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Research on Planning and Design of Multi-Story Prefabricated Electric Bicycle Charging Parking Lot in Urban and Rural Areas

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Abstract: In recent years, disorderly parking and difficult charging of electric bicycles have been challenges in urban management. The rapid growth of electric bicycles is in contradiction with the lack of dedicated parking spaces and charging service facilities in towns and villages. To solve the issue of parking and charging electric bicycles in limited urban and rural spaces, prefabricated building technology is applied to the design of a multi-story electric bicycle parking lot. The multi-story prefabricated electric bicycle parking lot is utilized in urban and rural planning and design to upgrade parking facilities in old urban areas, land-constrained commercial areas, as well as counties, towns, and rural areas with inadequate municipal facilities. Multi-story prefabricated electric bicycle parking lots are the application exploration of industrial buildings, and promote the high-quality development planning and construction of towns and counties and villages. Compared with the single-story metal charging station, the multi-story assembled electric bicycle parking lot has the characteristics of integrating parking and charging, being more durable and safer in structure, accommodating a large number of vehicles, and improving the space utilization rate.

Keywords: Prefabricated building; Electric bicycle; Parking lot

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1. Introduction

Since 2022, the number of electric bicycle sales in China has grown exponentially after governments around the country relaxed their policies on electric bicycle driving. China is currently the world's largest electric bicycle production and sales country, and now electric bicycles have gradually become the main means of transportation for people to commute. According to statistics, at present, there are nearly 400 million electric bicycles in China, but the existing urban and rural construction planning lacks special parking spaces for electric bicycles, charging facilities, and parking lots, which leads to indiscriminate parking of electric bicycles and illegal occupation of municipal roads and urban public space, affecting residents' daily traffic. Random charging causes fire and explosion, causing safety hazards to society. Therefore, to solve the parking and charging problems of electric bicycles in towns and villages, the design of a multi-story prefabricated electric

bicycle charging parking lot is conceived [1].

2. Policy background, theoretical analysis, and research hypothesis

According to the statistics of the National Fire and Rescue Service from 2022–2023, there were 18,000 fires caused by electric bicycles nationwide in 2022, and 21,000 similar fire accidents in 2023, an increase of 17.4% [2]. The popularity of electric bicycles does not adapt to the original urban planning, causing a series of problems in society. When residents use electric bicycles daily, there is a lack of specified parking spaces in urban and rural areas, whether in residential areas or towns.

Due to the increasing number of battery-induced fires caused by improper use of electric bicycles, more local governments and residential property management companies prohibit residents from bringing electric bicycles into the house to charge batteries. Some even prohibit residents from parking electric bicycles in residential areas and buildings. This has caused conflicts between the government, property management companies, and electric bicycle users [3]. The parking, charging, and safety management of electric bicycles have become a difficult problem for local governments. More cities, towns, and villages have tried to solve the problems of residents using electric bicycles, such as "parking difficulties, charging difficulties, management difficulties," and introduce management methods for electric bicycle charging and parking, hoping to alleviate the problem of electric bicycles becoming a fire hazard in towns and villages. Local street and residential property management companies are also trying to find some relatively independent safe areas in the limited space of the city, and simply transform these areas to set up temporary parking spots for electric bicycles, equipped with charging facilities to centralize management of electric bicycles. At present, the recommended electric bicycle parking shed on the market is mainly open-air, single-story side parking, and the structure is a very simple welded metal steel bar. However, the number of parking lots is small, the structure is not durable, and the fire resistance is poor. Based on the above analysis, this paper proposes three hypotheses to solve the parking problem of electric bicycles in the long run:

(1) The existing space (comprising of the original parking lot and garage) of the urban residential area is transformed to enhance its utilization rate and establish a multi-story three-dimensional electric bicycle parking lot to fulfill the residents' demand for parking nearby.

(2) During the planning and construction of counties, towns, and villages, enhance the planning and design of municipal roads, the allocation of public parking lots and charging facilities. Utilize the limited land to construct multi-story charging parking lots for electric bicycles and raise awareness of orderly and standardized parking and charging among residents in counties and villages.

(3) Using the structural characteristics of prefabricated buildings to design and construct multi-story electric bicycle parking lots, to achieve the requirements of a fast construction period, saving space, accommodating a large number of parking spaces, and simple facility configuration.

