Urban-Act
Integrated Urban Climate Action
for Low-Carbon & Resilient Cities

Urban Planning Guidelines for Carbon Reduction and Resilience under the Context of Climate Change – A Case Study of Xi'an

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Registered offices
Bonn and Eschborn, Germany

GIZ Office China
Tayuan Diplomatic Office Building
1-13-2 14 Liangmahe Nanlu,
Chaoyang District 100600 Beijing, PR China
T +86 10-8527 5180
F +86 10-8532 1405
E giz-china@giz.de
I www.giz.de/china

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The Urban-Act project is implemented on behalf of the International Climate Initiative (IKI) of the Federal Government of Germany. Within the Federal Government, the IKI is anchored in the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN).

Project Director
Heinrich Gudenus

Head of China Component
Liu Tong

Author
Si Jie, Zhang Quan, Li Changjiang, Wu Su, Sha Yan, Jin Shan, Liu Jiayu, Li Yueying
Xi'an City Planning & Design Institute
Tianji University

Translation
Enter Consulting (Shanghai) Co., Ltd

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Beijing Zhuochuang Advertising Co., Ltd

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1. General Provisions

1.1 Guiding Philosophy

Guided by Xi Jinping's Thought on Ecological Civilization, this work supports the national strategy on carbon peaking and carbon neutrality. It implements the policy frameworks including the Comprehensive Work Plan for Energy Conservation and Emissions Reduction under the 14th Five-Year Plan, the Action Plan for Carbon Dioxide Peaking before 2030, and the Implementation Plan for Peaking Carbon Emissions in Urban and Rural Development Sector. We undertake research on territorial-spatial planning approaches that incorporate low-carbon and resilience principles, and actively advance pilot projects for low-carbon, resilient cities.

1.2 Overall Objectives

This study will examine the fundamental low-carbon and resilience characteristics of different unit types in Xi'an. It will establish key control indices and a differentiated indicator system for each unit type, and will formulate precise, effective, and time-phased carbon-reduction and resilience measures to serve as a reference for national pilot programs on low-carbon and resilient cities. For industrial units, the objectives emphasize controlling carbon emission intensity per unit land area and promoting optimization of the industrial energy mix. For residential units, the objectives emphasize intensive land use, optimized spatial layout, promotion of low-carbon transport, and expansion of carbon-sequestration areas. For urban renewal units, priorities include adjusting functional mixes, improving building energy performance, promoting low-carbon transport, and expanding carbon-sequestration areas. For ecological units, the focus is on coordinating the carbon-sink potential between the unit and the broader urban system, creating a continuous blue-green spatial network, and enhancing the stability of the city's overall ecological carbon sinks.

1.3 Basic Principles

1. **Adhere to a low-carbon orientation:** Centered on the dual-carbon goals, place primary emphasis on carbon reduction and enhancement of carbon sinks, and propose planning and construction guidance to support whole-process low-carbon strategies in pilot areas.

2. **Strengthen targeted research:** Set specific carbon-reduction targets, identify the key overall and dimensional indicators for carbon reduction in pilot areas, and ensure that carbon-reduction indicators are measurable.

3. **Select indicators that are dynamic and rational:** Benchmark indicator selection against standards used in cities with advanced carbon-emission performance, and combine these indicators with real-time feedback during implementation so that indicators can be adjusted dynamically to guide development effectively.

4. **Localize characteristic indicators:** Pay special attention to Xi'an as a historic cultural city and ancient capital, and translate its local characteristics — for example, cultural resilience — into measurable indicators within the indicator system.

1.4 Basic Concepts

A Carbon-Reduction and Resilience-Enhancement Unit is defined as a neighborhood block delineated by urban roads and composed of closely interconnected plots. Through a comprehensive assessment of carbon emissions and emission intensities across energy, buildings, transport, and ecological elements, the unit aims to strengthen resilience potential and achieve carbon-reduction and resilience objectives. Units are classified into four types: Industrial Units, Residential Units, Urban Renewal Units, and Ecological Units.

Industrial Unit: A block containing a substantial share of industrial and office land. Its core characteristics include a dominance of factories and office buildings, resulting in high carbon emissions from energy use and buildings. This category covers both industrial parks and office parks (hereafter collectively referred to as "Industrial Units").

Residential Unit: A block primarily composed of residential land. Its core characteristics include a predominance of housing, together with community public services such as schools and sports facilities that support daily life.

Urban Renewal Unit: A block typically formed by historic and cultural neighborhoods and their adjacent protection areas. Its core characteristics are high density, strong concentration, and a pronounced cultural landscape.

Ecological Unit: An independent, non-built parcel—such as urban parks, wetland parks, or large public squares—that has a certain scale and potential for enhancing carbon sinks.

Modular Optimization Guidance: Targeted strategic guidance for achieving carbon-reduction and resilience objectives. Guidance is categorized into carbon reduction-led and resilience-led types.

Binding Indicators: Indicators that must be achieved within the planning period.

Guiding Indicators: Indicators that are encouraged to be achieved within the planning period.

Assignment of Near-Term Planning Indicator Values: The value ranges assigned to planning indicators over the next five years.

Assignment of Long-Term Planning Indicator Values: The value ranges assigned to planning indicators over the next 10–15 years.

Indicator Value Assignment: The process of determining numerical intervals for relevant indicators. This process references applicable standards and integrates data analysis from studies of different unit types to implement segmented management and control. When indicators are already governed by existing standards, evaluate their intrinsic development mechanisms and performance characteristics across different standard segments to inform differentiated control. For indicators that lack established standards, set calibrated management flexibility based on mechanistic analysis. On this basis, develop a comprehensive control framework for low-carbon resilience unit indicators and specify indicator values for distinct planning horizons. Aligned with current norms and standards, and following the principle that binding indicators should at least reach their lower-bound requirements while guiding indicators should aim for their upper-bound targets, define near-term and long-term indicator ranges for each unit type.

2. Overall Strategic System

2.1 Low-Carbon and Resilient Spatial Layout

A low-carbon and resilient spatial layout is a core strategy for realizing sustainable urban development. The plan optimizes building placement and design, and regulates plot size, building density, and floor-area ratio (FAR). It ensures compliance with natural ventilation and solar access conditions, thereby reducing the reliance on mechanical heating and cooling. Furthermore, the strategy increases the functional mixing within units, balancing peak and off-peak electricity demand to achieve an overall energy efficiency equilibrium.

2.2 Green and Sustainable Building Construction

Building-related carbon emissions are a primary source of urban construction carbon emissions. The strategy utilizes green building technologies to raise the proportion and star rating standards of green buildings. It specifically increases the percentage of green, nearly-zero-energy (NZEB), and low-carbon buildings—particularly within industrial parks—and accelerates the green and low-carbon retrofitting of existing buildings.

2.3 Renewable and Clean Energy Systems

Renewable and clean energy systems contribute to optimizing the energy structure and reducing carbon emissions, while simultaneously enhancing the city's energy security and capacity to cope with climate change. The plan reduces the reliance on traditional fossil fuels (such as coal, oil, and natural gas) by increasing the share of sources like photovoltaics (PV), solar thermal energy, and ground-source heat pumps (GSHPs) in the energy supply of built-up urban areas. It also promotes a higher proportion of rooftop PV installations, enabling buildings to achieve energy self-generation and self-consumption.

2.4 Public Service Facilities for Daily Living

The strategic arrangement of public service facilities within neighborhood service catchments is designed to ensure convenient connectivity with residential areas, public activity centers, and transportation hubs. This approach creates a spatial layout model that is functionally diverse, intensive, and compact. Services are allocated based on the hierarchical tiers of the community life circle to match the distinct service needs of different population groups.

2.5 Green Travel and Low-Carbon Transportation

Green mobility options help promote a reduction in transportation-related carbon emissions. The plan improves the quality of public transport services by developing a multi-tier and multimodal bus system and strengthening rail transit construction. Simultaneously, it enhances the integration and transfer capability between rail transit stations and other public transport modes to boost convenience and ridership appeal. Concurrently, the strategy focuses on the planning and deployment of new energy infrastructure, such as strengthening the public charging network plan to achieve comprehensive charging station and pile coverage.

2.6 High-Carbon-Sequestration Green Spaces

The development of high-carbon-sequestration green spaces will promote the carbon storage and sink functions of urban ecological resources. The plan optimizes the green space layout: in the horizontal dimension, it utilizes corner spaces to create pocket parks, thereby improving green space connectivity and permeability; in the vertical dimension, it strengthens three-dimensional and vertical greening. Furthermore, the strategy promotes the planting of high-carbon-sequestration native species to boost the carbon sequestration intensity and ecological resilience of green spaces.

