

# ***Analysis of the Construction Path of Smart and Low-Carbon Outdoor Spaces from the Perspective of Sustainable Urban Theory: Taking Nanjing Station and Its Station Front Square as an Example***

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**Abstract.** With the rapid advancement of global urbanization, the sustainable development philosophy and China's dual-carbon goals have gained growing importance in urban construction. The intelligent and low-carbonization of outdoor spaces has become an important direction for urban development. This study takes Nanjing Station and its station front square as examples to explore the relevant paths for constructing intelligent and low-carbon outdoor spaces from the perspective of sustainable urban theory. This paper adopts the literature analysis method to provide certain theoretical support for the research. This article clearly points out that there are multiple development shortcomings in the square in front of Nanjing Railway Station. Its energy structure is monotonous, energy consumption management is lax, it overly relies on traditional energy sources and has serious ineffective energy consumption; the proportion of hard-paved surfaces is high and the greening system is weak, resulting in prominent heat island effect and carbon emission load; at the same time, the intelligent monitoring and operation management system is not perfect, and the utilization of space resources is also relatively wasteful. Based on this, an integrated optimization path of technological transformation, space optimization, and intelligent management is constructed. This can effectively improve the ecological and energy issues of the site and achieve the intelligent and low-carbon upgrade of the hub space.

**Keywords:** the theory of sustainable cities, smart low-carbon, outdoor space, Nanjing railway station

## **1. Introduction**

The urbanization process in our country is characterized by rapid development, large scale, and high consumption of resources and energy. Along with the advancement of urbanization, a series of environmental and energy-related issues such as water pollution, increased carbon emissions, and urban heat island effect have emerged [1]. To address these problems, some scholars have proposed the "sustainable urban renewal theory", which advocates promoting urban renewal based on the optimization of urban ecological environment while achieving coordinated development of

resources, environment, economy, and residents' lives [2, 3]. The country has also put forward corresponding policies and measures: In 2020, China proposed the "dual carbon" policy, aiming to achieve "carbon peak" by 2030 and "carbon neutrality" by 2060 [4]; In 2012, China first regarded smart cities as a new urban development model and gradually expanded the scale of pilot projects [5]. This paper will analyze the existing problems in the outdoor spaces of Nanjing Station and the station square in terms of energy utilization, environmental friendliness, and spatial intelligence. It further explores how to establish a smart and low-carbon outdoor space framework tailored for Nanjing Railway Station and its front square, grounded in sustainable urban theories. It will enrich the application of sustainable urban theory in transportation hubs and contribute to the urban's low-carbon, intelligent, and sustainable development. It will provide scientific paths and strategies for the renovation and optimization of Nanjing Station and the station square, and also offer practical guidance for the smart and low-carbon construction of similar areas in other cities.

## 2. Overview of Nanjing Railway Station and its station square

### 2.1. Analysis of location and traffic positioning

Nanjing Railway Station stands on Longpan Road in Xuanwu District, Nanjing, next to Xuanwu Lake. It serves as the city's core comprehensive railway transportation hub and northern gateway. The site integrates multiple transportation systems such as railways, urban main roads, overpasses, etc. (as is shown in Figure 1), and has both cross-regional passenger flow distribution and old city commuting service functions. The traffic positioning is highly complex. The station square is responsible for passenger gathering, transfer, and urban image display functions. The density of people and vehicles is high, and the space load and energy consumption level are also high. As a typical high-density urban public space, it possesses great demonstration significance for the research on intelligent and low-carbon renewal of existing urban spaces.

