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Effect of Ground Stack for Additional Internal Force and Deformation of Underground Pipeline

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Abstract: Based on a three-dimensional finite element model of an underground pipeline, the influence of additional ground loads on the stress characteristics of the pipeline was studied. Furthermore, the effects of different soil properties, load locations, and varying burial depths on the pipeline's stress characteristics were analyzed. The research results show that as the distance between the load center and the pipeline axis increases, the positions of the pipe's maximum displacement, bending moment, and shear force along the axis decrease significantly. However, when this distance reaches a certain value, the pipeline's maximum vertical displacement and internal forces approach zero. Different pipelines exhibit minimum values of maximum axial displacement and vertical displacement in soft soil, while maximum axial displacement occurs in clay, and the largest vertical displacement is observed in sandy soil. The maximum axial displacement of UPVC pipes in clay is twice that of soft soil. The vertical displacement of pipes made from different materials increases with burial depth, but for concrete and steel pipes, the maximum axial tension increases significantly with depth, whereas the change in UPVC pipes is more gradual.

Keywords: Finite element; Wall; Pipeline; Displacement; Axial force; Bending moment

Online publication: November 25, 2024

1. Introduction

The large-scale finite element general software ABAQUS is used to carry out numerical simulation of the pipeline, to study the influence of the ground wall on the mechanical characteristics of the lower pipeline, and to determine whether the pressure generated by the additional load generated by the upper wall on the pipeline exceeds its design pressure value [1]. In the simulation process, the model is simplified to a certain extent, and its basic assumptions are:

(1) The engineering geological conditions are simplified, and the soil layers are assumed to be uniformly distributed in the simulation process.

(2) The material of the soil layer is assumed to be an isotropic material.

(3) Boundary and loading conditions of the model: the upper surface is a free surface, and the lower surface is fully constrained, with displacement constraints applied in the X and Y directions. The surrounding

sides are horizontally constrained, with horizontal displacement constraints applied in the X direction. A gravity load is applied to all elements of the model [2].

(4) The model does not consider the regional tectonic stress, only the stress caused by gravity.

2. Finite element model of pipeline

To simplify the calculation, the constitutive model of the geotechnical material used in this paper is the Mohr-Coulomb constitutive model, and the pipeline adopts the elastic material model [3]. **Table 1** shows the material parameter characteristics of each material partition. Simultaneously, to consider the interaction between the soil and the pipeline, the Mohr-Coulomb contact model is used between the pipeline and the soil, and the embedded contact is used for the contact between the pipeline and the soil [4].

Table 1. Material parameters

Material	Density (g/cm^3)	E (Pa)	μ	Cohesion (kPa)	Internal friction angle (°)	Expansion angle (°)
Pipeline	7.8	2.05e11	0.3	/	/	/
Clay soil	1.85	4.5e7	0.35	25	24	15

3. Calculation results

3.1. Pipe overlaid flag stand

The flag stand is 4.8 m long, 1 m high, 3.3 m wide, and the pipeline is buried 1.3 m deep. The pipe diameter is 273.1 mm × 6.4 mm. The pipeline passes through the lower part of the longitudinal center of the flag platform, and the standard value of constant load is 25 kN/m^2, as shown in **Figure 1**.

The top flag platform is simplified as a uniform load acting on the foundation soil, as shown in **Figure 2**.

Figure 1. Pipe overlaid flag stand

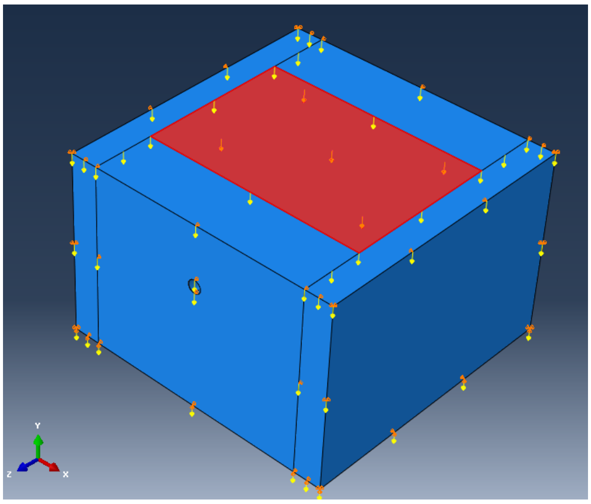
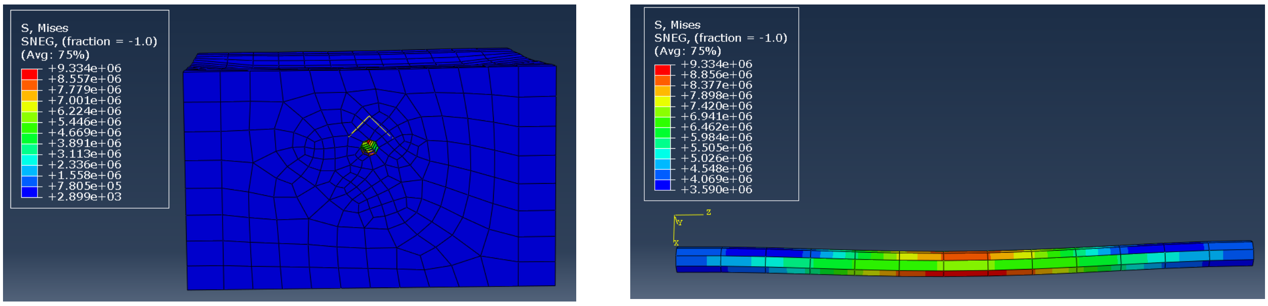


Figure 2. Diagram of load action of a calculation example

In order to determine whether the force of the lower pipe meets the design value when the wall is laid on the upper part of the pipe, the force of the pipe after the wall is laid is analyzed, as shown in **Figure 3**.



(a) Overall (b) Pipeline

Figure 3. Mises stress diagram of pipeline

It can be seen from the calculation that the Mises equivalent stress generated by the upper wall to the pipeline is 9.33 MPa, and its maximum value appears at the bottom of the pipeline.

3.2. Pipe overlaid brick wall

The pipelines are mainly buried in the cover layer with an average depth of 1.3 m. The width of the overlying wall is 0.40 m, the height of the wall is 4.5 m, the length of the wall is 4 m, the standard value of constant load is 86 kN/m^2, and the standard value of ground stacking or personnel load is 2.5 kN/m^2, as shown in **Figure 4**.

The top wall is simplified as a uniform load acting on the foundation soil, as shown in **Figure 5**.

Figure 4. Brick wall on the pipeline

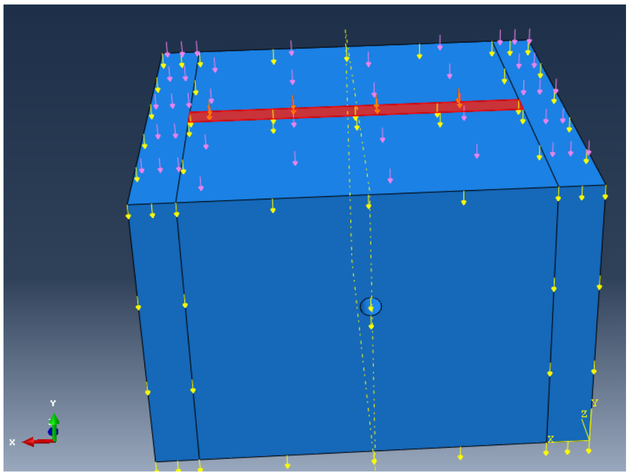
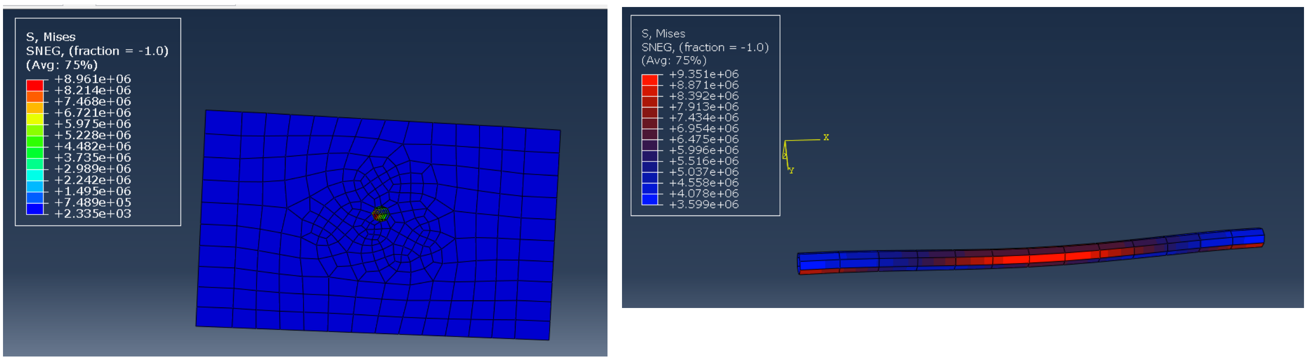


Figure 5. Diagram of load loading

To determine whether the force of the lower pipe meets the design value when the wall is laid on the upper part of the pipe, the force of the pipe after the wall is laid is analyzed, as shown in **Figure 6**.



(a) Overall (b) Pipeline

Figure 6. Mises stress of pipeline

As shown in **Figure 6**, it can be seen from the calculation that the Mises equivalent stress generated by the upper brick wall to the pipeline is 8.96 MPa, and its maximum value appears at the top of the pipeline.

4. Conclusion

The large-scale finite element analysis software ABAQUS was used to calculate the additional pressure generated when a wall is placed above the pipeline. The results show that the stress on the pipeline under working condition 1 exceeds the design allowable value of 10 MPa, which could pose a danger. In working condition 2, the stress is close to 10 MPa, making it similarly dangerous

Disclosure statement

The author declares no conflict of interest.

References

[1] Huang S, Lv Y, Peng Y, 2016, Dynamic Response of Sandy Slope Under Coupling of Earthquake and Groundwater. Geotechnical and Geological Engineering, 34(3): 889–899.

[2] Huang S, Lv Y, Peng Y, et al., 2015, Effect of Different Groundwater Levels on Seismic Dynamic Response and Failure Mode of Sandy Slope. Plos One, 10(11): e0142268.

[3] Muleski GE, Ariman T, Aumeri CR, 1979, A Shell Model of a Buried Pipe in Seismic Environment. Pressure Vessel Technology, 1979(101): 44–55.

[4] Chiou YJ, Chi SY, 1996, Numerical Modeling for Buckling of Buried Pipelines Induced by Compressive Ground Failure. Journal of the Chinese Institute of Engineers, 19(3): 321–332.

[5] Newmark NM, Hall WJ, 1975, Pipeline Design to Resist Large Fault Displacement. Earthquake Engineering Res Inst, 1975: 416–425.

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Application Strategies of Pipe Jacking Technology in Municipal Rainwater Pipeline Engineering

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Abstract: Traditional construction techniques have a significant impact on the environment and are associated with long construction durations in the construction of municipal rainwater pipelines. Pipe jacking technology, a new type of pipeline construction method, enables non-excavation construction and can address the shortcomings of traditional pipeline construction. This article analyzes the concept and application advantages of pipe jacking technology. Combining engineering examples, it explores the application strategies of pipe jacking technology in the construction process of municipal rainwater pipelines for reference.

Keywords: Municipal engineering; Rainwater pipeline; Pipe jacking construction

Online publication: November 28, 2024

1. Introduction

During the construction phase of municipal engineering, pipelines constitute an important aspect of the work. As a non-excavation pipeline construction method, pipe jacking technology has minimal impact on ground buildings and activities during its application. Therefore, it offers significant advantages in the construction of rainwater pipelines. However, the pipe jacking construction process also entails risks, requiring careful control of key points to ensure construction quality.

2. Overview of pipe jacking construction technology

2.1. Concept of pipe jacking construction technology

Pipe jacking construction technology, widely applied in municipal rainwater pipeline projects, falls under the category of non-excavation construction techniques. During the construction process, relevant managers and workers must conduct a detailed analysis of the potential negative impacts that the project may cause, necessitating continuous optimization and improvement of this technology. Additionally, the use of pipe jacking technology can reduce construction noise, minimizing disturbance to surrounding residents even during nighttime operations. While this method allows for deep underground work, its relatively high research and development costs can somewhat increase overall construction expenses and extend the project timeline. Therefore, companies need to select and apply various pipe jacking techniques based on the specific environmental and geological conditions encountered during the actual construction process. Furthermore, the application of pipe jacking technology in municipal rainwater pipeline construction requires vertical alignment with the ground surface, aided by jacks, to establish a solid foundation for the project [1].

2.2. Advantages of pipe jacking construction technology

In recent years, the scale of urban development in China has been expanding continuously, with concurrent improvements in urban transportation and economy. However, many municipal rainwater pipelines in older urban areas still face issues such as leakage and aging, necessitating reasonable upgrades and renovations in densely populated regions [2]. The application of pipe jacking construction technology in municipal rainwater pipeline projects offers numerous advantages. It not only avoids many demolition steps but also ensures safety and stability during the construction phase. Moreover, it enables effective cost control and improves construction efficiency to a certain extent. Consequently, pipe jacking construction technology stands out as a preferred choice in current municipal rainwater pipeline projects [3].

Furthermore, the rational application of pipe jacking construction technology in municipal rainwater pipeline projects can minimize the impact of traditional construction methods. It reduces adverse effects on surrounding roads and vegetation, thereby enhancing the protection of the local ecological environment. Simultaneously, the construction activities have minimal impact on adjacent high-rise buildings and the daily lives of residents, minimizing the occurrence of engineering accidents and risks. As a result, this technology has gained recognition from numerous construction companies and the general public [4].

3. Application strategy of pipe jacking construction technology in municipal rainwater pipeline engineering

3.1. Project overview

This project starts at the inspection well of the new road and crosses the existing road to construct a municipal rainwater pipeline. However, through field investigations, it was found that there are various important pipeline facilities such as water supply pipelines, sewage pipelines, and gas pipelines near the existing road. Therefore, it is necessary to design and plan ahead of time based on actual conditions before the construction work begins, to ensure the smooth construction of the municipal rainwater pipeline project and avoid impacts on various pipelines. Additionally, geological survey results indicate that the pipeline construction of this project needs to cross the pebble layer. Due to the strong bearing capacity, strong water permeability, and resistance to deformation of the pebble layer, the open hand-dug jacking method needs to be applied to carry out the construction work [5]. Furthermore, due to the high traffic volume on the road, it is also necessary to consider the disturbance to the ground during the construction process and coordinate with relevant departments to semi-close the road section to ensure smooth construction.

3.2. Introduction to engineering construction technology

3.2.1. Open construction technology

An important component of open construction technology is the hand-dug tool pipe. However, in practical applications, the hand-dug tool pipe involves direct excavation of the construction surface by construction workers. Before excavation, it is necessary to observe the local soil conditions and working surface and develop corresponding measures to address problems encountered during construction. Additionally, the hand-dug tool pipe has advantages such as ease of application and low cost, but its main disadvantage is its high requirement for groundwater level. Therefore, detailed measurements and appropriate adjustments to the groundwater level are required before construction [6].

Moreover, the extruded tool pipe is also an important part of the open construction technology. Its main working principle is to disconnect the working surface using a breastplate. The extruded tool pipe is mainly a trumpet-shaped conical cylinder. When this tool is forcefully extruded, the main body is squeezed into the trumpet mouth, forming a long soil column through the trumpet mouth. When the soil column reaches a certain length, it can be cut off with steel wire and transported to the ground using soil transportation equipment. Therefore, through relevant research and practice, it can be understood that this method is more suitable for wet clayey soil, sandy soil, and large and medium-diameter pipelines. The extruded tool pipe also has advantages such as simple operation and safety [7].

3.2.2. Closed construction technology

In closed construction technology, the hydraulic cutting head is an important piece of equipment. Simultaneously, there is a sealed pipe in front of the head, which contains a mud suction port, high-pressure water gun, mud transportation pipeline, and grating. Additionally, a vertical hinge is installed on the sealed pipe to improve the flexibility of the tool. Therefore, when using the hydraulic cutting head, it is easy to separate the left and right deviations from the upper and lower deviations without mutual interference, and the deviation position can also be identified. Furthermore, it is necessary to adjust the hinge position according to the actual situation and different needs, to effectively meet the requirements of pipe jacking construction under various soil conditions.

4. Installation of pipe jacking construction equipment

4.1. Installation of guide rails

Before installing the guide rails, relevant staff should first check the center position of the pipeline and calculate the guide rail gauge to ensure that the centerline of the reserved hole overlaps with the centerline of the guide rail. Moreover, when selecting the guide rail, detailed analysis is required based on the pipe diameter. Since this project has chosen a crane rail, it is necessary to use railway nails to fix the guide rail [8]. Additionally, when setting the center elevation of the guide rail surface, it should be based on the designed elevation of the pipeline ditch bottom, while ensuring that the two have the same slope. This improves the stability and safety of the guide rail installation and ensures that problems such as deformation, displacement, or settlement do not occur during pipe jacking construction.

4.2. Installation of pipe jacking equipment

During the installation of pipe jacking equipment, a large crane is required to transport the jack to the preset position, and supports are needed to fix it. In the installation and fixing process, a jack should be set on each side of the pipeline, ensuring they are symmetrical on both sides. Since the jack cannot be directly applied to the pipeline for jacking, it is necessary to install a jacking iron to increase the contact area and disperse the stress to some extent [9]. Furthermore, the size and installation position of the jacking iron should be clarified according to actual needs, and when the jacking force is close to the compressive strength of the pipeline, it is necessary to appropriately add annular or U-shaped jacking irons.

5. Application of pipe jacking construction technology

5.1. Inspection before jacking

To ensure the overall quality of pipe jacking construction work, it is necessary to conduct pre-construction inspections. Firstly, all equipment should be inspected to ensure their normal operation. Secondly, all piping materials should be inspected to clarify their quality. Finally, the slope, centerline, and elevation of the guide rails should be checked to ensure they meet the actual requirements.

5.2. Jacking process

Firstly, in this project, manual excavation is mainly used for pipe jacking construction. The excavation work should be timely coordinated with the jacking operation to minimize jacking force limitations. Before excavation begins, the soil layer should be cut with a blade, followed by layer-by-layer excavation from top to bottom. During excavation, the excavation scope should be reasonably controlled to prevent collapse issues, thus ensuring the normal progress of pipe jacking construction. Additionally, relevant management and construction personnel should monitor the excavation situation in real time to avoid over-excavation, thereby minimizing the impact on the foundation and preventing pipe-end settlement. Furthermore, if the excavation area encounters a weathered rock, which is difficult to excavate manually, methods such as water drilling for coring or rock breaking with a pneumatic pick should be applied. The excavated soil should be promptly transported out using a four-wheel transport trailer to facilitate subsequent construction work [10].

Secondly, a crane should be selected based on the actual situation and requirements of the project to carry out pipe-lifting work, with manual assistance. During the construction process, nylon lifting belts should be used to fix both ends of the pipe, which is then placed in the working pit using the crane. It is important to note that the pipe-lifting process should be stable and slow. Workers should also use hemp ropes for traction to ensure the pipe remains stable. When lowering the pipe, the speed should be minimized to avoid damage and ensure project quality.

Thirdly, during the jacking process, the principle of “excavate first, then jack; excavate as you jack” should be strictly followed. In the initial stage of construction, the jacking speed should be reasonably controlled and kept as low as possible. Only after the pipe has been jacked a certain length and is tightly in contact with the soil can the jacking speed be appropriately increased. Additionally, after one jack is completed, detailed measurements should be taken. If deviations are found, timely corrections should be made, and jacking operations can only continue after installing the jacking iron. After jacking out one section of the pipe, the jack should be retracted. The next section of the pipe should be lifted into place and adjusted before continuing the jacking work. This process should be repeated until the jacking work is complete. During the jacking process, thixotropic mud can be injected around the pipe section to reduce resistance. If there are obstacles underground, reasonable methods should be used to remove them before continuing the jacking work. In case of special situations such as a significant increase in jacking force, jacking must be immediately stopped, and workers should promptly leave the pipe. The cause of the accident should be analyzed, and only after taking safety measures to eliminate the abnormality can excavation and jacking be resumed.

Then, during the pipe jacking construction, if the allowed total jacking force is lower than the jacking resistance and it is difficult to complete the jacking in one go, it is necessary to reasonably set up relay stations for segmented relay jacking. However, if the jacking exceeds a certain length during the construction process of this project, it is necessary to set up the relay station at the middle position of the pipe and divide the pipeline into two sections. The relay station mainly includes a jack, a rear shell, and a front shell, where the rear shell is connected to the rear pipe, and the front shell is connected to the front pipe, with the main connection method being a socket-type connection. Additionally, both the pipe section’s outer diameter and the shell’s outer diameter have relatively high rigidity and strength, as well as manufacturing precision. During the jacking work, all jacks are reasonably arranged along the circumference and connected to the front shell using fasteners, forming a certain pushing force to jack the pipeline ahead of the relay station.

Finally, in the construction process of municipal rainwater pipeline engineering, the pipe interface is an extremely important component that can directly affect the construction quality. If not handled properly, it may even lead to pipe leakage problems. However, in this project, steel socket joints are mainly used. Therefore, during pipe lifting, it is necessary to avoid lifting through the pipe and instead use lifting belts at both ends of the pipe to prevent damage to the pipe socket. Before lowering the pipe, it is also necessary to timely clean the soil and debris at the socket position, put a rubber ring on the socket, and install a force transmission wooden pad. During the pipe-lowering process, attention should also be paid to transportation work, and the pipes should be placed as slowly as possible to reduce collisions, thus ensuring the safety of the pipeline. Only after the pipeline is placed can the jacking continue. After the pipe jacking work is completed, it is necessary to remove debris and soil from each socket joint, ensure that the entire pipeline has no leakage problems, and then use the specific sealing paste to fill the pipe joints to improve the overall quality of the project.

6. Grouting on the back of loose soil pipes

Due to the loose soil around the pipe jacking and the existence of gaps between the strata and the outer wall of the pipeline, it is necessary to perform back grouting on the completed jacked pipeline to achieve the purpose of compacting the gaps. This can also prevent pipeline leakage and sinking problems. In this project, the grouting holes are threaded pipe grouting holes set during the pipeline production process, and the grouting fluid used is double-liquid slurry. During grouting, it is necessary to install pre-made grouting pipe heads on the pipeline, and reasonably control the grouting volume and pressure. Only when there is a proper amount of slurry and grouting pressure in one grouting hole can the valve be closed. Finally, the grouting hole is sealed before continuing to the next grouting hole. The above operation is repeated until all grouting is completed.

7. Backfill construction and closed water test

Before carrying out pipe jacking construction, the corresponding machinery should be used for excavation. The quality of the working pit should be checked promptly, and only when it meets relevant standards and requirements can the next step of construction continue. Additionally, surrounding obstacles should be surveyed before pipe jacking construction, and backfilling should be performed at corresponding locations. Soil should be transported into the pit using transport vehicles and loaders, followed by leveling and compaction to improve the overall quality of the municipal rainwater pipeline project and provide convenience for people’s lives.

8. Conclusion

In summary, the application of pipe jacking technology in the construction of municipal rainwater pipelines not only has a small impact on the environment but also high construction efficiency. During the practical application stage of the technology, technicians are required to proceed from reality, combining the hydrological and geological environmental characteristics of the construction area, and selecting technical application measures based on the actual needs of the project. They should standardize the technical application process, perform quality control work in construction links, leverage the advantages of pipe jacking technology, and provide support for the high-quality construction of rainwater pipeline projects.

Disclosure statement

The author declares no conflict of interest.

References

[1] Gu W, 2023, Research on Rainwater Pipe Network Design Method in New Municipal Road Engineering Planning Scheme - Taking Tianwang West First Road in Area B of Chengdu Medical City as an Example. Value Engineering, 42(18): 4–6.

[2] Lan S, Lu Y, 2022, Design and Planning of Rainwater Pipe Network for Municipal Roads. Building Technology Development, 49(7): 50–53.

[3] Gao J, 2024, Key Technical Points of Rainwater and Sewage Separation Pipeline Construction in Municipal Engineering. Building Materials and Decoration, 20(5): 4–6.

[4] Zhong L, 2023, Analysis of Main Influencing Factors and Design Schemes for the Layout of Drainage Pipelines in Municipal Roads. Bulk Cement, 2023(6): 169–172.

[5] Li X, 2022, Design of Sewage and Rainwater Pipelines in Municipal Water Supply and Drainage Engineering. Town Construction, 2022(9): 328–330.

[6] Fu C, Zhang S, 2023, Analysis of Quality Control Countermeasures for Municipal Pipe Network Rainwater and Sewage Pipeline Construction. Real Estate Guide, 2023(18): 149–150, 153.

[7] Mi X, Yan F, Xiao Y, 2022, Construction Technology of Dragging Pipes for Rainwater Pipelines in Complex Sections. Yunnan Hydropower, 38(10): 131–135.

[8] Zhao Y, 2024, Key Technologies for Long-distance Pipe Jacking Construction of Municipal Sewage Pipelines. Scientific and Technological Innovation, 2024(14): 91–94.

[9] Li F, 2024, Non-excavation Pipe Jacking Construction Technology in Municipal Water Supply Construction. Water Safety, 2024(10): 139–141.

[10] Liu Z, 2024, Construction Technology of Earth Pressure Balance Pipe Jacking Undercrossing Municipal Main Roads. Engineering Construction and Design, 2024(2): 143–145.

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Optimization of Wetland Plant Selection and Configuration in Urban Water Environment Ecological Restoration Projects

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Abstract: In urban water ecological restoration projects, the selection and configuration of wetland plants are crucial for water quality improvement, ecological diversity enhancement, and landscape beautification. Different plants have different characteristics, and a scientific and rational selection and optimization of plant species is needed. This paper proposes an optimized plant selection and configuration scheme for urban water ecological restoration based on the ecological characteristics and pollutant removal performance of wetland plants. It analyzes the diversity, removal mechanisms, and configuration modes of wetland plants, taking into account ecology, aesthetics, and cost-effectiveness, to provide scientific evidence for wetland plant configuration and support water environment management decision-making.

Keywords: Wetland plants; Water environment restoration; Plant configuration optimization; Pollutant removal; Ecological restoration

Online publication: November 28, 2024

1. Introduction

Nowadays, urban water environment pollution is severe and is hindering sustainable development. Industrial and domestic wastewater has put tremendous pressure on the aquatic ecosystem, leading to deteriorating water quality and ecological imbalance. Wetlands, which are eco-friendly restoration measures, are widely used. The selection and rational configuration of wetland plants are crucial to the removal of pollutants and the stability of the ecosystem. Choosing suitable wetland plants and configuring them scientifically and effectively is the key to efficiently restoring urban water environments. In this context, this paper systematically explores the optimal configuration strategies of wetland plants in water environment restoration, providing scientific references for solving urban water pollution problems.

2. Current status of urban water environment pollution and the demand for wetland restoration

The problem of water environment pollution in cities has become increasingly serious in the context of accelerating urbanization and has already begun to harm the stability of ecological systems and the quality of human life. The sources of water pollution are diverse, including industrial wastewater, domestic sewage, agricultural runoff, and urban surface runoff. When various pollutants enter the water body, they not only cause a significant deterioration of water quality but also cause damage to the diversity of aquatic organisms and the functioning of ecological systems. The excessive release of nutrients such as nitrogen and phosphorus can lead to the eutrophication of water bodies, causing excessive algal growth and the formation of water blooms, further degrading the habitat of aquatic plants and fish, and gradually destabilizing the ecosystem [1]. The heavy metals, organic pollutants, and microplastics generated during urbanization have a cumulative effect, not only accumulating in the food chain but also posing a long-term potential threat to human health.

Among various water body restoration methods, wetland restoration has attracted widespread attention due to its eco-friendly nature, relatively low cost, and long-term ecological benefits [2]. Wetland systems possess superior pollutant removal functions through multiple mechanisms, including physical, chemical, and biological processes, and are effective in removing nitrogen, phosphorus, organic matter, and some heavy metals. Wetland plants, as the core constituent parts of the wetland system, play a crucial role in restoring the environment by adsorbing, depositing, and transforming pollutants through their root systems. The surface of plant roots provides a good habitat for microorganisms, further enhancing the wetland's pollutant degradation capacity. Different types of wetland plants have unique features in terms of pollutant removal efficiency, adaptability, and ecological functions.

The urgent need for urban water environment restoration requires the implementation of wetland restoration projects, which are largely dependent on the scientific configuration of wetland plants. The scientific configuration of wetland plants not only significantly improves the efficiency of pollutant removal, but also improves the ecological structure of water bodies and enhances the overall environmental quality of the city. The plant selection and configuration in urban water body restoration projects should be based on the plant's ecological adaptability, pollutant removal capacity, and contribution to the stability of the overall water ecosystem [3]. In addition to the ecological value, the planting of wetland plants also needs to consider their aesthetic value, balancing ecology and landscape to achieve a win-win situation of ecological and social benefits. Therefore, it is of great practical significance and potential application value to deeply study the strategies of wetland plant selection and configuration optimization in urban water environment restoration.

