

# Layout and optimization of charging piles for new energy electric vehicles – A study on Xi'an urban area

Yi Jiang\*

School of Automotive Academy, Chang'an University, Xi'an, 710000, China

**Abstract.** This paper analyzes the current layout of public charging stations within the third ring road of Xi'an central urban area and the daily charging needs of residents, the main problems in the layout of electric vehicle charging stations in the central urban area of Xi'an were found, the differentiated demand analysis of living space charging was carried out, and the location model of electric vehicle public charging station facilities in the central urban area of the city was constructed, the location selection and optimization of electric vehicle public charging stations in the central urban area of Xi'an were studied. At the same time, a reasonable pile configuration was carried out, finally, the layout scheme of electric vehicle public charging stations in the central urban area was formed, the main shortcomings of the current charging pile layout and the factors (demand side) that should be considered in the current and future charging pile layout are concluded, and the layout and optimization of charging piles for clean energy in the future are prospected.

## 1 Introduction

In first- and second-tier cities, people use big data to reasonably and effectively analyze the layout of charging piles, so that they can fully meet the needs of users, reduce investment costs, and encourage the construction of new energy vehicles. New energy vehicle infrastructure must include charging stations, and making charging convenient is essential to fostering the long-term growth of these vehicles. Therefore, explore and study a high-quality charging pile layout scheme, which can not only facilitate the charging of new energy vehicle owners, meet their needs, relieve their charging confusion, but also save costs and improve the profitability of related enterprises and enhance the competitive advantage of charging pile operators. Smart electric vehicles are still in the process of adoption, and the completeness of charging facilities is often a key factor restricting its popularity, especially in some third- and fourth-tier cities where the transportation infrastructure has yet to be improved, the insufficient number of public charging piles and the unreasonable layout are more notable [1].

Correct and reasonable mathematical modeling of urban infrastructure (such as urban roads, buildings, greening, residential areas, squares, etc.) is the prerequisite for the study and optimization of charging pile layout. In the layout and optimization of new energy-electric vehicle charging piles, many scholars at home and abroad have adopted different research

methods. It can be seen that in terms of charging pile layout optimization, there are many algorithms that can be used, the relevant charging pile layout optimization algorithm is also constantly evolving, each optimization method has its advantages and merits, and has certain reference significance.

Electric vehicle public charging stations are an important foundation for the development of electric vehicles. Currently, the rapid progression of the electric vehicle sector has garnered significant attention from domestic and international scholars in recent years. One particular area of focus is the scientific and rational selection of sites and the strategic layout planning of new energy vehicle public charging stations. In this context [2]. This paper will start with the research status at home and abroad of electric vehicle ownership, charging demand forecast, Location model, and layout method of the public charging station. This study critically examines the layout approach employed for public charging stations catering to electric vehicles within the central urban area of Xi'an. Through comprehensive analysis and consolidation of findings, this research endeavors to provide valuable insights and recommendations for urban planning and construction in similar contexts.

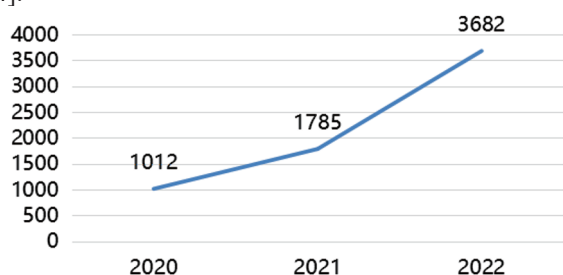
## 2 Charging station development and layout in Xi' an

Through the collaborative construction of the government and all aspects of society, within the third ring road of Xi'an's central urban area, 352 charging

\* Corresponding author: [196081209@mail.sit.edu.cn](mailto:196081209@mail.sit.edu.cn)

stations and 7845 charging piles are connected to statistics [3]. In terms of administrative districts, the number of charging stations and charging piles built in Wei yang District, Yan ta District, High-tech Development Zone and Qu jiang Cultural Industry Zone ranks among the top four in the central urban area.

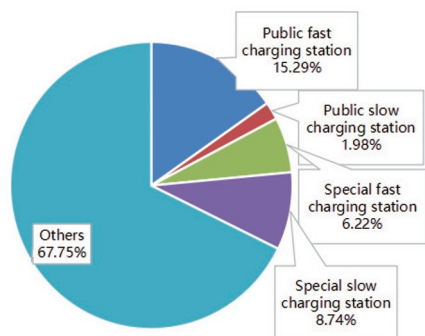
As of October 2022, 187 new charging stations and 3,682 new charging piles have been added in Xi'an, By the end of 2022, the city will build a moderately advanced, suitable, intelligent, and efficient charging infrastructure system to ensure that the demand for charging services for new energy electric vehicles is met. From 2020 to 2022, 6,479 new charging piles were built in the city, As shown in Figure 1, 1,012 were completed in 2020, 1,785 in 2021, and 3,682 in 2022. It is evident that there have been an increasing number of new charging piles in the Xi'an urban region during the last three years, and development opportunities are favorable [4].