3. Current status of electric bicycle parking

3.1. Urban and rural planning lagging behind the demand for electric bicycle use

3.1.1. Analysis of urban parking of electric bicycles

Firstly, the existing non-motor vehicle parking spaces in society are planned according to the size of bicycles, the number of bicycles owned by each family, and the previous usage habits [4]. In the existing urban space, most of these parking spaces have been parked with bicycles and urban shared bicycles. As a result, the remaining parking spaces for non-motor vehicles can no longer accommodate the increasing number of electric

bicycles.

Secondly, although the electric bicycle is mostly classified as a non-motor vehicle with its size (1,700 mm × 500 mm × 1,100 mm) being closer to the motorcycle (1,890 mm × 250 mm × 940 mm). The parking area is 1.2–1.8 times that of the ordinary bicycle, so the required parking space is larger. With the surge in the number of electric bicycle users in recent years, the existing non-motor vehicle parking spaces are difficult to meet the parking needs of electric bicycles, resulting in no designated areas to park, thus users park wherever they please. This results in various chaotic situations (**Figure 1**).

This leads to a few problems. Firstly, indiscriminate parking. Many electric bicycles do not comply with the required parking areas, causing issues like occupying pedestrian pathways and other vehicle parking spaces. Secondly, illegal occupation. Some electric bicycles are parked in areas where parking is prohibited, such as fire passages, residential corridor spaces, and various public spaces in cities, which bring hidden dangers to evacuation and emergency paths during emergencies. Thirdly, non-standard parking. Some electric bicycles are not placed neatly and are stacked too high when parked, resulting in blocked vision, traffic obstacles, and safety hazards.

Figure 1. Electric bicycles and other vehicles occupy parking spaces on urban roads (Source: Beijing News, 2024-04-11)

3.1.2. Analysis of parking electric bicycles in counties, towns, and villages

With the improvement of the living standards of residents in counties, towns, and villages, the number of cars and electric bicycles owned by residents has increased year by year. The demand for vehicle parking is in contradiction with the current situation that the road system planning of counties and villages has not been perfected for a long time (**Table 1**). For example, the roads in villages and towns are narrow and curved, the mountain roads have ups and downs, and some roads are not equipped with pedestrians and non-motorized lanes, parking lines, or parking spaces. This mixed traffic of people and vehicles causes daily safety hazards for "residents. Additionally, there are more broken roads and fewer pedestrian bridges. Residential buildings are mainly single-story or multi-story self-built "handshake buildings" with dense spacing. Once these buildings lack parking spaces, only a few have motor vehicle parking garages inside the first floor, which is shared with the living room. The population density of towns and villages is high but there is a lack of planning and construction of large underground and above-ground public parking lots, as well as a serious shortage of public facilities such as charging stations. The per capita income of township residents is not high, and their educational level and quality are limited. Most people are not accustomed to paying for parking, so families with many electric vehicles often charge them directly in self-built houses or park them outside (**Figure 2**). Additionally, there is a lack of property management units in counties, towns, and villages, and many migrants live there. To facilitate charging and parking, disorderly parking and charging of electric bicycles is common, increasing the fire risk compared to cities.

Figure 2. Dongguan Street Village self-built hall corridor electric bicycle parking (Source: China Industrial Network, 2024-01-03)

Table 1. Analysis of current planning problems of municipal road system in towns and villages

Status quo	Results in	Solution measure
Urban planning is backward and management approval lagging behind	The construction of self-built houses is not humanized, the space is small, and the distribution is dense	Improve the planning system, adjust and standardize the follow-up construction
The municipal system is not well-planned	The roads are narrow and winding, and people and cars are mixed	Widen the road and install non-motorized lanes
Municipal land planning is inadequate, and some roads are not equipped with pedestrian and non-motorized lanes	There are more broken roads, fewer pedestrian bridges, and fewer traffic green belts and buffer zones	Open up the broken road, set up pedestrian bridges, green belts, buffer areas, and increase the municipal transport land
Regional financial funds and non-agricultural land are tight, and there is a lack of public support facilities	There is no parking spaces, few public parking lots, and no charging facilities for electric bicycles	Increase the number of parking spaces, build parking lots in villages, and make more use of three-dimensional parking lots