3. Ecological characteristics and pollutant removal mechanisms of wetland plant selection

Wetland plants play a crucial role in the process of urban water environment restoration. Their ecological characteristics have a direct impact on the efficiency of pollutant removal. Wetland plants can effectively remove nutrients such as nitrogen and phosphorus from water bodies, as well as some heavy metal pollutants, through the absorption, transfer, and degradation of their roots, stems, and leaves. These plants have a strong tolerance to pollution, especially in micro-polluted and heavily polluted water bodies, where they show high adaptability [4]. Some root systems that are well-developed, such as reeds and cattails, can adsorb suspended particles and heavy metals, and other pollutants through their extensive root network, forming a natural filtration system. Wetland plants can secrete a variety of organic compounds during their growth, providing nutrients for microbial communities and further promoting the degradation and transformation of pollutants. The ecological adaptability and diversity of these plants provide a rich selection for water environment restoration.

The core mechanism by which wetland plants play a role in pollutant removal is the synergistic action of physical, chemical, and biological processes [5]. Physical adsorption, achieved through the interaction between plant roots and sediment interfaces, can effectively capture suspended solids, heavy metals, and many more. Chemical precipitation relies on the compounds secreted by plant roots, which undergo complex oxidation-reduction reactions with water pollutants, thereby removing organic pollutants and heavy metals from the water. The microenvironment of the plant root zone creates suitable conditions for the proliferation of microorganisms, especially the alternating distribution of anaerobic and aerobic environments in the root zone, which enables microorganisms to efficiently degrade organic matter and transform nitrogen, phosphorus, and other pollutants, further enhancing the effect of water purification. The multi-faceted role mechanism of wetland plants makes them highly adaptable and flexible in responding to different types and concentrations of pollutants.

The selection of wetland plants should not only take into account their ability to remove pollutants but also consider the mutual suitability between plants and the environment, especially the importance of biodiversity for the long-term stability of wetland ecosystems. The combination of different wetland plants is beneficial for improving the resilience of the entire ecosystem, so that the wetland ecosystem can show higher resilience when facing pollution pressure [6]. Combining salt-tolerant plants with those that have a high tolerance to heavy metals can achieve more efficient purification effects for different polluted environments. Selecting suitable wetland plants and properly configuring them can help build a stable and sustainable ecosystem in water body restoration, achieving a balance between plants, microorganisms, and the water environment, thus providing a solid ecological foundation for the long-term management of urban water pollution.

4. Patterns and principles of wetland planting

The planting pattern and principles of wetland plants directly affect the overall performance of water body restoration, and in wetland restoration projects, a reasonable planting pattern can maximize the purification function of wetland plants and ensure the stability and diversity of the ecological system. Common wetland planting patterns include community-based, layered, and belt-shaped methods [7]. The community-based planting focuses on the community structure of plants, and usually, multiple plants are planted in a larger area to enhance the purification effect through the synergistic action of plants. This method is suitable for large-scale wetland restoration projects and can effectively enhance the resilience and stability of the system. The layered planting method, on the other hand, divides the plants into layers based on their height, root distribution, and growth habits, forming a multi-layer structure above ground, on the surface, and underground, which can improve the filtration efficiency of water flow and promote the decomposition and absorption of pollutants.

In the process of wetland plant configuration, adhering to scientific planting principles is crucial to ensuring the restoration effect. When planting wetland plants, the first thing to consider is the ecological adaptability of the plants, and suitable plants for the local water environment should be selected to ensure their stability in the polluted environment. It is necessary to ensure the diversity and stability of the plant community structure to improve the resilience and restorative capacity of the entire wetland system [8]. Different plants have different removal efficiencies for pollutants, and a diverse plant combination can form a complementary system. For example, plants with well-developed root systems can effectively adsorb solid pollutants, while plants with strong resistance to pollution can survive and continue to play a restorative role in environments with higher pollution loads.

Another important principle in wetland planting is to focus on the organic combination of water purification function and landscape function. Wetlands are not only an important part of water body restoration but also a key node in the urban green space landscape. Therefore, when planting, consideration should be given to aesthetic effects [9]. By combining plants of different colors, heights, and shapes, a rich sense of layering can be created, enhancing the aesthetic value of the wetland and improving the ecological awareness and sense of participation among citizens. In response, a rational wetland planting configuration should also consider the economic feasibility of cost and maintenance, scientifically configuring plants to reduce the need for subsequent management and maintenance, thus achieving a balance between ecological, social, and economic benefits.

5. Optimization strategies for plant configuration in urban water environment restoration

In the restoration of the urban water environment, the optimization strategy of plant configuration is of great importance, which directly determines the purification effect and long-term stability of the wetland ecological system. The core of optimizing plant configuration lies in selecting suitable plant species based on the characteristics of different pollutants and the actual water environment and scientifically designing their distribution patterns. Analysis of the types and concentrations of water pollutants can effectively combine plants with different decontamination abilities to form a multi-functional purification system [10]. In water bodies with high nitrogen and phosphorus content, plants with high nutrient absorption capacity, such as cattails and reeds, can be given priority to accelerate the control of eutrophication. In water bodies with severe heavy metal pollution, plants with heavy metal adsorption ability, such as water lilies and artemisia, can be planted to improve the removal of heavy metals.

The diversity and growth habits of wetland plants are different, and a rational planting strategy can effectively enhance the resilience of the ecological system so that it can maintain a stable purification effect in the face of pollutant impacts or changes in hydrological conditions. Different species, shapes, and growth periods of plants can be introduced to construct a multi-layered, multi-functional ecological structure [11]. Combining floating plants, submerged plants, and emergent plants can make them effective in different water depths and habitats, which not only enhances the comprehensive removal of pollutants but also enhances the interactions between plants and improves the self-regulatory capacity of the wetland ecosystem, ensuring that it has strong resilience under various external interference and achieves sustainable water environment restoration effects.

Plant configuration optimization also needs to consider the combination of ecological restoration and urban landscape functions, paying attention to the coordination of ecological benefits and aesthetic value. Wetlands, as part of the city's green infrastructure, not only bear the function of water quality purification but also serve as an important component of the urban ecological landscape [12]. During the optimization of plant configuration, consideration can be given to factors such as plant height, color, and seasonal changes to design plant communities with a sense of hierarchy and aesthetic effects, thereby enhancing the diversity of the wetland landscape. Rational plant configuration can also reduce the management cost of wetlands and reduce the maintenance needs of subsequent restoration projects. By implementing plant configuration optimization strategies, wetlands will no longer be mere tools for water environment governance but can become ecological landscape nodes in the city, thereby enhancing the public's environmental awareness and ecological literacy and providing strong ecological support for the sustainable development of the city.

6. Evaluation of the implementation effect of wetland planting configuration

The implementation effect assessment of wetland planting is an important link to ensure that urban water environment restoration projects achieve their expected results. It is also a key means to verify the scientificity and effectiveness of planting optimization strategies. The evaluation content usually covers multiple dimensions, including water quality improvement, ecosystem stability, and landscape effects [13]. In terms of water quality improvement, the main focus is on monitoring the removal rates of major pollutants such as nitrogen, phosphorus, chemical oxygen demand (COD), and heavy metals in water bodies. Long-term tracking of pollutant concentration changes is carried out to evaluate the actual effects of wetland plants in removing organic pollutants, controlling eutrophication, and reducing heavy metal content. Data on water quality improvement can be obtained through regular sampling and laboratory analysis, which can determine whether the wetland plant configuration has effectively achieved the degradation and removal of pollutants, thereby providing the scientific basis for further configuration adjustments.

When assessing the stability of wetland ecosystems, it is important to focus on the growth of wetland plants, biodiversity, and the activity of microbial communities. The healthy growth of wetland plants indicates that they have strong adaptability and purification capabilities. The biodiversity index reflects the resilience and regeneration capacity of the ecosystem. The activity of microbial communities is a key reference factor for assessing the internal biological remediation capacity of the wetland system, as microorganisms play a core role in pollutant degradation [14]. When evaluating the effectiveness of wetland plant configuration, one can observe parameters such as plant coverage and species richness to measure the stability of the system, and can also use molecular biology techniques to detect the diversity and activity of rhizosphere microorganisms to analyze the contribution of microbial-plant synergistic action to the efficiency of pollutant removal.

As an indispensable part of the urban ecosystem, wetlands are not only capable of providing ecological benefits in water environment restoration but also play an active and important role in improving the urban landscape and living environment for residents. Assessing the aesthetic effects, landscape hierarchy, and seasonal changes of wetland planting can determine whether the wetland planting configuration has effectively improved the overall landscape quality of the city [15]. By conducting public feedback surveys, the situation of the wetland ecological restoration project in residents' environmental awareness and ecological literacy can be understood, and the social impact of the project can be evaluated accordingly. A scientifically reasonable wetland planting configuration is not only capable of achieving ecological restoration functions but also should enhance the public's sense of identification and participation in ecological protection through its landscape effects, ultimately achieving the comprehensive benefits of urban water environment governance.

7. Conclusion

The scientific and rational planting of wetland plants in urban water environment ecological restoration is of great significance. Selecting plants with strong adaptability and high purification ability, optimizing the configuration mode and evaluating it, can improve water quality, restore ecological balance, and enhance the urban landscape and residents' ecological awareness. Its successful implementation is a manifestation of sustainable development and ecological civilization construction in cities. In the future, wetland restoration technologies and planting strategies will continue to be optimized to provide more scientific and comprehensive solutions for urban water body restoration, thereby contributing to urban ecological construction.

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References

[1] Han J, 2024, Research on Urban Water Environmental Ecology Monitoring and Spatial-Temporal Evolution Patterns. Cleaning World, 40(10): 90–92.

[2] Li G, Cui G, Zhu Y, et al., 2024, Restoration and Comprehensive Treatment of Urban Water Environment. Residence & Industry, 2024(10): 61–63.

[3] Yang Z, 2024, Study on the Ecological Carrying Capacity of Urban River Water Environment for Wastewater Absorption. Environmental Science and Management, 49(10): 159–163.

[4] Wang Q, 2024, Key Points and Strategies for Ecological Restoration of Urban River Water Environment. Heilongjiang Environmental Bulletin, 37(09): 117–119.

[5] Yan L, Han X, Fan Y, 2024, Research on Integrated Technology for Urban River Ecological Construction and Water Environment Safety Assurance. Leather Making and Environmental Protection Technology, 5(17): 58–60.

[6] Song W, Zhao Z, Han L, et al., 2024, Analysis of Ecological Water Environment Treatment Scheme for Urban Rivers. Leather Making and Environmental Science and Technology, 5(16): 67–69.

[7] Chen X, Zhu H, Jia D, et al., 2024, Study on the Calculation Method of Ecological Restoration Water Threshold for Typical Urban Rivers. Water Resources and Hydropower Technology (Chinese and English), 2024: 1–13.

[8] Wang Z, Sun G, 2024, Application Research on Multi-dimensional Ecological Restoration Technology in Urban Water Environment Governance. China Strategic Emerging Industries, 2024(14): 147–149.

[9] Wang D, 2024, Application Research on Multi-dimensional Ecological Restoration Technology in Urban Water Environment Governance. Future Urban Design and Operation, 2024(01): 44–46.

[10] Ding X, Zhao S, Wang Z, 2024, Research Progress on Urban Water Environmental Ecological Restoration Technology. Guangdong Chemical Industry, 51(2): 90–91 + 115.

[11] Shi H, Wang Y, Chen C, 2023, Research on Ecological Safety Evaluation of Urban Water Environment. Water Resources Planning and Design, 2023(5): 34–40.

[12] Wang Y, 2022, Water Environmental Ecological Restoration and Analysis of Environmental Flow Requirements in a City. Hunan Water Resources and Hydropower, 2022(2): 48–50.

[13] Wang Z, 2021, Urban Water Environmental Ecological Restoration Issues and Solutions. Shanxi Water Conservancy, 37(01): 11–12.

[14] Shi L, 2020, Urban Water Environmental Ecological Restoration Issues and Solutions. Engineering Technology Research, 5(13): 242–243.

[15] Sun C, 2019, Research on Urban Water Environmental Restoration. Smart City, 5(23): 145–146.

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Research on the Renovation of Rural Buildings Suitable for Aging Populations Based on Cross-Analysis

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Abstract: Based on the intersection of "Implementing the National Strategy to Actively Cope with Population Aging" and "Guiding Opinions on Future Rural Construction" in Zhejiang Province, this study constructed the evaluation index system of rural age-appropriate building space. This is done by analyzing the current situation locally and internationally, summarizing the existing problems, and optimizing countermeasures. The cross-analysis method is adopted by fully listening to the opinions of the elderly and introducing a professional team to transform the physical, psychological, and rural natural environment of the elderly. The renovation strategies of building layout, indoor and outdoor space, and supporting facilities for the elderly are put forward. Looking to the future, including the application of intelligent technology, the development of a community pension model, and multi-party cooperation, it aims to create a comfortable, safe, and convenient living environment for rural elderly people, improve the quality of life, promote rural revitalization and actively respond to the challenges of population aging.

Keywords: Cross-analysis; China; Aging population; Rural building renovation

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1. Introduction

With the acceleration of population aging in China, actively addressing the needs of the aging population has become a national strategy. At the same time, the implementation of the rural revitalization strategy has created new opportunities for rural development. In the context of these two major policies, accelerating the renovation of rural buildings to make them suitable for an aging population holds great practical significance [1]. The purpose of this study is to develop a set of evaluation indices for aging-friendly building spaces in rural areas, aimed at improving the quality of life for the rural elderly, promoting rural revitalization, and proactively addressing population aging.

2. The importance of age-appropriate building space in rural areas

Firstly, it is essential to meet the needs of the elderly. Rural areas have a large elderly population with higher requirements for safety, convenience, and comfort in their living environments. Renovating building spaces to be age-appropriate can address the daily needs of the elderly and improve their quality of life [2].

Secondly, the renovation will support rural revitalization. By making rural building spaces more age-friendly, it can encourage more elderly residents to remain in rural areas, bringing additional human resources and consumer demand to boost the rural economy. This renovation can also enhance the overall image and attractiveness of rural areas, further supporting the rural revitalization strategy.

Thirdly, this approach actively addresses population aging. Renovating rural spaces for aging populations is an important step in responding to the challenges of an aging society. Improving the living environment for elderly residents can enhance their self-care capabilities and well-being, while also reducing the caregiving burden on families and society [3].

3. Research on rural aging-friendly building space, locally and internationally

3.1. Local research status

3.1.1. Existing problems

Domestic research on aging-friendly rural buildings primarily identifies the following issues: inadequate infrastructure, such as uneven roads and a lack of barrier-free facilities; limited spatial flexibility that fails to meet the diverse needs of the elderly; and wasted natural resources, as the rural natural environment is not fully utilized in age-friendly design [4].

3.1.2. Optimization countermeasures

To address these issues, domestic scholars have proposed various optimization strategies. Progressive transformation, spatial complexity, predictive design, attention to detail, and maximizing existing advantages offer new approaches for the protection and development of traditional villages. Transformation strategies for traditional village landscapes in Hunan include adjustments to waterfront areas, public buildings, and road spaces. From the perspective of smart governance, these strategies advocate for age-appropriate renovations in rural building spaces, supported by a smart elderly care system. They emphasize that the design of elderly care spaces should meet the needs of the elderly while prioritizing safety and comfort. Additionally, an age-friendly transformation demand scale has been developed to assess the home environment needs of rural elderly individuals with disabilities.

3.2. International research status

International research on age-friendly rural renovation focuses on maximizing the cost-effectiveness and overall benefits of age-appropriate interventions. It emphasizes that sustainable transformations of cities and villages should begin with technical and social diagnostics, followed by comprehensive assessments aimed at enhancing social benefits and economic value. An innovative approach has been introduced for designing rural architectural environments with tailored parameters for different age groups of the elderly, aiming to maximize benefits.

4. Renovation method of rural buildings suitable for aging population based on cross-analysis

The renovation method of rural age-appropriate building space based on cross-analysis aims to create a more comfortable, safe, and satisfying living environment for rural elderly people [5].

The first step of cross-analysis is to combine the physiological characteristics of the elderly with the physical characteristics of the building space. Considering that the physical function of the elderly is declining and the movement may be inconvenient, it is necessary to pay attention to barrier-free design in the renovation of architectural space. For example, door openings were widened for wheelchair access, gentle ramps were installed instead of stairs, and strong handrails were installed in hallways and toilets [6]. Simultaneously, use non-slip ground materials to reduce the risk of elderly people slipping.

Secondly, from the perspective of psychological needs, elderly individuals in rural areas often have a strong desire for social interaction and care. Increasing public activity spaces by transforming the building layout—such as creating shared courtyards or activity rooms for the elderly—can provide spaces for communication and recreation, helping to alleviate their loneliness [7].

Thirdly, a cross-analysis is conducted in conjunction with the advantages of the rural natural environment. By leveraging the fresh air and beautiful scenery of the countryside, leisure walks and viewing platforms can be incorporated around the building to encourage outdoor activities for the elderly, promoting both physical and mental health. Small gardens can also be created for the elderly to engage in planting, adding to the enjoyment of life.

During the renovation process, it is essential to fully consider the opinions and suggestions of the elderly. Through methods such as questionnaires, symposiums, and other forms of feedback, their actual needs and expectations should be understood, allowing for continuous adjustments to the transformation plan. Concurrently, professional design teams and elderly care service institutions should be involved in the renovation of age-appropriate rural building spaces to ensure that the renovated areas are not only aesthetically pleasing and functional but also meet the specific needs of the elderly, thereby laying a solid foundation for the development of rural elderly care [8].

5. Space transformation strategy of rural aging buildings

The renovation strategy for rural aging building spaces includes optimizing building layouts, renovating indoor spaces, improving outdoor environments, and providing supporting elderly service facilities. The architectural layout should prioritize ventilation, lighting, public spaces, and the efficient use of idle buildings. Indoor design should focus on functional zoning, lighting, ventilation, and age-friendly features. Outside, barrier-free facilities should be added, roads improved, and leisure areas and greenery enhanced. Elderly service facilities should be tailored to local needs, encourage social participation, strengthen management and operation, and establish a comprehensive service system. These strategies aim to create a comfortable, safe, and convenient living environment for rural elderly residents, ultimately improving their quality of life [9].

5.1. Building layout optimization

In the renovation of aging building spaces in rural areas, the optimization of the building layout can be approached from the following aspects.

Firstly, scientifically plan the location and orientation of the buildings. Consider local climate conditions and topography to ensure a reasonable layout that promotes good ventilation and lighting. For example, the direction of openings should align with the prevailing wind direction to allow natural airflow into the interior. The building's orientation should also be adjusted according to the angle of sunlight, ensuring the elderly can fully enjoy sunlight.

Secondly, increase the spacing between houses moderately. This not only improves ventilation and lighting but also provides a quieter living environment for the elderly. Additionally, small gardens or green spaces can be planned in the open areas between houses, creating a natural atmosphere [10].

Thirdly, reserve sufficient space for public activities. Create a multifunctional square equipped with leisure benches, patio umbrella, and other amenities, making it convenient for the elderly to gather, chat, and enjoy the sun. Develop a beautiful garden with a variety of flowers and greenery, providing an ideal place for the elderly to walk and appreciate nature.

Fourthly, repurpose idle building resources. Old houses and warehouses in rural areas should be evaluated and transformed into elderly service facilities such as activity centers and daycare centers. During the transformation, focus on functionality and comfort while improving the efficiency of resource utilization.

Finally, ensure integration with the overall rural environment. In architectural design, retain the characteristic landscapes and cultural elements of the countryside, allowing new buildings to complement the rural style and contribute to a harmonious, livable atmosphere.

5.2. Interior space renovation

The renovation of interior spaces in aging buildings in rural areas should consider multiple aspects. Firstly, optimize functional zoning scientifically. Position the bedroom near the entrance to facilitate access for the elderly and reduce mobility challenges. Place the bathroom adjacent to the bedroom for convenient nighttime use. Plan the interior layout to ensure that furniture placement does not obstruct movement paths and leaves sufficient activity space for the elderly [11].

Secondly, focus on improving the lighting and ventilation effect. The window size can be expanded, and the glass material with good light transmission can be used to increase the intake of natural light. Install ventilation equipment or reasonably designed vents to ensure air circulation and improve living comfort. Moreover, the comprehensive implementation of age-appropriate design. Install strong and suitable height handrails on the indoor walls to provide support for the elderly to get up and walk. Lay non-slip floor tiles to reduce the risk of slipping. Modify the stairs to reduce the slope, increase the width of the steps, and set up a rest platform. Add barrier-free toilets, equipped with sanitary ware and auxiliary facilities that are convenient for the elderly. Furthermore, it can also have personalized decoration according to the preferences of the elderly to create a warm and comfortable living atmosphere.

5.3. Improvement of outdoor environment

In terms of improving the outdoor environment of rural aging buildings, firstly, implement barrier-free facilities. Install ramps and handrails on roads, entrances, and steps to ensure safe and smooth travel for the elderly [12]. Secondly, the countryside roads should be leveled and hardened. Eliminate potholes and obstacles, improve traffic conditions, and facilitate the elderly to walk and use assistive devices such as wheelchairs. Thirdly, increase leisure facilities and green landscapes. Install fitness equipment suitable for the elderly, such as walking machines, waist twisters, and many more to meet their fitness needs. Set up benches for the elderly to rest and chat. Arrange flower beds and plant various flowers to add beauty and vitality. Fourthly, make full use of the rural natural environment. Preserve the original trees, mountains, rivers, and other natural landscapes, and create an ecologically livable rural landscape. Some flowers and trees can be planted around the area to create an outdoor environment with scenery in all seasons and provide a comfortable outdoor activity space for the elderly [13].

5.4. Supporting elderly care service facilities

Rural elderly care service facilities need to consider various factors. Firstly, the actual situation of rural elderly care should be assessed. This includes constructing elderly homes and apartments, equipped with professional nursing staff and medical facilities, to provide centralized care services for the elderly.

Secondly, actively encourage social participation in rural elderly care. Through policy guidance and financial support, attract businesses and social organizations to invest resources in developing home-based care services [13]. To provide the elderly with home nursing, rehabilitation services, meal assistance, and other diversified services to meet the needs of different elderly people. Moreover, the management and operation of elderly care service facilities should be strengthened. Establish and improve management systems, standardize service processes, strengthen personnel training, and improve service quality and level.

Finally, establish and improve the elderly service system. Integrate the resources of the government, society, enterprises, and other parties to form a joint force to provide all-round and multi-level elderly care services for the rural elderly, including life care, medical care, cultural entertainment, psychological comfort, and so on.

6. Prospects for the aging-friendly transformation of rural building space in the future

6.1. Application of intelligent technology

In the future, the application prospect of intelligent technology is broad in the renovation of rural aging-friendly building space. Smart home systems will become an important means to improve the quality of life of the elderly. Through smart devices, the elderly can remotely control home appliances, such as adjusting lights, temperatures, and many more, without getting up to operate, greatly improving the convenience of life. Simultaneously, health monitoring equipment can monitor the physical conditions of the elderly in real-time, such as heart rate, blood pressure, sleep quality, and so on, and transmit the data to family members or medical staff to detect potential health problems in time [14]. The intelligent security system provides comprehensive security for the elderly. For example, door and window sensors trigger an alarm if they detect abnormal openings, and smoke alarms quickly sound in the event of a fire. Additionally, intelligent voice assistants can help the elderly complete various operational instructions, such as querying the weather, playing music, and the like, to add fun to the life of the elderly. The application of intelligent technology will make rural aging buildings more convenient, comfortable, and safe.

6.2. Development of community pension model

The community pension model will play an important role in the future of rural pensions. Community service centers for the elderly will be built to provide diversified services for the elderly, such as daycare, rehabilitation nursing, culture, and entertainment. In terms of daycare, the elderly can be provided with catering, rest, entertainment, and other services, so that they can be properly taken care of during the day. In terms of rehabilitation care, it is equipped with professional nursing personnel and equipment to provide rehabilitation training and nursing services for the elderly in need. In terms of culture and entertainment, various cultural activities are organized, such as calligraphy, painting, singing, and the like, to enrich the spiritual life of the elderly. The community aged care model can also promote communication and interaction among the elderly and reduce loneliness. By constructing community service centers for the elderly, the desire for aging-in-place can be fulfilled, improving the overall quality of life for elderly individuals.

6.3. Promotion of multi-party cooperation

The renovation of rural building spaces suitable for the aging population requires the combined efforts of the government, society, enterprises, and families. The government should increase investment in rural elderly care, formulate relevant policies and regulations, and provide policy support for the renovation of aging-friendly buildings. For example, introducing preferential policies to encourage enterprises to participate in the construction of rural elderly care facilities, as well as increasing financial investment in elderly care services to improve their quality.

Social organizations can support rural elderly care through donations and volunteer services. Enterprises can leverage their technological and financial advantages to provide products and services for the renovation of rural aging building spaces. This may include developing smart home equipment, as well as rehabilitation and nursing equipment tailored for the elderly, and participating in the construction and operation of rural elderly care facilities.

Families should take on the responsibility of supporting the elderly, offering both care and emotional support. Family members should pay closer attention to the life and health of elderly relatives, providing them with companionship and spiritual support.

Through multi-party cooperation, a powerful collective force can be built to jointly promote the renovation of rural buildings suitable for aging, ensuring a better quality of life for rural elderly residents in their later years [15].

7. Conclusion

The renovation of rural age-appropriate building space is of great significance, which is not only related to the happiness of the elderly but also promotes the revitalization of the countryside and actively responds to the aging population. By constructing an evaluation index system, adopting a cross-analysis method, implementing a multi-faceted transformation strategy, and looking forward to future development direction, we are committed to creating comfortable, safe, convenient, and humane living spaces for rural elderly people. Let us work together to integrate the resources of all parties, promote the renovation of rural buildings suitable for aging, make rural areas a warm home for the elderly to enjoy their old age, and contribute to the realization of national strategic goals and sustainable development of rural areas.

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References

[1] Du P, Wang Y, 2021, Opportunities, Challenges and Solutions for the Construction of Rural Elderly Care Service System under the Background of Rural Revitalization Strategy. 2021(2019–4): 172–178.

[2] Qin Y, 2022, Research on the Integration of Red Culture into the Aging Construction of Rural Building Space under

the Background of Rural Revitalization: A Case Study of Jintian Township, Anfu County. Chinese Science and Technology Journal Database (full-text edition) Social Sciences, 2022(6): 33–36.

[3] Xia ZZ, 2023, Multiple Paths for Counties to Actively Respond to Rural Population Aging under the Rural Revitalization Strategy. Social Sciences of Guizhou, 2023(7): 144–151.

[4] Zhu Z, Sang Y, Xu L, et al., 2024, Evaluation of Building Space Suitable for Aging in Future Villages: Based on 12 Future Villages in Hangzhou. New Urbanization, 2024(7): 53–55.

[5] Xu H, 2023, Research on the Design of "Age-Appropriate" Public Leisure Space, thesis, Lanzhou University of Technology.

[6] Cao Y, 2024, Research on Aging of Public Space based on Public Health Needs, thesis, North China University of Technology.

[7] Wu W, Luo S, 2023, Study on Spatial Construction Characteristics And Development Countermeasures of Rural Courtyard in southwest Hubei. Urban Architecture, 20(5): 30–33.

[8] Xue Y, Wang S, 2024, Literature Research on Smart Medical Aging based on Visual Econometric Analysis. Ergonomics, 30(2): 73–80.

[9] Cui C, 2020, Research on Comprehensive Age-Appropriate Renovation Design of Existing Urban Residential Areas Based on Home-Based Community Nursing Model, thesis, Tianjin University.

[10] Lu T, 2021, Rural Human Settlement Environment Optimization and Residential Architecture Design Path Exploration. Beauty and Times, City, 000(002): 25–26.

[11] Guo J, Liang X, Xie Y, et al., 2023, Research on Aging Adaptation of Old Residential Interior Space Under Home Care Model. 2023(32): 166–169.

[12] Xu H, 2023, Research on the Design of "Age-appropriate" Public Leisure Space, thesis, Lanzhou University of Technology.

[13] Chen D, 2024, Study on the Effect of Core Strength and Fitness Path Exercise on Fall Risk Factors in Elderly Men, thesis, Tianjin Institute of Physical Education.

[14] Li T, Xu H, Ma S, et al., 2023, Analysis on Aging Adaptation of Public Space in Old Residential Areas Under the Background of Urban Renewal. Housing and Real Estate, 2023(34): 103–105.

[15] Wei S, Wang D, Zhang Y, et al., 2023, A Study on the Adaptation of Aging in the Future Rural Health Scene: A Case Study of Longmen Ancient Town, Fuyang District, Hangzhou. House, 2023(30): 142–145.

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Architecture and Sustainability: Integrating Health Performance Indicators in Sustainable Architecture — A Comprehensive Study on Enhancing Human Well-Being and Environmental Efficiency

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Abstract: The phrase "health and well-being" includes various aspects such as social, psychological, and physical factors. The way we design, construct, and operate buildings greatly affects people and their experiences. Costs associated with employees make up a significant part of expenses, and enhancing the well-being of those in the workplace can boost productivity. Optimizing buildings offers benefits, but it also presents challenges, particularly regarding energy consumption, material usage, and environmental impact. Eco-friendly buildings provide a solution to balance our comfort with the requirements of the environment. This article examines the impact of buildings on people and the environment, suggesting a framework for a "health performance indicator" to improve the research and practice of sustainable buildings, ultimately aiming to enhance both human and ecological well-being.