**Fig. 1.** Number of Newly Built Charging Piles in Xi 'an Central Area from 2020 to 2022 (picture credit: Original)

(1) Combined with the authoritative statistics and analysis of relevant departments of the comprehensive management of smart electric vehicles and Charging equipment in Xi'an:

The results are shown in Figure 2, the third ring road in Xi'an's central metropolitan region has a 15.14% utilization rate for both fast and slow charging stations. and the utilization rate of slow charging stations is 1.98%. The utilization rate of dedicated fast charging stations is 6.16%, and the utilization rate of slow charging stations is 8.65%, and the utilization rate of public fast charging stations is significantly higher than that of other types of charging stations. It can be seen that the permanent urban population wants to obtain popular, convenient and fast charging services [5].



**Fig. 2.** Charging station utilization in the Third Ring Road of Xi 'an Central Area (picture credic: Original)

### 3 Disadvantages of the existing charging pile layout

#### 3.1 Low proportion of vehicle pile configuration

The first is that top-down public charging pile planning relies on parking lot construction, and most cities currently lack sufficient parking lot construction.

At this stage, the overall number of public charging stations and the proportion of vehicle piles are insufficient. According to actual research and residents' feedback, the early construction of public charging stations in the third ring road of Xi'an central urban area was mainly a model of combining municipal parking lots, with the rapid development of the electric vehicle industry, in addition, the shortage of urban land within the third ring road of the central urban area of Xi'an, the pile ratio is as low as 1:14 [6]. When planning the layout of public charging stations in the third ring road of Xi'an central urban area, attention should be paid to the land for public services that are most closely related to residents' daily charging needs, to ensure that the proportion of charging piles meets the requirements and the total number of public charging stations meets the requirements to meet the actual charging needs and service levels of residents.

In addition, there will always be a gap between the estimate of the number and distribution of new energy vehicles in the plan and the number and distribution of new energy vehicles in the actual city. When this gap is particularly large, the phenomenon of insufficient charging piles will be exposed.

#### 3.2 Unevenly distributed public charging stations

In addition, because the construction of some electric vehicle charging piles is a market-oriented behavior, there is bound to be a mismatch of insufficient areas in some areas and excess in some areas.

With the development of the overall city in the third ring road of Xi'an's central urban area, the planning is constantly updated, and the existing public charging stations in the city are built at different stages, so there is no systematic and overall planning. At present, most of the public charging stations in the third ring road are spontaneously built by charging operators from the bottom up, resulting in an unreasonable layout. There are multiple public charging stations in a certain area, while some areas are not laid out, although the needs of the region are taken into account to a certain extent, the systematic consideration of the overall layout of the city is insufficient [7]. At this stage, the urban land in the third ring road is tight, especially after years of development in the third ring road, the interior of the city is scattered with buildings of different periods, old and new, and these are also the charging needs of residents, in the context of urban renewal and stock planning, large-scale demolition and construction cannot be carried out, it can only begin by organizing the existing construction land, which will result in tighter restrictions on the locations and designs of public charging stations,

an uneven distribution of resources, and a lack of a network of public charging stations that are both efficient and convenient and match supply and demand.

#### **4 Determining factors for further development of charging station**

##### **(1) Urban population and social-economic development level**

Under normal circumstances, the economic level and population of a city will directly affect the number of public new energy charging stations, and the practical experience proposed by domestic and foreign cities in the planning process of public charging stations also clearly points out that with the increase of population size, the demand for urban public charging stations has also risen sharply.

##### **(2) Electric vehicle ownership**

The pressure of urban mobility increases as the number of electric vehicles in cities rises, and the demand for travel charging also increases, and experience shows that for every 7 additional electric vehicles, at least 1 new charging pile is added [8].

##### **(3) Public charging station accessibility**

Accessibility at public charging stations refers to how difficult it is for electric vehicles to reach the public charging station site. Public charging station accessibility depends on the setting of public charging station entrances and exits. Different road classes and traffic flow conditions affect the entrances and exits of public charging stations. The easier it is for an electric vehicle to reach a public charging station for charging behavior, the more attractive it is to charging actors.

