations is an important factor affecting the layout of charging stations, which has a significant impact on the service quality and construction cost of charging stations. It is the most core configuration parameter of charging stations. Reasonable arrangement of the number of charging stations can greatly reduce costs and to some extent increase the user's experience during use, which has a significant impact on the layout of charging stations.

5.2. Power and capacity of charging stations

Given the diverse specifications and models of electric vehicles in the market, each with its corresponding power demand, charging stations should be set with different power levels to meet the needs of new energy vehicle users. Fast charging (DC) stations and slow charging (AC) stations should be set up according to the actual needs of users. For example, fast charging stations can be emphasized in commercial areas, while more slow charging stations can be set up in residential areas. At the same time, the capacity of the charging station is determined based on the target users and

charging needs, and the appropriate capacity of the charging station is used to meet the needs of as many users as possible while controlling costs.

5.3. Peak Charging Demand

The peak charging demand period refers to the time when the user's demand for charging services reaches its peak during a certain period of time. The location and quantity of charging stations should fully consider the demand and frequency of charging. Relevant data should be obtained through extensive data research and market research to predict the peak charging period. This data can include the time distribution of user use of charging stations, usage statistics, and user behavior prediction. After understanding the information during the peak period, we can adjust the number and location of charging stations accordingly. In locations that frequently appear during peak hours, such as commercial areas, office buildings, residential areas, and tourist attractions, more charging stations should be installed to meet the needs of users. This layout strategy ensures that users can easily find available charging stations when their needs are most concentrated.

5.4. Geographical location and traffic flow are key factors in determining the layout of charging stations

We need to understand the user's travel habits and the distribution of traffic flow in order to set up charging stations in suitable locations. We need to choose areas with heavy traffic as the main layout area. This includes places such as commercial districts, office buildings, residential areas, and tourist attractions, as these are usually places where people travel more frequently and charging needs are more concentrated. In addition, it is also possible to consider setting up charging stations around highway service areas and major transportation hubs such as airports, stations, and parking lots to provide charging services for electric vehicles traveling long distances. Of course, the establishment of charging stations in roadside and other areas should fully consider the issues of road congestion and pedestrian flow to avoid inconvenience caused by the space occupation of charging stations.

5.5. User convenience

User convenience is one of the factors that cannot be ignored in the layout strategy of charging stations. We should ensure that users can easily use charging stations and engage in other activities while charging. We can set up charging stations at the entrance of the parking lot, so that users can conveniently charge while parking. Similarly, setting up charging stations near convenience stores allows users to charge while shopping, which can meet the charging needs of car owners and improve the utilization rate of the venue. Alternatively, dedicated charging stations can be established in areas with high frequency usage to meet the charging needs of a large number of electric vehicles.

In addition, to make it easier for users to find charging stations, we need to provide sufficient parking spaces and clear signage. These measures help to improve user satisfaction and improve the efficiency of charging stations (piles), greatly reducing the ineffective occupation of time and space by users.

5.6. Maximizing coverage

Charging stations should cover the entire Hangzhou city as much as possible, taking into account the development differences in different regions and allocating resources reasonably. To avoid the embarrassing problem of the tram running out of battery without a nearby charging station, where nearby charging stations can only push or call trailers.

5.7. Operational management requirements

The design layout of charging stations should consider the needs of operational management, including equipment maintenance, safety management, data monitoring, etc. This can ensure the efficient operation and sustainable development of the charging station.

5.8. Impact of Power Load

The layout of charging stations should fully consider the layout of the power grid within the city, avoiding areas with high electricity consumption to avoid power overload caused by the use of charging stations.

6. CONCLUSION

Due to the rapid development of the electric vehicle industry and the traffic problems caused by Hangzhou becoming a new first tier city, various factors are driving the development planning of new energy vehicles in Hangzhou. The focus is on the range of new energy vehicles and the need for urban energy utilization. Based on the theory of central location, this article studies the layout of new energy vehicle charging piles in Hangzhou, Zhejiang Province, Research has shown that the layout of new energy charging piles should be influenced by factors such as the number of new energy vehicles, range, daily use, and traffic conditions. An optimization strategy for the layout of new energy vehicle charging piles has been developed, aiming to improve the relevant content from the number of new energy charging piles, their functions and capacity, and the peak value of new energy charging piles, in order to better construct the layout of new energy charging piles.

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