Keywords: Sustainability; Sustainable architecture; Water and energy efficiency

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1. Introduction

Human beings spend nearly 90% of their time in buildings, which largely impacts human health, happiness, performance, and safety [1]. Buildings consume a lot of energy and materials, have an impact on the environment, and are expensive to maintain. Thus, sustainable construction becomes an effective way to improve human lives while also protecting the environment. It has the potential to contribute to the achievement of global sustainability goals such as climate change, the development of sustainable and prosperous communities, and the promotion of economic growth. The advantages of sustainable construction are environmental, social, and economic [2]. As a result, it is critical to construct and renovate sustainably. This article will examine the beneficial and detrimental impacts of buildings on individuals and the environment, and we will provide a framework for establishing direct, objective, and leading "health performance indicators" for future studies on buildings and health [3].

2. Sustainable communities and sites

A construction project has a significant impact on the local community and the site itself [4]. There is a significant likelihood of loss of diversity, and cultural value, among other economic and use-values due to the construction of the proposed commercial development. The project must also meet sustainable community standards and reduce the rate of carbon emissions. With more than 55% of the global population living in cities, the risk of higher carbon emissions remains high [5]. The development will have to provide occupants with a place to relax, connect with nature, and take a break from the artificial world. Designing a mini-park or a futuristic garden will be ideal here given the limited space. Primarily, creating sustainable communities will require:

(1) Emphasis on achieving Zero-Net carbon operations at the site and limiting fossil fuel use [6].

(2) Building with low to zero embodied carbon, or carbon sequestering materials, and consideration of embodied carbon at all levels of design and planning, including infrastructure and building reuse, site selection and landscape, and interior fittings and finishes

Therefore, the contractor will have to ensure that the site details and specifications have the least adverse effects on the environment, people, and communities. To achieve these goals, the site layout should meet the requirements set out by Leadership in Energy and Environmental Design (LEED) for sustainable sites such as pollution prevention, site assessment, protection or restoration of habitat, rainwater management, heat island reduction, creation of open spaces, and light pollution reduction [7]. To achieve these, it will require:

(1) Protecting disturbed areas during site preparation, such that the construction team must recognize the value of trees and incorporate that in the project specs.

(2) Controlling soil erosion that may result from site disturbances to prevent the pollution of nearby waterways and foul sewers.

(3) Controlling site boundary to limit the project's disturbance area to a smaller footprint to maintain the existing footpaths, bike lanes, and accessible routes along N 12th St, W Norris St, and N Marvine St.

(4) Consider completing landscaping exercises first to reduce site disturbance, reduce the risk of soil erosion, and allow the plants to regenerate as construction continues.

(5) Include fuel usage protocols in the project specs to limit pollution.

3. Water efficiency

The notion of water efficiency is a multi-faceted concept. It refers to "doing more and better with less" by making the most of the available resources, cutting down on resource consumption, and lessening the pollution and environmental effects of using water to produce goods and services at every point of the value chain as well as the provision of water services [8]. The advantages of green buildings for energy and water saving have been extensively researched and acknowledged [9]. We presented a system and metrics for evaluating building health for energy and water saving.

The volume of water on Earth is finite. Thus, it requires efficient use of water resources to serve the growing global population, especially with freshwater for domestic and agricultural use. In urban areas, like the proposed site, the primary water management problem is controlling surface run-offs. In most old cities like Philadelphia, the drainage system combines the sewer system and sanitation where pipes handle both sewer and runoff. Combined sewers may overflow, releasing treated and untreated sewers into rivers when the treatment plants are overwhelmed during rainy seasons. Thus, the proposed building will have to utilize various techniques to harvest rainwater and minimize surface runoff, such as the following.

(1) Vigilant stormwater management is needed to minimize runoff during construction, using retention areas and porous materials for paving to maximize water infiltration. The site infrastructure must hold at least 1.5" of rainwater per Philadelphia Water Department (PWD) regulations.

(2) Encourage green infrastructure within the site such as rain gardens, vegetated roofs, and bioswales. Vegetated roofs have proven highly advantageous for stormwater management, thermal insulation, evaporative cooling in summer, and reducing heat islands in urban areas.

4. Material and resources

Construction materials constitute a significant portion of a building's carbon dioxide emissions. Therefore, the project specifications must include strategies to reduce embodied carbon emissions from materials like concrete and wood. The first step will involve conducting a Life Cycle Assessment (LCA) of construction materials to determine their carbon footprint across the value chain. That will require working with Athena Sustainable Materials Institute (ASMI) to conduct the materials' LCA to meet material disclosure under LEED [10]. The building will also follow the American Institute of Steel Construction (AISC) sustainable steel material attributes in the selection of steel used for concrete reinforcement and other construction works. Using innovative timber and timber products and encouraging the supply of wood from suppliers with the least carbon footprint will also reduce the building's carbon footprint. Since concrete is the primary cause of embodied carbon in buildings, the development shall consider the following.

(1) Substituting cement with other supplementary cementitious materials (SCMs) or using larger aggregate may be applicable to reduce the amount of cement used.

(2) Lightening the weight of slabs using lightweight concrete with high strength or incorporating voids in the concrete using things like proprietary air-filled recycled plastic spheres to reduce the amount of concrete that will be required in the construction project.

(3) Using non-fossil fuel-based SCMs to reduce carbon emissions such as glass pozzolan [11].

(4) Encourage suppliers to use carbon sequestration, where the carbon dioxide released during cement manufacture is captured and injected back into the concrete during mixing.

(5) Designing the building with a vision of material optimization and efficiency.

5. Energy efficiency

In emerging economies, building construction is expected to be a very intensive activity in the coming years. This is mainly due to the increase in population, growing wealth, growing desire for improved lifestyles, and increasing pace of urbanization [12]. The energy demand for space cooling and heating is growing rapidly across the globe. Most of these countries are in tropical and warm climate regions. The prevailing temperatures in these countries make space cooling and heating a necessity.

Energy efficiency remains a significant problem in most buildings today. To ensure that the building will have a high energy efficiency rating, it will need to incorporate the use of reflective glasses to reduce heat gain, solar panels to reduce reliance on fossil fuel for heating and cooling, and utilize materials and systems that will seek to maximize the building's passive solar gain. For heat gain and loss efficacy, solar control glass will be the best option. The glass allows only sunlight to enter the offices, creating a brighter indoor environment. However, it prevents the passage of sunlight heat by reflecting and largely radiating it, resulting in a cooler environment. It also prevents ultraviolet (UV) rays from entering and reduces exposure to zero, making the building more sustainable.

To maximize the passive solar gain, the building will be designed with full consideration of the direction of the sun and the prevailing wind directions to allow natural cooling and heating of the building spontaneously. The proposed heating, ventilation, and air conditioning (HVAC) system that will be used is the variable refrigerant flow (VRF) and variable refrigerant volume (VRV) [13]. Heat pumps and heat recovery are used in VRF and VRV systems. Heat pump systems can heat or cool a building at any time, making them ideal for open-plan spaces. Heat recovery systems can provide simultaneous heating and cooling to several areas, making them an ideal solution for a building with multiple rooms [14]. **Table 1** shows the R-values, the thermal resistance measure, of different materials.

Table 1. The suggested R-values

R-Values/Name	Dimension (inch)
Spray polyurethane foam	6.6 per inch of thickness
Thermoplastic polyolefin (TPO)	0.24 per inch of thickness
Metal	0.00 per inch of thickness
Built-up roof (BUR) gravel	0.34 per inch of thickness
Extruded polystyrene (XPS) Insulation	5.0 per inch of thickness
Polyisocyanurate (Polyiso)	5.5 per inch of thickness
BUR smooth	0.24 per inch of thickness
Expanded polystyrene (EPS) Insulation	3.85 per inch of thickness
Ethylene propylene diene monomer (EPDM)	0.33 per inch of thickness

6. High-performing exterior cladding

Traditional louvered or Venetian blind systems will be used to allow users or an automated control system to tailor the adjusted angle of blockage based on solar position, daylight availability, glare, or other criteria. Another option is to use between-pane acrylic prismatic panels that are either fixed or used as a system of exterior louvers to block direct sunlight while admitting diffuse daylight. Vertical window panels will be adjusted at least seasonally to block sunlight and prevent color dispersion.

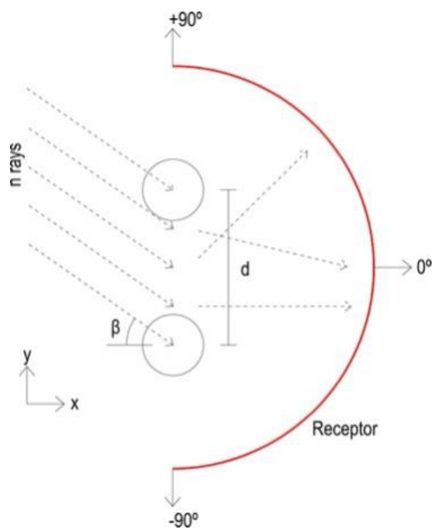

Figure 1. Ray-tracing basic modeling setup: *n* light rays are spread out around two cylinder-shaped louvers that are *d* units apart. Over a half-circle receiver, the scattering features of the screen system were tested at different elevation angles [15].

Table 2. Room and material surface photometric properties

Room surface photometric properties	Reflectance/Transmittance
Wall	0.6 (grey, diffuse)
Ceiling	0.8 (white, diffuse)
Floor	0.3 (grey, diffuse)
Window	0.64 (double panes, transmittance) 0.8 (single pane, transmittance)
Shading material photometric properties	**Overall reflectance and materials**
Rod	0.92 (specular, polished aluminum)
New louver (exterior)	0.92 (specular, polished aluminum)
New louver (interior)	0.92 (specular, polished aluminum)
Venetian blind	0.92 (specular, polished aluminum)

7. Conclusion

Preliminary research reported so far indicates that green buildings have superior measured and perceived results for indoor environmental quality and health status compared to non-green buildings. The design for health is increasingly integral to green buildings, and the need for high-quality health indicators will be essential as researchers assess the efficacy of these programs in comparison to LEED-certified and conventional structures. They are beneficial in developing research aimed at identifying certain building-related qualities in green or other structures that enhance occupant health.

Disclosure statement

The author declares no conflict of interest.

References

[1] Allen JG, MacNaughton P, Laurent JG, et al., 2015, Green Buildings and Health. Current Environmental Health Reports, 2(3): 250–258. https://doi.org/10.1007/s40572-015-0063-y

[2] Bandyopadhyay B, Banerjee M, 2022, Decarbonization of Cooling of Buildings. Solar Compass, 2: 100025. https://doi.org/10.1016/j.solcom.2022.100025

[3] Designing Buildings, 2020, "Variable Refrigerant Flow VRF". https://www.designingbuildings.co.uk/wiki/Variable_refrigerant_flow_VRF

[4] Freeman T, 2002, Using Performance Indicators to Improve Health Care Quality in the Public Sector: A Review of the Literature. Health Services Management Research, 15(2): 126–137. https://doi.org/10.1258/0951484021912897

[5] Fowler KM, Rauch EM, Henderson JW, et al., 2011, Re-Assessing Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings. Pacific Northwest National Laboratory, Richland, Washington 99352.

[6] Kilkis S, 2007, A New Metric for Net-Zero Carbon Buildings. ASME 2007 Energy Sustainability Conference, 2007: 219–224. https://doi.org/10.1115/es2007-36263

[7] Knauf Insulation Experience Center, 2021, What is Sustainable Building? Accessed May 3, 2024. http://kiexperience.org/what-is-sustainable-building.html

[8] Kestner DM, Goupil J, Lorenz E, 2010, Sustainability Guidelines for the Structural Engineer. American Society of

Civil Engineers (ASCE) Library. https://doi.org/10.1061/9780784411193

[9] Climate Change Committee, 2024, Progress in Reducing Emissions 2024 Report to Parliament. Published July 18, 2024. https://www.theccc.org.uk/publication/progress-in-reducing-emissions-2024-report-to-parliament/

[10] Srinivas H, 2015, What is a Green or Sustainable Building? Green Construction. Published June 2015. https://www.gdrc.org/uem/green-const/1-whatis.html

[11] United Nations, 2018, 68% of the World Population Projected to Live in Urban Areas by 2050, Says UN. United Nations Department Of Economic And Social Affairs. Published May 16, 2018. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[12] Gutiérrez RU, Du J, Ferreira N, et al., 2019, Daylight Control and Performance in Office Buildings Using a Novel Ceramic Louvre System. Building and Environment, 151: 54–74. https://doi.org/10.1016/j.buildenv.2019.01.030

[13] World Bank Group, 2018, 3 Big Ideas to Achieve Sustainable Cities and Communities. Published January 31, 2018. https://www.worldbank.org/en/news/immersive-story/2018/01/31/3-big-ideas-to-achieve-sustainable-cities-and-communities

[14] World Green Building Council, 2016, The Benefits of Green Buildings. https://www.worldgbc.org/benefits-green-buildings

[15] Wan H, Cao T, Hwang Y, et al., 2020, A Review of Recent Advancements of Variable Refrigerant Flow Air-Conditioning Systems. Applied Thermal Engineering, 169: 114893. https://doi.org/10.1016/j.applthermaleng.2019.114893

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Optimization Methodology of ESGB on Weights, Evaluation Rating, and Calculation of Carbon Emissions

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Abstract: To cope with climate change, the Chinese government took the lead in advocating the aim of a Carbon peak by 2030 and carbon neutrality by 2060. In China, the total carbon emission of the whole construction process in 2020 was about 5.08 billion tons of carbon dioxide (CO_2), accounting for about 50.90% of the national carbon emission. Consequently, researchers come up with a series of standard assessments for green building optimization measures. Through analysis and comparison of Leadership in Energy and Environmental Design (LEED), WELL Building Standard (WELL), Building Research Establishment Environmental Assessment Method (BREEAM), and Evaluation Standard for Green Building (ESGB) standards, this study will draw conclusions on optimizing ESGB in terms of weighting, evaluation rating, and carbon emission calculations.

Keywords: LEED; WELL; BREEAM; ESGB; Green building; Optimization; Building life cycle management system

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1. Introduction

1.1. Research background

In the context of global warming, environmental deterioration, frequent natural disasters, and other ecological problems are becoming increasingly prevalent. As a result, environmental governance, particularly the reduction of carbon emissions, has become crucial. According to the 2022 China Building Energy Consumption and Carbon Emissions Research Report, carbon emissions from the construction sector accounted for 50.9% of the total emissions. This paper summarizes the evaluation criteria and scoring methods of LEED (U.S.), BREEAM (U.K.), WELL (U.S.), and China's green building standard evaluation system.

1.2. Global green building rating tools

This paper analyzes the weights, evaluation ratings, and carbon emission calculations for LEED, WELL, and BREEAM, and proposes optimization measures for ESGB. Moreover, the author has reviewed and visually analyzed both domestic and international studies related to the purpose and significance of this research, focusing on its direction and theoretical framework. The timeline of the Green Building Evaluation Criteria is shown in **Figure 1**.

1.2.1. The Leadership in Energy and Environmental Design (LEED)

The Leadership in Energy and Environmental Design (LEED) rating system was developed in the US in 1998 by the US Green Building Council (USGBC). LEED was fit for diverse types of buildings. Each of these schemes measures building sustainability according to the project performance for sustainable sites (SS), location and transportation (LT), water efficiency (WE), energy and atmosphere (EA), materials and resources (MR), indoor environmental quality (EQ), the innovation and design process (ID), and regional priority (RP) [1].

1.2.2. WELL Building Standard (WELL)

WELL Building Standard (WELL) is an abbreviation for the WELL Healthy Building Standard, which originated in the United States. The WELL Standard is a performance-based evaluation system that measures, certifies, and monitors characteristics of the built environment—such as air, water, nutrition, light, health, comfort, and spirit—that affect human health and well-being. It was developed by the International WELL Building Institute.

1.2.3. Building Research Establishment Environmental Assessment Method (BREEAM)

The latest version of the Building Research Establishment Environmental Assessment Method (BREEAM) was published in 2014. It consists of nine environmental categories (similar to the categories in LEED), which are: (1) Management, (2) Health and Wellbeing, (3) Energy, (4) Transport, (5) Water, (6) Materials, (7) Waste, (8) Land Use and Ecology, (9) Pollution, and an additional section on (10) Innovation. Various indexes (similar to the credits in LEED) and multiple credits (similar to the points in LEED) are outlined below [2].

1.2.4. Evaluation Standard for Green Building (ESGB)

Since August 1, 2019, the revised Evaluation Standard for Green Building (GB/T50378-2019) has been implemented. In addition to improvements and innovations, the updated index system now includes completely new indicators, forming six categories. Following this revision, the new standard has generally reached an internationally leading level.

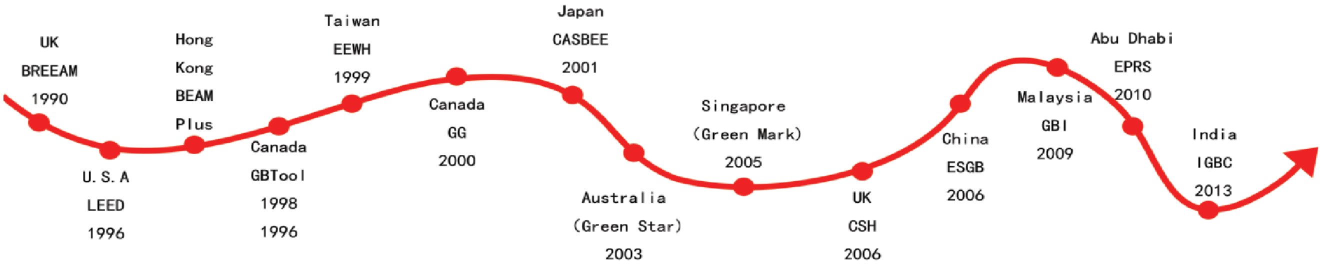

Figure 1. Timetable of mainstream GBRTs established worldwide

1.3. Valuable references

1.3.1. China

This paper provides a horizontal comparison between BREEAM and ESGB, with a particular focus on the similarities and differences in key performance indicators and weighting. Based on the points mentioned above, this paper offers detailed advice for the development of ESGB, contributing to the creation of the best green building assessment methodology suited for China [3].

By comparing the evaluation standard index systems, it is clear that although the evaluation indexes of all countries are based on energy conservation, there is no apparent building carbon emission index. Consequently, the application of a carbon emission index into the green building evaluation system is the main focus of this paper. Secondly, this paper establishes a green building life-cycle carbon emission calculation framework, summarizes the building carbon emission factors, and defines the calculation boundaries and life cycle inventory analysis method. Last but not least, by connecting specific cases, the evaluation standard for an integrated green building evaluation system of carbon emissions will be tested for its efficiency [4]. From Li's standpoint, this study develops an integrated data-driven contrast of the ESGBs of China and the United States. It aims to make clear the current circumstances and further enhance and optimize China's ESGB and popularize green building technologies [5].

1.3.2. International

This research aims to evaluate the difference between projects from versions 3 (v3) and 4 (v4) of the Leadership in Energy and Environmental Design Commercial Interiors (LEED-CI) rating system in China and the US at the Silver and Gold certificate levels [6]. According to Suzer, this study intends to examine the compliance and correlation between the most remarkable green building rating systems, LEED and BREEAM. Given the methodology of the study, the intents of evaluation norms in the latest versions for new constructions of LEED and BREEAM are analyzed and compared [2]. In Park's perspective, regarding the LEED certification as an evaluation system, this study forms an optimization algorithm that intends to originate from the minimum grade for an ideal LEED standard at minimal expense [7].

2. Results and discussion

2.1. Weights

For the green building evaluation systems of various countries, the proportion of indicators, or weights, varies, reflecting the emphasis each system places on promoting the green development of buildings. Weight is a measure that indicates the relative importance of each indicator in the green building evaluation system [3].

2.1.1. Weights in LEED

In LEED-NC2.2 and previous versions, there is no explicit weight system. In the LEED-NC2009 version, the concept of weight was introduced. The weights of the evaluation categories in the latest version of the LEED evaluation system are compared, and their weight ratios are shown in **Figure 2**.

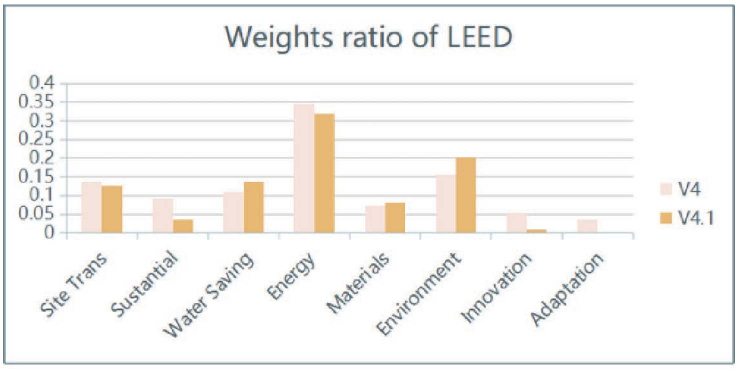

Figure 2. Weights comparison between V4 and V4.1 of LEED

2.1.2. Weights in WELL

The WELL evaluation standard pays more attention to the indoor environment, adding factors such as nutrition, fitness, and mood. The WELL building evaluation standard concerns the health and well-being of people in the constructed environment. In the scoring system, the weight of energy and atmosphere occupies the largest proportion, followed by indoor environmental quality [8]. The specific weight proportion is shown in **Figure 3**.

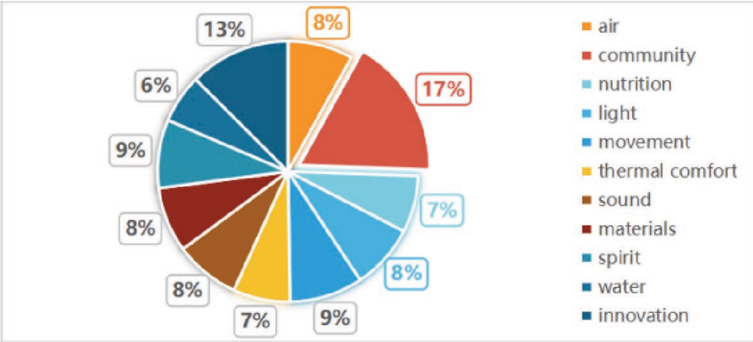

Figure 3. Weight ratio in WELL

2.1.3. Weights in BREEAM

BREEAM and other evaluation systems with a first-level weight system, despite the evaluation method, increase the calculation requirements. BREEAM system has the first-level weight system which is superior to the evaluation system without weight and the evaluation system with multi-level weight. The indicators' weights of BREEAM are shown in **Figure 4**.

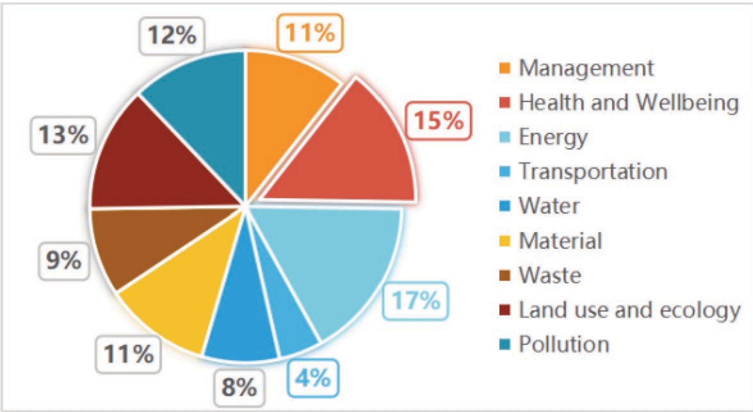

Figure 4. Weight ratio in BREEAM

2.1.4. Weights in ESGB

In the Evaluation Standard for Green Building, China defines green buildings as high-quality buildings that save resources, protect the environment, reduce pollution, provide healthy, applicable, and efficient space for people to use, and maximize the harmonious coexistence between man and nature during the whole life cycle. China's ESGB mainly focuses on the consideration of resource conservation and indoor environmental quality, where specific indicators are shown in **Figure 5**.

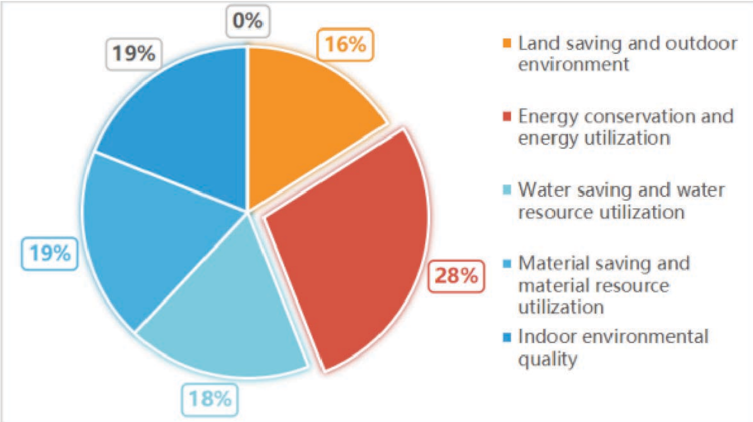

Figure 5. Weight ratio in ESGB

2.2. Evaluation system and calculation methods (ESCM)

With the development and progress of society, there are growing demands for the protection of nature and the improvement of environmental quality. Meanwhile, the construction industry, which is closely linked to human activity, is increasingly drawing attention to its green environmental performance. As early as the 1960s, American architect Paul Soleri introduced the concept of ecological architecture in his book Architectural Ecology: The City in Human Imagination.

2.2.1. ESCM in LEED

The evaluation criteria and weights of LEED v4.0 are as follows: the weight for site selection and transportation is 16%, sustainable site utility accounts for 10%, water efficiency accounts for 11%, energy and atmosphere accounts for 33%, materials and resources account for 13%, and indoor environmental quality accounts for 16%. Integrated design is a prerequisite, and design innovation is awarded as extra credit.

The evaluation method of LEED BD+C uses the cumulative score of each indicator, represented *as* $E = E1 + E2 + E3 + E4 + E5 + E6 + E7 + E8$ (where E is the total building evaluation score and E1–E8 are the scores for each evaluation index) [4]. The specific grade classification is shown in **Table 1**.

Table 1. LEED assessment level

Level	Platinum	Gold	Silver	Certification Level
Score	80+ pts	60–80 pts	49–59 pts	40–49 pts

2.2.2. ESCM in WELL

Certification represents the highest pinnacle of health achievement across all ten concepts. Projects may earn no more than 12 points per concept and no more than 100 points total across the ten concepts. The relevant specific calculation of WELL Certification is shown in **Table 2**.

2.2.3. ESCM in BREEAM

BREEAM sets standards for a broad range of sustainability issues for buildings, communities, and infrastructure in nine categories: energy, waste, water, materials, health and well-being, transportation, pollution, land use and ecology, and stewardship. The specific content is as follows in below **Table 3**.

Table 2. WELL certification of V2.Q1-Q2 2023

Total points achieved	Well certification		Well Core certification	
	Minimum points	Level	Minimum points	Level
40 pts	0	WELL Bronze	0	WELL Core Bronze
50 pts	1	WELL Silver	0	WELL Core Silver
60 pts	2	WELL Gold	0	WELL Core Gold
80 pts	3	WELL Platinum	0	WELL Core Platinum

Sourced from Wellcertified.com

Table 3. BREEAM Evaluation Criteria

Evaluation category	Threshold setting	Score	Weights	Total	Scoring ratio	Certification level
Management	√	23	10.5%		≥ 85%	Outstanding
Health and wellbeing	√	13	12%			
Energy	√	21	16.5%		≥ 70%	Excellent
Transport		9	4.5%			
Water	√	9	7.5%	100%	≥ 55%	Very Good
Material	√	11	11%			
Water	√	6	8.5%		≥ 45%	Good
Land use and ecology		10	17.5%			
Pollution		14	10%		≥ 30%	Pass
Innovation		10	10%	10%		

2.2.4. ESCM in ESGB

The green building evaluation index system consists of seven types of indicators, including land saving and outdoor environment, energy saving and energy utilization, water saving and water resource utilization, material saving and material resource utilization, indoor environmental quality, construction management, and operation management. Operation evaluation should cover seven categories of indicators. The score of the seven indicators Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, and Q_7 is calculated by dividing the actual score value of the score item of the participating building by the total score value of the score item applicable to the building and multiplying by 100 points. The additional score Q_8 for extra points is determined according to the relevant criteria. The total score of green building evaluation is calculated according to the following formula, in which the weights *w1* to *w7* of the seven index scoring items of the evaluation index system are calculated according to the below formulation. The ESGB's specific evaluation criterion is shown in **Table 4**.

$$\boldsymbol{\Sigma Q} = W_1Q_1 + W_2Q_2 + W_3Q_3 + W_4Q_4 + W_5Q_5 + W_6Q_6 + W_7Q_7 + Q_8$$

Table 4. ESGB evaluation criterion

	Land and out-environment, W_1	**Energy utilization, W_2**	**Water utilization, W_3**	**Materials utilization, W_4**	**In-environment, W_5**	**In-management, W_6**	**Using-management, W_7**	**Innovation**
Design evaluation	0.21	0.24	0.20	0.17	0.18			+0.10
	0.16	0.28	0.18	0.19	0.19			
Operation evaluation	0.17	0.19	0.16	0.14	0.14	0.10	0.10	
	0.13	0.23	0.14	0.15	0.15	0.10	0.10	
Score average	100 pts	100 pts	100 pts	100 pts	100 pts	100 pts	100 pts	10 pts
Score	≥ 50 pts (Each evaluation category evaluates the score item ≥ 40 pts)			≥ 60 pts (Each evaluation category evaluates the score item ≥ 40 pts)			≥ 80 pts (Each evaluation category evaluates the score item ≥ 40 pts)	
Certification level	One-star level			Two-star level			Three-star level	

2.3. Carbon Emissions Calculation (CES)

Currently, the calculation of building carbon emissions has been studied by quite a few people locally and internationally. The calculation of building carbon emissions is mainly the carbon emissions in the operating stage of the building. Most of the research on building carbon emissions in China is based on the whole life cycle of the building. Nevertheless, the current studies are not wholly comprehensive, and there may be omissions in some aspects of calculation, or calculation overlaps in each stage of calculation, which leads to inaccurate calculation [4].