3.2. Random charging of electric bicycles is dangerous and has caused many fires

At present, most electric bicycles in China use lead-acid batteries, with a small portion using lithium batteries. Lead-acid battery-powered electric vehicles require non-removable charging. Therefore, electric bicycle parking facilities need to have charging functions to ensure battery life. Electric bicycle manufacturers recommend that users maintain the battery charge between 20% and 90% as much as possible. Users should charge their bicycles promptly after daily use. The optimal time to charge is when 50%–70% of the driving distance has been used, with a full charge generally taking 6–10 hours [5]. Since there are small numbers of slow charging facilities on the market, users will save trouble by bringing the batteries or electric vehicles to residential buildings to charge and risking accidental fires by randomly connecting wires to charge. Since 2022, there have been more than 10,000 electric bicycle fires across the country, causing casualties. Illegal parking and charging of electric bicycles bring danger to the living environment. Accidents occur in old cities, urban villages, counties, towns and villages, and other areas. These densely populated and built-up areas are at high risk. Once a fire starts due to wire aging, it can quickly spread to surrounding buildings, easily causing casualties.

4. Overview of project research

4.1. Design introduction

Prefabricated concrete modular building technology is a new type of building technology that has been applied to a certain extent in the domestic market in recent years. In addition to the application of prefabricated

buildings in residential and public buildings, its application scope can be further expanded to the design and construction of parking lot buildings [6]. The design of the multi-story prefabricated electric bicycle charging parking lot combines with the requirements of "sunshade, rainproof and safe non-motor vehicle parking lot and facilities should be set according to the local bicycle infrastructure construction" when the existing buildings in Shanghai are renovated [7]. As well as the latest requirements of the Notice on Issuing the Regulations on the Allocation of Parking Spaces for Construction Projects in Guangzhou issued by the Guangzhou Municipal Bureau of Planning and Natural Resources in July 2023, the allocation of parking spaces are 100% construction of charging facilities to meet the needs of direct meter installation and power connection and to address the parking and charging of electric bicycles as design purposes. The whole parking lot is assembled and constructed by prefabricated high-performance concrete panels and prefabricated staircases at the site of the project. There are a few production module components that can be modified and customized according to different space sizes and required layers. The space between the existing buildings is transformed to build an electric bicycle parking place with a charging function. It is suitable for old urban areas, commercial areas with land shortages, and counties, towns, and rural areas with insufficient municipal facilities [8].

4.2. Design site selection and analysis

Electric bicycles are the daily means of transportation used by residents. **Table 2** shows the statistics and analysis of residents' current parking status and usage of electric bicycles. Ease of use is the primary requirement, followed by the number of parking spaces, charging facilities, fire resistance, safety management issues, etc. Parking requirements close to home result in residents parking electric bicycles in a "haptic parking" manner. This is also the key to the subsequent series of contradictions. Electric bicycle parking space should be as close to the residence as possible. **Figure 3** shows the location of parking spaces for electric bicycles. The parking problem of electric bicycles is more related to the transformation of the existing building community [9]. At present, many local governments, such as Longyan City, Xiamen City, and Qingyuan City in Fujian Province, have issued policies to include centralized electric bicycle parking and charging fields in the renovation of old residential areas [10–12].

Table 2. Electric bicycle parking status and residents' demand statistics

Current state	Design requirement
Lack of space to park, parking scattered	Close to the residence
The existing parking is inconvenient and the number of parking spaces is small	Enough parking space, centralized parking, easy to take and place
Lack of charging stations, fire risk, lighting, and other facilities	The parking space is fully equipped with charging stations, fire protection, shading, rain protection, lightning protection, lighting, drainage and monitoring facilities
Causing safety hazards, space occupancy, and fire problems	Safe parking space, centralized parking
The contradiction between government, property management, and users	Property companies and residential district business committees, village committees can assist management
The outdoor space is disorderly and the supporting facilities are insufficient	Interior space with sufficient facilities
Urban planning and current policies lagging behind	Rational planning and people-oriented

The overhead floor of connected residential buildings is taken as the design site. As shown in **Figure 4**, bicycles can only be placed in a single layer in the original space, and they are placed in a disorderly manner.

The tenants' electric bicycles lack space to be placed, and can only be placed in various odd spaces of the community, which affects the entry and exit of other residents and cause security risks. Therefore, the utilization rate of the space is explored, the number of parking spaces are increased, and the space is transformed into a prefabricated three-story electric bicycle charging parking lot in the form of a three-dimensional parking garage. The parking lot has 3 stories above ground, with a length of 1,620 mm and a width of 9,000 mm. Each level is 2,200 mm, with a net height of 1,900 mm and a total height of 6,800 mm. The total construction area is 437.4 m^2. The parking lot is divided into 3 rows, creating 3 charging parking areas on each floor, with an average of 20 charging parking spaces per area and 53 charging parking spaces per floor, as shown in **Figure 5**. Each parking space is 1.02 m^2, each parking area is 145.8 m^2, and the total number of parking spaces across the 3 layers is 159. The facility also features a "car-electric separation and sharing power change mode." Additionally, there are 2 smart charging cabinets, each capable of charging 12 electric bicycle batteries. Based on the assumption that each family owns 1 electric bicycle, the parking lot can accommodate the charging and parking needs of up to 183 households [13].