3. Carbon Reduction and Resilience Enhancement Strategies for Industrial Units

3.1 General Requirements

The core objectives for carbon reduction and resilience enhancement in industrial units are to manage the carbon emission intensity per unit area and promote the optimization of the industrial energy structure. Management and control targets are divided into four aspects: streamlining the entry criteria for low-carbon industrial clusters, controlling the proportion of clean energy usage, regulating the share of green mobility, and enhancing greening and carbon sinks with high sequestration capacity. By vigorously promoting the large-scale application of renewable energy, and adapting to local conditions to promote solar water heating systems, building-integrated photovoltaics (BIPV), and shallow geothermal energy utilization, the renewable energy penetration rate of individual plots will be increased, thereby enhancing the utilization efficiency of the regional energy system.

3.2 Indicator System

An indicator system for carbon reduction and resilience enhancement in industrial units is constructed, using Development Benefits, Building Form, Facilities and Equipment, and Greening and Carbon Sinks as the criterion layers. Development Benefits focus on the Low-Carbon Industry Entry and Exit Mechanisms, emphasizing the balance between the low-carbon potential and economic benefits of introduced enterprises. This is assessed using the Annual Energy Output Rate, Reduction Rate of Carbon Intensity per Unit of Industrial Added Value, Industrial Added Value per Capita, and Proportion of Green Industry Added Value in Total Industrial Added Value. Industrial buildings typically have a large scale and extensive footprint. Effective control of the building form is a core means of practicing low-carbon and resilient cities and parks in urban planning. The selected indicator for Building Form in industrial units is the Ratio of 2-Star and Above Green Building Area within the park. Energy-saving measures in Facilities and Equipment provide effective carbon control for the large-scale production within industrial units. Core indicators include: Renewable Energy Usage Ratio/Facility Installation Ratio, Share of Energy-Efficient and New Energy Vehicles, Charging Pile Configuration Rate for New Energy Vehicles in New Parking Lots, and Air and Water Pollution Monitoring. Regarding greening and carbon sinks, increasing the area of high-carbon-sequestration green spaces is an essential measure. Green Coverage Ratio is selected as the core indicator. The indicator system was developed with reference to relevant policies and standards, as shown in the table below.

Table 1: Indicator System for Carbon Reduction and Resilience Enhancement in Industrial Units
Source: Prepared by author

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Development Benefits	Energy Output Rate	≥ RMB 30,000/ tce	≥ RMB 50,000/ tce	Binding	Zhejiang Province Technical Guidelines for the Evaluation of Green and Low-Carbon Industrial Park Construction (2022 Edition)	Low-Carbon
	Reduction Rate of Carbon Intensity per Unit of Industrial Added Value	3-10%	≥10%	Binding	Plan for the Green Development of Industrial Sectors during the 14th Five-Year Plan Period	

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Development Benefits	Industrial Added Value per Capita	> RMB 200,000/ person	> RMB 250,000/ person	Binding	T/CIECCPA 010-2023 Guidelines for low-carbon green assessment of industrial parks	Low-Carbon
	Proportion of Green Industry Added Value in Total Industrial Added Value	≥45%	≥60%	Guiding	Jiangsu Construction Specification for Provincial Demonstration Eco-Industrial Parks (Draft for Comments) (2021)	
Building Form	Ratio of 2-Star and Above Green Building Area	20-50%	≥50%	Guiding	Shenzhen Implementation Plan for the Pilot Development of Near-Zero Carbon Emission Districts	
Facilities and Equipment	Renewable Energy Usage Ratio / Facility Installation Ratio	5-15%	≥15%	Binding	Green Park Evaluation Requirements (2016)	Low-Carbon Resilience
	Share of Energy-Efficient and New Energy Vehicles	≥30%	≥50%	Guiding	Zhejiang Province Technical Guidelines for the Evaluation of Green and Low-Carbon Industrial Park Construction (2022 Edition)	Low-Carbon
	Charging Pile Configuration Rate for New Energy Vehicles in New Parking Lots	≥40%	≥50%	Guiding	Shenzhen Implementation Plan for the Pilot Development of Near-Zero Carbon Emission Districts	
	Air and Water Pollution Monitoring	≥ 0.06 units/km^2	≥ 0.1 units/km^2	Guiding	Urban Resilience Evaluation Guide (Draft for Comments)	Resilience
Greening and Carbon Sequestration	Green Coverage Ratio	20-30%	≥35%	Binding	T/CIECCPA 031-2023 General principles for assessment of zero-carbon park	Low-Carbon Resilience

3.3 Enhancement of Core Dimensions

The Overall Scale of a residential unit determines its population capacity, which directly determines the scale of residents' energy needs and, consequently, the total carbon emissions from residential buildings. Production energy use is also a major contributor to carbon emissions. We should consider installing smart IoT electricity metering devices, utilizing on-site renewable energy generated from industrial processes, and constructing integrated terminal energy supply systems to achieve real-time or near-real-time carbon neutralization. Building layout impacts park carbon emissions in two ways: first, by modifying the modular arrangement of buildings and the ground floor area to alter carbon emissions per unit area; second, by focusing on the building facade's window-to-wall ratio and form factor to ensure construction stays within reasonable limits. The core of green mobility within industrial units lies in upgrading transportation modes and managing travel demand to enhance traffic flow efficiency and reduce carbon emissions. Regarding greening and carbon sinks, industrial units are primarily production-oriented, typically having limited large-scale ecological park development. Furthermore, vacant land, excluding buildings, is often dominated by impervious surfaces. Therefore, it is necessary to increase the green coverage ratio as much as possible to enhance the carbon sink base.

1. Overall Scale: Controlling Land Development Intensity

Controlling land development intensity and applying differentiated Floor Area Ratio (FAR) regulations: The strategy establishes differentiated FAR standards to guide office units toward high-density and high-efficiency development. Based on the current development status and actual land demand, encourage higher FARs in urban central areas to minimize the impact of urban expansion on the surrounding natural environment.

Improving comprehensive resource utilization efficiency and balance development benefits: The plan restructures high-carbon industries by setting limits on the Energy Output Rate and the Reduction Rate of Carbon Intensity per Unit of Industrial Added Value. Currently, the energy use structure varies across different parks within industrial units, and energy utilization efficiency needs to be significantly enhanced. Parks should be encouraged to be classified and tiered, with strategies to manage their overall scale and area and guided by corresponding indicators.

2. Building Layout: Encouraging Regular Plot Morphology

Optimizing plot perimeters and encouraging regular plot shapes: The unit manages the development intensity of parks. For existing plots, it increases FAR and building density through underground space development, building renovation, and expansion, thereby minimizing new land consumption. This enhances the clarity and identity of street spaces and urban development spaces, while also reducing infrastructure construction and maintenance costs.

3. Facility Environment: Increasing Renewable Energy Equipment

Increasing renewable energy equipment and boosting the share of green mobility: Based on the specific conditions of each industrial park, such as the Jingwei Industrial Park and the High-tech Software Park, smart IoT electricity metering devices should be installed. Utilize renewable energy generated from industrial processes and construct integrated terminal energy supply systems to achieve real-time or near-real-time carbon neutralization.

4. Greening and Carbon Sinks: Strengthening Greening Construction Within Units

Strengthening greening construction within office and industrial units: Most industrial unit areas prioritize industrial buildings, lacking a greening-focused development strategy. Greening construction and building form optimization should be integrated and jointly directed towards vertical development. The strategy promotes the expansion of green roofs and vertical greening to enhance carbon sequestration capacity, mitigate the park's urban heat island effect, and comprehensively improve the industrial unit's carbon reduction and resilience capabilities.

3.4 Modular Optimization Guidance

1. Carbon Reduction-Led: Optimizing Energy Conversion and Utilization, Maximizing Ecological Carbon Sinks

Promoting energy conversion and application, with a focus on integrating low-carbon mobility and ecological carbon sink systems: The strategy includes adding rooftop PV installations, promoting electricity conservation within the park, and exploring a balanced electricity efficiency model between enterprises and the park. It advocates for the use of new energy vehicles and rationally organizes arterial, secondary, and local roads to implement green mobility and low-energy transportation systems. It enhances ecological carbon sequestration capacity by promoting the full use of underutilized land and constructing extensive green infrastructure within the park to strategically offset carbon emissions from construction land. Additionally, the plan emphasizes overall road greening construction within the park, where green belts on both sides of roads and the application of ecological tree species can effectively capture particulates and sequester carbon, thereby enhancing carbon sequestration capacity.