2.3.1. CES and its influential factors

Greenhouse gases are mainly composed of CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCS), Perfluorocarbons (PFCS), and sulfur hexafluoride (SF_6). The main component of which is CO_2. To uniformly measure the environmental impact of other greenhouse gases except CO_2, carbon emissions generated by other greenhouse gases other than CO_2 are converted into carbon dioxide equivalent (Kg CO_2/Kg). Carbon dioxide equivalent refers to the mass of CO_2 that is needed to convert the environmental impact of a certain mass of greenhouse gas into the same environmental impact. Global Warming Potential (GWP) is the value of the unit mass conversion of greenhouse gases other than CO_2 into carbon dioxide equivalent [4].

2.3.2. CES in operating construction phase

In this paper, the carbon emissions generated by the four parts of heating, ventilation, and air conditioning (HVAC), domestic hot water, lighting, elevator, and renewable energy are calculated respectively, and the carbon sequestration amount of the building green space carbon sink system is calculated. Last but not least, the carbon emissions of these five parts are added in total. The calculation formulas of each part are referred to the Building Carbon Emission Calculation Standard [4]. The formula for calculating the carbon emissions of each system in the operation stage of a building is as follows:

$$C_{\mathrm{yx}} = \frac{\sum_{i=1}^{n}(W_i \times \mathrm{q}_i) - Cc\,) \times n}{A}$$

$$W_{\mathrm{i}} = \sum_{j=1}^{n}(W_{i,j} - WR_{i,j})$$

Where C_{yx} is the carbon dioxide emissions generated by the building during its operation phase, i is the type of building energy, j is the system type, q_i is the influence factor of building carbon emission. W_i is the building energy consumption, Cc is the annual carbon emissions fixed by the carbon sink system on the building green space, n represents the service life of the project building, and A represents the construction area of the project.

2.3.3. Building carbon sequestration system

Urban green carbon sink means that green plants absorb carbon dioxide in the air, and fix carbon dioxide in the plant body or soil. At present, local research on carbon sinks mainly focuses on forests, grasslands, and wetlands. The formula for calculating the carbon sink of urban green plants by the green plant type-area method is as follows:

$$C_s = \sum_{i=1}^{n} A_i \times p_i \times \mathrm{n}$$

Where C_s is the carbon sequestration amount of green plants, i is the type of green plants, and p_i is the annual carbon sequestration amount per unit area of a certain kind of green plant.

2.3.4. CES in construction and demolition phases

The carbon emission boundaries of buildings in the construction and demolition stages are defined from two aspects, namely, the time boundary and the space boundary [4]. Building demolition and the carbon emissions of the building demolition stage can be calculated according to the method of the building construction stage. The calculation formulas for the construction and demolition phases are referred to as the Building Carbon Emission Calculation Standard. The carbon emission calculation formula of the building construction stage:

$$MC_{jz} = \sum_{i=1}^{n} CE_{jz,i} \times f_{jz,i}$$

The formula of building demolition stage is as follows:

$$MC_{cc} = \sum_{i=1}^{n} CE_{cc,i} \times f_{cc,i}$$

In the formula, MC represents the carbon emissions in the construction or demolition stage of the building, CE_i is the number of mechanical platforms used in the construction or demolition stage of the building, and f_i is the carbon emission factors of the construction machinery, specifically according to carbon emission factors.

2.3.5. CES in building materials production and transportation stage

Building materials do not produce any greenhouse gases during use, and the source of carbon emissions at this stage is greenhouse gases generated by fossil fuels consumed in the mining, production, transportation, and processing of building materials and raw materials [4]. The carbon emission calculation formula for the building materials production and transportation stage is as follows:

$$C_{JC} = \frac{C_{sc} + C_{ys}}{A}$$

Where C_{sc} is the carbon emission of building materials production stage in the whole life cycle of the building, C_{ys} is the carbon emission generated during the transportation of building materials throughout the building life cycle, C_{jc} is the total carbon emission during this period. Carbon emission formula of building materials production stage is as follows:

$$C_{sc} = \sum_{i=1}^{n} M_i \times F_i$$

Where i is the type of building materials, M_i is the consumption of building materials, and F_i is the carbon emission shadow of building materials sound factor. Carbon emission formula of building materials transportation stage is as follows:

$$C_{ys} = \sum_{i=1}^{n} M_i \times D_i \times T_i$$

Where D_i is the transportation distance of building materials from the production site to the construction site and T_i is the influence factor of carbon emission during the transportation of building materials.

3. Conclusion

3.1. Optimization of weights in ESGB

According to the weight comparison of the green construction evaluation system locally and internationally, the following conclusions can be drawn to improve and enhance China's ESGB green construction evaluation system:

(1) The weight ratio should be adapted to local conditions and people-oriented.

(2) The weight ratio needs to set thresholds of different heights according to the score level.

(3) The weight ratio needs to be more quantitative, set multi-level weights, and set weights flexibly according to changes in objective conditions.

(4) According to the weight and scoring criteria of the green construction evaluation system.

(5) The ESGB evaluation system is recommended to include the design stage, construction stage, operation stage, demolition stage, and many more.

3.2. Optimization of ESCM in ESGB

This paper summarizes the scoring standards and certification levels of different green construction evaluation systems, both locally and internationally, and analyzes their respective advantages and disadvantages. The following recommendations are proposed:

(1) Establish an efficient certification and evaluation process by integrating expert certification into the design and construction drawings of the building scheme. Conduct regular reviews every two years at all stages of the building life cycle, collect data for feedback during the completion and operation stages, and establish a green building expert evaluation responsibility system.

(2) From the perspective of evaluation indicators, China's ESGB lacks consideration of human health, detailed indoor quality evaluation standards, and harmony with the outdoor natural environment. More of these considerations should be incorporated into the evaluation indicators.

3.3. Optimization of CES in ESGB

There are many ways to divide the entire life cycle of buildings, and the calculation of building carbon emissions overlaps with those of the building materials industry and transportation. Furthermore, most carbon emission calculation systems are not perfect. Therefore, this paper divides the life cycle of buildings into three stages: the building operation stage, the building construction and demolition stage, and the building production and transportation stage. Carbon emissions are calculated according to different emission factors in each stage. Most importantly, we are committed to achieving the target of carbon peak and carbon neutrality on schedule.

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References

[1] Ade R, Rehm M, 2020, The Unwritten History of Green Building Rating Tools: A Personal View from Some of the "founding Fathers". Build. Res. Inf., 48(1): 1–17.

[2] Suzer O, 2019, Analyzing the Compliance and Correlation of LEED and BREEAM by Conducting a Criteria-Based Comparative Analysis and Evaluating Dual Certified Projects. Building and Environment, 147: 158–170. https://doi.org/10.1016/j.buildenv.2018.09.001

[3] Ai YJ, 2016, Comparative Study of British BREEAM and Chinese Green Building Evaluation Standards, thesis, Nanchang University.

[4] Ma Y, 2021, Research on Green Building Evaluation System Based on Carbon Emission Analysis of Green Buildings, thesis, Hebei university of engineering.

[5] Li X, Fang W, Liu X, et al, A Comparative Analysis of Green Building Rating Systems in China and the United States. Sustainable Cities and Society, 93: 104520. https://doi.org/10.1016/j.scs.2023.104520

[6] Zhang X, Zhan C, Wang X, et al, 2019, Asian Green Building Rating Tools: A Comparative Study on Scoring Methods of Quantitative Evaluation Systems. Journal of Cleaner Production, 218: 880e895. https://doi.org/10.1016/j.jclepro.2019.01.192

[7] Pushkar S, 2020, Evaluating LEED Commercial Interior (LEED-CI) Projects Under the LEED Transition from V3 to V4: The Differences Between China and the US. Heliyon, 6(8): 1–11. https://doi.org/10.1016/j.heliyon.2020.e04701

[8] Park JY, Choi SG, Kim DK, et al, 2017, Credit Optimization Algorithm for Calculating LEED Costs. Sustainability, 9(9): 1607. https://doi.org/10.3390/su9091607

[9] Zhang Y, Lin S, Li F, 2016, WELL has Analyzed the Differences Between Standard and LEED and Green Building Samsung System. Building Science and Technology, 2016(22): 44–47.

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Research on Big Data Coding System Based on the Classification of Artificial Materials and Mechanical Equipment in Construction Engineering

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Abstract: By analyzing and comparing the current application status and advantages and disadvantages of domestic and foreign artificial material mechanical equipment classification coding systems, and conducting a comparative study of the existing coding system standards in different regions of the country, a coding data model suitable for big data research needs is proposed based on the current national standard for artificial material mechanical equipment classification coding. This model achieves a horizontal connection of characteristics and a vertical penetration of attribute values for construction materials and machinery through forward automatic coding calculation and reverse automatic decoding. This coding scheme and calculation model can also establish a database file for the coding and unit price of construction materials and machinery, forming a complete big data model for construction material coding unit prices. This provides foundational support for calculating and analyzing big data related to construction material unit prices, real-time information prices, market prices, and various comprehensive prices, thus contributing to the formation of cost-related big data.

Keywords: Data of labor; Materials; Equipment; Classification; Big data coding system

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1. Introduction

In the current era of "big cloud intelligent connection," the construction industry is also increasingly dependent on big data and information data, of which the "construction engineering artificial material equipment machinery data standard" is one of the most important basic data support. The standard aims to improve the efficiency and quality of modern computer applications in construction engineering. Its advantages include providing a set of unified static coding machines, using the method of line and surface combination, to realize the unified management of the information data of the machine throughout the project life cycle [1–3].

2. Analysis of the coding system

Foreign OmniClass, a classification system for the construction industry, has been widely adopted and applied in North America. IFC/IFD technology is the definition of building and construction engineering data, aiming to promote different specialties in the construction industry and different software in the same profession to share the same data source, and to achieve data sharing and interaction [2–4].

The development and application of foreign coding systems provide a good reference for the information development of China's construction industry. The national standard GB50851-2013 "Code for Data Classification and Coding of Artificial Materials and Machinery Equipment" is formulated based on the OmniClass standard, and the specific classification and coding numbers are adjusted. The basic principles and methods of information classification are proposed, which lays a theoretical foundation for the development of China's building coding system. The Ministry of Housing and Urban-Rural Development has also promulgated relevant standards and specifications, such as "Unified Standard for Application of Building Information Model" GB/T51212-2016, "Standard for Classification and coding of Building Information Model" GB/T51269-2017 and "Standard for storage of Building engineering Information Model" GB/T51447-2021, and many more [5]. The continuous improvement and upgrading of these coding technical standards, jointly promote the reform and upgrading of the coding system, realize the sharing and interaction of data, adapt to the growing market demand and technological development, improve the digitization level and information level of the construction industry, and promote the transformation and upgrading and sustainable development of the construction industry [4].

However, the existing coding system primarily involves issues such as serial number coding, the mixing of names and attributes, inability to generate codes automatically, non-convertible units, and the inability to automatically assign codes to new materials. Therefore, it is necessary to develop more effective coding methods to improve the efficiency and practicality of the labor and machinery coding system, align with the national cost reform policy, and adapt to a market-oriented economy.

3. Coding ideas and calculation model

3.1. Material attribute labeling

If a certain class of material has *n* feature items and *Y* represents the commonly used attribute values under a feature item, the material can be expressed as a vector with *i* rows and 2 columns. It is denoted as:

$$\mathrm{M} = \begin{pmatrix} 1 & Y1 \\ 2 & Y2 \\ 3 & Y3 \\ . & . \\ . & . \\ n & Yn \end{pmatrix}$$

Where the first column represents the feature item, and the second column represents the number of attribute values under the feature item. For example, Y_1 means that the common attribute value of the first feature is Y_1, and so on. As shown in the example in **Table 1**, 0101 steel bars can be expressed as:

$$\mathrm{M} = \begin{pmatrix} 1 & 6 \\ 2 & 6 \\ 3 & 29 \\ 4 & 20 \\ 5 & 11 \\ 6 & Yn3 \end{pmatrix}$$

Table 1. Examples of forward-coded feature items and attribute values

Category encoding and name	Eigenvalue serial number	Characteristic item	Number of attribute values	Attribute value 1	Attribute value 2	Attribute value 3	Attribute value 4	Attribute value 5	Attribute value 6	Attribute value 7	Total
0101 Rebar	1	Variety	6	General	Hot-rolled disc strips	Cold-rolled ribbed rebar	Threaded Rebar	Cold-rolled and twisted rebar	Reserved		$6 \times 6 \times 29 \times 20 \times 11 = 229,680$
	2	Levels	6	General	Level I	Level II	Level III	Reserved			
	3	Diameter	29	Comprehensive	Φ 4	Φ 4.5	Φ 5	Φ 5.5	Φ 6		
	4	Material	20	Comprehensive	Q195	Q215	Q235A	Q235B			
	5	Intensity rating	11	General	HPB235	HRB335	HRB400	reserve			
	6										

3.2. Calculation and significance of the quick count

By defining the quick calculation number, the ranking value of specific materials can be calculated quickly and conveniently. The quick number is the number of materials under a certain characteristic of that material, and also the spacing of materials with adjacent attribute values [5,6].

Define the quick number S_i: The quick number is calculated by multiplying the attribute values of the feature items in descending order of their sequence numbers. This is expressed as:

$$\text{Si} = \prod_{i=n}^{i} Y\,(\text{i} + 1)$$

In particular, the quick number of the last feature is defined as 1, i.e., $S_n = 1$. For example, if a material vector of a particular property is represented as:

$$\text{M} = \begin{pmatrix} 1 & 6 \\ 2 & 6 \\ 3 & 29 \\ 4 & 20 \\ 5 & 11 \\ 6 & 3 \end{pmatrix}$$

Then the quick number vector of that material can be obtained as:

$$\text{S} = \begin{pmatrix} 114840 \\ 19140 \\ 660 \\ 33 \\ 3 \\ 1 \end{pmatrix}$$

In the example above, the quick calculation number is 114840, meaning that the variety of 0101 steel bars is hot-rolled discs, with 114840 kinds of materials available. The varieties of 0101 steel bars are hot-rolled disc bars of grade 1, totaling 19,140 types of materials. Additionally, there are 660 types of 0101 steel bars that are hot-rolled disc bars, grade 1, and have a diameter of 6mm.

For the last item in the material vector, regardless of the number of properties associated with the reserved characteristics, the quick number is 1. The quick number for the penultimate feature, “strength grade,” is calculated as the number of attribute items under that feature (3) multiplied by the quick number of the subsequent feature (1):

$$3 \times 1 = 3$$

The quick calculation number for the third penultimate feature, “material,” is the number of attribute items under that feature (11) multiplied by the quick number of the subsequent feature (3):

$$11 \times 3 = 33$$

Thus, the quick calculation numbers are as follows: 660 for diameter, 19,140 for grade, and 114,840 for variety.

3.3. Forward coding calculation model of coding value

If the unique attribute value of a particular material is represented as:

$$Z = \begin{pmatrix} Z1 \\ Z2 \\ Z3 \\ . \\ . \\ Zn \end{pmatrix} \text{ where } i \leq Y_i,$$

then the third column of the extended vector *M* can represent the unique attribute value positioning of a particular material. The specific material can be fully expressed as:

$$M = \begin{pmatrix} 1 & Y1 & Z1 \\ 2 & Y2 & Z2 \\ 3 & Y3 & Z3 \\ . & . & . \\ . & . & . \\ n & Yn & Zn \end{pmatrix}$$

It is clear that the total number of species for this class of materials is given by:

$$\prod_{i=1}^{n} Y_i \sum_{i=1}^{n} Si(\square)$$

For example, if the material attribute vector *C* for a particular attribute is represented as:

$$C = \begin{pmatrix} 1 & 6 & 3 \\ 2 & 6 & 4 \\ 3 & 29 & 5 \\ 4 & 20 & 6 \\ 5 & 11 & 7 \\ 6 & 3 & 2 \end{pmatrix}$$

Then the quick number vector of the material can be obtained as:

$$S = \begin{pmatrix} 114840 \\ 19140 \\ 660 \\ 33 \\ 3 \\ 1 \end{pmatrix}$$

The sequence number of the material can then be calculated as:

(Attribute Vector – 1) × Quick Number Vector

The calculation is as follows:

(3-1) ×114840+ (4-1) ×19140+ (5-1) ×660+ (6-1) ×33+ (7-1) ×3+ (2-1) ×1=289924..

The calculation process is shown in **Table 2**.

3.4. Coded backward analysis model for coded values

Similar to Section **3.3**, if a specific material is known to be coded as A and belongs to the material attribute matrix, the first attribute value number of the material can be obtained by dividing the number of codes by the first quick number and rounding up according to the reverse operation. The result of dividing the number of codes by the quick number is used to calculate the attribute value of the second layer, and this process continues

Table 2. Example of forward coding calculation procedure for coded values

Category coding	Category name	Characteristic item	Number of attribute values (PCS)	Quick count	A material eigenvalue explanation		Query feature serial number	Calculate the value	Row position	Coding	Remarks
0101	Rebar	Variety	6	114840	Grade I, hot-rolled disc-bar Q235A rebar	Hot-rolled disc strips	2	114840	0134013	010113 4013X	4-bit category code +0000553+ 1-bit unit code
		Levels	6	19140		Level I	2	19140			
		diameter	29	660		Unlabeled diameter	1	0			
		Material	20	33		Q195	2	33			
		Strength rating	11	3		Unlabeled strength	1	0			
		Reserved	3	1			1	0			

until the code of the last layer is calculated.

$$M = \begin{pmatrix} 1 & Y1 \\ 2 & Y2 \\ 3 & Y3 \\ . & . \\ . & . \\ n & Yn \end{pmatrix}$$

The calculation example is as follows: Assuming that the attribute table and characteristic values of a certain type of material are shown in **Table 1**, the attribute value of a specific material coded as 113 can be obtained, and the calculation process is shown in **Table 3**.

3.5. Simplification and optimization of coded attribute values

Taking into account the various types and brands of workloads, the product models determined by different manufacturers are circulating in the market. This situation leads to a significant number of classifications based on the attribute values of specific feature items of the machinery. As a result, the "workloads metadata" must be marked in the feature items or attribute values to ensure usability. Therefore, it is essential to consider the comprehensiveness, accuracy, and ease of use of both the feature values and attribute values of the machinery [6–8].

Firstly, this coding system adds a specific attribute value of "synthesis" to each attribute value. When the user is unsure how to fill in the feature item, is unclear about the specific attribute value under a feature item, forgets to fill in the attribute value, or finds that the selected representative value is not fully included in the attribute value list, the "synthesis" option can be utilized [9].

Secondly, the representative value is selected as the specific attribute value, which can reduce the invalid input amount. For the non-representative attribute value, linear or non-linear parameters can be introduced, and the relevant attribute information can be obtained by calculating the method of inserting the value.

Thirdly, considering that there are inaccuracies in the selection of representative values, the positioning position of features and attributes, the selection and ranking order of representative attribute values need to be determined later according to the use frequency recorded by the system, to ensure that users can find the attribute faster and improve customers' sense of use [10].

4. Application of coding attributes

4.1. Screening and statistics of hierarchical attributes

Now, the attribute of a particular material is defined as, A_{ix}, where *i* is the sequence number of feature items and *x* is the sequence number of attribute values. The material can be expressed as:

$$M = \begin{pmatrix} 1 & Y1 & Z1 \\ 2 & Y2 & Z2 \\ 3 & Y3 & Z3 \\ . & . & . \\ . & . & . \\ n & Yn & Zn \end{pmatrix}$$

To calculate the number of a specific material (where the attribute is A_{ix}), the total is obtained by dividing the total number of the material by Y_i, denoted as:

Table 3. Coding inverse analysis model of coding values

Features	Code name	Number of attribute values	Quick count		Attribute value of the material		Redundant		Look up the property sheet of the material	Look up the property sheet of the material
			Formula	Results	Calculation formula	Results	Calculation formula	Results	Results Explained	Coding interpretation
Breed	X1	6	X2~X6 characteristic value concatenation	114840	The number of codes divided by the quick count is rounded up	1	The number of codes divided by the number of quick computations is complimentary	113	Value of the attribute numbered 1 in the variety: that is, synthesis	Steel with HRB500 strength grade and Q235A material without filling in the type, grade, and diameter of the steel bar
Levels	X2	6	X3 to X6 concatenation of eigenvalues	19140	The remainder of X1 is divided by the speed count and rounded up	1	Take the remainder of X1 and subtract it from the quick number,	113	Value of the attribute numbered 1 in the level: that is, synthesis	
Diameter	X3	29	X4 to X6 concatenation of eigenvalues	660	X2 Take the remainder divided by the speed count and round up	1	Take the remainder of X2 and divide it by the number of quick computations,	113	Value of the attribute numbered 1 in diameter: i.e., synthesis	
Material	X4	20	X5~X6 concatenation of eigenvalues	33	X3 Take the remainder divided by the speed count and round it up	4	X3 takes the remainder of the result and divides it by the quick number,	14	The value of the property numbered 4 in the material	
Strength class	X5	11	X6 to X6 eigenvalue concatenation	3	X4 Take the remainder divided by the speed count and round up	5	Take the remainder of X4 and subtract from the quick number,	2	The value of the attribute numbered 5 in the strength level	
Reserved	X6	3	/	1	/	3	/	0	Reserve the value of the property numbered 3 in the property	

$$\prod_{i=1}^{n} Y\,i/Yi$$

We can divide these codes into segments, each of which contains S_i numbered items:

$$\frac{\left(\frac{\prod_{i=1}^{n} Y\,i}{Yi}\right)}{Si}$$

The first of these materials is numbered (X-1) × Si + 1, and the last material is numbered X × Si. According to the database list, the material attribute values can undergo multi-level attribute screening to meet the needs of cost data and machine data statistics. Furthermore, we can utilize language expressions from computer programming statements to perform statistics, screening, expansion, and other data-related actions.

4.2. Set the weight parameters of the attribute value

Considering the complexity of the user, certain weight parameters can be set for the attribute value, to simplify and sort optimization processing in the later stage. The identity of the user is determined as the general user, supplier, consulting institution, etc., and the validity of the encoding and the meaning weight of the new encoding is judged by giving the user the weight of the identity. For example, you can give a specific attribute value of a material machine and "comprehensive" this attribute value of different weights, through the calculation of weight parameters, to get a material machine unit price [11].

5. Software development and model application

This model needs to rely on labeled material properties, so a material property list needs to be determined in advance. It can be implemented using database programs such as Matlab, MySQL, or natural language program files such as NLP. The development goal is to convert the previous manual coding into automatic coding through automated programs, thus greatly reducing the workload of manual coding. At the same time, the program is used for automatic error correction to form an accurate coding model [12]. Building on the need for an automated coding solution, the next steps involve establishing a comprehensive coding meta-system for the components of the labor and materials mechanism.

(1) Establish the coding meta-system for the components of the labor and materials mechanism, compile the "labor and materials machine metadata" coding table, expand the relevant XML and JavaScript (JS) files, and save the essential metadata in the database.

(2) Based on database technology, the development includes the material coding name normalization module, the coding calculation module, the eigenvalue calculation module, and the eigenvalue statistics module.

(3) Load the "machine metadata" coding table into the database through each module. Based on the positioning of the metadata in the matrix and the relevant attributes of the name, automatically encode the model components and perform reverse decoding calculations. According to the source of the data, assign different weights to various types of units for the given data input, and use data analysis to calculate the machine code [13–15].

(4) Establish the database file for the coding and unit price of the machine to create a comprehensive big data model of the machine code unit price. This will provide essential support for various big

data applications, including statistical analysis, unit price calculations, and real-time market price evaluations.

Of course, in developing a new coding system, it is essential to fully consider the actual conditions of project construction and to widely solicit opinions and suggestions from all stakeholders. This approach will ensure that the new coding system can be effectively utilized and promoted. Simultaneously, the management and maintenance of the new coding system should be strengthened, with timely updates and improvements made to ensure its effectiveness and practicality.

6. Closing remarks

This paper constructs a set of standard mathematical models for the data coding of worksheets and develops a comprehensive coding system. The coding scheme enables the automatic calculation of worksheet codes through forward coding, facilitating horizontal feature exploration and vertical penetration of attribute values. This approach meets the needs for slicing analysis and statistical calculations of worksheet data using big data in the future.

Additionally, the coding scheme allows for reverse analysis; by examining the coded values, one can identify the names of materials, feature items, and attribute values, ultimately determining the specifications and models of materials. This capability significantly aids the engineering industry in conducting big data statistics and analyses of material machinery. However, due to limitations in personal knowledge and experience, the model presented in this paper may contain some inaccuracies or gaps.

Through the analysis, application, and research of artificial materials and mechanical equipment, this paper establishes a standard mathematical model and coding calculation system, resulting in a unified data interaction solution.

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References

[1] Ministry of Housing and Urban-Rural Development, 2013, Data Standard for Artificial Material Equipment and Machinery for Construction Engineering GB/ T50851-2013. Chinese Standard.

[2] Ni J, Li J, Shang L, et al., 2016, Application and Promotion of Data Standard of Artificial Material Equipment and Machinery for Construction Engineering GB/ T50851-2013. Construction Science and Technology, 310(07): 47–48.

[3] Fu Y, 2012, Data Standard and Application Of Artificial Material Equipment and Machinery in Construction Engineering. China Construction Information, 515(20): 44–45.

[4] Sha P, 2018, Research on the Type and Coding of IFD Standard Expansion in BIM Design of Railway Bridge. Railway Standard Design, 62(11): 77–81. https://doi.org/10.13238/j.Issn.1004-2954.201801100004

[5] Ministry of Housing and Urban-Rural Development of the People's Republic of China. Classification and Coding Standard of Building Information Model: GB/T 51269-2017. China Building Industry Press, Beijing, 2017: 4–6.

[6] Wang C, 2022, Research and Software Development of BIM Basic Data Production System for Engineering Construction. Electronic Technology and Software Engineering, 2022(16): 63–66.

[7] Yang X, Gao NP, Huang J, 2023, Research on Building Construction Cost Documentation Based on Building Information Classification System. Construction Cost Management, 2023(05): 19–24.

[8] Cai L, Wang C, 2022, Research on Identification Coding Structure of Highway Engineering Information Model. Journal of Shenzhen University (Science and Technology), 39(04): 424–431.

[9] He L, 2024, Research on Optimization strategy of Engineering Cost Management based on ERP database. Engineering Cost Management, 35(01): 30–36.

[10] Fan QX, Lu YM, Zhou SW, et al., 2019, Research and Practice on Intelligent Construction Technology System of Jinsha River Hydropower Project. Journal of Hydraulic Engineering, 50(03): 294–304.

[11] Huang Y, Du J, Huang S, 2023, Construction of Data Management System for Iron and Steel Business Owners. Shandong Metallurgy, 45(02): 53–55.

[12] Liu Z, Zhou Y, 2021, Research on Science and Technology Big Data Resources And Classification. Science and Technology Innovation, 2021(18): 123–126.

[13] Li X, Wang Y, 2004, Price Informatization of Construction Materials, Machinery and Labor. Jilin Building Materials, 2004(06): 43–44.

[14] Ma M, 2011, Discussion on the Dynamic Price Management of Construction Engineering Materials. Science and Technology Vision, 2011(03): 150–151.

[15] Ou Q, Li X, 2020, Research on Development of Price Information Compilation System of Construction Engineering Materials. Journal of Literature and Literature, 2020(41): 195.

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Study on the Countermeasures to Improve the Public Outdoor Leisure and Fitness Function on the Two Rivers and Four Banks in the Main Urban Area of Chongqing

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Abstract: The main urban area of Chongqing is surrounded by two rivers and set against each other. With its unique waterfront landscape, it has the resource conditions to become a leisure tourism destination. Intending to enhance people's happiness, improve city quality, and promote Chongqing's main urban area to become a tourist destination, this paper finds out the existing problems in the construction of public outdoor leisure and fitness facilities on the two rivers and four banks of Chongqing's main urban area through investigation and analysis based on relevant experiences at home and abroad, takes the value chain theory as the guidance, and to find solutions to the problem. On this basis, combined with the law of economic operation, this paper puts forward the guiding ideology, principles, development goals, functional orientation, and development path for the improvement of public outdoor leisure and fitness on two rivers and four banks in the main city of Chongqing, and accordingly puts forward the policy system and guarantee measures for its improvement.