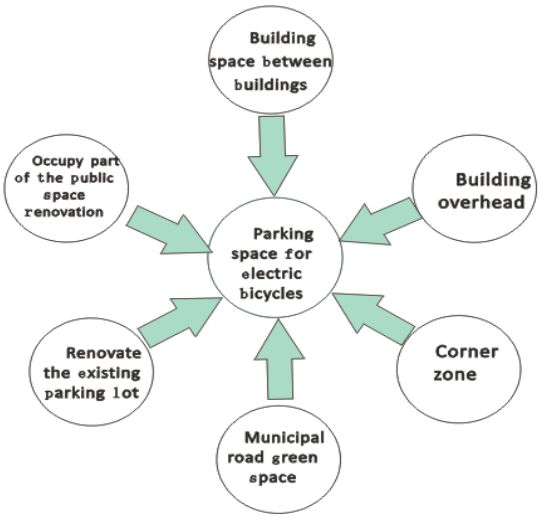

Figure 3. Electric bicycle parking space analysis diagram (based on **Table 2**)

Figure 4. Status of non-motor vehicle parking in building space of a residential district (Source: Photo by Liya Fang)

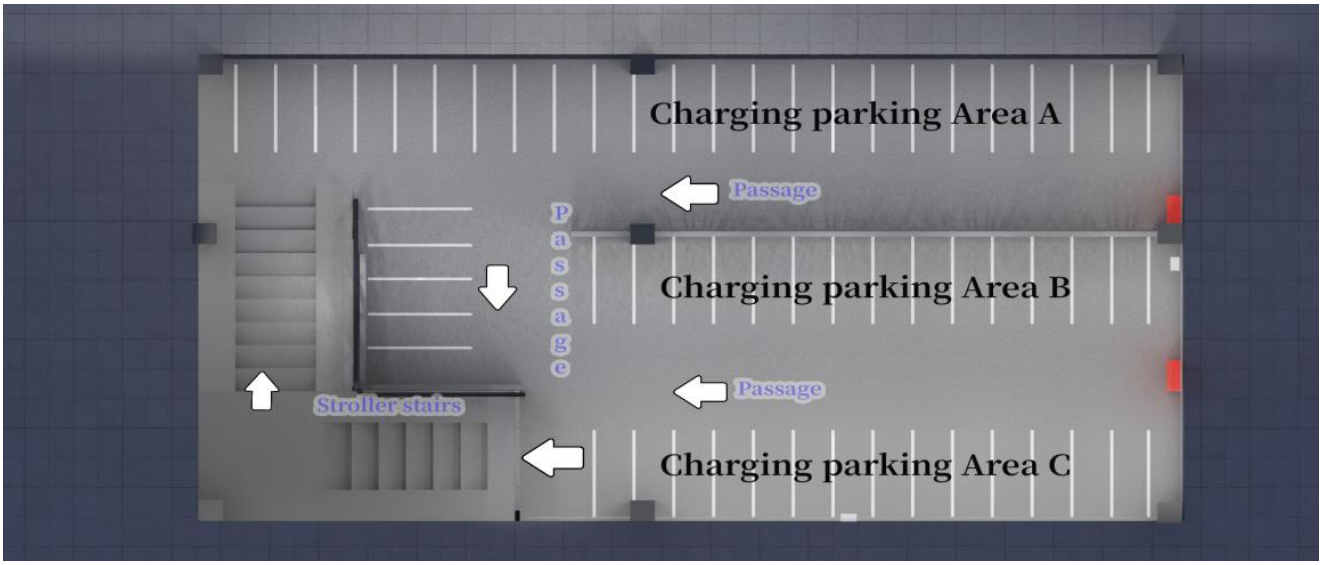

Figure 5. The second-floor layout of the prefabricated multi-story electric bicycle parking lot (Source: Design by Liya Fang)

Figure 6. 3D design of multi-story assembled electric bicycle charging parking lot at multiple angles (Source: Design by Liya Fang)