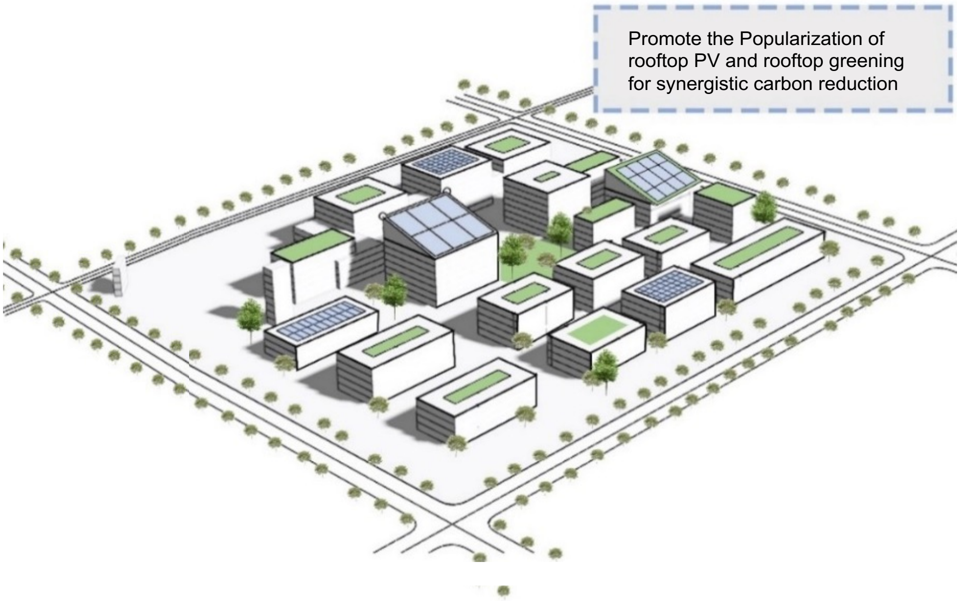

Figure 1: Conceptual Diagram of Carbon Reduction Strategies for Industrial Units

Source: Prepared by author

2. Resilience-Led: Strengthening the Overall Disaster Prevention System of the Park

Improving material supply and assurance and developing resilient transportation: The plan establishes material support industrial units to ensure urban material reserves through logistics hubs, facilitating the timely mobilization of materials based on time division, disaster type, and distance. It forms a resilient, closed-loop transportation network for both internal circulation and external connections through measures such as appropriate traffic diversion, rational traffic flow distribution, and efficient parking and drop-off facilities.

4. Carbon Reduction and Resilience Enhancement Strategies for Residential Units

4.1 General Requirements

Residential units are characterized by large-scale and high-capacity residential areas. The relationship between building configuration and carbon emissions is critical, and there is significant potential for carbon reduction through low-carbon mobility and community green spaces. The core objectives for carbon reduction and resilience enhancement are managing land development intensity, optimizing the allocation and layout of public service facilities land, increasing public transportation coverage, and increasing green space per capita. Requirements for carbon reduction and resilience in residential units are proposed across four dimensions: Overall Scale and Capacity, Building Layout, Transportation, and Greening and Carbon Sinks. The aim is to reduce the unit's total carbon emissions and carbon intensity, boost the Green Mobility Share and ecological resilience, thereby reducing CO2 emissions from resident travel and building energy consumption, lessening the environmental load, and shaping a low-carbon, green urban living space.

4.2 Indicator System

An indicator system for carbon reduction and resilience enhancement in residential units is constructed, with Overall Scale—Building Layout—Facility Environment—Greening and Carbon Sinks as the core criterion layer. Residential units have high development density, advocating for a development model featuring Small Blocks and Dense Street Networks. Overall Scale controls the total carbon emissions and intensity related to overall scale and capacity through three aspects: Floor Area Ratio, Building Density, and Total Land Area. Building Layout controls carbon emissions related to the 3D urban morphology from two aspects: the building configuration and the proportion of high-rise buildings. Furthermore, once the overall development of a residential area is determined, micro-adjustments to the proportion and layout of public service land are one effective way to control carbon emissions. The Facility Environment dimension focuses on resident travel and facility accessibility. Selected indicators include: 15-Minute Walkability Coverage for Community Health Facilities, 5-Minute Walkability Coverage for Community Elderly Care Facilities, Accessibility to Cooling/Heat Refuge Spaces, Distance to the Nearest Metro Station, and Green Mobility Share. Among these, the 5-minute walking coverage rate for community elderly care facilities and the accessibility to cooling/heat refuge spaces are Xi'an-localized indicators based on its hot weather conditions and aging population characteristics. Regarding Greening and Carbon Sinks, the green space ecological resources in residential units include parks and various community greenery. Increasing the unit's Green Coverage Ratio and considering the Per Capita Public Open Space are core indicators. The indicator system was developed with reference to relevant policies and standards, as shown in the table below.

Table 2: Indicator Framework for Carbon Reduction and Resilience Enhancement in Residential Units
Source: Prepared by author

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Overall Scale	Floor Area Ratio (FAR)	(1.0, 2.8)	(2.0, 2.7)	Binding	Code for Planning and Design of Urban Residential Areas Urban Resilience Evaluation Guide Xi'an Technical Regulations for Urban and Rural Planning Management	Low-Carbon
	Building Density	(20%, 32%)	(24%, 32%)	Binding		
	Total Land Area	(5.5ha, 15ha)	(3.5ha-5.5ha)	Guiding		

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Building Layout	Public Service Land Use Ratio	≥10%	(15%, 20%)	Guiding	Code for Planning and Design of Urban Residential Areas	Low-Carbon
	Proportion of High-Rise Buildings	(30%, 50)	≤30%	Binding	Beijing Local Standard: Community Resilience Evaluation Guide	
	Building Configuration	Enclosed + Mixed	Enclosed	Guiding	——	
Facility Environment	15-Minute Walkability Coverage for Community Health Facilities	≥75%	≥80%	Binding	Xi'an Territorial Spatial Master Plan Code for Planning and Design of Urban Residential Areas	Resilience
	5-Minute Walkability Coverage for Community Elderly Care Facilities (Xi'an Localized Indicator)	≥70%	≥70%	Binding		Low-Carbon Resilience
	Accessibility to Cooling/Heat Refuge Spaces (Xi'an Localized Indicator)	15-Minute Walkability	5-Minute Walkability	Guiding	——	
	Distance to Nearest Metro Station	＜1.2km	＜0.8km	Guiding	Guidance on green and low-carbon community construction and evaluation technology	Low-Carbon
	Green Mobility Share	≥70%	＞80%	Guiding	Green Travel Creation Action Plan Xi'an Territorial Spatial Master Plan	
Greening and Carbon Sequestration	Per Capita Public Open Space	($7m^2$, $8.3m^2$)	＞$8.3m^2$	Binding	Beijing Local Standard: Community Resilience Evaluation Guide	Low-Carbon Resilience
	Green Space Ratio	≥35%	≥40%	Binding	Code for Planning and Design of Urban Residential Areas	

4.3 Enhancement of Core Dimensions

The Overall Scale of a residential unit determines its population capacity, which directly determines the scale of residents' energy needs and, consequently, the total carbon emissions from residential buildings. Building layout impacts the carbon emissions of residential areas through two main channels: first, through the building's spatial configuration, which directly affects solar access; and second, by influencing the microclimate within the residential area. The Facility Environment determines the configuration of public transportation infrastructure, which directly influences residents' Green Mobility Share and thus dictates the unit's total transportation carbon emissions. Public transit stop coverage effectively mitigates traffic congestion, improves traffic flow efficiency, and thereby reduces carbon emissions. Regarding Greening and Carbon Sinks, increasing the Green Coverage Ratio in residential areas enhances overall carbon sequestration capacity, effectively regulates the microclimate, lowers ambient temperatures, and consequently reduces building carbon emissions. Furthermore, Public Open Space not only improves the community's wind environment but can also serve as emergency evacuation sites, providing safe refuge and boosting the overall resilience of the community.

1. Overall Scale: Controlling Floor Area Ratio and Building Density

Controlling land use scale and optimizing floor area ratio and building density: Based on the Small Blocks and Dense Street Networks concept, rationally managing the planar land use scale is central to adjusting FAR and Building Density. Residential units often exhibit a high concentration of high-rise buildings and high FAR, often exceeding relevant regulatory standards. Future residential construction must implement low-carbon and resilient design, specifically limiting the FAR for high-rise buildings to 2.8 or below.

2. Building Layout: Enhancing the Degree of Building Enclosure

Enhancing the degree of building enclosure: The plan guides the development of compact, comfortable, and pleasant courtyard-style layouts. Simultaneously, it promotes natural ventilation through rational spatial arrangement to improve the wind environment and regulate the microclimate, thereby reducing energy consumption.

3. Facility Environment: Improving Public Transportation Coverage

Promoting low-carbon mobility and improving public transportation coverage: Based on population density within residential units and from a supply-demand optimization approach, the strategy enhances the coverage of metro stations. The goal is to achieve a Metro + Bus Green Mobility Share of 55% by 2030, and increase the Rail Transit Station 300m Coverage to 45%, thereby encouraging and guiding residents toward low-carbon travel modes.

4. Greening and Carbon Sinks: Integrating Internal and External Ecological Green Spaces into Networks and Loops

Maximizing the potential of ecological resources and organizing them into networks and loops: Within and around residential compounds, the plan identifies and develops transformable ecological resources, organizing them into interconnected networks and loops. Within ecological green spaces, the strategy emphasizes the combination of evergreen and deciduous vegetation, and employs a multi-tiered planting strategy (trees, shrubs, and groundcover). High-carbon-sequestration native species suitable for Xi'an are planted around commercial buildings. Furthermore, three-dimensional greening is comprehensively strengthened by planting climbing plants like Boston ivy and installing vertical landscape features, which holistically enhances the low-carbon resilience capacity of the residential unit.