Keywords: Two rivers and four banks in the main city of Chongqing; Public outdoor recreation and fitness; Policy measure

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1. Introduction

The "Two Rivers and Four Banks" in Chongqing's main urban area refers to the waterfront zones where the Yangtze River and Jialing River flow through the city. The Yangtze River section extends from Tongguanyi in Jiulongpo District and Yu Cave in Banan District, down to Wubao and Mudong in Banan District, covering 120 km. The Jialing River section runs from Wentang Gorge in Beibei, down to Chaotianmen in Yuzhong District and Jiangbeizui in Jiangbei District.

The improvement of leisure and fitness functions of urban waterfront in other countries began in the 1960s. Some authors classified and compared waterfront development types, development functions, waterfront space landscape construction, and development modes, and obtained the elements and principles of successful waterfront development [1]. Research on the functional development of public outdoor leisure and fitness in China's urban waterfront areas began with the rise of tourism and the advent of leisure-focused lifestyles. Development strategies for the Xiangjiang River have been proposed from a geographical perspective, and basic principles for urban waterfront development have been outlined [2,3]. Suggestions have been made regarding concepts, functions, and spatial planning [4]. The two rivers and four banks area in Chongqing has been studied from a brand marketing perspective, with an emphasis on the public accessibility of urban riverside spaces [5,6]. There is also a call to enhance the cultural significance of waterfront areas [7]. Further studies explored recreational opportunities in informal green spaces along riverbanks in mountainous cities, analyzed decision-making paths for quality-oriented urban waterfront renewal, and examined the redevelopment of urban waterfront areas [8–10].

Based on current research, this study finds the following: Firstly, while research on improving public outdoor leisure and fitness functions in urban waterfront areas has been relatively comprehensive, many studies focus more on technology and less on policies and safeguarding measures, lacking forward-looking and actionable policy solutions. Secondly, the construction of urban waterfront areas in China has generally neglected the development of public outdoor leisure and fitness functions, which has created an inherent "congenital deficiency" in the growth of the recreation, sports, leisure, and tourism industries. This has constrained urban economic development and failed to meet people's growing demand for fitness and leisure activities. Thirdly, research on enhancing public outdoor leisure and fitness functions along the two rivers and four banks in Chongqing's main urban area still requires further exploration, particularly at the policy level. Therefore, it is necessary to conduct policy research on improving public outdoor leisure and fitness functions in this area of Chongqing.

2. Problem analysis

2.1. Existing problems

Since Chongqing became a directly administered municipality, successive governments have played a key role in promoting the construction and development of the two rivers and four banks in the city's main urban area. Significant achievements have been made in the construction of Binjiang Road and the riverside areas along these waterways. However, overall, there remains a gap between this development and the Chinese government's guiding principles of "innovation, coordination, green development, openness, and sharing." Furthermore, the current state of development does not align with Chongqing's status as a municipality directly under the Central Government, nor does it adequately support the city's goal of becoming an internationally renowned tourist destination and a scenic city celebrated for its mountains and rivers. These shortcomings are evident in several ways, as outlined below.

Firstly, there is an overemphasis on the capacity of the riverside highway and real estate investment in the area, leading to a lack of attention to the public's outdoor leisure and fitness needs. This neglect results in insufficient publicity for the waterfront area and a functional complexity that has led to a limited number of related facilities and services, which are of low quality.

Secondly, each administrative area operates independently, resulting in poor continuity of the riverside leisure and fitness spaces, with outdoor leisure and fitness corridors that are not interconnected.

Thirdly, there is a lack of infrastructure and public services, which creates poor access conditions and difficulties with parking. Finally, cultural refinement is insufficient, and there is a lack of overall brand building. These issues contribute to the lack of vitality in the two rivers and four banks of Chongqing's main urban area, highlighting the urgent need for improvements to meet the public's outdoor leisure needs.

2.2. Root cause of the problem

The above problems are compounded by natural conditions. For instance, the riverbanks are characterized by varying convexities and widths. The construction of viaducts and vertical retaining walls serves as a necessary measure to navigate the terrain and geomorphic challenges posed by Chongqing's mountainous landscape and river city. Additionally, limitations arise during different stages of development; however, the more significant issues lie within the system and mechanism. The root causes can be identified as follows.

Firstly, there is a lack of understanding regarding the unique characteristics of the area. The main urban area of Chongqing is a prime real estate location, featuring two rivers and four banks, which are backed by mountains and water. Many development initiatives prioritize real estate projects, and in some regions, the land financial development model has led to the aggressive appropriation of shoreline resources. Due to the absence of overall planning, the two rivers and four banks are fragmented into discontinuous plots by real estate developments, resulting in a chaotic riverside landscape that poses significant challenges for future remodeling.

Secondly, there is an absence of a comprehensive planning mechanism for the leisure development of the two rivers and four banks in Chongqing's main urban area. The property rights of land resources in this area are complex and fragmented, involving multiple administrative departments, which complicates management efforts.

2.3. Solutions to the problems

Based on the aforementioned reasons, improving the functions of public outdoor leisure and fitness solely through the units involved in the two rivers and four banks of Chongqing's main urban area is quite challenging and unlikely to result in comprehensive progress. Drawing from relevant domestic and international experiences, the enhancement of public outdoor leisure and fitness functions in this area requires the implementation of a Public-Private Partnership (PPP) model. This approach should be guided by the government, with supportive policies and measures in place to promote and ensure its reasonable development.

3. The overall design of public outdoor leisure and fitness functions on two rivers and four banks in Chongqing's main urban area

3.1. Guiding ideology

It is essential to clarify that the government is leading the effort to enhance public outdoor recreation and fitness along the two rivers and four banks in the main urban area of Chongqing. This can be achieved through the formulation of an operable and forward-looking policy system along with safeguard measures. The goal is to establish this area as a leisure function hub for the national central city, an ecological corridor for sustainable development, a cultural stage for healthy living, and a showcase for the image of an international metropolis.

3.2. Basic principles

The basic principles include reasonable positioning, overall planning, optimizing structure, integrating resources, highlighting key points, and improving overall levels.

3.3. Development goal

Transform the two rivers and four banks into Chongqing's public outdoor leisure and fitness belt, an urban landscape display area, and an important tourism corridor for the community.

3.4. Development orientation

Create a beautiful and comfortable landscape garden that serves as a "public living room" for the community.

3.5. Strategic path

Adopt a strategic path characterized by "government leadership, policy promotion, market promotion, and collaboration between government and business."

4. Policy suggestions for improving public outdoor leisure and fitness functions on two rivers and four banks in Chongqing's main urban area

Based on the actual situation and the Tourism Law of the People's Republic of China, as well as the Outline of National Tourism and Leisure Development (2022-2030) and other relevant laws and regulations, and considering the characteristics of the two rivers and four banks—specifically their wide coverage, large quantity, numerous construction and usage subjects, and dispersed nature— the following policies and measures are proposed.

4.1. Strengthen government leadership, improve institutions, and improve organizational guarantee

(1) Elevate the improvement and management of the leisure and fitness functions of the two rivers and four banks in Chongqing's main urban area to the municipal management level. Establish the "Leading Group for the Construction of the Two Rivers and Four Banks in the Main Urban Area of Chongqing" along with its office. Implement a joint meeting system to coordinate developing and constructing relevant areas.

(2) Clearly define the management bodies along with their rights, responsibilities, and interests at all levels. The management subjects are further refined to include the competent functional departments, construction units, property rights units, user units, and relevant administrative regions of Chongqing. Based on the nature and characteristics of these various management subjects and their relationship with the improvement of sports and leisure functions along the two rivers and four banks in the main urban area of Chongqing, the respective rights, responsibilities, and obligations should be clearly defined.

(3) Establish a coordination and liaison mechanism among Chongqing municipal departments. Actively promote the establishment of a cooperation framework between people's governments at all levels and their functional departments. Jointly study and address major issues in the process of enhancing the construction of sports and leisure functions along the two rivers and four banks in Chongqing's main urban area. This will ensure the efficient and orderly progress of key project planning, land use, environmental protection, and related initiatives.

(4) Establish a comprehensive management system for the leisure and fitness functions along the two rivers and four banks in Chongqing's main urban area. Adhere to established procedures and standards, and progressively enhance the relevant management framework.

(5) Establish and enhance the supervision and assessment system for key projects and important tasks, and implement a work responsibility and accountability system.

4.2. Formulate plans and emphasize the leading role of planning

(1) Formulate a development plan for outdoor recreation and fitness along the two rivers and four banks in

Chongqing's main urban area, and adjust and improve district-level planning in related areas. Ensure coordination between the enhancement of sports and leisure functions and the planning of urban development, industry, ports, highways, and environmental protection, while emphasizing the guiding and regulatory roles of the plan.

(2) Break down barriers and strengthen overall planning. Relevant districts should align with municipal plans, timely optimize and adjust their local planning, and move beyond the traditional construction models of districts, towns, and streets. The aim is to develop the two rivers and four banks in Chongqing's main urban area into an organically integrated outdoor leisure and fitness corridor.

(3) The planning should integrate the existing geomorphic features, reflect a clear hierarchy, and highlight Chongqing's beautiful landscape. It is important to achieve an organic balance between functionality and aesthetics, emphasize key areas, and create a harmonious integration of mountains, water, and city. The design should develop an appealing urban public space that meets market demand. While ensuring the tidiness of the two rivers and four banks in Chongqing's main urban area, the unique characteristics of each section should also be showcased.

(4) Establish construction standards and technical specifications to enhance the outdoor leisure and fitness functions along the two rivers and four banks in Chongqing's main urban area. Based on the level and type of each facility, refine the design, construction, management, and maintenance standards, along with technical specifications, to support supervision, assessment, evaluation, and law enforcement. This ensures that planning and design remain cutting-edge, scientific, and consistent.

(5) Adopt differentiated approaches and implement them step-by-step. It is essential to fully consider the specific conditions of each area and continue promoting the initiative while also accounting for the market demand and positioning of each location, avoiding a one-size-fits-all approach.

(6) Plan the integration of leisure and fitness functions along the two rivers and four banks in Chongqing's main urban area with municipal infrastructure such as urban roads, highways, and ports, ensuring thorough preparation in advance.

4.3. Promote the market, engage government and business, and increase policy support for leisure development

(1) Governments at all levels should fulfill their roles in comprehensive coordination, communication, and liaison, effectively manage project investments, and guide social forces in investing in and operating the leisure industry.

(2) Actively explore the Public-Private Partnership (PPP) model, collaborate with both government and business and promote the construction and management of outdoor leisure and fitness facilities.

(a) Effectively address the sources of construction and management funds. Clarify the channels, methods, and measures for improving the leisure and fitness functions along the two rivers and four banks in Chongqing's main urban area. This includes defining the responsibilities and obligations of governments, departments at all levels, and affiliated units regarding construction, maintenance, and management funds, specifying the proportions of funding, and establishing timelines for implementation.

(b) Establish a special fund account for multi-party financing. First, create a fund account specifically for improving leisure and fitness functions along the two rivers and four banks in Chongqing's main urban area. Second, lower the barriers to multi-party financing. Following the principle that "those who benefit should bear the burden," encourage all levels of government and enterprises to raise funds independently. Banks should provide low-interest or interest-free loans, and there should be active applications for urban renewal funds, tourism adjustment funds, and infrastructure relocation funds. Additionally, encourage social investments in related projects.

(3) Enhance government support for the construction and functional improvement of leisure and fitness facilities, and ensure the rational allocation of construction funds across all levels, including urban development, transportation, and parks along the two rivers and four banks in Chongqing's main urban area.

(4) Governments at all levels should support the recruitment and training of high-end leisure and fitness professionals, prioritize employee training and skill development, and provide human resources support for the development of the leisure and fitness industry along the two rivers and four banks in Chongqing's main urban area.

4.4. Strengthen management and actively build the brand of leisure and fitness area of the two rivers and four banks of Chongqing's main urban area

(1) Build the brand of the two rivers and four banks leisure and fitness area in Chongqing's main urban area based on a cluster of leisure and fitness industries, creating a competitive advantage for the region.

(2) Establish and improve a diversified cooperation mechanism involving government, industry, education, and research. This will enable continuous innovation of the leisure and fitness brand for the two rivers and four banks in Chongqing's main urban area and enhance its competitiveness.

5. Conclusion

With the establishment of China's all-round well-off society, the country's urban spatial patterns have undergone significant transformation in recent years, driven by industrial restructuring and urban renewal. Focusing on the improvement of public outdoor leisure and fitness facilities along the two rivers and four banks in Chongqing's main urban area, this paper proposes policy measures and suggestions based on Chongqing's specific circumstances.

These have two key levels of significance. Firstly, as the manager of urban renewal, the role of the government in the urban renewal process and how to effectively perform these roles offer valuable reference points. Secondly, exploring the government's public management behavior and operational mechanisms provides theoretical insights for improving government efficiency and refining management practices.

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References

[1] Ann B, Dick R, 1996, The New Waterfront. Thames & Hudson, London.

[2] Fudong Z, 2001, Comparative Study on the Development of Xiangjiang Scenic Belt and Rhine Scenic Belt. Journal of Tourism Studies, 2001(03): 57–59.

[3] Bihu W, Jia J, 2002, Developing and Managing Urban Waterfront Tourism/Recreational Spaces: A Case Study of Wuhan City, China. Geography and Territorial Studies, 2002(02): 99–102.

[4] Keshi C, Qian L, Yan Z, 2016, Exploration of Regeneration Strategies for Waterfront Areas at Port-City Interfaces: A Case Study of the Old Port in Marseille, France. Urban Development Research, 23(04): 27–31 + 38 + 153.

[5] Yong L, 2008, Harmony-Oriented Beautification of Riverside Areas: A Case Study on the Urban Image of "Two Rivers and Four Banks" in Chongqing's Main City. City Planning Review, 2008(05): 49–52.

[6] Wantai H, Hai H, Tao J, 2010, Reshaping Mountains, Cities and Waterfronts through Cultural Ecology: Urban Design for the Two Rivers and Four Banks Riverside Zone in Chongqing's Main City. Urban Planning Review, 34(01): 73–76.

[7] Qu Q, Qin Y, Weibo F, 2021, Preliminary Quantitative Evaluation Study on Waterfront Tourism Resources along Two Rivers and Four Banks in Chongqing's Urban Area. Land and Natural Resources Research, 2011(03): 59–61.

[8] Dan L, Wenyi S, Rongrong L, 2024, Construction of a Recreation Opportunity Spectrum for Informal Green Spaces along Riverbanks in Mountainous Cities: A Case Study from Two Rivers and Four Banks in Chongqing. Landscape Architecture, 31(02): 64–72.

[9] Guang C, 2024, Research on Decision-Making Pathways for Quality-Oriented Renewal of Urban Waterfront Areas. Planner, 40(S1): 78–85.

[10] Ting S, Weichen L, Wei W, et al., 2023, Research Progression and Future Prospects Regarding Redevelopment Initiatives at Urban Water Fronts. Advances in Geographic Sciences, 42(02): 392–405.

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Seismic Resilience Analysis of a Concrete-Framed Hospital Building with Viscous Dampers

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Abstract: To study the seismic resilience of a concrete-framed hospital building with viscous dampers, the elastoplastic time history analysis of a three-story concrete-framed hospital building under moderate and rare earthquakes was carried out by finite element analysis software. The structure's overall response was studied, meanwhile, the seismic resilience of the building was evaluated from three aspects: repair cost, repair time, and casualties. The results show that viscous dampers can effectively reduce the repair cost, repair time, and casualties under earthquakes. Compared with the structure without dampers, the repair cost and repair time of the structure with dampers have been reduced by 67% and 69% respectively under moderate earthquakes, 42% and 39% respectively under rare earthquakes, and the seismic resilience grade has been increased from zero to one star.

Keywords: Medical buildings; Viscous dampers; Seismic resilience; Repair cost; Repair time

Online publication: November 27, 2024

1. Introduction

Ensuring the continuation of hospitalization services and reducing overcrowding in emergency departments is critical for minimizing social and economic losses after earthquakes [1]. However, seismic damage surveys have shown that although the structure of the hospital building does not collapse, the damage to non-structural components such as medicine cabinets and medical equipment also leads to medical function disruption. More recently, the 2017 Mexico earthquake forced the main hospital to be evacuated after it suffered major damage, resulting in the patients being transferred to other hospitals [2]. Therefore, the seismic resilience of hospital buildings, including the functional recovery after the earthquake, is very important, and related research has also received great attention in recent years.

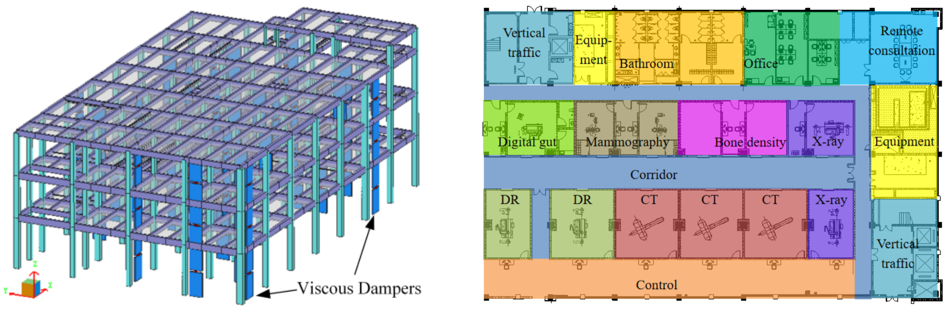
The Chinese seismic resilience evaluation standard, Seismic Resilience Assessment of Buildings (SSRAB) GBT38591-2020, has been published. This standard uses elastoplastic time history analysis of building structures and Monte Carlo simulations to calculate building repair costs, repair times, and casualties, thereby quantifying the seismic resilience index of buildings [3]. While the standard still lacks medical-related equipment seismic fragility parameters cannot be directly used in the seismic resilience evaluation of hospital buildings.

The viscous damper is a speed-related energy-consuming member, that adds damping to the structure without changing its stiffness and brings great convenience to the design of the structure. The viscous damper can effectively reduce the seismic shear force and seismic drift of the structure, while the influence on the seismic resilience of the building is not very clear. In this paper, the seismic resilience of a three-story concrete-framed hospital building with viscous dampers was analyzed based on the standard SSRAB and medical equipment fragility parameters, which provides a reference for the seismic resilience evaluation of similar hospital buildings.

2. Hospital building with viscous dampers

The hospital building is a three-story reinforced concrete frame structure and its total area is about 12,000 m^2. The building height is 20.3 m and its plane size is about 110 m × 37 m. There are seismic seams in the middle of the building, which divide the building into two parts, left and right. This paper takes the right part as the example, which structure modal is shown in **Figure 1(a)**, and the layout of the medical function room on the first floor is shown in **Figure 1(b)**.

The construction costs of the main structural components, enclosure and decoration components, heating, ventilation, air conditioning (HVAC) plumbing and equipment, and main medical equipment are 19.58, 14.75, 13.50, and 50.68 million Chinese yuan, respectively. The construction cost of the main medical equipment is highest, which takes about 51.4% of the total. The main medical equipment in this paper is classified into three categories, which are large, medium, and small medical equipment. The seismic fragility parameter of large medical equipment refers to the data of diesel generators in standard SSRAB. The seismic fragility parameter of medium and small medical equipment refers to the shaking table test data in previous studies [4,5].



(a) Building structure model (b) Medical function room layout

Figure 1. Schematic diagram of the hospital building

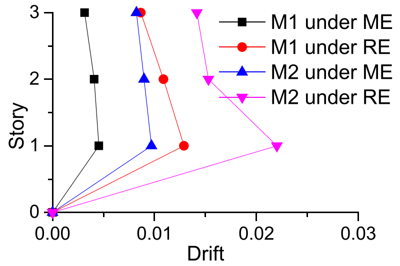
3. Seismic resilience analysis

3.1. Elastoplastic time history analysis

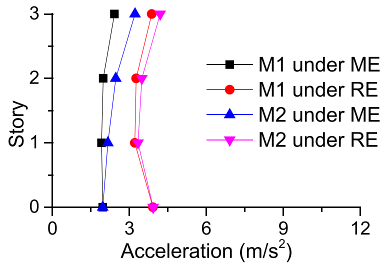
Software SAUSG-RES was used to establish the finite element model of the hospital building structure with (modal M1) and without (modal M2) viscous dampers. Fiber beam element was used to simulate the frame beams and columns and the Maxwell model was used to simulate the viscous dampers. The viscous dampers do not change the natural periods of building and the first three natural periods of model M1 and M2 are 1.21 s, 1.13 s and 1.09 s respectively.

Eleven groups of strong earthquake records were selected as the input motions of time history analysis, which response spectrum fit well with the design spectrum. The ratio of the peak acceleration of the main and secondary direction of earthquake motion is 1:0.85, and the peak acceleration of the main direction was scaled to 200 gal and 400 gal under moderate earthquake (ME) and rare earthquake (RE) respectively.

The mean value of story drift and floor acceleration for modal M1 and M2 under 11 groups of earthquakes ME and RE are shown in **Figure 2**. The viscous dampers can effectively reduce the structural floor response through the response comparison of modal M1 and M2. Compared with the structure without viscous dampers, the maximum story drift in a structure with viscous dampers is reduced by 49.2% and 38.8% under ME and RE respectively, and the maximum floor acceleration is reduced by 22.2% and 8.2% under ME and RE respectively.



(a) Mean value of story drift



(b) Mean value of floor acceleration

Figure 2. Comparison of structural response under earthquake motions

3.2. Additional engineering demand parameter generation

A large sample of the engineering demand parameter (EDP) vector is necessary to accurately estimate the cost of damage, while the computational cost hampers the time history analysis. Therefore, additional correlated EDP vectors are generated using a simulation method. The process enables the efficient generation of large numbers of artificial EDP vectors that have the same statistical distribution as the seed data that were generated by the dynamic analyses of the building model.

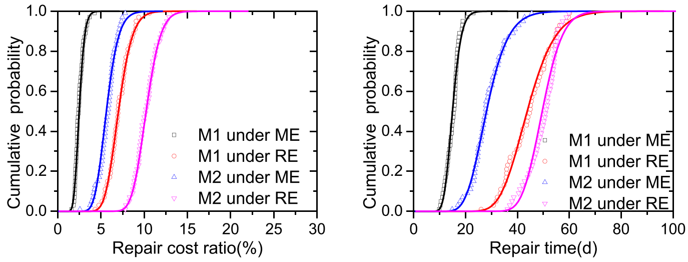
3.3. Seismic resilience index calculation

3.3.1. Repair cost ratio

The repair cost ratio cumulative probability of buildings model M1 and M2 under earthquakes ME and RE is shown in **Figure 3(a)**, in which 84% quantile of the probability distribution is used as the repair cost ratio index. The repair cost ratio index of models M1 and M2 is 2.80% and 7.03% under earthquake ME, while 8.61% and 12.0% under earthquake RE. The building can be rated as one star when the repair cost ratio index is less than 10% under ME, which can be further rated as two stars when the repair cost ratio index is less than 10% under RE. Thus model M1 can be rated as two stars while model M2 can only be rated as one star.

3.3.2. Repair time

The repair time cumulative probability of buildings model M1 and M2 under earthquakes ME and RE is shown in **Figure 3(b)**, in which 84% quantile of the probability distribution is used as the repair cost ratio index. The repair time index of models M1 and M2 is 16 d and 33 d under earthquake ME, while 52 d and 54 d under earthquake RE. The building can be rated as one star when the repair cost ratio index is less than 30 d under ME, which can be further rated as two stars when the repair cost ratio index is less than 30 d under RE. Thus, model M1 can be rated as one star while model M2 can only be rated as zero star.



(a) repair cost ratio (b) repair time

Figure 3. Seismic resilience index

3.3.3. Casualties

Casualties are related to the degree of damage to both structural and non-structural components of a building. As the 84% quantile of the mortality rate probability distribution of model M2 is greater than 0.01%, model M2 can only be rated as zero stars. While the mortality rate index of model M1 is less than 0.01% and its injury rate index is less than 0.1%, thus model M1 can only be rated as one star.

3.3.4. Resilience grade

The Resilience Standard takes the lowest grade of the three resilience index as the seismic resilience grade of the building. Although the repair cost of model M2 can be rated as one star, the repair time and casualties can only be rated as zero stars, so its seismic resilience grade is zero stars. Similarly, the repair cost of model M1 can be rated as two stars, but the repair time and casualties can only be rated as one star, so its seismic resilience grade is one star. Thus, adding viscous dampers can improve the seismic resilience grade of concrete frame hospital buildings from zero star to one star.

4. Conclusion

Based on the comparison of time history analysis and seismic resilience analysis between concrete frame structure hospital buildings with and without viscous dampers, the following conclusions can be drawn:

(1) Adding viscous dampers can reduce the maximum story drift of concrete frame structure hospital building by about 40% to 50% and maximum floor acceleration by about 10% to 20%.

(2) Compared with the structure without dampers, the repair cost and repair time of the structure with dampers have been reduced by 67% and 69% respectively under moderate earthquakes, 42% and 39% under rare earthquakes.

(3) Adding viscous dampers can effectively reduce the repair cost, repair time, and casualties, thus improving the seismic resilience of concrete frame hospital buildings from zero star to one star.

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The authors declare no conflict of interest.

References

[1] Hassan EM, Mahmoud H, 2019, Full Functionality and Recovery Assessment Framework for a Hospital Subjected to a Scenario Earthquake Event. Engineering Structures, 2019, 188: 165–177.

[2] Hassan EM, Mahmoud HA, 2018, Framework for Estimating Immediate Interdependent Functionality Reduction of a Steel Hospital Following a Seismic Event. Engineering Structures, 168: 669–683.

[3] Yang TY, Moehle J, Stojadinovic B, et al., 2009, Seismic Performance Evaluation of Facilities: Methodology and Implementation. Journal of Structural Engineering, 135(10): 1146–1154.

[4] Liu J, Zhai C, Yu P, et al., 2023, Experimental and Numerical Analysis of Wheeled Medical Equipment with Adjacent Wall Subjected to Earthquakes. Journal of Building Engineering, 72: 106635.

[5] Yu P, Zhai C, Liu J, et al., 2023, Shake Table Tests for the Seismic Performance Assessment of Desktop Medical Laboratory Equipment Considering the Effect of Adjacent Walls and Restrainers. Structures, 50: 1922–1933.

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Study on the Wind Erosion Resistance of Desert Soil Induced by Bacillus Megaterium

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Abstract: With the intensification of global climate change and the worsening of land degradation, desertification has emerged as a significant global issue threatening ecosystems and human activities. The technique of Microbial Induced Calcium Carbonate Precipitation (MICP) has been widely applied in soil stabilization and engineering geology in recent years. This study conducts experiments using Bacillus megaterium to solidify desert sand via MICP, aiming to explore its feasibility as a novel ecological method for desert protection. Experimental results indicate that desert sand treated with MICP exhibits a significant enhancement in wind erosion resistance, providing a potential solution for desert management and land restoration.

Keywords: MICP; Soil stabilization; Wind erosion resistance

Online publication: November 27, 2024

1. Introduction

1.1. Desertification and its global impact

Desertification is regarded as one of the most severe environmental threats facing global ecosystems, impacting not only the natural environment but also directly threatening human survival and development. According to the United Nations Convention to Combat Desertification (UNCCD), over 12 million hectares of land are lost annually due to desertification, affecting the livelihoods of one billion people worldwide [1]. Desertification leads to land degradation and food security issues, triggering socio-economic problems such as migration, increased poverty, and conflict. Regions severely affected by desertification include sub-Saharan Africa, parts of the Middle East and North Africa, certain areas of South America, and arid and semi-arid regions in Asia, particularly in Northwest China [2]. As climate change intensifies and population pressures increase, the issue of desertification has become more urgent, posing a formidable challenge to global ecological security [3].

1.2. Impact of dust storms on the environment and humanity

Dust storms, as a concomitant phenomenon of desertification, frequently occur in arid and semi-arid regions, posing significant threats to both the environment and human health. Wind erosion not only depletes soil by removing organic matter and minerals but also damages plant root systems and disrupts regional water cycles and climate patterns [4]. For instance, the frequent spring dust storms in Northern China not only harm local ecosystems but also negatively impact air quality in downwind countries and regions [5]. Once these dust particles enter the atmosphere, they can easily cross borders and affect air quality and climate change as far away as North America and Europe [6]. Additionally, dust storms lead to increased traffic accidents, respiratory diseases, and infrastructure damage, imposing a substantial burden on economic development [7].

1.3. Current status and limitations of windbreak and sand fixation technologies

To combat the harms of desertification and wind erosion, various countries have adopted a range of windbreak and sand fixation technologies, such as vegetation restoration, mechanical windbreaks, and chemical stabilizers. Vegetation restoration is a common ecological measure that stabilizes soil and reduces wind erosion by planting drought-resistant plants [8]. However, in extremely arid environments, the effectiveness of vegetation restoration is often limited due to water scarcity and poor soil quality, requiring substantial funding and long-term maintenance. Moreover, extreme weather conditions associated with climate change make it difficult for vegetation to survive long-term, further restricting the adoption of this technology [9].

Mechanical windbreaks, such as sand barriers and grids, can effectively block wind and sand in the short term, but their high costs and complex maintenance make large-scale implementation challenging. Chemical stabilizers, another effective technology, enhance soil wind resistance by altering its physical and chemical properties. However, their potential environmental toxicity and high costs hinder widespread application [10].