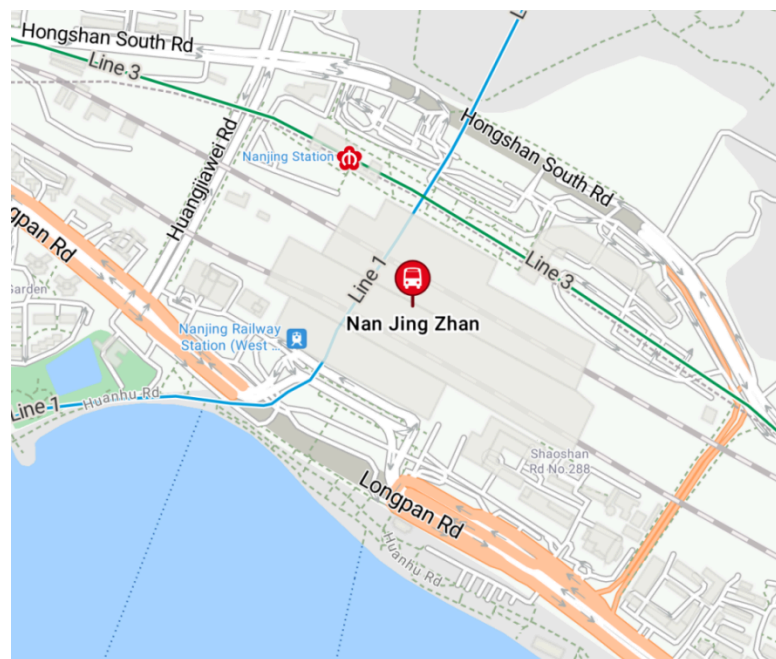


Figure 1. The geographical location of Nanjing Railway Station

## 2.2. Existing facility configuration

The overall layout of the front square of Nanjing Station is dependent on the main station building. The spatial form is spacious and regular, with a large area of hard surfaces as the main body (as is shown in Figure 2). The overall structure presents a longitudinal spatial layout of "station building - main square - municipal roads". In terms of lighting facilities, the square mainly uses traditional street lamps and conventional LED lamps (as is shown in Figure 3), without energy-saving functions such as intelligent dimming and time-based control. The energy consumption mode is fixed and there is obvious waste. In terms of greening facilities, the green coverage rate of the site is low. It mainly consists of edge strip greenery, point-like trees and lawns. The plant species are single and the ecological carbon fixation, cooling, dust retention functions are weak. In terms of public service facilities, the basic convenience facilities in the site are complete, but the overall layout is uneven and there is a shortage of facilities in the core area. While basic electronic information devices are available, the site lacks advanced smart and low-carbon equipment for environmental monitoring, intelligent early warning and operational management. The entire facility system remains conventional, with inadequate intelligent service capabilities.



Figure 2. Nanjing Railway Station Front Square

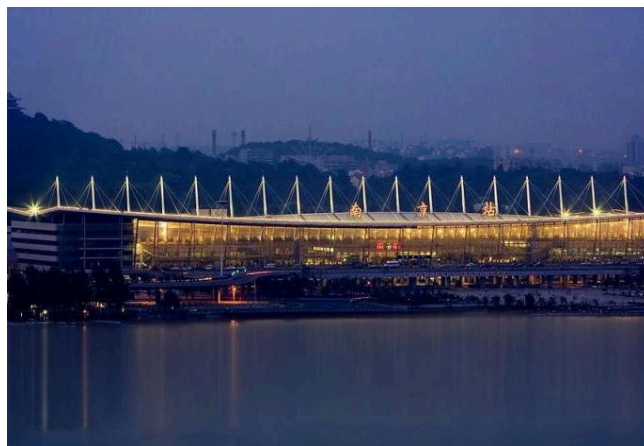


Figure 3. The night scene in front of Nanjing Railway Station Square

### **3. Analysis of existing problems in the square in front of Nanjing Railway Station**

#### **3.1. Traditional energy utilization structure and loose energy management**

From the perspective of low-carbon and sustainable development, the front square of Nanjing Railway Station suffers from conspicuous defects in its energy system. Firstly, the energy structure is single, relying entirely on traditional municipal thermal power, without the application of solar power and other clean energy sources. The high-carbon characteristic is prominent, making it difficult to meet the requirements of dual-carbon development. Secondly, the energy consumption of equipment operation is loose. Lighting, advertising, and other equipment operate throughout the day without adjusting according to time periods and the dynamics of people's movements, resulting in serious waste of energy during off-peak hours when the equipment is idle. Thirdly, there is a lack of a digital energy monitoring and refined management system. Management and operation rely on manual experience, making it impossible to achieve scientific energy conservation and reduction, and the operation is in a state of high energy consumption and high emissions, remaining in a loose and extensive mode for a long time.