4.4 Modular Optimization Guidance

1. Carbon Reduction-Led: Applying Low-Carbon Technologies, Promoting Low-Carbon Lifestyles

Encouraging the installation of rooftop PV systems: The guidance recommends increasing the PV installation ratio and applying low-carbon technologies. New PV installation models involving multiple stakeholders (the community, residents, and enterprises) should be explored to create Near-Zero Carbon Communities. Through this mechanism, PV panels should be utilized to power ground-level community public amenities/infrastructure, such as corridor lights, street lights, community LED display screens, charging piles, smart waste recycling bins, and electric bicycle charging stations. Projects where developers install rooftop PV systems may be considered for a Floor Area Ratio bonus of up to 3%.

Encouraging retrofitting rooftops and balconies for greening: Low-carbon lifestyle principles and practices should be promoted, and a Carbon Rewards System (or “Carbon Point Bank”) should be established for the residential unit. Residents are encouraged to accumulate “carbon credits/points” through low-carbon behaviors, which can then be redeemed for sustainable products. Concurrently, comprehensive low-carbon education and outreach (both online and offline) should be delivered to foster residents’ environmental responsibility.

2. Resilience-Led: Improving Infrastructure and Enhancing Community Resilience

Promoting the decentralization of public service infrastructure: The guidance suggests facilitating the integration of high-quality public service resources (such as healthcare, culture, and sports) into the community level. Furthermore, refined management of these resources should be implemented based on different needs across demographics (all ages), time of day, and seasonal variations, while concurrently maximizing public resource efficiency.

Enhancing community disaster preparedness and response capacity: Based on the Community Life Circle concept, regular resilience assessments should be conducted. Furthermore, the development of Urban Health and Safety Units should be promoted, holistically improving overall disaster mitigation, self-rescue, and mutual assistance capabilities at the grassroots level.

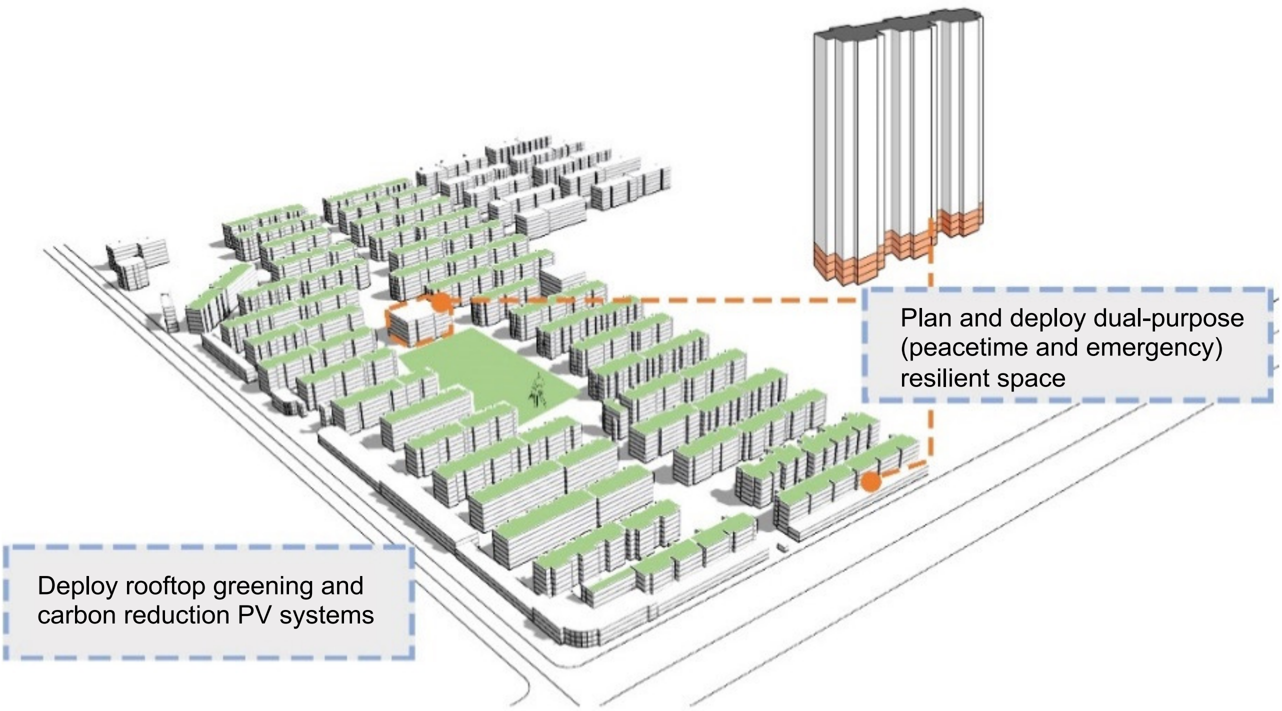

Figure 2: Conceptual Diagram of Carbon Reduction and Resilience Enhancement Strategies for Residential Units
Source: Prepared by author

5. Carbon Reduction and Resilience Strategies for Renewal Units

5.1 General Requirements

Renewal units encompass diverse urban functions, including historical sightseeing and tourism, cultural and leisure activities, commercial services, and residential uses. The variety, density, and functional mixture of these activities are positively associated with crucial urban outcomes such as urban vitality, transportation efficiency, and community sustainability. This section proposes carbon reduction and resilience strategies for renewal units across four dimensions: block functions, energy technologies, facilities and the built environment, and greening and carbon sequestration. The aim is to lower the carbon intensity of buildings and enhance both the functional and ecological resilience of the block. The core dimensions for carbon reduction and resilience enhancement are determined as functional proportion regulation and facilities and environment optimization. The principal management targets focus on four areas: regulating functional proportions, optimizing the energy consumption structure of buildings, promoting low-carbon transportation, and increasing ecological space.

5.2 Indicator System

An indicator system for the carbon reduction and resilience of renewal units is constructed, centered around four core criteria layers: block functions, energy technologies, facilities and the built environment, and urban greening and carbon sequestration. The block functions criterion prioritizes the degree of functional mixing within the renewal unit and the public accessibility ratio of street-facing cultural and tourism units, aiming to increase the share of cultural and tourism activities, enhance functional mixing, and improve spatial utilization. The energy technologies criterion focuses on the vacancy rate and the energy-saving rate of existing buildings. The facilities and built environment criterion emphasizes green and low-carbon travel modes and associated measures, selecting indicators such as bus-stop coverage, distance to the nearest metro station, share of green mobility, and the proportion of new and clean energy buses. Given the typically high-density characteristics of renewal unit construction, the greening and carbon sequestration dimension requires infill greening. The selected indicator is the per capita area of park green space within built-up areas. The indicator system was developed with reference to relevant policies and standards, as shown in the table below.

Table 3: Indicator System for Carbon Reduction and Resilience Enhancement in Renewal Units
Source: Prepared by author

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Block Function	Degree of Functional Mixing	(0.3,0.5)	(0.5,1)	Guiding	Existing Research	Low-Carbon
	Public Accessibility Ratio of Street-Facing Cultural and Tourism Units (Xi'an Localized Indicator)	≥70%	≥70%	Guiding	LB/T 082-2021 Classifications for Tourist and Leisure Streets; GB/T 36309 Classifications for Public Cultural Resources	Resilience
Energy Technology	Average Energy-Saving Rate of Public Buildings	≥72%	≥72%	Binding	General code for energy efficiency and renewable energy application in buildings GB 55015-2021	Low-Carbon
	Commercial Vacancy Rate	≤5%	≤3%	Guiding	GB/T 39067-2020 Public service specification for office building	

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Facility Environment	Bus Stop Coverage	100%	100%	Binding	Guidance on green and low-carbon community construction and evaluation technology	Low-Carbon
	Distance to Nearest Metro Station	＜1.2km	＜0.8km	Guiding		
	Green Mobility Share	≥70%	≥80%	Guiding	Green Travel Creation Action Plan Xi'an Territorial Spatial Master Plan	
	Ratio of New and Clean Energy Buses	≥55%	≥60%	Guiding		
Green Carbon Sinks	Per Capita Park Green Space Area in Built-Up Areas	(17,20)	>20	Binding	Beijing Local Standard Urban Resilience Evaluation Guide Xi'an Territorial Spatial Master Plan	Low-Carbon Resilience

5.3 Enhancement of Core Dimensions

Renewal units involve multiple land-use functions, including historical and cultural land uses, cultural leisure, commercial services, and residential living. The strategy is to foster mixed-use development, encouraging the integration of residential, commercial, and public-service land to achieve a compact and efficient land utilization layout. This includes introducing diverse industrial categories and new historical and cultural-tourism formats to reduce the public-accessible building vacancy rate. For high-density historical blocks, narrow building spacing, prolonged operational lighting periods, and significant building energy consumption, coupled with fire risks in timber structures, necessitate renovation and retrofitting. This renovation should focus on controlling building spacing and reducing energy demand. Regarding the facilities and environment dimension, high-density crowds and instantaneous peak flows require close attention to node organization and evacuation capacity. The lack of large-area ecological greening within renewal units necessitates implementing infill greening within the block to enhance ecological resilience and environmental ecological benefits.