1.4. The rise of microbial-induced calcium carbonate precipitation technology

In recent years, scientists have begun to explore the use of biotechnology for windbreak and sand fixation, particularly through the MICP technique. This technology utilizes microbial metabolic activities to induce calcium carbonate precipitation, thereby enhancing soil strength and stability. This method has significant advantages in terms of environmental protection and sustainability, as the microbial-induced calcium carbonate precipitation process resembles natural mineral deposition, providing long-term soil stabilization and reducing soil loss [11].

The application prospects of MICP technology are vast, especially under extreme climatic conditions, as it can serve as an efficient, low-cost, and sustainable solution. Furthermore, this technology has minimal adverse environmental effects, avoiding the common pollution issues associated with chemical stabilizers. Although MICP has shown promising results in laboratory and small-scale trials, its large-scale application still faces technical challenges, such as controlling microbial activity and improving induction efficiency [12].

1.5. Objectives and significance of the study

This study aims to explore the application potential of MICP technology under wind erosion conditions, particularly its effectiveness in different wind speed scenarios. By comparing traditional windbreak measures with MICP technology, this research will provide a theoretical foundation and technical support for future large-scale applications. The findings will not only offer new insights for desertification control in arid and semi-arid regions but also contribute to mitigating the impacts of dust storms on human society and the environment, thereby enhancing global ecological security [13].

2. Methods

2.1. Materials and methods

2.1.1. Study area and climatic conditions

The experimental site selected for this study is located in a typical desertification area of arid and semi-arid regions in Northwest China. This area, situated in the Kashi, exhibits a typical continental climate with extremely low annual precipitation of only 50 mm, while the annual evaporation exceeds 2,000 mm. The region is characterized by widespread desert, frequent wind erosion activities, and high average annual wind speeds of 6.2 m/s, with frequent dust storms in spring. The severity of desertification in this area is evident in land degradation, soil salinization, sparse vegetation, and loss of biodiversity. The selection of this study area is based on its typical desertification characteristics and the testing requirements for MICP technology. The sandy conditions in this region provide valuable reference data for testing the effectiveness of MICP technology and its subsequent application.

2.2. Materials

2.2.1. Sand samples

The sand samples used in the experiments were collected from the top layer (0 cm to 30 cm) of typical desertified soil in the study area. The soil, after weathering, consists of medium to fine sand particles with a diameter ranging from 0.1 mm to 1.0 mm. Sample preparation involved naturally air-drying the collected sand to remove organic matter and other impurities, followed by sieving to eliminate particles larger than 2 mm to ensure consistency and repeatability in the experiments. The physical and chemical properties of the soil were determined through laboratory analysis, including particle size distribution, organic matter content, pH, and moisture content. The specific characteristics of the sand samples are as follows:

(1) Particle size distribution: 85% between 0.1 mm to 0.5 mm, 15% between 0.5 mm to 1.0 mm.

(2) pH: 8.1.

(3) Organic matter content: < 0.5%.

(4) Moisture content: 5%.

2.3. Microbial culture medium and strains

The primary strain used for the Microbial Induced Calcium Carbonate Precipitation (MICP) technology is a highly efficient urea-decomposing strain of the Bacillus genus. This strain is capable of rapidly hydrolyzing urea and producing calcium carbonate precipitation through its metabolic activities. The selection of this strain is based on its adaptability to extreme environments and its high urea hydrolysis activity. To ensure microbial activity, a standard peptone water medium was used, supplemented with urea and calcium chloride as substrates for inducing the precipitation reaction. The cultivation conditions for the strain were maintained at 30°C in a constant temperature incubator with a pH of 7.0. To maximize strain activity, the cultivation time before each experiment was limited to 24 hours, ensuring that the bacterial cells were in the logarithmic growth phase.

3. Experimental design

3.1. MICP experimental design

This study employs a combination of field simulation experiments and laboratory experiments to evaluate the effectiveness of MICP technology in wind erosion resistance under varying wind speeds and environmental conditions. The experimental design consists of the following three steps.

3.1.1. Microbial cultivation and preparation of biological treatment solution

For the MICP experiments, Bacillus megaterium, known for its excellent calcium precipitation ability, was utilized. The specific cultivation process is as follows:

(1) Medium preparation: LB medium (10 g/L peptone, 5 g/L yeast extract, 10 g/L sodium chloride) was used as the basic nutrient source for bacterial culture.
(2) Cultivation conditions: The bacteria were incubated at 37°C in a constant temperature shaker for 24 hours until the bacterial concentration reached an OD600 of 1.0.
(3) Preparation of bacterial suspension: Following cultivation, the bacterial suspension was centrifuged (4,000 rpm for 10 minutes), and the supernatant was discarded. The bacterial pellet was resuspended in sterile water to achieve the desired concentration (1.0 × 10^8 CFU/mL). Subsequently, a urea precipitation solution was prepared with an initial urea concentration of 1.0 M, mixed with the cultured bacterial suspension in a 1:1 ratio to obtain the final biological treatment solution.

3.1.2. Spraying treatment of precipitation solution

The prepared precipitation solution was uniformly sprayed onto the surface of the sand samples at a rate of 200 ml/m^2. Various types of treatment solutions were set up, including the biological treatment solution, urea solution, and distilled water, to investigate the effects of different treatments on sand fixation effectiveness.

3.1.3. Wind tunnel experiment

To simulate wind erosion conditions in a natural environment, a wind tunnel was employed to simulate wind erosion environments at different wind speeds. Three groups of comparative experiments were designed:

(1) Biological treatment group: Sprayed once with bacterial suspension and urea solution.
(2) Urea treatment group: Sprayed only with urea solution.
(3) Distilled water treatment group: Sprayed only with distilled water.

Each sand sample weighed 570 g. After treatment, the samples were maintained in the laboratory for 24 hours before being placed in the simulated wind tunnel, where wind erosion experiments were conducted for 8 minutes at wind speeds of 3 m/s, 6 m/s, 9 m/s, 12 m/s, and 15 m/s. The mass of the sand samples was recorded before and after the experiments to calculate mass loss due to wind erosion, as shown in **Table 1** and **Figure 1**.

Table 1. Data of wind erosion quality (g)

Wind speed (m/s)	3	6	9	12	15
Biological treatment	4.41	5.89	10.84	21.57	55.36
Urea treatment	256.18	369.57	570	570	570
Distilled water treatment	299.34	483.03	570	570	570

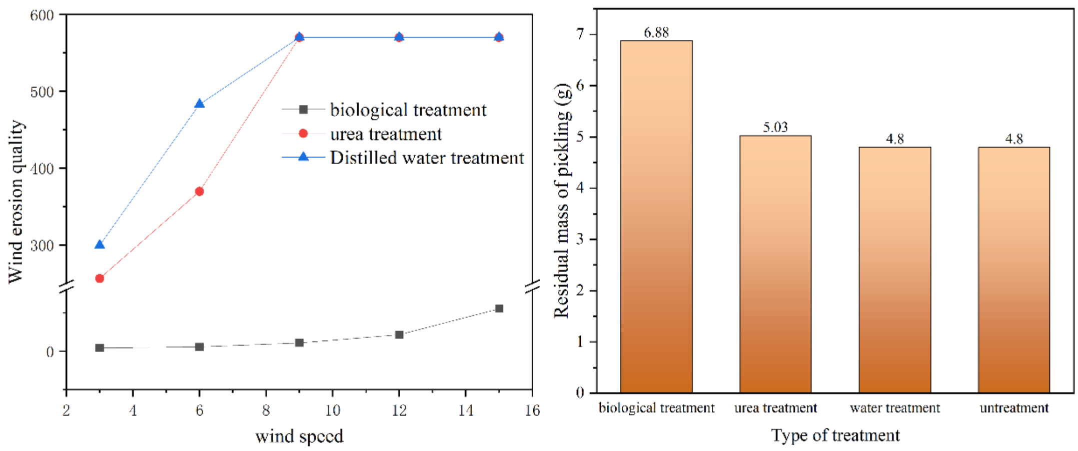

Figure 1. Data of wind speed and residual mass of pickling on different treatment types

4. Data collection and analysis

The primary data collected during the experiments included:

(1) Soil wind erosion resistance: The changes in wind erosion resistance of the sand samples before and after treatment were assessed by recording the mass loss. The residual mass of each group of sand samples was weighed at the end of each experiment to calculate the wind erosion mass.

(2) Calcium carbonate precipitation amount: The amount of calcium carbonate generated was measured by acid washing the treated soil samples.

4.1. Data measurement and analysis

The initial and post-experimental masses of the sand samples were measured using a high-precision electronic balance (accuracy of 0.01 g).

5. Results and discussion

5.1. Comparison of wind erosion resistance

According to the experimental results, the bacterial suspension + urea treatment group exhibited a significant advantage in wind erosion resistance. Under varying wind speed conditions, particularly at the lowest wind speed (3 m/s) and highest wind speed (15 m/s), the mass losses for this group were 0.41 g and 5.77 g, respectively, significantly lower than those of the other treatment groups. This indicates that MICP technology effectively enhances the wind erosion resistance of the sand samples through microbial-induced calcium carbonate precipitation. Although mass loss increased with wind speed, this treatment group maintained relatively low loss amounts, demonstrating the stabilizing effect of the calcium carbonate precipitation layer on the particles.

5.2. Comparison between the urea treatment group and the distilled water treatment group

In the experiments involving the urea treatment group and the distilled water treatment group, both groups experienced maximum mass loss (570 g) when wind speeds reached 9 m/s or above, indicating that the soil samples had nearly completely lost their wind erosion resistance. Even at lower wind speeds (3 m/s and 6 m/s), both groups exhibited significant mass loss. This suggests that neither the urea treatment nor the distilled water treatment had a substantial effect on improving the wind erosion resistance of the sand samples, failing to produce effective particle stabilization and deposition reactions.

5.3. Mass analysis after acid washing

5.3.1. Untreated and distilled water treatment groups

The mass of sand after acid washing for both groups was 4.8 g, indicating that distilled water treatment had no significant effect on restoring the mass of the sand samples. During the acid-washing process, both groups lost a considerable amount of surface particles and binding materials, and could not stabilize or deposit back into the samples, leading to low wind erosion resistance.

5.3.2. Urea treatment group

The mass of the sand samples treated with urea after acid washing was 5.03 g, slightly higher than that of the untreated and distilled water treatment groups. However, due to the absence of microbial activity, the amount of calcium carbonate precipitation was limited, resulting in only marginal improvement in wind resistance. This slight increase in mass may be attributed to ionic deposition from urea, but it was insufficient to significantly enhance the stability of the sand.

5.3.3 MICP treatment group

The mass of the sand samples treated with MICP after acid washing was 6.88 g, significantly higher than that of the other treatment groups. Through microbial-induced calcium carbonate precipitation, this treatment markedly increased the bonding strength between soil particles, forming a stable layer that resisted dissolution during the acid washing process. The calcium carbonate deposition effectively enhanced the structural integrity of the sand, greatly increasing its wind erosion resistance.

6. Conclusion

The experimental results demonstrate that MICP technology significantly enhances the wind erosion resistance of desert soil through microbial-induced calcium carbonate precipitation, particularly under high wind speed conditions, effectively reducing mass loss of the sand. In contrast, the urea treatment and distilled water treatment did not significantly improve the soil's wind resistance, yielding only minimal effects. Therefore, MICP technology shows great potential in combating desertification, especially in arid regions severely affected by wind erosion, with broad application prospects.

Disclosure statement

The author declares no conflict of interest.

References

[1] United Nations Convention to Combat Desertification (UNCCD), 2022, Global Land Outlook 2.

[2] Smith P, Calvin K, Nkemet J, et al., 2020, Which Practices Co-Deliver Food Security, Climate Change Mitigation and Adaptation, and Combat Land Degradation and Desertification? Global Change Biology, 26(3): 1532–1575.

[3] Bao Y, Cheng L, Yang L, et al., 2017, Desertification: China Provides a Solution to a Global Challenge. Frontiers of Agricultural Science and Engineering 4(4): 402–413.

[4] Anderson DT, 1966, Soil Erosion by Wind: Cause, Damage, Control.

[5] Zhang L, 2016, Causes and Prevention of Dust Storm Weather in Northern Regions. Modern Agriculture, 2016(07): 109–110.

[6] Firor J, 1990, The Changing Atmosphere: A Global Challenge. Yale University Press, Connecticut.

[7] Goudie AS, Middleton NJ, 2001, Saharan Dust Storms: Nature and Consequences. Earth-Science Reviews, 56(1–4): 179–204.

[8] Rehacek D, Khel T, Kucer J, et al., 2017, Effect of Windbreaks on Wind Speed Reduction and Soil Protection Against Wind Erosion. Soil & Water Research, 12(2): 128–135.

[9] van Ramshorst JGV, Siebicke L, Baumeister M, et al., 2022, Reducing Wind Erosion Through Agroforestry: A Case Study Using Large Eddy Simulations. Sustainability, 14(20): 13372.

[10] Shakeel AM, 2016, Stabilization of Soil Using Chemical Additives. Global Research and Development Journal for Engineering, 1(12): 2455–5703.

[11] Seifan M, Berenjian A, 2019, Microbially Induced Calcium Carbonate Precipitation: A Widespread Phenomenon in the Biological World. Applied Microbiology and Biotechnology, 103: 4693–4708.

[12] Yu T, Souli H, Péchaud Y, et al., 2022, Optimizing Protocols for Microbial Induced Calcite Precipitation (MICP) for

Soil Improvement–A Review. European Journal of Environmental and Civil Engineering, 26(6): 2218–2233.

[13] Liu J, Li G, Li X, 2021, Geotechnical Engineering Properties of Soils Solidified by Microbially Induced CaCO3 Precipitation (MICP). Advances in Civil Engineering, 2021(1): 6683930.

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Study of the Interior Design Based on Elderly People's Psychological Behaviors and Requirements

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Abstract: Nowadays, the elderly have become an increasingly large group of people in China, but still many problems exist in their living space. This paper explores the physiological and psychological behavioral changes of the elderly, studies their living space requirements, and tries to put forward targeted design strategies in response. Therefore, making a better and more reasonable living space for the elderly as well as improving their living quality, finally helping the development of elderly-friendly design in China.

Keywords: Interior design; Elderly-friendly design; Elderly's requirement

Online publication: November 28, 2024

1. Introduction

China is experiencing a rapid population aging situation, and the trend of an increasingly aging society might run through the 21st century. According to recent population studies, by 2035, the proportion of the aging population which is aged 65 and above will exceed 22% of the total population in China, while by 2050, the proportion of people over 65 may exceed 28% [1]. Under the impact of the "silver wave," how to combine the physiological and psychological behavioral needs of the elderly, and how to provide a better living environment for them has become a hot issue for Chinese society. Thus, the study of interior design based on elderly people's psychological behaviors and requirements has certain practical value for current society.

2. Analysis of the elderly's physiological and psychological behavioral changes

With the growth of age, elderly people undergo a series of changes in terms of physiological status, mental states, and psychological behavioral characteristics.

2.1. Physiological changes

With aging, the physiological functions of the human body degenerate constantly. The most obvious is the body shape change, such as rickets, hunchbacks, pigmentation, and silver hair. Besides, sensory system degeneration like vision, hearing, touch, taste, and smell directly impact the living quality and feelings of the elderly. Such as blurred vision caused by visual aging, and hearing loss or deafness caused by auditory aging. Amongst all, auditory aging is the most frequent problem for the elderly, at least 1/3 of the elderly over 65 undergo the inconvenience due to auditory aging in China [2]. Additionally, auditory aging also deepens the communication barriers between the elderly and others, leading to loneliness and a sense of inferiority, even resulting in bad mental states such as suspicion, melancholy, and irritability. Hearing loss can also degenerate autonomous ability and thinking ability [3].

2.2. Mental changes

Compared with physiological changes, mental changes of the elderly need more attention and observation. With aging, the degeneration of brain nerve cells leads to cognitive ability loss, which is also one of the omens of Alzheimer's Disease [4]. Moreover, communication barriers caused by physiological changes, and lower sense of security caused by surrounding changes such as the death of friends at the same age, lead to mental problems, especially in the following aspects:

(1) Existential anxiety: such as physiological disorders and death panic, the elderly tend to worry about their own survival which leads to depression and anxiety.
(2) Loneliness: such as cognitive disorders and living alone, they tend to show depression and lower living enthusiasm.
(3) Feeling of dependency: with the contact between the elderly and society decreases, they tend to require more response from their family. Otherwise, they will show suspicion, irritability, and depression.

2.3. Psychological behavioral changes

The activity periods and territories of the elderly are more regular than those of younger people. Their high-frequency activity periods are typically from 7 a.m. to 10 a.m., 2 p.m. to 5 p.m., and 6 p.m. to 8 p.m. [5]. Common indoor activities include cooking, eating, and resting, while outdoor activities often involve strolling. The activity territories consist of personal residences, communities, and public spaces. Personal residences offer the elderly private spaces that help process negative emotions, whereas communities or public places provide open and interactive environments, reducing the occurrence of negative emotions such as loneliness and anxiety.

3. Existing problems in the living spaces of the elderly

Elderly people in China are highly concentrated in economically developed areas such as the Yangtze River Delta and the Pearl River Delta [6]. In these regions, around 54% of the elderly live in residences that were built more than 20 years ago [7]. These residences suffer from "birth defects"—issues stemming from incomplete design considerations at the time of construction, along with evolving design experiences and regulations. As a result, several pain points have emerged, particularly in the following aspects.

3.1. Insecurity

There are numerous potential safety hazards in the daily lives of the elderly due to the deterioration of their physical abilities, such as risks of collisions and falls, which threaten their well-being. Many older residences, where most elderly people live, have safety-related issues, such as steep staircases or bathrooms without anti-slip flooring, increasing the risk of falls. Moreover, unprotected wall corners can cause injury in case of a collision.

3.2. Inconvenience

Due to the degradation of the elderly's physical functions, they are highly dependent on convenient and efficient living spaces. While residences built 20 years ago often featured hanging cabinets, the storage spaces are now too high to be easily reached, posing a potential fall risk when the elderly use stools to access them. Furthermore, unreasonable traffic flow and functional spaces increase the living burden for elderly individuals.

3.3. Less variable spatial design

Rooms and functional spaces in older residences tend to be less adaptable, as walls, ceilings, and furnishings are fixed and cannot accommodate different life stages and needs. For example, narrow doorways and passageways create difficulties for the elderly when using wheelchairs or nursing beds, while small bathrooms pose challenges for barrier-free design.

3.4. Low intelligent system design

Fall risks often lead to further injury or even death, particularly for those who live alone. When they fall and have no means to call for help, it delays effective treatment. Older residences are generally less equipped with intelligent systems or communication applications, limiting the elderly's ability to connect with the outside world, let alone facilitate direct observation from the outside.

3.5. Less emotional support

After retirement, the elderly's social identity changes, and their connection with the public weakens. As a result, they tend to spend more time with their family than before, leading to stronger feelings of dependency on their family.

Old residences rarely consider the emotional needs of the elderly. For example, indoor public spaces like living rooms are often poorly designed, which leads to inadequate family interactions. Additionally, the color and material selections are frequently inappropriate, making it difficult to provide a sense of warmth and belonging for elderly individuals.

4. Design strategies based on the elderly's requirements

Through the analysis above, existing problems in the living space of the elderly can be seen. In response, four design strategies are proposed as follows.

4.1. Create safe territory

A series of security designs can be adapted to provide a sense of security.

4.1.1. Design details

The elderly are highly threatened by potential safety hazards like collision risk and fall risk. To decrease the occurrence of the potential risks, several design details should be considered.

Firstly, the corner construction of walls and furnishings. Sharp corners can be fatal when people fall onto them, so it is necessary to prevent sharp and vertical-angle corners, instead, filleted corners or corners with protections can be used. Secondly, height differences should be avoided to provide wheelchair-friendly environments, gentle slopes can be used too. Thirdly, to avoid unexpected barriers to the indoor traffic flow which disturbs the elderly from walking around, furniture should be well collected or less designed. It has been discussed that the floor areas occupied by furnishings should be less than 50% in elderly people's residences [8]. Lastly, floor material selection is vital, especially for the kitchen and bathroom, the floor should be designed in anti-slip materials or with rough texture on the surface.

4.1.2. Intelligent system

With the development of modern science and technology, more and more intelligent facilities can be applied to the living space to ensure safety. Such as water or gas monitoring alarms, provide real-time monitoring, and prevent bad accidents when people forget to turn off the switch. Indoor video monitoring constantly monitors the actions of the elderly, alerts the alarm, or sends reports when abnormal actions occur. Sensor lights can be used to prevent difficulties when the elderly walk around at night.

4.2. Create a familiar and convenient environment

As they age, the elderly's ability to adapt to new environments weakens, leading them to rely heavily on familiar surroundings that provide a sense of security. They often exhibit nostalgic and conservative mental states. Compared to younger people, the elderly tend to choose convenient, efficient, and familiar spaces. Living in such environments helps them maintain their independence and enhances their sense of self-identity. Therefore, targeted design proposals should be developed based on thorough design investigations, with an in-depth understanding of the elderly's living habits and requirements.

4.2.1. Elderly-friendly scales

Firstly, the width of doorways and passageways should be increased to 1.0 m and 1.2 m, respectively, to ensure accessibility for wheelchair users. The barrier-free design in the living room and bathroom requires at least one area with a diameter of 1.5 m to allow the wheelchair to move easily. Furthermore, the width of the aisle beside the bed should not be less than 80 cm to accommodate bedside care and nursing needs [9].

Secondly, the height of switches, door handles, and worktops in the kitchen or bathroom should be relatively lower for wheelchair users. For example, the height of light switches should not exceed 1.2 m, and research suggests that the height of kitchen worktops for wheelchair users should be designed within the range of 690 mm to 840 mm [10].

Thirdly, the traffic flow length from the bedroom to the bathroom and from the kitchen to the dining room should be short and direct. Designing the bathroom adjacent to the bedroom and the kitchen near the dining room can better accommodate the living needs of the elderly.

4.2.2. Atmosphere creation

For elderly individuals, the ability to perceive different functional spaces is weaker than their ability to detect changes in color or light and shadow [11]. Therefore, the application of various colors can enhance the elderly's sensory capabilities. According to previous research, elderly individuals prefer bright tones such as orange, green, red, and yellow over other colors [12]. Walls and decorations in these colors can create a more inviting living atmosphere for them. Additionally, using bright colors in different functional spaces or on guiding signs can provide a sense of security for elderly individuals.

Moreover, proper material selection directly impacts the creation of the atmosphere. Compared to stone and metal, which convey luxurious and calm qualities, wood and fabrics offer mild and gentle characteristics that are better suited for the living spaces of elderly people.

4.3. Variable space design

People have different living requirements at various stages of life. Therefore, variable space design should be employed to accommodate these diverse needs. For instance, transitions from independent walking to wheelchair use, as well as changes from normal vision to blindness, create specific requirements for scale and functional spaces. Designers should anticipate these changes and make proposals based on careful consideration of the user's potential future needs.

4.4. Emotional supportive design

Elderly individuals primarily express their emotions through interactions with their offspring and are keen on family-oriented activities. Therefore, emotionally supportive design aims to create interactive spaces that foster family togetherness, enhancing the elderly's sense of belonging.

A living room with a larger area can accommodate family activities, allowing three or four generations to communicate fully in this space. The design of a Kitchen-Dining-Living (KDL) area facilitates long-lasting family interactions by integrating cooking, dining, and resting spaces, thus meeting the elderly's need for family engagement.

Decorations that evoke emotional resonance for the elderly, such as family photos and sculptures, can enhance the environment. Furthermore, incorporating beautiful houseplants not only improves the living space but also enriches the leisure time of the elderly. Using bright, warm colors and soft materials contributes to a cozy and peaceful atmosphere, promoting a positive mood for the elderly.

5. Conclusion

In this study, the analysis of the elderly's physiological and psychological behavioral changes reveals the existing problems in their living space. In response, four design strategies have been carried out, hoping to provide certain theoretical support for the elderly's living space design projects, and to meet their requirements, thus improving their living quality and then promoting the harmonious development of our society.

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References

[1] Chen W, Guo Y, 2023, Negative Population Growth and Population Ageing in China. Social Sciences of Beijing, 2023(08): 101–112.

[2] Xu N, 2023, Study on Interior Design of Nursing Home based on Behavioral Characteristics of the Elderly, thesis, Nanjing Forestry University.

[3] Yin YK, 2021, Research on the Design of Nursing Home for the Aged Based on the Elderly's Environmental Perception, thesis, Dalian University of Foreign Languages.

[4] Niu XY, 2015, Current Status and Prospect of Cognitive Training for Alzheimer's Disease in China. Chinese Journal of Geriatric Heart Brain and Vessel Diseases, 17(03): 225–226.

[5] Weng ZY, 2021, A Study on the Adaptability of Public Green Space in Open Residential Areas: A Case Study of Coastal Sailuo City. Spatial Governance for High-quality Development: Proceedings of the 2020 China Urban Planning Annual Conference (19 Housing and Community Planning). Beijing University Of Technology, 2021: 17. https://doi.org/10.26914/c.cnkihy.2021.035882

[6] Fang H, Xue BX, Zhao ZQ, 2015, From "Aging" to "Longevity Cities": The Geographical Distribution of China's Elderly Population. The New Normal: Inheritance and Change: Proceedings of the 2015 China Urban Planning Annual Conference (09 Urban Master Plan). Urban Planning Society of China, Guiyang Municipal People's Government: Urban Planning Society of China, 2015: 841–847.

[7] Beike Research Institute, 2021, Report on the Status and Future Trends of Community Home Care for the Elderly. Published October 14, 2021. https://research.ke.com/121/ArticleDetail?id=450

[8] Hao X, 2017, Research and Practice of Design Standards for The Elderly Under The Home Care Model, thesis, Beijing University of Civil Engineering and Architecture.

[9] Yang Y, Ge XD, 2024, Strategies of Elderly Oriented Residential Renovation on Home-based Elderly Care Model. Journal of Anshan Normal University, 26(04): 77–82.

[10] Zheng YM, Ma GT, 2024, Ergonomics-based Study on Aging-friendly Design of Kitchen Furniture. Design, 37(05): 101–103. https://doi.org/10.20055/j.cnki.1003-0069.001622

[11] Zhao PF, Liu Q, 2023, Research on the Design of Living Space for the Aged Based on Multi-sensory Theory. Design, 36(13): 86–90. https://doi.org/10.20055/j.cnki.1003-0069.000877

[12] Fu Y, Wang ZT, Hui R, et al., 2021, Analysis of Visual Comfort Distance and Color Preference of the Elderly in the Living Space of Elderly Care Institutions. Journal of Shenyang Jianzhu University (Natural Science), 37(02): 338–345.

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Review of Key Technologies and Applications in Intelligent Transportation Systems

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Abstract: The development of Intelligent Transportation Systems (ITS) is closely intertwined with the growth of every city, serving as a critical component of smart city construction. This paper provides a concise overview of the concept and overall framework of smart transportation. It emphasizes the application of key technologies, including Traffic Element Identification and Perception, data mining, and Smart Transportation System Integration Technology, in the field. Furthermore, the paper elucidates the current practical applications of smart transportation, showcasing its advancements and implementations in real-world scenarios.

Keywords: Smart city; Intelligent transportation; Smart bus; Smart parking

Online publication: November 28, 2024

1. Introduction

Intelligent Transportation integrates advanced Information Technology (IT) such as the Internet of Things (IoT), cloud computing, big data, and mobile internet into traditional intelligent transportation systems to provide real-time traffic data services [1]. In the new era, constructing intelligent transportation systems to achieve smart travel is a crucial aspect of national transportation development. It is a significant initiative in building a powerful transportation nation and an excellent opportunity for intelligent transportation upgrades in the post-pandemic era. The strategic connotation of smart travel includes ensuring transportation safety, achieving convenient travel, promoting green travel, and creating smart travel solutions. Building intelligent transportation systems is a vital measure for achieving sustainable transportation development and upgrading the transportation industry chain. By leveraging these high-tech advancements, the goal is to enhance traffic management, improve safety and efficiency, and ultimately foster a more sustainable and intelligent transportation infrastructure.

2. Overview of intelligent transportation

Intelligent transportation represents an advanced iteration of ITS, integrating sophisticated technologies like the

Internet of Things, cloud computing, big data, and wireless sensing. Its application is projected to significantly increase the capacity of congested roads and overall transportation during peak times while decreasing traffic accident rates by 80 percentage points [2].

Intelligent transportation encompasses various fields, including highways, railways, civil aviation, and waterways. The challenge for intelligent transportation is how to integrate information from multiple platforms and analyze the data to uncover potential traffic patterns, thereby providing better services to road users [3]. In an intelligent transportation network, pedestrians, vehicles, and surrounding infrastructure can all act as sensing terminals, connected to form an urban road network information system. These terminals use technologies such as Radio Frequency Identification (RFID), Global Positioning System (GPS), and infrared sensing for intelligent identification. They are interconnected according to specific protocols and continuously exchange information.

The transition from ITS to intelligent transportation represents a qualitative leap both in theory and application. The framework of intelligent transportation is becoming increasingly clear, as depicted in **Figure 1**. The framework in previous research, enhanced with auxiliary networks, exemplifies intelligent transportation [4]. Vehicles adjust speed dynamically based on environmental feedback and aid drivers in decision-making during unexpected incidents.

