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UTILIZATION STRATEGIES OF URBAN GREEN SPACE AND UNDERGROUND SPACE UNDER HIGH-DENSITY URBANIZATION

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ABSTRACT

The urbanization process leads to continuous rapid expansion of urban scale and urban population, which causes "urban diseases". Urban green space improves the ecological environment and further ameliorates the quality of public services. However, due to the contradiction between the rapid expansion of urban requirement and increasingly tight resources, it is difficult to build a large amount of green space, and it is hard to fully provide its ecological restoration and public services. The contradiction between the residents' healthy living demands and the green space insufficient development becomes more prominent. Therefore, Therefore, in order to improve the efficient and sustainable development of green spaces and explore effective underground space utilization strategies, this paper applies a systematic review and comprehensive analysis method, focusing on the utilization strategy of the underground space of the urban green space, aiming to resolve the urban crisis and promote the health function of green space. This paper proposes three steps for the utilization of urban green space and underground space:1) rational and orderly development planning; 2) multiple and complex utilization functions; 3) an ecologically harmonious built environment. The findings of the study provide the right way to protect and utilize surface and underground landscapes and green spaces in a rapidly urbanizing China, while being able to further promote urban development.

1. INTRODUCTION

The rapid development of urbanization has further aggravated the "urban diseases" such as land constraint, inadequate infrastructure and environmental and ecological imbalance in cities. Nowadays, how to improve the urban environment and enhance the quality of living has become an important issue [1] [2]. Urban underground space development is an important component of urban construction and an important means of achieving sustainable urban development and solving "urban diseases"[3][4][5][6]. Urban green spaces play a vital role in regulating the urban structure, promoting the health of residents and improving the environmental climate [7][8][9][10]. The underground space of urban green spaces has become the primary choice for the development of underground space in high-density cities because it has less influence and constraints on the above-ground space, it is less expensive to develop and has a huge impact on urban ecology and the quality of life of residents[11][12][13].

At present, the development and utilization of urban underground space have entered a rapid development stage, and research on underground space in urban green areas is increasing[14][15][16].

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In terms of synergistic planning, the coupling of urban space above and below ground is becoming more and more intense as a result of rapid urbanization [17][18]. The synergistic planning of public green space and underground space has become an important response to the dilemma of urban development and the public aspirations of residents[19][20]. In terms of land use, the composite development model of super-green and super-underground space benefits is important in establishing an organic link between the city, the public and the environment, as well as improving the intensive use of land[21][22][23][24]. In terms of ecological construction, the use of underground space in urban green areas is an important part of building an urban public green space system. This has a catalytic role in enhancing the self-cleaning capacity of the urban environment, realizing the harmonious development of man and nature and establishing an eco-friendly city[25]. In addition to theoretical research, a large number of urban green space underground development projects have been carried out in various countries. Shenzhen, China, provides an effective path for the sustainable development of underground space in high-density cities through spatial and temporal planning, coordinated development, green ecology and intelligent management of underground space[26]. The Place des Chevaliers in Paris, France, combines the functions of above and below ground use, providing the public with a comprehensive underground neighborhood with convenient functions and a beautiful environment. The underground cleaning plant in Tokyo, Japan, has been converted into a green park through the incineration room, reducing urban pollution and expanding the green space[27]. It can be seen that the protection and development, efficient use and ecological goodness of the underground space of urban green space is an important element in the construction of high-density urban underground space[28]. However, research on the in-depth development of underground space in urban green areas is still in its infancy, and project practice lacks systematic and complete theoretical support. Under the contradiction between the rapid expansion of urban space demand and the increasing tension of land resources, a single solution path is no longer sufficient to cope with the need for underground space development in high-density cities. A comprehensive development strategy for underground space in urban green spaces should be established with urban development planning as the core, multi-functional composite use as the focus, and environmental and ecological harmony as the support.

In order to avoid the disorderly development of urban green space and the continuous deterioration of the human living environment and ecological environment[19], this paper proposes rationalized, compounded and ecological planning and design principles with a view to solving the problems of disorderly utilization, single function, and land contraction [29].This paper focuses on the development of the underground space of urban green space. The utilization strategy is explored from different perspectives including reasonable and orderly development planning, multiple and composite functions, as well as an ecological and harmonious building environment. So that the rational, efficient and sustainable development of urban green space underground space can be promoted. With the rapid high-density urbanization in China, this work is meaningful to improve the effectiveness of using urban resources, expand the provision of public services, and protect the ecological environment on the ground, by combining ecological landscapes and multiple functions with limited urban resources. Therefore, the ecology and sustainability of urban green space can be fully performed.