#### **3.2. Weak ecological base, high carbon emissions and environmental load**

The front square shows inadequate ecological performance. Dominated by extensive impermeable hard paving, the site has weak rainwater infiltration capacity. During the rainy season, surface runoff is prone to form, thereby increasing the pressure on urban drainage systems. During the dry season, the hard pavement significantly retains heat, leading to a prominent heat island effect on the site and poor spatial comfort. At the same time, the current green layout is scattered and lacks diversity, with limited ecological regulation capabilities. It is unable to effectively mitigate the carbon emissions generated by human and vehicle activities, and the ecological restoration function is severely inadequate. Moreover, the drop-off area of the square is crowded with traffic, and during peak hours, there is a common phenomenon of idling vehicles idling and mixed traffic of people and vehicles. Built-up vehicle exhaust and heat worsen local air pollution and carbon output. This forms a problematic spatial feature: excessive hard paving, insufficient greenery and high emissions, which imposes sustained adverse impacts on the micro-ecology of the old urban area.

#### **3.3. Intelligent construction overview, poorly managed space operations**

The site is not equipped with digital monitoring devices covering pedestrian flow, environmental indicators, energy consumption and other key parameters, so real-time operational data of the venue cannot be acquired. The efficiency is low and the response is slow. Due to the lack of intelligent dynamic control measures, the square space cannot adapt to the changes in peak and off-peak human flows, resulting in waste of resources such as peak congestion and idle space during off-peak hours. Overall, the venue still follows a traditional and extensive management mode, without establishing a digitalized, refined intelligent operation and maintenance system. Accordingly, it cannot satisfy the construction requirements for modern intelligent and low-carbon public spaces.

## **4. Optimization solutions and implementation paths for smart and low-carbon outdoor spaces**

### **4.1. Application paths of intelligent and low-carbon technologies**

In response to the deficiencies in energy utilization, ecological environment and intelligent management on site, we have built a technical application system covering three modules: clean energy, sponge ecology and intelligent monitoring. Firstly, promote low-carbon energy transformation. Install distributed photovoltaic equipment on the roof of the square corridors and idle green spaces, and build a small-scale clean power supply system to replace some traditional energy. We replace traditional lamps with intelligent energy-saving LED lights, equipped with dynamic perception technology for environmental parameters and adaptive lighting adjustment technology based on AIoT technology [6], to achieve time-based lighting and demand-based lighting, reducing ineffective energy consumption. Secondly, introduce sponge city technology. And we replace the impervious pavement in the core area with ecological permeable pavement, add small rain gardens and ecological retention strips, and combine with native trees, shrubs and grass layers to enhance the rainwater storage capacity and the carbon sequestration and cooling effect of the site, alleviating the heat island effect. Integrate the sponge facilities into the outdoor public space, collaboratively shaping a more resilient and dynamic urban spatial form [7]. Finally, build a comprehensive intelligent monitoring system. Install monitoring terminals for people flow, air quality and energy consumption, to achieve real-time collection of site operation data, visual management, and provide data support for precise spatial operation maintenance, energy-saving regulation and congestion relief.

### **4.2. Optimization path of spatial planning**

Reconstruct the site's spatial layout in line with the principles of sustainability, people-orientation and ecology. It rationally partitions areas for pedestrian circulation, rest and waiting, ecological greening and non-motor vehicle parking. Clarify the functional boundaries and solve the problem of mixed and occupied spaces; evenly arrange rest pergolas, convenient seats, and barrier-free facilities to enhance the age-friendliness of the space. Optimize the traffic flow lines, strictly implement the separation of pedestrians and vehicles, and the separation of entry and exit, standardize the parking order of motor vehicles and non-motorized vehicles, reduce idling and stagnant vehicle emissions, and lower the carbon emissions of transportation. Revitalize the idle hard spaces of the site and transform them into small-scale green landscapes and low-carbon rest spaces, achieving simultaneous improvement in space utilization and ecological benefits.