##### **(4) Residents' daily charging behavior needs**

From the perspective of supply and demand balance, the demand side of the actual urban residential population should match the supply side layout of the living space public charging station to confirm that the spatial layout of the urban electric vehicle public charging station can meet the daily charging needs of residents, and also meet the goals of urban construction land resource utilization and social equity [9]. Otherwise, the shortage of public charging stations in densely populated areas of cities will lead to the pressure of using public charging stations and give users a poor charging experience, which is contrary to the original intention of public charging stations in living spaces to provide residents with better life needs; The layout of public charging stations in living space is too dense, which will cause poor economic use of urban land use, so that the shortage of land resources will be wasted. Therefore, considering the matching relationship between its layout and the spatial distribution of the residential population is very important for the planning of the distribution of public charging stations in the living space, and at the same time, scientific and reasonable guidance and control are carried out on the placement of charging stations in the living area.

The structure, operation, and management of public charging stations for electric vehicles are all based on the demand for charging. Its core charging demand covers

not only the energy supply of electric vehicles but also additional needs produced by the location of public charging stations. Charging demand is based on travel purposes, daily travel chains, and daily life activities.

By summarizing the reference experience of China's electric vehicle public charging station layout planning, it is found that the essence of meeting residents' charging needs is to reduce charging costs, that is, charging people must charge in daily life and meet the needs of recreation, travel, and other behaviors to charge within a reasonable and acceptable range.

#### **5 Outlook**

The new energy vehicle industry is a strategic emerging industry that Xi'an focuses on supporting and developing. The construction of a new energy vehicle charging pile is one of the seven major areas of "new urban infrastructure construction", as a key link in the industrial chain of new energy vehicle development, further vigorously promotes the construction of charging infrastructure, especially public charging facilities, and accelerate the formation of a complete supporting charging network, which can effectively advocate the use of new energy vehicles and their promotion. The following improvements, countermeasures, and recommendations can be made for the development and usage of public new energy vehicle charging piles in light of the inadequacies indicated above and the issues mentioned to be taken into account:

(1) Increase the number of public charging piles and improve coordination with the development of electric automobiles

The development of domestic public charging piles and new energy vehicles is currently uncoordinated; on the one hand, there are not enough public intelligent charging piles, and new energy vehicles and public charging piles make up a sizeable portion of both; on the other hand, there are not many high-power DC fast charging piles, and if more public charging piles are built, the number of new energy vehicles and public charging piles will increase [10].

(2) Enhance public charging pile management to lower equipment failure and mismatch rates

Public charging piles should be updated in time to improve the compatibility of public charging piles and reduce mismatch. Therefore, it is necessary to formulate corresponding rules and regulations, standardize the operation and management of charging piles at public charging stations, arrange special personnel to supervise and manage on site, and guide new users to use public charging piles correctly to eliminate uncivilized charging behavior [11].

(3) Reduce the cost of electric vehicles and the electricity used by public smart charging stations.

Charging price has a greater impact on the overall satisfaction of national residents with the construction and use of public charging piles and the utilization rate of public charging piles, policies for the benefit of the populace should be developed to lower charging rates in order to increase the satisfaction and usage rate of public

charging sites and better support the popularization of new energy cars [12].

## 6 Conclusion

This paper summarizes the relevant research on the layout of electric vehicle public charging stations at home and abroad from two aspects: electric vehicle ownership forecast, charging demand forecast, and layout location model, and finds that the shortcomings of the existing charging pile layout are mainly divided into two aspects, namely: (1) the proportion of vehicle pile configuration is low, the total amount does not meet the demand and the layout of public charging stations is not systematic, and the resource distribution is uneven, and at the same time, by analyzing the factors that should be considered in the layout of charging piles (demand side), the architecture, planning, and management of public charging stations for electric vehicles are all based on determining the charging demand. Charging demand is an important medium connecting residents' charging behavior and public charging station site selection, and is the premise for realizing the layout planning of electric vehicle public charging stations in the central urban areas of first- and second-tier cities. Moreover, public fast charging station utilization is significantly higher than that of other types of charging stations, indicating that the urban permanent population wants to get general, convenient and fast charging services.

Secondly, this paper summarizes the relevant policies and industry technical specifications of domestic governments at all levels for electric vehicle charging infrastructure and finds that the fundamental goal of the development of the electric vehicle industry is to ensure the reasonable construction of charging infrastructure and meet the changing needs of its users under the premise of meeting the rapid development of the electric vehicle industry. According to the analysis of the article, the number of new charging piles in Xi'an urban area has steadily increased in the past three years and has good development prospects.

The practice of domestic public service facility allocation emphasizes the construction of charging facilities in existing parking lots, public service facilities, and commercial service industry facilities under the guidance of charging demand in proportion.

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