2. METHODS/APPROACH

This project is conducted by following steps: 1) the advanced development process of urban green space and the underground space application is reviewed and analyzed to explore an available utilization strategy of space under urban green space. 2) the contradiction between the current urban green space development and urban development demands in China is deeply analyzed. The restrictive factors of urban green space underground space utilization are concluded. 3) Based on the current problems in the utilization of urban green space and underground space in China, a strategy for the combined development of green space and underground space is proposed to promote the orderly, deep, and sustainable development of underground space.

This paper adopts the method of systematic review and comprehensive analysis to sort out the research context of urban green underground space, and focuses on the research issues of this paper based on hot spots and frontiers. VOSviewer is a software developed by The Centre for Science and Technology Studies (CWTS) in 2019. It can perform bibliometric analysis by drawing scientific knowledge maps[30]. It is the mainstream software for literature review and comprehensive analysis. This paper will use this software to track the research process and research focus of “green underground space”, and provide the basis for the research questions of this paper. In this paper, a search of the web of science core database revealed a total of 167 articles related to “green underground space”. After that, the 167 Ris data were imported using VOSviewer software, and the keywords with a frequency greater than 2 were selected for clustering mapping. As can be seen from the figure, there are two broad research clusters for the study of underground space in green spaces: the spatial planning cluster and the construction technology cluster. Within the two clusters, seven research clusters can be distinguished by different colors. The green area represents the urban planning research cluster; the purple area represents the green infrastructure research cluster; the red area represents the energy and performance research cluster; the orange area represents the functional modelling research cluster; the brown area represents the engineering structures research cluster; the blue area represents the propagation prediction research cluster; and the yellow area represents the inverse algorithm research cluster. Among the spatial planning clusters, one can see the related urban planning, land use, urban ecosystems and green infrastructure are the main areas of research (Fig.1). Meanwhile, the quality, performance, development patterns, ecological services and green infrastructure of green underground space in the context of urbanization has become a popular subject of research in recent years (Fig.2). As can be seen, high-density urbanization poses many new challenges for underground space development. This paper will propose specific strategies to address three main problems: the lack of coordination between underground space and urban development, the inadequate development of functional underground space and the poor ecological benefits of the city.

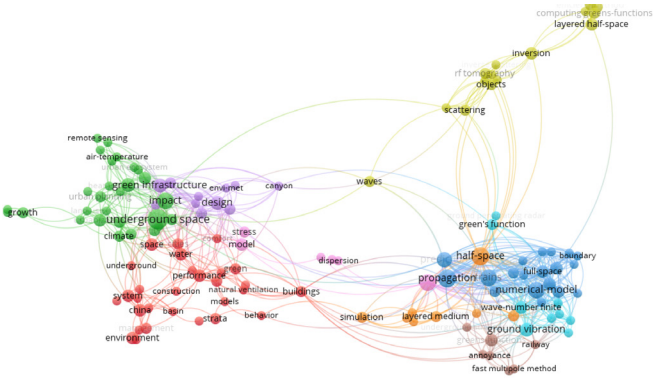

***Figure 1**: Green Underground Space Study Clustering (Self-drawing 2021)*

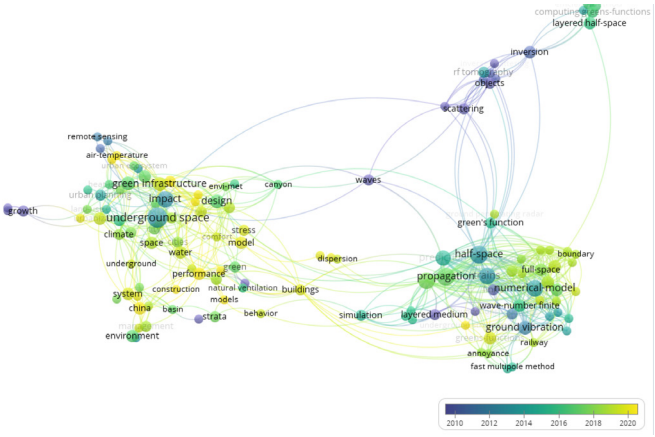

***Figure 2**: Frontiers of Green Underground Space Research (Self-drawing 2021)*

3. FINDINGS AND SOLUTIONS

Considering the increasingly high-density development of large/medium-sized cities in China, this project proposed three steps for urban green space and its underground space utilization, namely, the reasonable and orderly development planning, multiple and composite utilization functions, and ecologically harmonious building environment.

3.1 Reasonable and Orderly Development Planning

The overall urban planning is an important basis and guidance for the development and utilization of underground space. The ground and underground spaces should be designed and developed collaboratively. The using intensity of urban green space and underground space is limited by the utilizing capacity of urban underground space. The development of urban green space and underground space is a three-dimensional model (Fig. 3), which is closely related to its position, function, terrain and geological conditions in the city. Therefore, both the city development trend and the capacity of urban underground space should be taken into consideration. The short-term development and long-term designation should be planned separately to reserve sufficient capacity for deep utilization. Different 3D developing modes should be designed according to different conditions. The space location, function, building scale, structure, developing process, and spatial combination are connected with the green space for an organic whole.