### **4.3. Innovation of smart management strategies**

Long-term operation and maintenance is the key to the sustainable implementation of smart and low-carbon spaces. By building a smart management platform powered by on-site monitoring data, we can realize intelligent operation and maintenance covering energy consumption regulation, equipment inspection, passenger flow guidance and green irrigation. This reduces labor costs and improves management accuracy. Establish a regular low-carbon management system, formulate standards for equipment energy-saving operation, green maintenance of greenery, and traffic order control, and incorporate low-carbon operation into the daily management system. At the same time, add low-carbon science popularization signs and smart publicity facilities to popularize the concepts of green travel and low-carbon energy conservation, guiding the public to actively participate in

space ecological protection and low-carbon operation, forming a "technology empowerment + space optimization + public participation" sustainable operation model, and promoting the transformation of Nanjing Station front square from a traditional passage space to a smart and low-carbon urban gateway space.

## 5. Conclusion

Based on the theory of sustainable cities, this paper takes Nanjing Station and its outdoor space in front of the station as the research object, focusing on the issue of intelligent and low-carbon construction of outdoor spaces at old city transportation hubs. It systematically explores the site's inherent deficiencies from three core dimensions: energy utilization, ecological environment, and intelligent operation and maintenance. The research finds that the front square of Nanjing Station has problems such as traditional energy structure, loose energy control, excessive proportion of hard paving, weak ecological regulation capacity, and shallow intelligent system. Although it has basic electronic guidance facilities, it lacks refined intelligent services and low-carbon operation and maintenance systems, and the overall sustainable development level of the space is insufficient. Accordingly, this paper puts forward targeted optimization strategies from three perspectives: intelligent and low-carbon technology application, spatial planning optimization, and operational management innovation. Through clean energy transformation, sponge ecological renewal, intelligent monitoring empowerment, and spatial order organization, the current situation of high energy consumption, weak ecology, and loose operation and maintenance can be effectively improved, and the green and intelligent transformation of the hub space can be facilitated. This research still has certain limitations. It only focuses on surface renovation strategies, does not quantify the carbon emission reduction benefits, and does not conduct in-depth discussions in combination with policies and operation and maintenance funding mechanisms. Future research can quantify renovation benefits based on long-term field monitoring, optimize collaborative renewal strategies for hub spaces integrated with the urban TOD development model, and further improve the scientificity and practical feasibility of intelligent and low-carbon renovation for outdoor spaces of similar transportation hubs.

## References

- [1] Qiu Guoyu & Zhang Xiaonan. (2019). Characteristics of Urbanization in China in the 21st Century and Its Ecological Environmental Challenges. *Advances in Earth Science*, 34(06), 640-649.
- [2] Liu Di. (2023). Research on the Model of Sustainable Urban Renewal and Policy Recommendations - Based on the Analysis of Market Rationality and Social Rationality. *Urban and Rural Planning*, (06), 19-28.
- [3] Liu Yafei, Cui Can & Wan Yong. (2025). Practical Exploration and Theoretical Framework Research for Sustainable Urban Renewal. *Journal of Natural Resources*, 40(01), 39-57.
- [4] Wang He & Yin Lu. (2025). Research on Ecological City Planning and Design under the "Dual Carbon" Policy. *Urban Construction Theory Research (Electronic Edition)*, (32), 10-12.
- [5] Wu Han, Wei Dongming & Xie Shang. (2026). Research on the Impact of National Smart City Construction on Regional Inclusive Development. *Journal of Northwest Minzu University (Philosophy and Social Sciences Edition)*, (02), 118-128.
- [6] Ma Yongdun & Chen Yousi. (2026). Research on Intelligent Lighting Energy Saving and Low Carbon Strategies Driven by AIoT Technology - Taking the Special Planning of Sponge City in Hefei as an Example. *Intelligent Building and Smart City*, (05), 73-75.
- [7] Song Xuehong. (2026). Research on the Synergistic Optimization of Sponge City Concept and Urban Ecological Space Planning - Taking the Special Planning of Sponge City in Hefei as an Example. *Intelligent Building and Smart City*, (05), 73-75.