4.3. Design model of a multi-story prefabricated electric bicycle charging parking lot

The prefabricated electric bicycle parking lot as shown in **Figure 6** is an integral frame structure [14]. The load-bearing design of the main parts is based on live load, with either an independent or raft foundation used depending on site conditions. Most parking lot buildings adopt prefabricated construction technology, with both

external and internal walls being clean walls. The main precast concrete components are floor slabs (composite slabs with embedded pipelines), vertical wall slabs (composite slabs with embedded pipelines), frame columns, composite beams, and staircases [15]. Secondary accessories include metal railings, stair railings, control boxes, main electricity meters, explosion-proof lighting fixtures, lightning protection grounding facilities, surveillance cameras, charging sockets, metering meters, and barrier-free facilities. Fire equipment accessories include fire extinguishers and smoke alarms. Using C35 concrete, HRB400 rebar, a 400 × 400 mm wall column, with the minimum thickness of each prefabricated floor is 120 mm and the thickness of the vertical wall panel is 60 mm. The thickness of cast-in-place is not less than the prefabricated part, and the surface of the prefabricated board is made into a rough surface [16]. The span of the laminated floor is designed according to the standard mode of the actual situation. The prefabricated staircase is anchored directly into the cast-in-place portion of the laminated slab through steel bars to form a strong connection to the main body. The concrete members of the exterior wall frame of the parking lot are fixed by connecting them to the existing wall of the building with the connecting parts. The prefabricated components used to assemble the multi-story parking are attached with material information, clearly indicating the installation position and size, and a two-dimensional code sticker is attached to facilitate the construction workers to check the construction method of the components by scanning the code with their mobile phones. The precast concrete component wall panel is embedded in the hydropower pipeline according to the design drawings, and the pipeline layout is ensured to meet the safety distance. The first floor of the parking lot is equipped with a general distribution box, and each floor must be equipped with explosion-proof lighting fixtures, drainage pipes, and lightning protection grounding facilities. Continuous drains should be set up around the first-floor plate to discharge rainwater to the nearest municipal pipe well, to ensure that parked electric bicycles can be charged normally even in thunderstorm weather. The top floor of the parking lot can be equipped with solar panels or photovoltaic panels to collect environmentally friendly energy as the supplementary power supply of the parking lot [17].

The parking lot is an open environment, the parking method of vehicles is vertical, and each parking space is 1,700 mm × 600 mm. The channels width is 1,700 mm, the two-stage stairs are used with the staircase width at 2,500 mm, and the two sides of the tread are provided with 600 mm wide up-and-down push lanes. Users can walk a few steps from the residential building to the first-floor entrance of the prefabricated multi-story building to enter the parking lot. Each floor of the parking lot is divided into three charging areas, A, B, and C. Each charging area is equipped with an intelligent charging meter, to achieve a multi-control machine that can jointly control 20 outputs and charge 20 vehicles at the same time. In the future, users will be able to use the shared parking mode, and each parking lot will be equipped with parking markings and charging sockets [18]. Users can connect the charging plug of electric bicycles at the parking lot, and charge them by swiping bank cards or scanning the QR code with the WeChat program. The smart meter has a current detection function. When the smart meter detects that the electric bicycle in the parking position is fully charged or the load power is too large, the socket will automatically turn off power as protection to prevent safety hazards caused by overload and short circuits. The smart charging meter installed will charge according to the charging time, which is convenient to use.

4.4. Project benefits

4.4.1. More durable and safe structure

Most of the existing electric bicycle charging stations on the market are single-story iron-made charging sheds (**Figure 7**). This kind of charging station is generally located next to municipal roads or in open spaces of urban blocks. Several galvanized square pipes are used as structural supports, and colored steel plates are simply