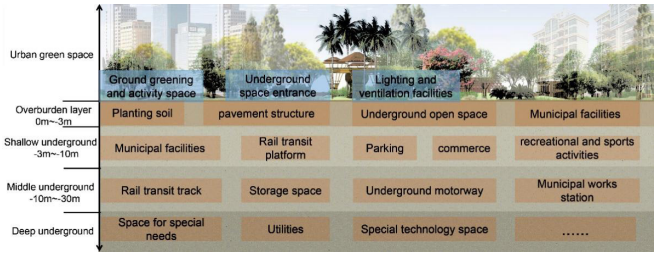

***Figure 3:** Three-dimensional model for urban green space and underground space development (Self-drawing 2021)*

3.2 Multiple and Composite Utilization Functions

The combined development of urban green space and underground space can arrange the ground and underground functional spaces, so that the urban land under a certain area can accommodate more functions to achieve function concentration. Multiple functions can be comprehensively developed to promote the accumulation of ground and underground space. Combining the urban green space and underground commercial space can somehow expand the public green space's benefits, create a commercial environment for the land, and realize the economic benefits of underground space. The combined development of urban green space and parking, storage, pipelines, and other functional facilities can solve the problem of insufficient urban facilities. Utilizing the underground space of urban green space will perform the advantages of their respective space functions, and complementary and mutually beneficial functions will be realized (Fig. 4).

***Figure 4:** Multi-dimensional combination of underground city planning (Self-drawing 2021)*

3.3 Ecologically Harmonious Building Environment

The rapid high-density development of cities causes critical urban pollution. The development and usage of urban underground space can promote the construction of urban green space, which is helpful to improve the living environment. When backfilling the underground space, soil filling can be selected. Partially backfilling the soil that is suitable for different greening plants growth can increase the choice of plant species, and enrich the greening level. Utilizing the spoils excavated in the underground space to carry out soil pile formation and mountain formation, and complete the remodeling of the landforms, to realize the greening and three-dimensional greening of the four seasons. At the same time, making full use of the underground space of urban green space, and transferring some urban functions underground can reduce environmental pollution, and save land resources for urban greening and public services. So that, both urban ecology social benefits of green space can be promoted. For instance, the reconstruction scheme of Shenzhen Dayun Center follows the principle of ecological priority, advocates

the sustainable utilization of resources, constructs a good landscape greening system, and promotes the construction of ecological healthy city (Figure 5).

Figure 5: *The reconstruction scheme of Shenzhen Dayun Center (Self-drawing 2021)*

With land resources in high-density cities under severe strain, there is an urgent need to develop a comprehensive underground development strategy for green spaces that balances the promotion of urban development with the enhancement of the human environment. This paper systematically proposes rationalized, composite and ecological planning and design principles and contents, providing a theoretical basis and practical guidance for the study of the efficient use of urban green space, which is important for the construction of an urban green underground space research system. However, the development of underground space in urban green spaces is participated by multiple subjects, and the needs of multiple parties, including the government, designers and the public, need to be considered. Therefore, the development work should start with top-level planning, formulate relevant laws and regulations, and form the systematic plan to guide the orderly development of urban green space and underground space. The pre-development stage can generate a development design plan that meets the needs of all parties through the participation of multiple subjects in decision-making. At the same time, there are various types of underground space in urban public green spaces, and this paper does not distinguish between park green spaces, square green spaces, street green spaces, community green spaces and other types. The study will continue to explore the comprehensive three-dimensional development mode of underground space for different green space types, so as to promote the combination of multiple ecological landscapes and limited urban resources in a targeted manner, and promote the deeper development of underground space utilization of green space.

4. CONCLUSION

The negative impacts from city high-density urbanization have seriously violated the demands of urban residents for a healthy living environment. As an important public space that promotes the living environment and improves human health, the inadequate usage of urban green space brings development resources loss. In this term, it is meaningful to find a reasonable way to enhance the value of the underground space. However, the barriers between disciplines, including architecture, landscape, planning, and civil engineering make it impossible for us to solve the fundamentals of the underground space utilization of urban green space from the perspective of coupling. Calling on all disciplines to form a consensus, re-examining their disciplines in the context of high-density urban development, attaching importance to the development and utilization of urban green space and underground space, and protecting the ground landscape and environment are all valuable to rationally use urban resources, produce the largest agglomeration benefits, and find the most beneficial approach to sustainable development, which makes the city a model of healthy living.

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