1. Block-Level Functions: Promoting Mixed Land Use

The strategy seeks to balance low-carbon goals with commercial vitality by promoting mixed land utilization. This involves increasing the mixed utilization degree of public spaces, appropriately integrating urban green space and plaza land with commercial and service land, and recreational and health-related land. In central urban areas, the integration of residential, commercial, and public-service land uses is encouraged. Simultaneously, the proportion of leisure and entertainment commercial land should be moderately controlled, while the mixed utilization of various commercial functions is encouraged. The plan encourages compact and efficient land utilization layouts. It also promotes introducing diverse industrial categories and new historical and cultural-tourism formats to reduce the public-accessible building vacancy rate. The land-use functional mix for the urban unit should not fall below 30%, with 50% or more being optimal. In historical and cultural blocks, as well as industrial heritage blocks, the public accessibility ratio of street-facing cultural and tourism units should be greater than 70%.

2. Energy Technologies: Reducing Building Energy Consumption

Reducing building energy consumption and improving overall energy efficiency: This involves implementing management and retrofitting strategies for carbon reduction in renewed commercial buildings and industrial plants, optimizing the building energy consumption structure, and increasing the average energy-saving rate. During the building operation phase, energy conservation and emission reduction are to be achieved through the application of green building technologies. The optimization of building envelope structures is encouraged. The use of daylighting and natural ventilation is promoted to enhance building energy efficiency. Based on relevant standards and research calculations, the average energy-saving rate for public buildings should exceed 72%. The specific heat consumption (per unit area) should be lower than 0.26 GJ/m².

3. Facilities and Environment: Strengthening Public Transport Hub Organization and Evacuation

Prioritizing public transport, the strategy strengthens urban rail transport and infrastructure construction: It optimizes infrastructure within renewal units by increasing the density of bus stops and metro stations. Guided by the principle of bus priority, non-motorized transport is encouraged for short-distance travel. Concurrently, urban rail transport construction is strengthened, pedestrian environments around rail stations are optimized, and the transfer capacity between rail stations and other public transport modes is enhanced. Bus stop coverage within a 500-meter radius in the urban area should reach over 90% in the near term and achieve 100% full coverage in the long term. The distance to a rail transport station should be within 1.5 km, with 0.8–1.2 km being the desirable range.

4. Greening and Carbon Sequestration: Enhancing Ecological Resilience and Environmental Benefits

Enhancing ecological resilience and environmental ecological benefits: This requires increasing green-space coverage within the unit and diversifying vegetation forms. The strategy encourages the planting of trees (arbor) to increase the proportion of multi-layered vegetation (arbor, shrubs, and grass) within green spaces, thus enhancing the composite layering of plant configurations. Furthermore, high carbon-sink tree species should be selected wherever possible, based on local conditions. Based on the ratio of urban park green space area to the total resident population, the per capita area of park green space within built-up areas should not be lower than 17 m²/person.

5.4 Modular Optimization Guidance

1. Carbon Reduction-Led: Optimizing Land Use Structure and Building Energy Consumption

Managing commercial facility proportions and promote intensive and efficient land development: Renewal units are characterized by a diverse yet concentrated mix of functional forms. Given the high proportion and carbon emissions of commercial facilities, their ratio must be strategically managed to balance low-carbon goals with economic vitality. Specifically, optimization strategies focus on three areas: First, enhancing the mixed-use integration between commercial consumption spaces and other public areas. This involves promoting the appropriate co-location of urban green spaces, plazas, and other leisure/recreation plots with commercial service and entertainment land uses. Second, encouraging a compact and highly efficient land use layout. This includes introducing new industrial categories and cultural/historical tourism-related consumption forms, thereby reducing the vacancy rate of public buildings. Third, implementing managerial and retrofit-based carbon reduction measures for commercial and industrial renewal buildings. This serves to optimize the building energy consumption structure and raise the average energy-saving rate.

Optimizing the building energy consumption structure and increasing the average energy-saving rate: The strategies above involve focused managerial and retrofit-based carbon reduction for commercial and industrial renewal buildings. This includes: upgrading the thermal insulation performance of older residential districts to minimize heat loss, and deploying intelligent energy management systems in commercial buildings.

2. Resilience-Led: Improving Infrastructure and Upgrading Disaster-Prevention Space

Enhancing safety and evacuation capacity: Given the significant population base of the renewal units, the pressure for personnel and vehicle evacuation is considerable during disasters or other emergencies. The focus must be on optimizing the configuration of public transportation facilities and emergency evacuation spaces. This involves two core strategies: First, optimizing the construction of infrastructure within the renewal units. This means increasing the density of bus and metro stations to improve the city's emergency evacuation capability. Second, appropriately upgrading, replacing, or preserving non-built spaces, such as green areas and parks. This allows for the mandatory safety zoning of urban land, thereby enhancing the city's overall safety and disaster prevention capability.

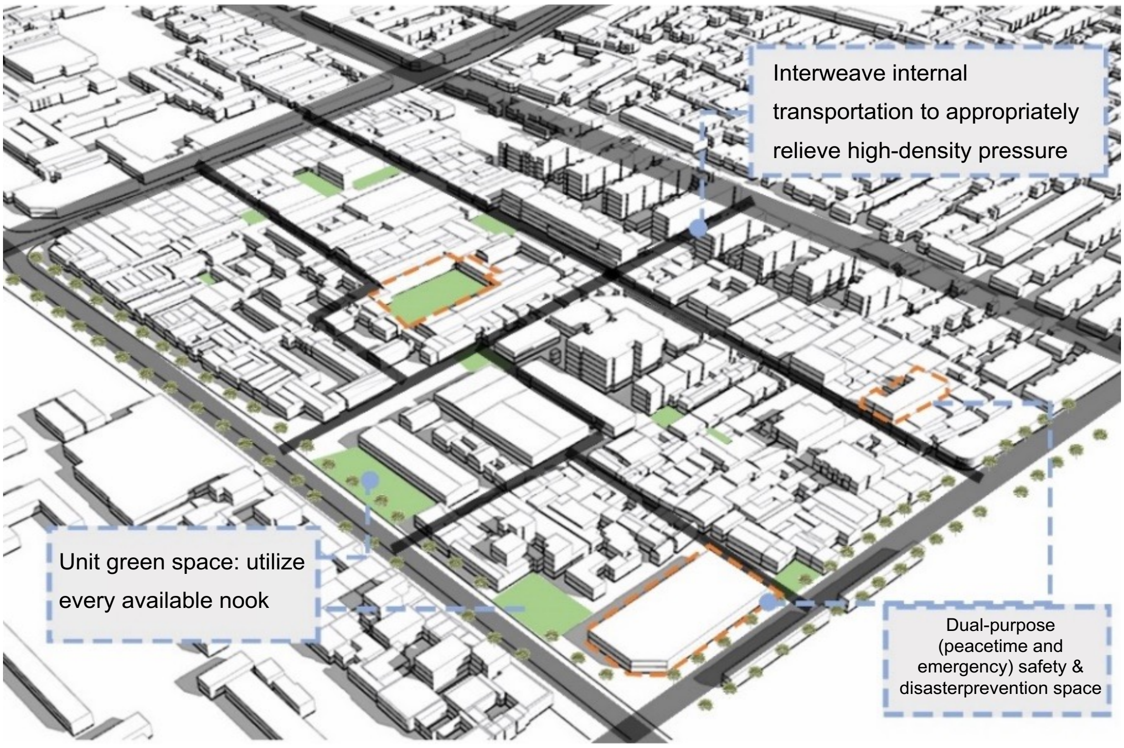

Figure 3: Conceptual Diagram of the Carbon Reduction and Resilience Enhancement Strategies for Urban Regeneration Units
Source: Prepared by author

6. Strategies for Carbon Reduction and Resilience Enhancement in Ecological Units

6.1 General Requirements

Ecological units intrinsically offer the carbon sequestration potential of their ecosystems. By establishing a complete and continuous urban blue-green space system, the overall stability of the city's ecological carbon sink can be effectively secured. The core management objectives for these ecological units are to optimize plant community structures, enrich biodiversity, and increase the green volume. The essential controlling factors for synergistically enhancing carbon sequestration and resilience are determined across three dimensions: green space scale, spatial morphology, and vegetation type. The overall carbon sequestration capacity of the ecological units is comprehensively improved through measures such as increasing the green coverage ratio, elevating the proportion of multi-layered vegetation (tree-shrub-groundcover), increasing the ratio of native plant species, encouraging the development of vertical greenery, and safeguarding the site's native ecological integrity.