welded and coated with anti-rust paint as the ceiling, built-in with a charging meter and electrical socket. The temperature has a great impact on the battery, and the battery should be stored in an environment of 0℃ ~ 20℃ and no higher than 40℃ [5]. Poor battery quality, short circuits of wires, high temperature, or overcharge will damage the battery, and cause combustion or explosion. Once it burns up, the fire spreads fast, the duration is long with high temperatures. It is not easy to extinguish, resulting in a large number of toxic fumes leading to emergency escape difficulties, which is easy to cause casualties. In 2024, there were several fire accidents caused by the charging or spontaneous combustion of electric bicycles in electric bicycle sheds in Guangzhou (**Figure 8**). In many cases, the fire is caused by electric bicycle batteries. The time taken from the start of the fire to the explosion took only 40 s and produced a lot of smoke. Within three minutes, the temperature reached 1,200℃, causing the ambient temperature to exceed 660℃. This high temperature can burn people near the iron-made charging station and cause the structure to melt and collapse, forcing people to escape. The prefabricated multi-story electric bicycle charging parking lot uses concrete and steel as main component materials, the wire tube is embedded in the concrete module, the circuit design is more standardized, and has lightning protection and grounding facilities. With waterproof, lightning protection, and high-temperature resistance characteristics, the service life can reach up to 10–20 years which is more durable and safe than the iron-made charging station. **Table 3** shows the parking forms and comparative analysis of electric bicycle parks.

Figure 7. Metal electric bicycle charging shed (Source: Photo by Liya Fang)

Figure 8. An electric bicycle shed fire in Haizhu district, Guangzhou (Source: The Paper, 2024-07-05)

Table 3. Electric bicycle parking form and comparative analysis

Form	Advantage	Shortcoming
Single-deck type	Simple construction, short cycle, low cost, short life, less car storage, scattered	The number of vehicles accommodation is small
Outdoor	Simple construction, flexible use of the site, weak vehicle protection, quick depreciation of facilities, large parking lot numbers, and scattered distribution	Electric vehicle failure from sun and rain: battery overheating from sun, short circuit from rain
Elevated indoor	Effectively shade from the sun and rain, generally single-story parking, easy to use, more concentrated distribution	Lack of lightning protection and fire protection facilities, battery-induced fire can easily spread to other vehicles and surrounding buildings
Multi-story indoor structure	A large number of vehicle accommodations, shade from the sun and rain with lightning protection, vehicle protective wall, easy-to-support charging facilities, convenient centralized access, long building life	Construction requires a larger space, higher cost than other forms

4.4.2. Meeting the number of vehicles, simultaneous parking and charging, saving time and cost

The current electric bicycle charging station only has a single-story structure, and can only charge 10–20 vehicles at the same time. The user must calculate their electric bicycle charging time, and park the vehicle in other areas after charging. This mode of separation of parking and charging does not meet the needs of users. The multi-story assembly electric bicycle charging parking lot not only meets the needs of users to charge and park simultaneously but also uses the principle of three-dimensional space. By overlapping the assembly plate in the city, counties, towns, and villages, from single-story to multi-story, the number of electric bicycle parking charging stations increased several times, and the location outside the parking space is equipped with an intelligent charging cabinet. This provides users with the function of a battery charging cabinet to meet the requirements of unified charging, unified management, and storage. After the parking lot is completed, the electric bicycle charging power supply for residential use will have an electricity unit price of ¥0.59, which is lower than the average unit price of ¥0.9/kWh (¥0.50 for electricity and ¥0.40 for service fee per hour) at commercial charging stations. Reducing user charging costs supports the sustainable development of green power vehicles [19].

4.4.3. Flexible site selection and smaller use of space for construction

Because of its higher safety, the prefabricated parking lot can be set up closer to residents with flexible and diverse locations. It can not only be built in the public space of cities, counties, towns, and villages, but also in the elevated floors of residential buildings, podium buildings, and the space in between buildings. The building facade wall panels can be easily built in the factory through molds. It includes the texture of fair-faced concrete, decorative brick, stone, and various textures of decorative concrete, which are integrated into the original residential areas as public service facilities [20]. Prefabricated components are adopted, and most of its components are produced in the factory. After the component materials are transported to the site, the assembly construction can be completed using the original site space of the residential area. The construction period is short by avoiding the large area of on-site material processing sites, office facilities, and temporary facilities. Moreover, as a structure, the construction procedure of the parking lot is simple thus construction costs are more economical.