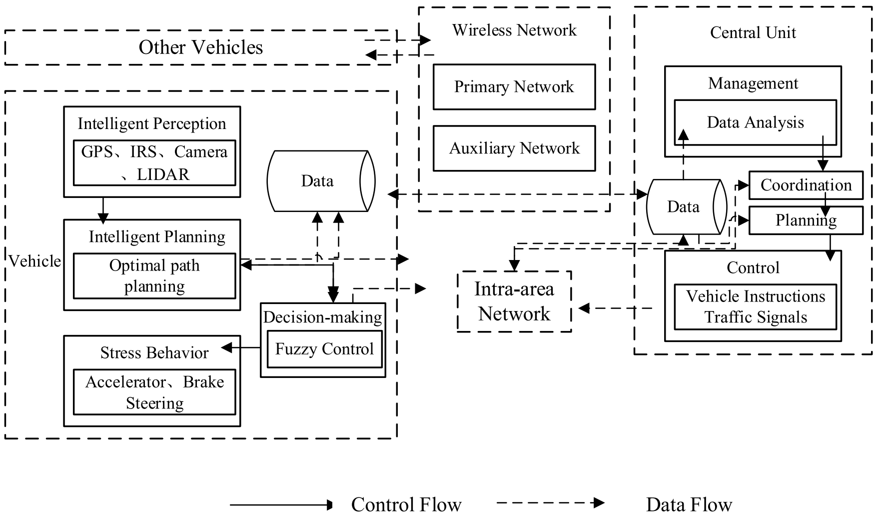


Figure 1. Improved AUTOPIA general framework

3. Key technologies of smart transportation

3.1. Traffic element identification and perception

Intelligent recognition and wireless sensor technology are pivotal for object identification in smart transportation systems. Objects are tagged with unique barcodes, Quick-Response (QR) codes, or RFID tags encoding their characteristics and location, read by intelligent devices for identification and decision-making [5]. Wireless Sensor Networks (WSNs) form a multi-hop, self-organizing network of low-cost micro-sensor nodes within the monitoring area, offering flexibility, cost-effectiveness, and ease of deployment [6]. In smart transportation, sensors are divided into collection and sink nodes. Collection nodes, as embedded systems, gather and process environmental data before transmitting it to other nodes or the sink node. The sink node integrates data from collection nodes and forwards it to the processing center [7]. As the IoT's underlying network, WSNs enhance smart transportation's safety, reliability, and sensitivity. However, sensor node energy consumption and lifespan are crucial, as neglecting them can lead to substantial maintenance costs.

3.2. Data processing

The complexity of smart transportation data, characterized by vastness, diversity, and heterogeneity, spans from basic facility and vehicle data collection to intricate traffic incident detection requiring real-time, accurate processing. Key techniques include Data Fusion, Vitalization, etc.

Data Fusion is a multidisciplinary technique integrating Artificial Intelligence (AI), communication, decision theory, and estimation theory. It processes multi-source information at data, feature, and decision levels [8]. Preprocessing aligns diverse sensor data for consistency, reliability, and accuracy [9]. In intelligent transportation, isolated data handling is inefficient. Data Mining converts noisy data into valuable knowledge [10]. A Statistical Package for the Social Sciences (SPSS) Modeler study analyzed traffic data, revealing flow relations with time, holidays, and weather, confirming mining reliability [11].

Data Vitalization is an innovative technique that animates data via "Vital Cells" capable of storage, mapping, and computation, evolving autonomously with data description changes and adapting to user behavior [12]. In transportation, it promises a data-driven evolution, leveraging Point of Interest (POI), GPS, and passenger flow data to analyze urban traffic and offer services like navigation, location-based alerts, and traffic rerouting [13].

3.3. Smart transportation system integration technology

Currently, smart transportation systems are fragmented across provinces, cities, departments, and scenarios, forming "information islands" due to a lack of data sharing, leading to high costs and unrealized potential. Urgent research on system integration technology, categorized as data and equipment integration, is needed.

Data integration has two application approaches. One is the fusion of data within a single platform system, such as the integrated processing of multiple sensor information from vehicle monitoring modules. The other is the analysis and processing of related data from multiple platforms and sensors across different periods, leveraging fused data to predict traffic information [14].

Equipment integration is necessary for legacy systems to transition to smart transportation without immediate replacement. A unified standard system and management regulations can create a standardized platform integrating government, enterprise, and research resources in the smart transportation industry. Large enterprises can lead industrialization, forming a comprehensive management system [15].

4. Typical applications

Presently, extensive research has been carried out on diverse aspects of smart transportation. From terminal intelligence, there are smart vehicles, intelligent traffic signals, and others. Broadly, smart transportation includes smart buses, taxis, ports, etc. In terms of functionality, it covers license plate recognition, Closed-Circuit Television (CCTV) surveillance, traffic flow control, vehicle dispatch, smart parking, route planning, navigation, and assisted driving systems. This article briefly discusses the current status of smart transportation through several typical applications.

4.1. Smart bus

Public buses, the primary urban transportation mode, offer advantages over private cars in capacity, fuel efficiency, land use, and cost. The Smart Bus System integrates advanced technologies like intelligent recognition, network communication, and Geographic Information System (GIS) for efficient management in dispatching, operations, route planning, and passenger services. This system resembles a mini-IoT for transportation, with in-vehicle sensors, platform equipment, and Integrated Circuit (IC) cards collecting data transmitted to the dispatch center for processing. Real-time information on bus arrivals, surroundings, and passenger flow is then displayed via smart signs and displays [16].

Based on Wuhu's bus system, previous literature proposed a public transportation integration framework using Service-Oriented Architecture (SOA) [17]. It employs the Fisher clustering algorithm to analyze IC card data and passenger flow patterns, introducing a time-segmented adaptive dispatching algorithm tailored to passenger flow fluctuations. Cities like Beijing, Suzhou, and Changzhou have implemented smart bus systems, enhancing residents' travel.

Figure 2 depicts the transport system model adopted in the proposed architecture, leveraging advancements in intelligent systems, communication technologies, and sensors. Dimitrakopoulos introduced the concept of cognitive transport networks, where infrastructure, vehicle, and personal device sensors collect data transmitted via various communication technologies. Advanced data processing, like big data or mining, generates new knowledge to improve public transport.

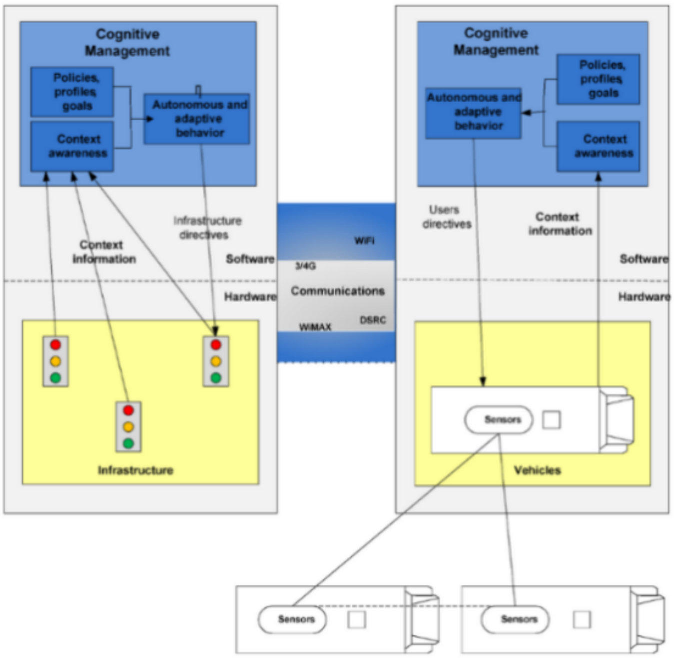
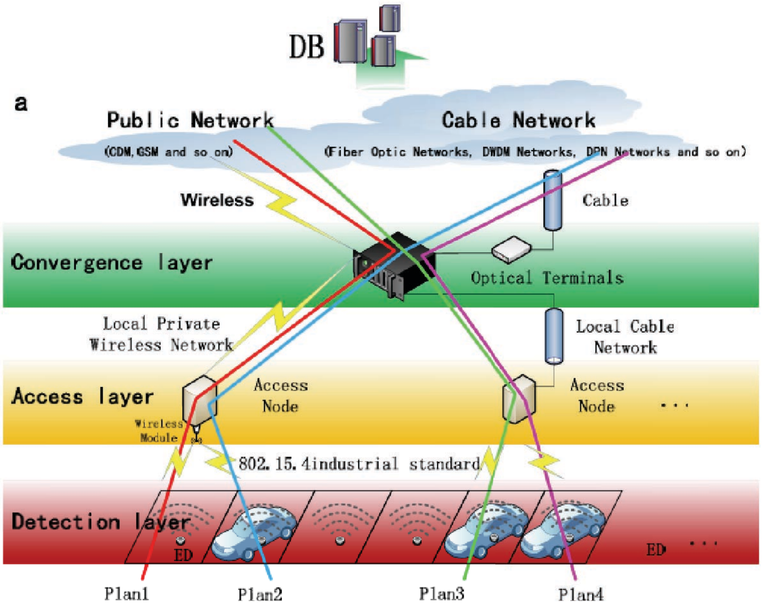


Figure 2. Concept illustration of the cognitive transport network based on the cooperation of all elements of the transport network (infrastructure, vehicles, and users) [18]

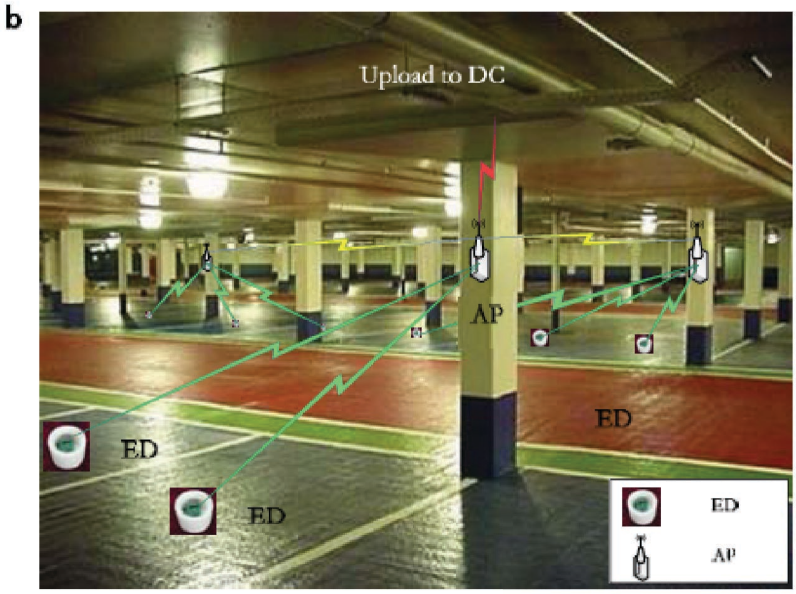
4.2. Smart parking

Magnetic sensor-based parking surveys in intelligent systems, crucial for planning with facility details, utilization rates, and indices are considered. Real-time space availability supports parking management, strategy, and driver needs. Surveillance-enabled surveys update availability, enhancing guidance systems to expedite parking and cut emissions. Magnetic sensors excel in cost, size, weight, power, and installation compared to others. The system uses WSN for data capture, as shown in **Figure 3(a)**.

The frame comprises three layers: detection, access, and convergence, especially for long transmission distances. In the detection layer, data from electronic devices (Electronic Devices (EDs) or sensors) is sent to the access layer via 802.15.4 industrial standard, then to the convergence layer via local wireless or cable networks. Ultimately, data reaches the Data Center (DC) similarly to the access layer path. Four plans exist for data transmission in WSN. In parking lots, a two-layer WSN can detect spaces if data is only uploaded to the local DC (see **Figure 3(b)**, where AP stands for Access Point).



(a) General case: when the transmission distance is far [19]



(b) Special case: when the transmission case is closed [19]

Figure 3. Working frame of WSN

Ali Cloud pioneered smart parking by deploying a payment system in Hangzhou covering over 20,000 spaces across various districts. This system utilizes smart sensors to detect vehicle entry and exit, alerting parking attendants via handheld devices, and enhancing space turnover efficiency [20]. Li proposed an embedded monitoring system with enhanced real-time performance using ZigBee and Advanced RISC Machine (ARM) [21]. Shan from Liaoning Technical University developed a Ultra-High Frequency (UHF) reader paired with passive tags, overcoming RFID range limitations in standard parking lots for broader applications [22].

Indoor parking more often has complex environments, and their equipment is not easy to maintain, making precise indoor positioning and real-time response even more challenging. To address this, Zhang from Jiangxi University of Science and Technology's indoor smart parking management system utilizes Bluetooth for communication and installs guiding lights at intersections within the parking lot to provide reverse guidance for parking spaces.

5. Conclusion

This article commences with an exploration of the concept of intelligent transportation, subsequently delving into the pivotal technologies and evolutionary trajectory shaping this domain. Furthermore, it presents a concise synopsis of the hallmark applications of intelligent transportation. Subsequently, the article delves into the operating principles and showcases exemplary instances of smart buses and smart parking systems. These systems leverage cutting-edge technologies to revolutionize public transportation and parking management, enhancing efficiency, reducing emissions, and enhancing the overall travel experience for commuters.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Yan G, Jin HL, 2019, Blockchain Technology and Simulation Case Analysis to Construct a Big Data Platform for Urban Intelligent Transportation. Journal of Highway and Transportation Research and Development (English Edition), 13(4): 77–87.

[2] Liu X, Wu M, 2012, Internet of Vehicles: Application of the Internet of Things in Urban Transportation Networks. Journal of Computer Applications, 32(4): 900–904.

[3] Zhang G, 2013, Intelligent Transportation Internet of Things and Comprehensive Transportation Information Services — A Record of the 30th Session of the "Transportation 7 + 1 Forum." Journal of Transportation Systems Engineering and Information Technology, 13(2): 1–8.

[4] Codoy I, Milanés V, Pérez J, et al., 2013, An Auxiliary V2I Network for Road Transport and Dynamic Environments. Transportation Research Part C, 2013(37): 145–155.

[5] Gan Q, 2012, Research and Application of RFID in Intelligent Transportation Internet of Things, thesis, Xinjiang University, 2012: 10–15.

[6] Shi W, You H, Tang Y, et al., 2008, Application of Middleware in the Design of Wireless Sensor Network Nodes. Transducer and Microsystem Technologies, 27(7): 111–113.

[7] Liu C, 2011, Research on Road Traffic Monitoring System Based on Wireless Sensor Network, thesis, Huazhong University of Science and Technology, 2011: 1–10.

[8] Wang H, Zhu Y, Yang D, 2001, Data Fusion Technology and Its Application in Transportation Field. Computer and Communications, 19(z1): 42–45.

[9] Zhou B, Lu Y, Liu Z, 2007, Research on Data Preprocessing Technology in Multi-sensor Data Fusion. Infrared and Laser Engineering, 36(z2): 247–249.

[10] Zhu X, 2013, Application of Data Mining Technology in Transportation Field, thesis, Henan Normal University, 2013: 5–10.

[11] Guo H, Zhou J, 2013, Application of Data Mining in Intelligent Transportation Field. Modern Business Trade Industry, 2013(12): 152–153.

[12] Xiong Z, Luo W, Chen L, 2010, Data Vitalization: A New Paradigm for Large-Scale Dataset Analysis. IEEE 16th International Conference on Parallel and Distributed Systems (ICPADS), Shanghai, China, 2010: 5.

[13] Wang J, Li C, Zhang X, et al., 2014, A Survey on Data-Centric Smart City Research. Journal of Computer Research and Development, 51(2): 239–259.

[14] Yan X, Zhang H, Wu C, 2012, Research and Development of Intelligent Transportation Systems. 11th International Symposium on Distributed Computing and Applications to Business, Engineering and Science, Guilin, China, 2012(107): 321–326.

[15] Liu H, Huang J, 2014, Intelligent Transportation Internet of Things Technology and Industrialization. Journal of Engineering Studies, 2014(1): 20–29.

[16] Guo A, 2013, Research on Intelligent Public Transport System Based on Internet of Things, thesis, Xi'an University of Technology, 2013: 5–12.

[17] Zhou X, 2013, Research and Development of Intelligent Bus Dispatching and Monitoring Software, thesis, Nanjing University of Science and Technology, 2013: 41–46.

[18] Garcia CR, Quesada-Arencibia A, Cristobal T, et al., 2016, Systematic Development of Intelligent Systems for Public Road Transport. Sensors, 16: 1104.

[19] Na C, Lu W, Limin J, et al., 2016, Parking Survey Made Efficient in Intelligent Parking Systems. Procedia Engineering, 137: 487–495.

[20] Sina Tech, 2014, Ali Cloud Enters "Smart Parking" Market. Published August 8, 2014. http://tech.sina.com.cn/it/2014-08-08/11059542908.shtml

[21] Li Z, Wang F, 2014, Remote Monitoring System for Intelligent Parking Lot Based on Embedded System. Chinese Journal of Electron Devices, 37(4): 742–745.

[22] Shan X, 2012, Design of UHF Reader-Writer Based on Intelligent Parking Lot, thesis, Liaoning Technical University, 2012: 20–28.

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Evaluation of Thermal Comfort in Urban Parks in Guangzhou City

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Abstract: Thermal comfort evaluations for Yuexiu Park, Lushan Park, and Baiyun Lake Park in Guangzhou were conducted using field meteorological data collection, visitor questionnaires, and literature reviews. It analyzed the impact of green coverage, water body layout, and facility configuration on thermal comfort. The results showed that good green and water body design effectively lowered the temperature in the park and improved the thermal comfort of visitors, but the insufficient facility configuration in some open areas affected the experience. The visitor's experience is closely related to the natural environment and facility layout of the park. Therefore, in the future, park design should pay more attention to the rational configuration of shading, ventilation, and cooling facilities to improve thermal comfort, and encourage citizens to participate in the construction and management of parks to improve ecological quality and user experience. This study provides a reference for the improvement of thermal comfort in urban parks in Guangzhou and aims to promote the sustainable and human-oriented development of urban park design.

Keywords: Guangzhou City; Urban parks; Thermal comfort; Microclimate; Green coverage; Water layout; Sustainable design

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1. Introduction

1.1. Background and purpose of the study

Global climate change has led to an increase in extreme weather events and the urban heat island effect, which causes the temperature in urban centers to be higher than in suburban areas, affecting the comfort and health of residents. Urban green spaces, especially parks, have become an important means of alleviating the urban heat island effect. Parks not only provide leisure spaces but also improve the urban microclimate by increasing vegetation and promoting air circulation, thereby enhancing thermal comfort. However, as urban populations grow and expand, optimizing the layout and design of parks to maximize their role in alleviating the urban heat island effect has become an important topic in urban planning.

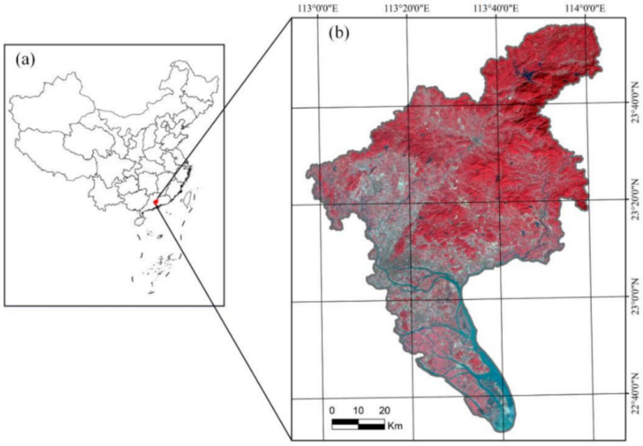

Figure 1. Remote sensing satellite positioning of Guangzhou

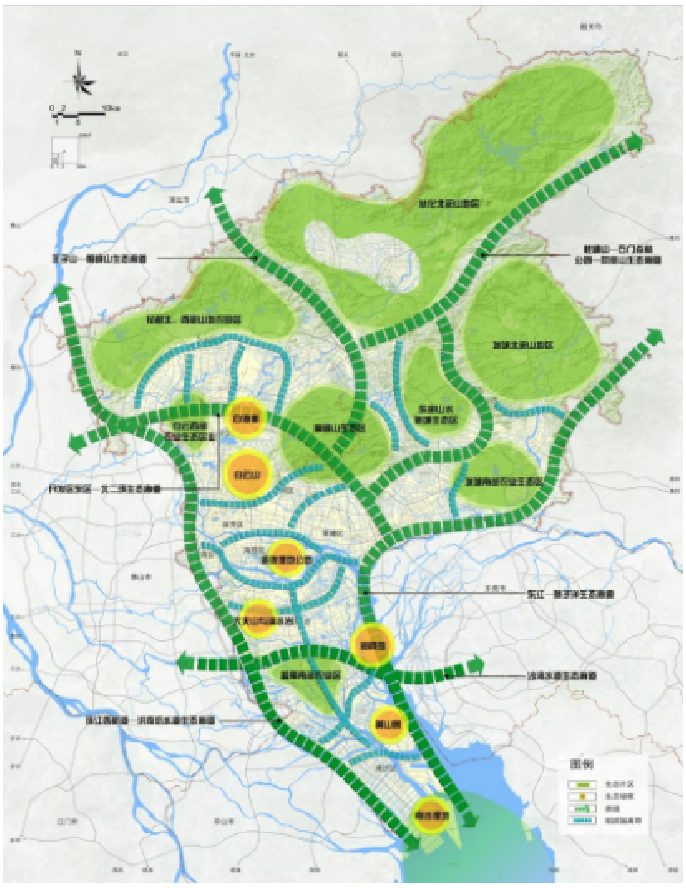

Figure 2. Urban ecological corridor morphology in Guangzhou

Guangzhou, as a subtropical city, experiences high temperatures and humidity in summer, challenging the thermal comfort of its residents. Urban parks are important facilities for mitigating the urban heat island effect, and their thermal comfort research is of great significance for improving the quality of life for citizens and providing reference for similar climate cities [1]. This paper takes urban parks in Guangzhou as the research object and evaluates their current thermal comfort status and influencing factors through field investigation and data analysis. It draws on domestic and foreign experiences to propose improvement suggestions, providing theoretical support and practical guidance for future park design and construction.

2. Objective and scope of the study

2.1. Subject of the study

This study focuses on the evaluation of thermal comfort in urban parks in Guangzhou City. Several representative parks in Guangzhou were selected as case studies, including Yuexiu Park, Luhu Park, and Baiyun Lake Park. These parks differ in terms of area, geographic location, function, and green coverage, and thus can better reflect the performance of different types of urban parks in Guangzhou in terms of thermal comfort [2].

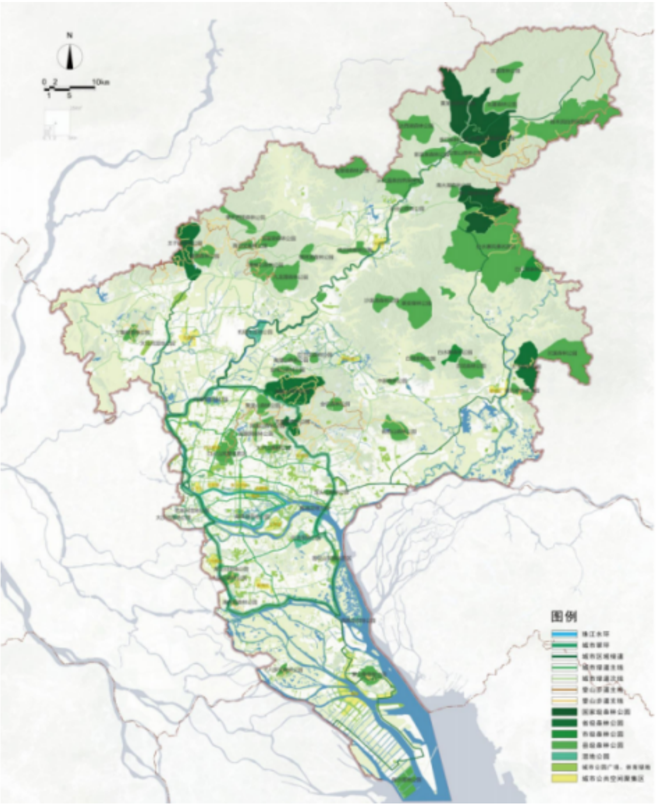

Figure 3. Distribution of urban parks in Guangzhou

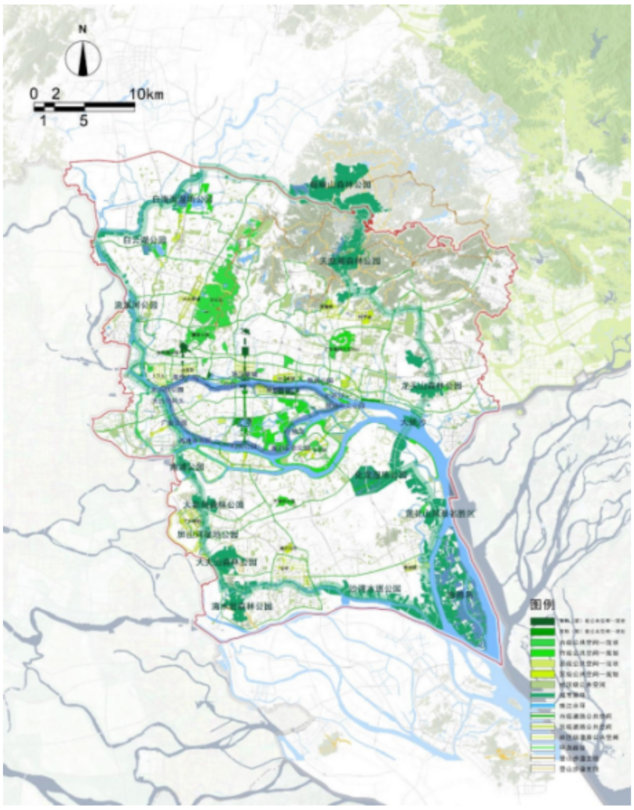

Figure 4. Distribution of parks in core urban areas of Guangzhou

Yuexiu Park, Luhu Park, and Baiyun Lake Park are three urban parks with their own characteristics in Guangzhou City, which provide diversified cases for the study of the thermal comfort of urban parks.

Yuexiu Park, located in the city center, with a total area of 88 hectares, is one of the oldest and largest parks in Guangzhou. Its rich vegetation, especially the arrangement of trees and shrubs, provides sufficient shade for the park, effectively reducing local temperatures and improving air humidity. However, the high density of surrounding buildings and traffic has a complex effect on the park's microclimate.

Luhu Park is located north of the city center and is known for its vast body of water and mountainous landscape. The green coverage rate of the park is high, with a large number of trees, shrubs, and flowers. The ecosystem composed of water area and green space plays a significant role in regulating microclimate. In addition, pavilions, walkways, and leisure facilities in the park provide good shade and cooling effects for visitors. Its high terrain and mountain location provide an advantage in airflow, creating a comfortable recreational environment for visitors.

Baiyun Lake Park is a relatively new urban park in Guangzhou, located outside Baiyun District, with a water area of more than 100 hectares. The park is mainly composed of artificial lakes and surrounding green belts, which have a significant influence on the microclimate of the surrounding area. It is located in the suburbs and close to the natural environment, the air quality is superior, and the temperature is slightly lower than in the urban area. The park is rich in vegetation species, distributed with many tree-lined paths and sunshade facilities, providing a good summer place for visitors.

Through the investigation and analysis of these three parks, this paper aims to explore their microclimate regulation effect and thermal comfort performance and provide a basis for the design and planning of urban parks in the future.

2.2. Research methodology

This study adopts a variety of methods to systematically assess the thermal comfort of urban parks in Guangzhou City, including the field survey method, comparative case analysis method, and literature review method. Through diversified research tools, combining quantitative and qualitative analyses, it seeks to provide a comprehensive and in-depth discussion on the thermal comfort of parks.

2.2.1. Field survey methodology

Field survey is one of the main methods in this study, aiming at obtaining microclimate data and visitors' subjective perception of thermal comfort in urban parks in Guangzhou. We selected Yuexiu Park, Luhu Park, and Baiyun Lake Park for data collection in different seasons and periods [3]. The data collection includes the following.

(1) Temperature, humidity, wind speed, and solar radiation: Professional meteorological equipment was used to collect meteorological data in different areas of the park, focusing on temperature, humidity, and wind speed under the shade of trees, in open spaces, and near water bodies. Each measurement point is collected at least three times to ensure data stability.

(2) Functional zoning of parks: Focus on the differences in thermal comfort between different functional zones in each park, such as open plazas, shaded paths, lakeside areas, children's play areas, etc., and analyze the climatic characteristics of the different zones and their impact on thermal comfort.

(3) Visitor physical comfort questionnaire: A questionnaire was used to record visitors' subjective perception of temperature, humidity, and overall comfort in the park. The questionnaire includes visitors' perceived body temperature in different areas, their satisfaction with the shading facilities, and whether or not they feel heat discomfort.

Data collection was scheduled during the hot summer period (July to August) and the mild winter period (January to February) to facilitate a comparison of the park's thermal comfort performance under different seasons. Moreover, data collection was conducted at three separate times of the day, early morning, midday, and evening, to capture the microclimate variations in the park under different sunlight conditions [4].

2.2.2. Comparative analysis of cases

A comparative analysis of three selected parks allows a better understanding of the differences in thermal comfort performance between different types of urban parks. The comparative case analysis method consists of the following steps.