6.2 Indicator System

An indicator system for carbon reduction and resilience enhancement in ecological units is established, centered on the principal criteria layers of "Overall Scale—Spatial Morphology—Facility Environment—Vegetation Type." Overall scale and spatial morphology constitute important indicator layers guiding low-carbon and resilience development. Specifically, green space scale and shape index will facilitate low-carbon park development, while the effective shelter area will benefit resilience-oriented park development. The indicators within the facility environment criteria layer are selected to evaluate the provision of low-carbon landscape facilities within the park system. The setting of indicator control thresholds must not only consider the value orientations of low carbon and resilience but also be tailored to local conditions regarding the plant growth environment. Therefore, the vegetation type criteria layer includes indicators for arbor-shrub coverage, tree coverage, and native tree species coverage. The entire system is constructed with reference to relevant policy and technical standards, as presented in the table below.

Table 4: Indicator System for Carbon Reduction and Resilience Enhancement in Ecological Units
Source: Prepared by author

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Overall Scale	Green Space Scale	(1ha, 2ha)	<1ha	Guiding	Pocket Park Development Guide (Trial)	Low-Carbon
Spatial Morphology	Effective Shelter Area	(55%, 60%)	>60%	Guiding	GB/T 40947-2021 Guidelines for the Evaluation of Safe and Resilient Cities	Resilience
	Shape Index	(1, 1.5)	>1.5	Guiding	——	Low-Carbon
Facility Environment	Low-Carbon Landscape Facility Ratio	>20%	>50%	Guiding	Technical Specification for Carbon-Neutral Parks	Low-carbon + Resilience

Criterion Layer	Indicator Layer	Near-Term Planning Target Value	Long-Term Planning Target Value	Indicator Attribute	Reference Standard	Low-Carbon / Resilience Orientation
Vegetation Type	Arbor-Shurb Coverage	(70%, 80%)	>80%	Binding	Xi'an Urban Greenery Planting Design Guidelines	Low-carbon + Resilience
	Tree Coverage	(60%, 70%)	>70%	Binding		
	Native Tree Species Coverage	(70%, 80%)	>80%	Guiding		

6.3 Enhancement of Core Dimensions

The scale of green space within ecological units indirectly influences the per-unit area carbon sequestration capacity of the ecological space. Different sizes of green spaces indirectly affect planting methods: ecological spaces smaller than 1 ha have limited functionality due to area constraints, primarily serving leisure and viewing purposes, resulting in a relatively high utilization rate. Spatial morphology also indirectly influences the carbon sequestration capacity of the ecological space. Different green space shapes indirectly influence planting design, and various planting designs, in turn, affect the multi-layered ground cover. Vegetation type has a significant correlation with the per-unit area carbon sequestration capacity of the ecological space. The ratio of trees, shrubs, and groundcover directly determines the green volume, which is not only an important parameter for plant carbon fixation but also a critical factor influencing green space carbon sinks. Increasing the green volume has a significant positive impact on elevating the carbon sequestration performance of ecological spaces.

1. Spatial Morphology: Creating Pocket Parks and Upgrading Riverside Green Spaces

Creating pocket parks and upgrading riverside green spaces: Flexible use must be made of existing irregular spaces—such as street corners, idle spaces beneath elevated structures, redeveloped sites, and derelict land. Pocket parks under 1 ha should be established in an opportunistic manner based on a service radius of 300–500m. Furthermore, pocket parks should target a green-coverage ratio greater than 75%. Arbor plantings should be planned to create enclosed or semi-enclosed spaces. This configuration can, on the one hand, achieve noise reduction, and on the other hand, tall arbors can increase the per-unit area carbon sequestration capacity of the green space.

2. Vegetation Type: Optimizing Plant Composition and Increasing Arbor-Shrub-Herbaceous Ratios

Optimizing plant composition and increasing arbor-shrub-herbaceous ratios: First, the proportion of trees, shrubs, and groundcover within ecological units should be raised by increasing arbor planting, thus improving the multi-layered complexity of the vegetation composition. Second, when optimizing vegetation planting, high-carbon-sequestration species should be selected as much as possible, tailored to local conditions. For arbors, high-carbon-sequestration native species such as Juniperus chinensis (1.23×10-2 t/a), Styphnolobium japonicum (9.5×10-3 t/a), and Platycladus orientalis (8.51×10-3 t/a) can be selected. Shrub selection can focus on high-carbon-sequestration vegetation such as Prunus persica 'flore pleno' (7.05×10-3 t/a), Malus spectabilis (6.63×10-3 t/a), and Prunus triloba (2.91×10-3 t/a).

6.4 Modular Optimization Guidance

1. Carbon Sink-Led: Enhancing Carbon Sequestration Benefits and Promoting Low-Carbon Infrastructure Utilization

Enhancing the carbon sequestration capacity of green spaces and promoting the application of low-carbon infrastructure: The ecological benefits of these green spaces can be maximized by increasing the arbor-shrub-herbaceous proportion and expanding the carbon sink area. Promoting biodiversity can further stimulate material cycling and energy flow within ecological units. In terms of promoting low-carbon infrastructure, examples include integrating solar photovoltaic panels with landscape lighting to enable on-site energy generation, thereby maximizing resource conservation and cyclical utilization.

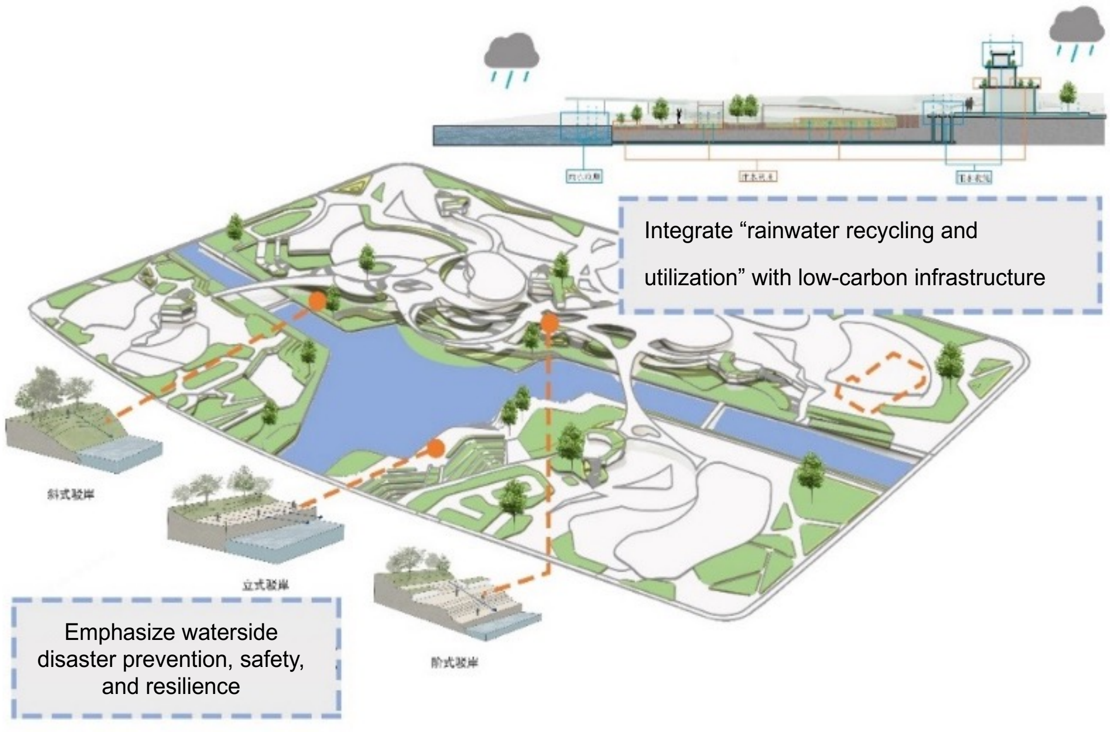

Figure 4: Conceptual Diagram of the Carbon Sequestration Enhancement Strategy for Ecological Units (1)
Source: Prepared by author

2. Resilience-Led: Assessing Hydrological Baseline and Improving Water-Related Disaster Mitigation Facilities

Resilience-led ecological units are also considered hydrological disaster prevention units, placing greater emphasis on safety and disaster mitigation functions. First, the focus must be on assessing hydrological baseline conditions and conducting flood-simulation analyses. This includes modeling different levels of inundation scenarios under extreme water levels and levee-breach conditions, as well as under variable rainfall intensities. Second, effective and rational planning measures should be applied to the deployment and utilization of relevant infrastructure, ensuring that the effect of levee reinforcement and resilience is genuinely achieved.