4.4.4. Example analysis

In 2011, the United States has adopted the prefabricated building technology to build parking lots. The Green Square parking lot building developed by the government in downtown Raleigh, United States, adopts the precast concrete frame structure inside, which can accommodate 900 parking spaces. The external wall of the building uses solar blades as the energy supply for the whole building (**Figure 9**) [21]. China's Jinan city built the country's first prefabricated multi-story underground civil air defense garage in 2023, and Wuhan is also building the country's largest assembled integrated parking building. The external wall of the building uses solar blades as the energy supply for the whole building (**Figure 10**) [22,23]. In recent years, with the development of three-dimensional parking equipment technology, intelligent information systems, and charging equipment, the form of a mechanical three-dimensional garage has made a qualitative leap. The form of the parking frame not only has a simple lifting, pit, horizontal, and lifting platform, but the overall structure has also developed from the past simple open-air steel frame type to the current combined with the building frame parking building. Various forms of three-dimensional bicycle parking racks have also appeared in the market. In the renovation of the old city, in the face of limited space, developers choose the combination of mechanical three-dimensional garages and an intelligent parking system to improve space utilization. For example, Yangtao Square, 1906

Science Park, located in Zhongshan Seventh Road, Liwan District, Guangzhou, formerly known as the old factory of Guangzhou Cigarette Factory, will be revitalized and transformed into a food experience park in 2023 as an old city industrial park. The developer has built two large intelligent mechanical three-dimensional garages, which greatly solves the problem of parking difficulties around the old city [24]. In addition, the parking garage combines electric vehicle charging pile technology, integrating parking and charging, and users can utilize license plate recognition and intelligent parking management services by pressing the button according to the operation prompt on the first floor of the parking garage (**Figure 10**). All these cases provide the technical basis for the design and research of a multi-story prefabricated electric bicycle charging parking lot.

Figure 9. USA Green Square parking lot (Source: Construction Network)

Figure 10. 1906 Science Park Yang Tao 3D Square parking lot (Source: Photo by Liya Fang)

5. Preparations before construction

Before the on-site construction of the multi-story prefabricated electric bicycle charging parking lot, the stacking site of prefabricated components should be a hardened site to ensure smooth drainage around the site and consider factors such as lifting capacity limitations [25]. During the construction of the parking lot, the push and place positions of the components should be designed and separated according to the structural requirements and lifting capacity, the transport approach of the prefabricated components, the placement points of the lifting equipment, the lifting and stacking routes should be calculated, and the installation and construction plan should be prepared to meet the lifting and installation of each component [26].

5.1. Technical control point of the construction process

The pre-buried casing or reserved hole at the wall and floor of the pipeline should be reserved in place on the prefabricated component at one time, the specifications should meet the requirements, and the coordinates and elevations should be correct. The production unit of prefabricated components should formulate production plans according to the site use requirements, design, and construction requirements of the user. After the precast concrete is poured, it should be operated and maintained promptly according to the provisions of the state concrete maintenance. After the precast member reaches 75% of the design value of the concrete compressive strength, and the cube compressive strength is not less than 15 N/mm, it can be demolded. The joint surface of all precast members and cast-in-place concrete should be rough, and the roughness should meet the requirements of JGJ1-2014, Technical Specification for Prefabricated Concrete Structures, while the convex of exposed coarse aggregate should be uniformly and continuously distributed along the entire assembly joint surface.

Mold requirements and inspection of prefabricated components are crucial to ensure the quality of final products. Firstly, the materials selected for the mold should have quality certificates or inspection reports. After the mold assembly is completed, it is necessary to carry out hair removal, rust removal, slag cleaning, and other work. The surface of the steel mold in direct contact with the concrete of the component should be evenly coated with a release agent. Secondly, for components with higher appearance requirements, special attention must be given to the splicing of templates, particularly at the junctions of the side and bottom molds. To prevent leakage that could negatively impact the component's appearance, it is essential to use sealing materials such as water sealing strips. Finally, the permissible size deviations and the methods for inspecting the prefabricated component mold must comply with the Technical Specification for Prefabricated Concrete Structure JGJ1-2014 [27]. Adhering to these specifications ensures that the prefabricated components meet the required standards of quality and precision.

The power switch, charging and billing equipment, fire hydrant box, and fire extinguishing equipment in the parking lot should be open-mounted. Also, the equipment should be placed clearly and easily, and assigned to check and maintain regularly.

6. Feasibility of urban and township electric vehicle parking lot planning transformation

6.1. Latest measures to standardize the parking management of electric bicycles across the country

Sanyanli Village, Baiyun District, Guangzhou is one of the urban villages in Guangzhou. There, in May 2024, an electric bicycle fire broke out at an outdoor charging point, causing several electric bicycles, shops, and outdoor billboards nearby to burn. After the fire, the government at all levels in Guangzhou organized personnel to investigate the illegal parking and charging problems of electric bicycles and adopted a series of fire prevention management measures. Sanyuanli Village and many other villages in Guangzhou prohibit electric bicycles from being parked in villages and residential areas [28]. The implementation of permits and parking registration for residents' electric bicycles, along with strict monitoring of vehicle parking status, involves regional urban management personnel working with the village committee and street office for extensive inspection of parking practices. Additionally, several simple electric bicycle charging booths and parking points have been constructed outside the area. While these measures may help reduce the risk of fires caused by electric bicycles, they do not address the fundamental issue of insufficient parking for electric bicycles at the source (**Figure 11**).