(1) Analysis of similarities and differences: Compare the similarities and differences between Yuexiu Park, Luhu Park, and Baiyun Lake Park in terms of their climate regulation functions. Focus on analyzing the effects of their greening design, water layout, functional zoning, and facility arrangement on thermal comfort.

(2) Comparison of environmental factors: By analyzing the geographical location of the parks, the green coverage, the type of vegetation, and the size of the water bodies, we identified the different effects of

the parks in mitigating high temperatures, enhancing air mobility, and humidity regulation.

(3) Microclimate data analysis: By comparing the meteorological data collected in the field, we analyze the cooling effect of each park during the high-temperature period, and explore the role of water bodies and greening design in regulating the microclimate inside and outside the park [5,6].

3. Research content and process

This part describes in detail the content of the field survey, the analysis of the results, and the comparative study of different types of urban parks in Guangzhou City, and puts forward targeted recommendations for improvement in the light of the microclimate regulation effect of the case parks and the subjective evaluation of thermal comfort by visitors.

3.1. Thermal comfort analysis of Yuexiu Park

3.1.1. Overview of the park

Yuexiu Park is a large and historic city park in Guangzhou, located in the city center area. With a total area of 88 hectares and a green space coverage of about 75%, the park has a rich vegetation structure of trees, shrubs, and lawns. The vegetation provides a natural barrier for microclimate regulation in the park, especially during the summer, when a large number of shaded areas in the park can significantly improve the thermal comfort experience in the park.

3.1.2. Field survey results

The survey data were concentrated in the hot summer period (July to August), and measurements were taken in the early morning, midday, and late afternoon of each day. The meteorological data collection equipment for temperature, humidity, and wind speed was used to measure the following.

(1) Temperature: Temperatures in the shaded areas inside the park were about 3°C to 4°C cooler than in the open areas, while the cooling effect was particularly noticeable near the man-made lake, where localized temperatures were about 5°C cooler than in other open areas of the park.

(2) Humidity: The air humidity was higher in the artificial lake area, especially along the lake shore, where it could be about 8 to 10 percentage points higher than in the open squares of the park. This contributes significantly to localized cooling.

(3) Wind speed: The wind speed in the park was lower in the densely green area, with an average wind speed of only 0.8 m/s. In the open plaza area, the wind speed was about 1.5 m/s, which is higher than that in the densely vegetated area but has no significant cooling effect.

3.1.3. Evaluation of thermal comfort for tourists

According to visitors' feedback, more than 60% preferred to stay in shaded areas or near bodies of water in summer, mainly because of the relatively lower temperatures in these areas and their physical comfort. Additionally, visitors generally reflected that the design of pavilions, shaded walkways, and lakeside benches in the parks provided better shelter from the summer heat during hot periods, but some visitors still considered that there were insufficient shading facilities in the open areas of the parks, which resulted in a tendency to feel hot and uncomfortable when moving around in these areas.

3.1.4. Analysis and summary

The thermal comfort of Yuexiu Park is mainly due to its high green coverage and the moderating effect of the water body. Especially in summer, the park's trees provide sufficient shade for visitors and the evaporation effect of the water body enhances the local cooling effect. However, the open plaza area of Yuexiu Park has higher temperatures and poorer thermal comfort due to the lack of shading measures. Therefore, increasing shading facilities in the open areas, such as more trees, parasols, and gazebos would further enhance the overall thermal comfort of the park.

3.2. Thermal comfort analysis of Luhu Park

3.2.1. Overview of the park

Located in the northern part of Guangzhou City, Luhu Park covers an area of approximately 50 hectares and contains a large number of natural lakes and artificial water bodies, with the lakes occupying approximately 30% of the entire park. Luhu Park is characterized by its unique landscape that combines natural landforms with man-made designs, with the combination of water bodies and vegetation providing a natural cooling effect.

3.2.2. Field survey results

Similar to the previous park, the survey data for Luhu Park was conducted during the hotter parts of the summer, focusing on documenting microclimate differences in different areas of the park, such as the following.

(1) Temperature: The area around the lake was significantly cooler than the rest of the area, with measured temperatures around 4°C to 6°C lower than in the open spaces of the park. Especially on the walkways close to the water bodies, the visitors' body temperature was very cool.

(2) Humidity: Humidity was significantly higher in the Lake District than in other areas, averaging 70% to 75%, well above the 60% or so measured in the open grass areas of the park. While the high humidity enhances the coolness to some extent, it may also trigger a feeling of stuffiness at lower wind speeds.

(3) Wind speed: The wind speed was higher in the lake area, averaging 1.2 m/s, and lower in the open area, at 0.6 m/s. Higher wind speeds help to enhance airflow, leading to better ventilation and heat dissipation.

3.2.3. Evaluation of thermal comfort for tourists

Within Luhu Park, 70% of visitors found the lakeside area to be the most comfortable in terms of body temperature, thanks to the evaporative cooling of the lake and higher wind speeds. Visitors generally reported that they spent more time at the lake than in areas such as the open plaza. Some visitors suggested that their summer experience was hampered by the more complex trail design in Luhu Park and fewer pavilions and seats in some areas.

3.2.4. Analysis and summary

The thermal comfort of Luhu Park benefits from the combined effects of its water bodies and vegetation, with the lake area, in particular, providing significant cooling. However, the overall thermal comfort experience is compromised by the lack of adequate rest and shade facilities along some areas of the trail. It is recommended that shade and resting facilities in the lakeside areas be added to future park plans to meet the needs of visitors seeking refuge from the heat during hot weather.

3.3. Thermal comfort analysis of Baiyun Lake Park

3.3.1. Overview of the park

Baiyun Lake Park is a new large-scale urban park built in Guangzhou in recent years. Located on the outskirts of Baiyun District, it covers an area of more than 200 hectares, with water bodies occupying nearly half of the park. Due to its distance from the urban core, Baiyun Lake Park has excellent air quality and a more extensive green belt design, making it an important place for people to go for hiking and leisure.

3.3.2. Field survey results

The survey of Baiyun Lake Park was also conducted during the high summer temperatures. Due to the large size of the park, the combination of water bodies and vegetation plays a significant role in regulating its internal microclimate.

(1) Temperature: The overall temperature in the park was about 2°C to 3°C lower than in the urban parks, especially in the areas where water bodies and green belts are combined, and locally the temperature was 4°C to 5°C lower than in the open spaces.

(2) Humidity: Due to the large size of the lake, the average humidity in the park reached more than 75%, with a significant evaporative effect on the water. Despite the high humidity, the winds in the lake area were fast, avoiding the stifling sensation triggered by high humidity.

(3) Wind speed: Wind speeds were higher in the water areas, averaging 1.5 m/s, much higher than in the densely green areas of the park (0.5 m/s). This contributes to enhanced physical comfort, especially during the hot summer months when high wind speeds are effective in ameliorating discomfort caused by high humidity.

3.3.3. Evaluation of thermal comfort for tourists

Feedback from visitors indicated that Baiyun Lake Park has a high overall thermal comfort level due to its extensive water bodies and green belts. Nearly 80% of visitors reported feeling noticeably cooler when lounging around the lake, especially during the high summer temperatures. Some visitors commented that the moderate wind speed of the park reduced the discomfort caused by high humidity, but due to the large size of the park, some areas lacked convenient resting facilities [7–9].

3.3.4. Analysis and summary

The thermal comfort advantage of Baiyun Lake Park lies in its large water bodies and extensive green belts, natural elements that play a significant cooling and moderating role during hot periods. However, there is still room for improvement in the overall configuration of the park's facilities, especially in some areas away from the water bodies, which lack the necessary shade and resting facilities, resulting in poor localized thermal comfort. It is recommended to increase the number of shade facilities and seats in the park to better serve the visitors.

4. Conclusion and outlook

4.1. The current situation of thermal comfort in Guangzhou City parks

With a high green coverage rate and water body design, Guangzhou urban parks are outstanding in improving thermal comfort. For example, Yuexiu Park, Luhu Park, and Baiyun Lake Park effectively improve the microclimate through plant shading and water evaporation, and the summer temperature was 3°C to 5°C degrees lower than the surrounding areas, alleviating the urban heat island effect. However, park design and facilities are still inadequate, such as the lack of open area shading facilities in Yuexiu and Luhu parks, resulting in low thermal comfort. Although the wind speed in Baiyun Lake Park is large, the layout of rest facilities in some areas is unreasonable. The questionnaire survey shows that more than 70% of tourists prefer cooling areas such as trees and water bodies, and have little interest in open squares and walking paths. Tourists reported that the unreasonable layout of facilities and insufficient rest areas affected the thermal comfort experience.

Therefore, the future park design should pay more attention to the thermal comfort of tourists' activity space, optimize the shading and ventilation design of open areas, rationally layout public facilities, and improve the comfort and convenience of rest areas to meet the needs of tourists in summer, and further improve the thermal comfort and use experience of urban parks [10].

4.2. Future directions for thermal comfort in urban parks

In the face of global climate change and the intensification of the urban heat island effect, the future design and planning of urban parks in Guangzhou should pay more attention to the issue of thermal comfort. By optimizing greening design and rationally allocating water bodies and facilities, urban parks in Guangzhou can better cope with hot weather and provide citizens with more comfortable outdoor activity spaces. The following are several future directions and suggestions.

4.2.1. Combining the natural environment with technological means

The future design of urban parks should combine the natural environment and modern technology more often to enhance thermal comfort. For example, techniques such as plant walls and green roofs are used to enhance the shading effect inside the park. At the same time, intelligent climate control devices, such as automatic sprinkler systems and intelligent fans, are used to further improve the local microclimate of the park. By combining technological means with natural landscaping, urban parks can provide a more comfortable environment in hot weather.

4.2.2. Enhancement of diversified greening design

The climatic characteristics of Guangzhou require more diverse greening designs for parks. Future park planning should enhance the rational mix of trees, shrubs, and lawns to form a multi-layered greening layout to maximize shading and cooling effects. Concurrently, more plant species adapted to the local climate should be introduced to enhance the ecological resilience of the parks and improve their ability to cope with extreme weather.

5. Concluding remarks

By studying the thermal comfort of three typical urban parks in Guangzhou, it was found that the green coverage, water layout, and facility configuration of urban parks play significant roles in enhancing the thermal comfort inside the parks. However, there is still room for improvement in the current park open areas and facility configurations in response to hot weather. The future design of urban parks should fully integrate the natural landscape with modern technology to enhance the thermal comfort of parks through diversified greening designs and reasonable facility layouts to provide citizens with more pleasant outdoor leisure spaces. Simultaneously, through the participation of citizens in park construction and management, the experience of using urban parks can be further improved, and the development of urban parks in Guangzhou can be promoted in a more sustainable and humanized direction.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Li X, Chen W, 2018, A Study on the Climate Benefits of Urban Parks in Guangzhou. Journal of Urban Planning,

2018(2): 59–66.
[2] Liu M, Wang H, 2019, Correlation Analysis of Urban Park Green Space System and Heat Island Effect--Taking Guangzhou as an Example. Journal of Ecological Environment, 28(6): 1204–1210.
[3] Wang L, Zhao W, Li J, 2017, Discussion on the Relationship Between Thermal Environment and Urban Park Landscape Design. Landscape Architecture, 24(4): 55–60.
[4] Guo Y, Sun J, 2020, Evaluation of Thermal Comfort in Urban Parks: A Case Study of Beijing. Journal of Environmental Engineering, 38(1): 82–89.
[5] Tang H, Qiu L, Wang Z, 2019, Effects of Urban Green Spaces on Microclimates and Thermal Comfort in Subtropical Climates: A Case Study in Guangzhou, China. Urban Forestry & Urban Greening, 42: 93–101.
[6] Lin B, Li X, Zhu Y, 2017, Impact of Urban Parks on Local Climate in Guangzhou: Modeling and Observations. Building and Environment, 117: 210–221.
[7] Zhang H, Li F, 2021, Research Progress and Prospect of Thermal Comfort in Urban Parks. Journal of Habitat, 33(5): 122–132.
[8] Li Y, Chen L, Liu X, 2018, Thermal Comfort and Outdoor Activities in Urban Parks in Guangzhou During the Summer. International Journal of Biometeorology, 62(7): 1193–1205.
[9] Yang L, Chen G, 2020, Research on thermal comfort evaluation methods of Urban Parks. Building Science, 36(8): 91–98.
[10] Chen W, Zhan Y, 2022, Urban Green Spaces and Outdoor Thermal Comfort in Subtropical Cities: A Case Study of Park Users in Guangzhou, China. Sustainable Cities and Society, 55: 102088.

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A Discussion on Innovative Methods for Green Engineering Management in Construction Engineering

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Abstract: With the rapid development of society, the construction industry has made significant progress. However, as environmental issues intensify, many construction projects contribute to pollution. In this context, applying green project management methods in construction can enhance energy conservation and environmental protection, reduce energy consumption and costs, and minimize environmental damage, promoting balanced development between the environment and the economy. Therefore, integrating green construction concepts into current construction projects is essential. Based on project requirements and construction activities, effective green project management strategies should be developed to improve management standards and promote more efficient green construction. This paper analyzes green project management in construction engineering and offers recommendations for reference.

Keywords: Construction engineering; Green engineering management; Management methods

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1. Introduction

In recent years, the importance of environmental protection in China has been increasing, and more attention has been paid to the harmonious development between man and nature, making full use of resources, environmental returns and other modes of thinking, building optimization design, and construction, to save energy, protect the environment, and to promote the environment and economic sustainable development [1]. However, there are many links and long construction periods in the construction of building engineering. To effectively embody the concept of green construction in building engineering and enhance energy-saving and environmental protection efforts, it is essential to strengthen management practices. This includes innovating and implementing more comprehensive and effective green project management methods, addressing the shortcomings of traditional project management, continuously improving the construction quality of projects, maximizing the value of green project management, and promoting the long-term development of construction enterprises.

2. Analysis of the significance and principles of green engineering management

2.1. Significance of green engineering management

For the implementation of green engineering management methods, its significance mainly lies in the following aspects.

(1) To address the shortcomings of traditional management. It is important to recognize that past engineering management was often characterized by crude practices, insufficient oversight in various construction phases, and a lack of clear management norms and standards. This resulted in environmental pollution and damage during construction, as well as high energy consumption [2]. Green engineering management places a greater emphasis on green construction concepts, focusing on environmental protection and energy conservation. This approach optimizes management content and methods, making engineering management more comprehensive and standardized. As a result, it further enhances energy savings and environmental protection in construction engineering while addressing the shortcomings of traditional management.

(2) To promote the coordinated development of the environment and the economy. Green engineering management emphasizes the harmonious interaction among people, buildings, and nature. This approach not only reduces the environmental impact of construction but also aligns with the natural laws of development to enhance the effectiveness of resource development and utilization. Consequently, it better fosters the coordinated development of the environment and the economy while improving construction standards [3].

(3) To meet the requirements of modern times. The implementation of green engineering management emphasizes the sustainable development of construction projects. By prioritizing sustainable development as a fundamental goal, it optimizes the management of construction design, execution, and use, thereby better aligning with contemporary needs.

2.2. Principles of green engineering management

For the principles of green engineering management, the following points are mainly included.

(1) Systematic principle. The construction engineering process involves many stages and influencing factors. When managing green engineering, it is essential for managers to consider various conditions, relevant provisions, and regulations. By adhering to the systematic principle, they can expand the depth and scope of management, thereby enhancing its effectiveness.

(2) The principle of objectivity. There is a significant difference between green project management and traditional management, which can make it challenging for many construction enterprises to accept green practices in the short term. Therefore, it is essential to adhere to the principle of objectivity, fully recognizing the importance of implementing green project management throughout the entire construction process [4]. The principle of considering both the economy and the environment. During green project management, it is essential to focus not only on the project's economic benefits but also on its environmental benefits. Therefore, both economic and environmental factors should be fully considered in the management process, and a more effective management approach should be developed to promote the coordinated development of the economy and the environment.

3. Innovative methods for green engineering management in construction projects

3.1. Applying BIM technology for full-cycle project management

During the construction phase of a building project, there are many stages involved. To enhance the innovativeness and comprehensiveness of green engineering management, Building Information Modeling (BIM) technology should be actively applied for full-cycle management and control of the project [5]. For example, during the design phase, BIM technology, computers, and scanning instruments can be used to collect and scan engineering data, analyze and process this information, and generate a three-dimensional model, making the design drawings more accessible. When reviewing and managing the construction design plan, Ecotect Analysis software can be utilized to input project information and specify three-dimensional editing views. Based on experience, a simplified model can be established to facilitate a direct understanding of various data, such as conducting collision tests to evaluate the feasibility, energy efficiency, and environmental impact of the design scheme [6].

If there are any parts of the design scheme that do not meet the requirements of green construction, they can be verified and confirmed, and the design unit and personnel can be required to revise and optimize the design scheme to ensure its feasibility. Simultaneously, green evaluation standards and construction parameters can be input into relevant software to generate corresponding BIM models, in which the energy-saving and environmental protection requirements for each construction material are displayed, and personnel can purchase construction materials based on the parameters provided. To fully utilize the role of BIM technology and improve the effectiveness of green engineering management, corresponding evaluation standards should be formulated, and regular assessment and evaluation should be carried out to understand the implementation quality of the green engineering management plan. The specific green engineering management evaluation standard table is shown in **Table 1**.

Table 1. Evaluation criteria for green project management

Classification	Project	Score
Implementation of the green management plan	The amount and proportion of environmental protection investment	
	Degree of project green planning	
	Quality of staff	
Utilization of green resources	Energy efficiency ratio	
	Material recovery rate	
	Usage rate of environmental protection materials	
	Efficient energy use	
	Resource consumption	
	Reuse rate of waste materials	
Control of the green environment	Measures and effects of sewage treatment	
	Construction waste disposal	
	Dust handling measures and effects	
	Silencing measures and implementation results	

3.2. Strengthening the application of energy-saving and environmental protection concepts

Site construction is a crucial aspect of construction projects and should be a key focus in green project management. To innovate management practices and enhance management levels, it is essential to strengthen the implementation of energy-saving and environmental protection concepts during the site construction phase. This involves taking various measures to protect the environment, reduce energy consumption, and achieve green construction [5]. In control of pollution factors, given the significant impact of environmental pollution, different pollution management strategies are necessary. For noise pollution, noise insulation can be installed around the construction site, and low-noise, low-vibration equipment should be selected. Reasonable construction hours should also be established. To address water pollution, sewage must be treated per established standards before discharge, avoiding any arbitrary release. Regarding construction waste pollution, effective on-site waste classification and management are essential, along with clear guidelines for waste disposal, to prevent personnel from improperly discarding waste.

In selecting materials for green environmental protection, it is essential to prioritize those that meet construction quality requirements. For example, in constructing external wall structures, materials such as aerated concrete, foam concrete, formwork concrete, and polystyrene hollow plates can be used. Foam concrete, in particular, has a large number of closed air holes, providing advantages in fire resistance and thermal insulation when used for external walls. In external thermal insulation, materials like fiberglass mesh cloth and rock wool can be selected. Fiberglass mesh cloth is notable for its strong flexibility and transverse tensile strength, enhancing the thermal insulation performance of external walls once installed.

During the construction of doors and windows, materials such as vacuum glass, foam glass, and low-radiation coated glass can be utilized. Vacuum glass, for instance, consists of two flat panes of glass that are sealed and vacuum-treated, significantly reducing indoor heat loss and achieving effective heat preservation in window and door structures. Additionally, we should focus on selecting green and environmentally friendly boards, including color boards, plastic boards, and hydrophobic boards. The effective use of these green materials can enhance the beauty, comfort, and functionality of building projects while also saving energy and construction costs. This approach contributes to the sustainable development of construction projects and the implementation of the green construction concept.

Focus on water-saving and energy-saving construction management. Firstly, regarding water conservation, it is important to install rainwater harvesting systems for the collection, treatment, and recycling of rainwater. This harvested rainwater can be utilized in construction and can also serve for irrigation of green areas or for flushing toilets during subsequent construction phases. Secondly, for energy conservation, Light Emitting Diodes (LEDs) should be installed along with an intelligent lighting control system. It is essential to plan the use of electrical equipment on-site carefully to reduce power consumption.

Furthermore, the active use of new green technologies is recommended. In line with the principles of green project management and the requirements for green construction, it is crucial to choose and implement innovative green technologies tailored to the specific conditions of the construction site. Examples include eco-cement, photovoltaic cells, and modular processing, all of which can help address environmental pollution issues and enhance the overall level of project management.

3.3. Improve the project management system and personnel training

On the one hand, in terms of the project management system, sustainable development should be the objective and the concept of green construction should be the benchmark. In light of the construction requirements for construction projects and the principles of green project management, a comprehensive project management system should be established. This system should further outline the contents and procedures of management, clearly define the responsibilities of various departments and personnel, and implement a legal responsibility system. Such measures will promote a more robust and reliable green project management mechanism, facilitating the efficient implementation of green project management practices.

The construction of engineering projects involves many stages and is related to various departments and units. It is essential to utilize information technology to establish a real-time communication mechanism that enhances coordination among participating units and departments while addressing environmental protection and energy conservation issues. During the green project management phase, it is crucial to identify responsible personnel for any issues that arise, request timely rectifications, and hold them accountable according to system requirements to improve the level of green project management. On the other hand, personnel training in green construction awareness and skills directly impacts energy conservation and environmental protection efforts, as well as the effectiveness of green project management. Therefore, we should organize training and learning activities for construction personnel to help them understand the concept of green construction, master advanced green construction technologies and methods, and continuously improve their construction capabilities [7].

As managers, we should strengthen our self-study, actively seek to understand more about green project management methods and techniques and cultivate a strong sense of green management. By doing so, we can effectively implement the concept of green construction throughout the entire construction process and maximize the impact of green project management. Furthermore, we need to enhance our efforts to attract and recruit talented individuals to participate in green project management, thereby building a professional management team that will support the efficient implementation of green project management and lay a solid foundation for the development of green building.

4. Suggestions for improving the effectiveness of green project management in construction projects

To enhance the effectiveness of green project management, we must highlight innovation and optimization in this area and provide impetus for the sustainable development of the construction industry. We should focus on relevant aspects and ensure that related work is executed effectively.

Firstly, we need to strengthen technology upgrades. To improve the construction level of green building engineering and effectively protect the ecological environment, it is essential to continuously research and upgrade green construction technologies, along with supporting hardware and software facilities, to facilitate and safeguard green construction.

Secondly, talent reserve must be prioritized. Construction enterprises should collaborate with colleges and universities to offer courses related to green project management, training professionals in this field to provide reliable support for subsequent green project management efforts.

Finally, we must formulate and implement more policies. The government should further develop and issue relevant policy documents, provide favorable measures, and increase investment in funding and technical support for green project management and construction. This includes lowering import tariffs on new energy equipment and incentivizing enterprises that utilize green construction materials. Such initiatives will encourage more companies to adopt green project management practices and apply energy-saving and environmentally friendly technologies in building engineering, continuously improving energy efficiency and environmental protection in construction.

5. Conclusion

To sum up, implementing green project management can enhance energy-saving and environmental protection in construction projects, mitigate environmental pollution, reduce energy consumption and costs, and achieve higher economic and social benefits. At this stage, it is crucial to recognize the significance of green project management and understand its foundational principles. By doing so, we can pursue innovation and optimization in green project management tailored to the specific requirements of construction projects, such as using BIM technology, promoting green construction concepts, refining project management systems, providing personnel training, and more. This continuous improvement will enhance the effectiveness of green project management and lead to high-quality outcomes in construction projects. Through technological upgrades, talent development, and the formulation and implementation of supportive policies, we can advance green construction practices and foster the sustainable development of the construction industry.

Disclosure statement

The author declares no conflict of interest.

References

[1] Lin Z, Gu H, Gillani ZK, et al., 2024, Impact of Green Work-Life Balance and Green Human Resource Management Practices on Corporate Sustainability Performance and Employee Retention: Mediation of Green Innovation and Organisational Culture. Sustainability, 16(15): 6621.

[2] Bai X, Liu W, 2023, A Novel Knowledge Management Method about Integrated Grounded Theory for Performance Assessment of Green Building Construction Engineering. Journal of Asian Architecture and Building Engineering, 22(4): 2309–2319.

[3] Ali A, Ma L, Shahzad M, et al., 2024, Managing Stakeholder Pressure for Megaproject Success and Green Innovation: The Key Role of Social Responsibility. Engineering Management Journal, 36(4): 366–377.

[4] Haque AM, Islam AM, Soh S, 2024, Green HRM Practices and Green Work Engagement: The Roles of Green Knowledge Sharing and Green Group Cohesion. Global Business and Organizational Excellence, 44(1): 16–31.

[5] Ning F, 2022, The Influence Mechanism of BIM on Green Building Engineering Project Management Under the Background of Big Data. Applied Bionics and Biomechanics, 2022: 8227930.

[6] To MW, Lam K, 2022, Green Project Management from Employees' Perspective in Hong Kong's Engineering and Construction Sectors. Engineering Construction and Architectural Management, 29(4): 1890–1907.

[7] Marczak BR, Seruga P, Jarossova AM, et al., 2024, Green Business Process Management in a Polish Municipal Waste Treatment Plant-Regional Case Study. Journal of Material Cycles and Waste Management, 26(5): 3262–3279.

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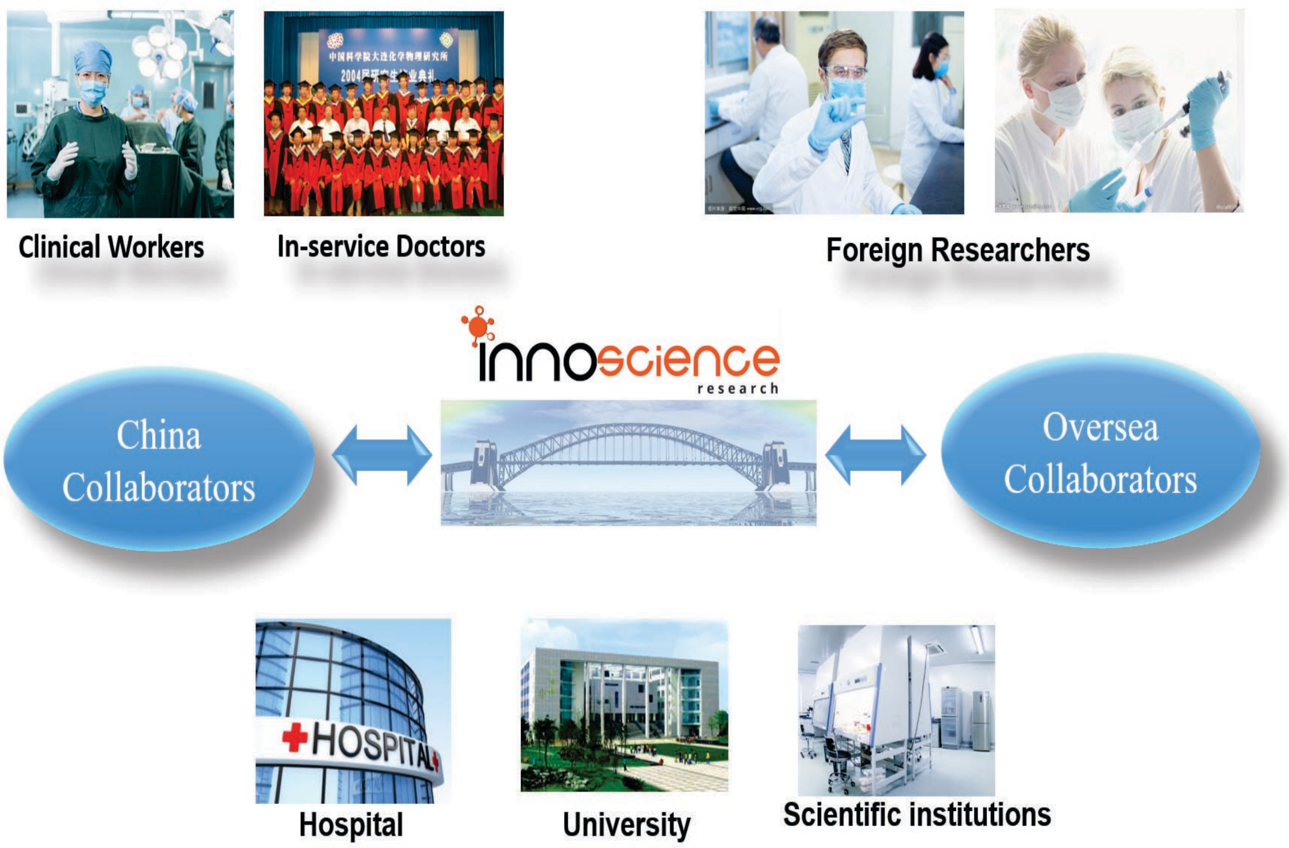

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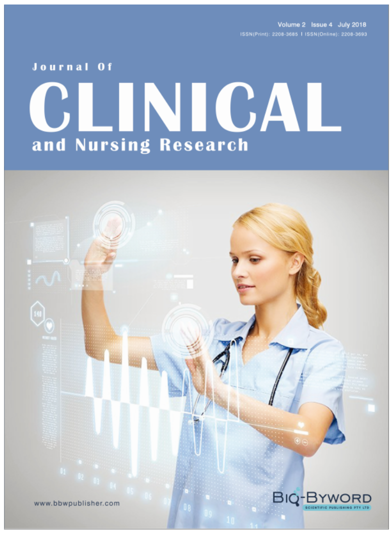

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