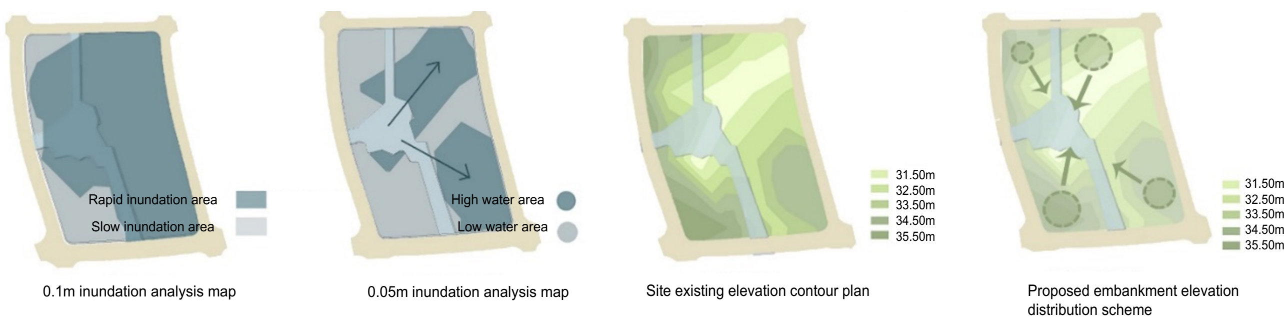

Figure 5: Conceptual Diagram of the Carbon Sequestration Enhancement Strategy for Ecological Units (2)
Source: Prepared by author

7. Case Studies of Carbon Reduction and Resilience Enhancement Strategies for Different Unit Types in Xi'an

7.1 Industrial Unit (Industrial Park) – Jingwei Industrial Park, Economic Development Zone (EDZ)

The BB-TB-03 unit of the Jingwei Industrial Park, covering 6.3 km^2, is situated in Gaoling District, Xi'an. It is integral to the northern "Gaoling–Jinghe–Airport Area" and the "Northern Advanced Manufacturing Cluster" Functional Grouping. The area hosts a robust core of industries, including the Changqing Oilfield Group and Shaanxi Automobile's new base—the largest heavy-duty vehicle industrial hub in western China. The clustering of over ten well-known auto-parts manufacturers around this company has, in recent years, established one of the most influential national bases for automotive R&D, production, and sales. Furthermore, the park includes major chemical industries, such as the Northwest region's largest Western New Materials Industrial Park and Sinochem Modern Environmental Chemical (Xi'an) Co., Ltd. (a national high-tech demonstration project producing the environmentally friendly refrigerant HFC-134a). Transportation infrastructure, including the Jinghe Bridge and the Jingwei-Weihe Bridge, connects the park north and south, enabling its rapid integration into Xi'an's 30-minute economic circle. This has established it as one of Xi'an's most critical manufacturing bases and a highly dynamic growth node along the "One Axis, Two Belts" development strategy—the "Ancient Capital Cultural Axis, Great Heritage Belt, and Silk Road Development Belt." However, this economic growth is accompanied by high carbon emissions. The existing industrial cluster primarily features low-rise workshops and warehouses, supplemented by mid-rise office buildings. Factory parcels occupy large areas, spatial organization is often disorganized, and land-use efficiency remains low. Furthermore, freight transport relies on non-clean energy heavy-duty trucks, resulting in high transportation-related carbon emissions. Core challenges requiring urgent attention and targeted carbon reduction and resilience strategies include the scarcity of ecological arbors within the park and the lack of deployment of renewable energy systems such as solar power.

1. Carbon Reduction Strategy: Retrofitting High-Performance Factory Buildings and Installing Renewable Energy Systems

(1) Retrofitting High-Performance Factory Buildings

The final assembly plant of the Shaanxi Automobile Industrial Park will serve as a benchmark enterprise for demonstrative retrofitting of high-performance factory buildings, aimed at driving the low-carbon and energy-saving upgrade of all factory buildings in the park. Existing structures will be renovated according to high-performance factory building technical standards. This includes integrated roofing design, the application of eco-friendly wall and flooring materials, insulated doors and windows, window shading, and the installation of photovoltaic panels and wind energy capture devices. For new factory construction within the park, the approach will be to promote prefabricated construction, utilizing various prefabricated building components and selecting environmentally friendly materials such as high-strength steel and low-E coated glass, thereby achieving a modular and energy-efficient construction process.

(2) Installing Renewable Energy Systems

Photovoltaic battery panels should be installed in designated PV-suitable areas across the park. Taking the parking lot of the Shaanxi Automobile Industrial Park as a pilot demonstration site, the parking lot canopies are areas with optimal solar energy utilization efficiency and can be used for the large-scale deployment of photovoltaic panels to generate clean electricity.

Renewable energy should be incorporated into production and logistics processes. Utilizing renewable energy generation to offset industrial carbon emissions aims to optimize the park's overall energy use structure. Furthermore, guidance will be provided for the clean energy transition and upgrading of on-site transport vehicles, along with the expansion of new energy charging facilities to support the park's low-carbon transportation transformation and enhance the green and self-circulating level of energy utilization.

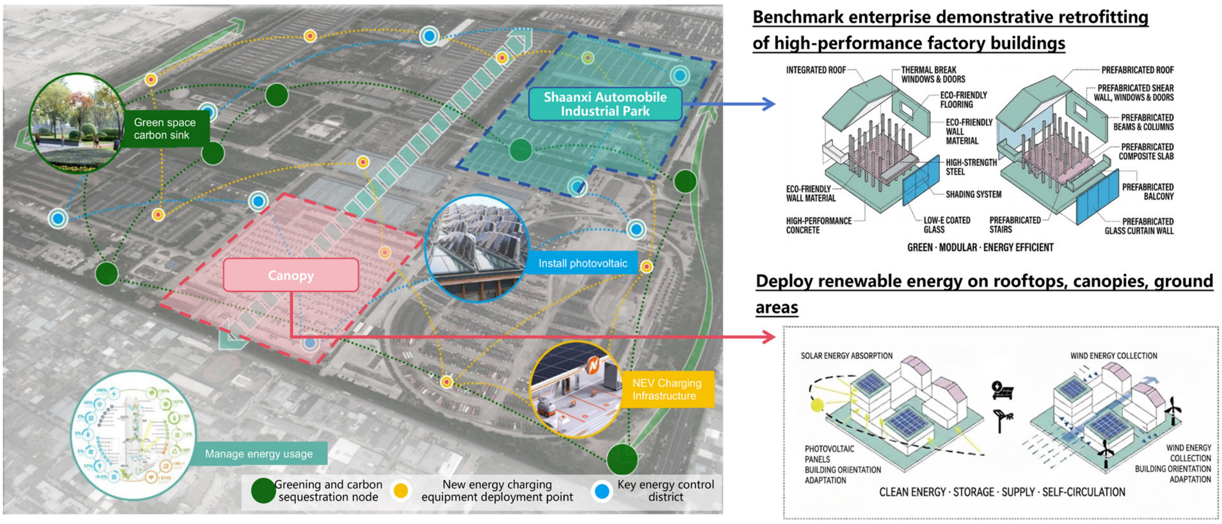

Figure 6: Industrial Park — Jingwei Industrial Park, EDZ Detailed Carbon Reduction Strategy Conceptual Diagram
Source: Prepared by author

2. Resilience Enhancement Strategy: Establishing an Ecological Resilience System and Deploying a Smart Monitoring Platform

(1) Establishing an ecological resilience system

The park will utilize vacant land along streets and within factory sites to establish a greenery-enhanced ecological resilience system. Using the sound green infrastructure of the Shaanxi Automobile Research Institute as a baseline, the park will construct a regional stormwater collection and infiltration system. Expanding the green space area and constructing an ecological network will enhance the ecosystem's stability and biodiversity, strengthening its buffering capacity against natural hazards (e.g., floods, droughts). Concurrently, this strategy will improve the park's microclimate and provide a more comfortable working environment for employees.

(2) Deploying a smart monitoring platform

The park will leverage smart-city technologies to establish an urban emergency response system. Within the park, an IoT-based smart freight monitoring system centered on vehicle operations will be deployed. This system will improve logistics efficiency, reduce traffic congestion and energy consumption, and enhance transportation safety and flow efficiency within the park.