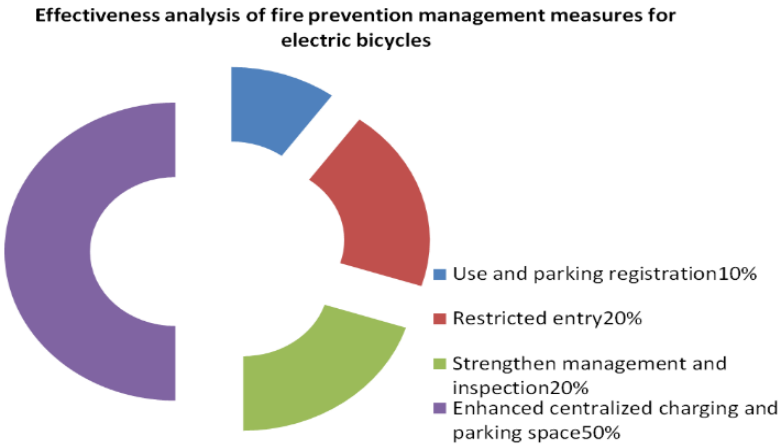

Figure 11. Effectiveness analysis of fire prevention management measures for electric bicycles (based on statistical analysis of questionnaires)

6.2. Feasibility analysis of urban electric bicycle three-dimensional parking planning

Given the large urban floating population and relatively well-developed road structure and parking facilities, the issue of electric bicycle charging and parking can be addressed through a multifaceted approach. This includes transforming the urban village environment, improving block environments and passenger stations, and undertaking urban renewal projects. By focusing on these areas, it is possible to increase the availability of multi-story parking lots and charging spaces, thereby solving the challenges associated with electric bicycle parking and charging.

6.3. Feasibility analysis of three-dimensional parking planning for electric bicycles in counties and villages

Counties, towns, and villages often face tight financial constraints and have limited non-agricultural land available. Therefore, the planning and design of multi-story electric bicycle charging parking lots should align with social management principles and local conditions, leveraging initiatives such as the "Beautiful Village Project," "Rural Revitalization Project," and the upgrading of tourist attractions. This approach should also encompass the development of village government squares, bus stations, cultural venues, public health stations, and other service facilities. For example, Baojing County in western Hunan has built 235 village parking lots through the "Rural Revitalization Project" in the past two years and plans to build 1,000 public parking lots in the next three years to solve the problem of rural parking difficulties [29]. At the same time, it is essential to promote daily education among residents to standardize vehicle parking practices and enhance fire safety awareness, thereby gradually improving the quality of life for township villagers.

7. Conclusion

How to solve the issue of charging and parking of electric bicycles has become a hot topic of livelihood in the current society. A prefabricated multi-story electric bicycle parking lot is not only an attempt to open up new fields of prefabricated building technology, but it is also suitable for supporting and complementing existing residential public facilities. It is a small project with fewer types of production components, a simple process, minimal construction waste, and the capability for customization and scalable mass production aligning with the requirements of green building and building industrialization. It also addresses the shortcomings of metal charging stations, offering a safer and more durable structure. Analysis of various domestic and international prefabricated parking lot planning in many governments' urban planning, township planning, and renovation of old residential areas, supports the hypothesis of this paper. The conclusion drawn is that the policy of applying multi-story assembled electric bicycle parking lots to the transformation of old residential areas is feasible, with an existing technical foundation available.

The design of the prefabricated multi-story electric bicycle charging and parking lot integrates both parking and charging functions simultaneously. It features a high parking capacity and low charging costs, offering a model for towns and villages to address the standardized charging and parking issues of electric bicycles effectively. This design is practical and promotes the high-quality development and planning of towns, counties, and villages, presenting significant market value. As technology advances, future developments are expected to enhance the construction of multi-story prefabricated electric bicycle parking lots with features such as clean water wall aesthetics, mechanical parking systems, automatic fire suppression, intelligent parking solutions, and photovoltaic power generation, making the parking lots even more advanced and efficient.

Disclosure statement

The author declares no conflict of interest.

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