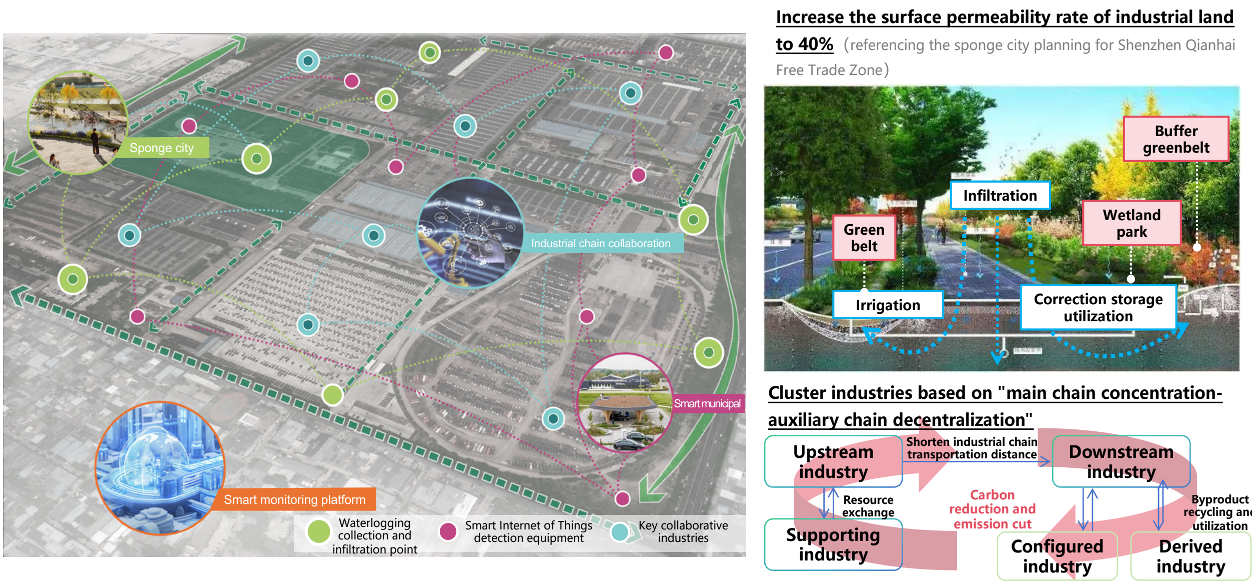

Figure 7: Industrial Park — Jingwei Industrial Park, EDZ Detailed Resilience Strategy Conceptual Diagram
Source: Prepared by author

7.2 Industrial Unit (Office Park) – High-Tech Information Industrial Park

The ZC-GX-03 Innovation-Oriented Unit for High-Tech Software and Information Industry, covering 3 km2, is located in Yanta District, Xi'an. It lies at the intersection of the "Ancient Capital Core Functional Zone," the "National Science & Technology Innovation Center Pioneering Zone," and the "Southern High-Tech and Education Cluster." The enterprises within the unit are functionally positioned to focus primarily on high-technology and software development. Core companies include Huawei's Xi'an Research Institute, the Xi'an Semiconductor Industrial Park, and BYD's High-Tech Factory. The overall environmental quality and aesthetic are favorable, with a good job-housing balance, comprehensive public service facilities, and well-developed block functions. However, challenges persist: office buildings primarily feature glass curtain-wall façades, resulting in energy consumption challenges related to indoor shading and building thermal insulation; high instantaneous traffic volumes cause significant traffic pressure during morning and evening peak hours.

1. Carbon Reduction Strategy: Establishing Regional Energy Cycling Hubs and Highlighting Active Mobility Demarcation

(1) Establishing a regional energy cycling demonstration hub

Led by XD Group, the unit will establish a Regional Energy Cycling Hub (or Integrated Energy Station). Blocks within the unit will be encouraged to participate in renewable energy generation, and a park-level energy conversion facility will be deployed to integrate renewable energy sources (such as wind and solar power), achieving a self-production and self-consumption cycle of regional renewable energy. A solid-waste resource treatment system will be configured within the unit. Utilizing renewable energy generation to satisfy the energy demands of this waste treatment system will intensify waste recycling and resource utilization.

(2) Highlighting active mobility demarcation

Active mobility routes, including pedestrian sidewalks and bicycle lanes, will be clearly demarcated to promote low-carbon commuting, divert short-distance motor vehicle trips, and effectively reduce traffic flow during peak hours.

2. Resilience Enhancement Strategy: Establishing an Ecological Resilience Base and Deploying an Emergency Public Service Network

(1) Establishing an ecological resilience base

The municipal buffer zone between the unit and the ring expressway will be utilized to construct the area's ecological resilience system. By expanding the green coverage and establishing gentle-slope wetlands, bioswales, and rain gardens, the unit will form an ecological sponge-resilience foundation to enhance the urban capacity to resist disasters such as drought and waterlogging.

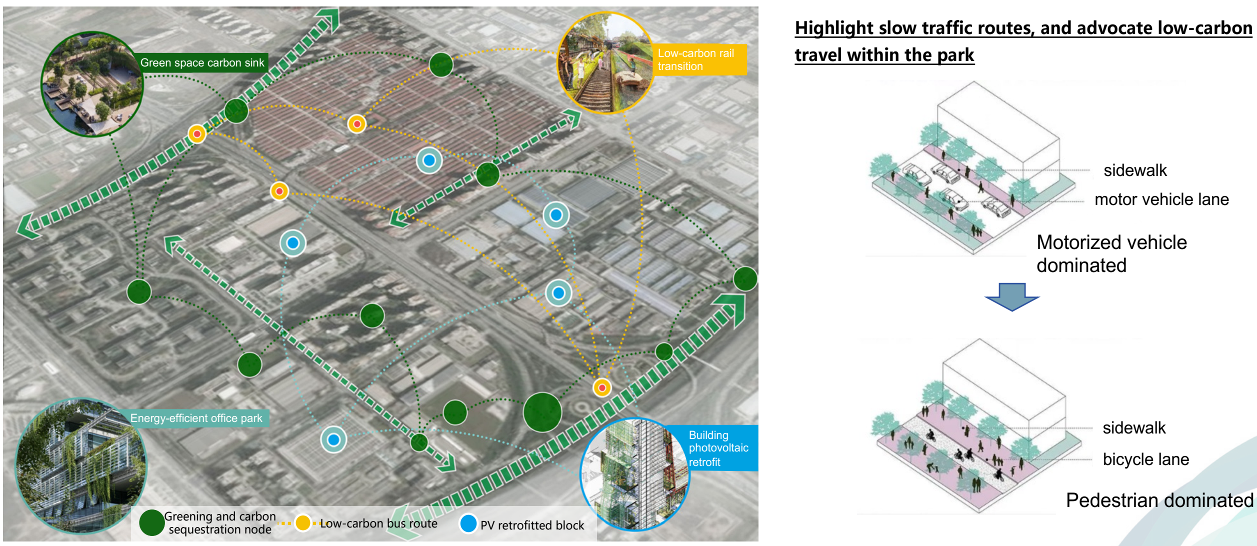

Figure 8: Office Park – Information Industrial Park Detailed Carbon Reduction Strategy Conceptual Diagram
Source: Prepared by author

(2) Forming a smart transportation backbone

A dual-purpose (peacetime and emergency) transportation monitoring and management system will be developed. This includes the deployment of smart interactive crossings, an intelligent traffic flow monitoring system, and an active mobility safety monitoring system. During normal operations, the system will be used to manage traffic flow and ensure road safety.

(3) Deploying an emergency public service facility network

Building upon the smart transportation system backbone, an emergency public service facility network will be established. During emergencies, the system will be utilized to evacuate vehicles and pedestrians and to rapidly designate emergency logistic corridors, comprehensively enhancing the district's resilience.

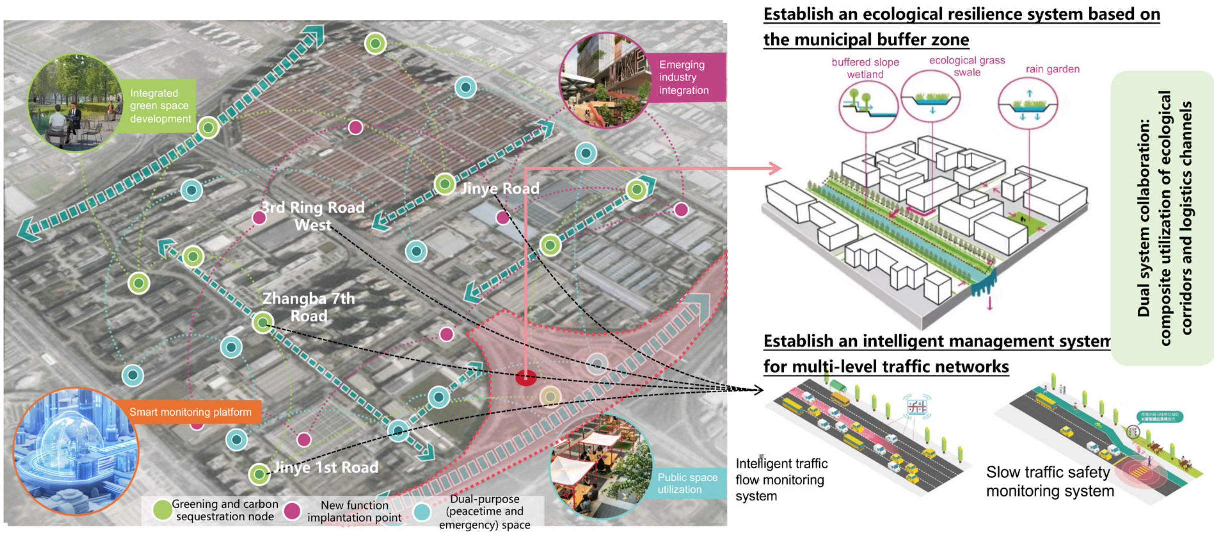

Figure 9: Office Park – Information Industrial Park Detailed Resilience Strategy Conceptual Diagram
Source: Prepared by author

7.3 Residential Unit – Livable Unit for Near-Term Development, EDZ

The CZ-JK-01 Livable Unit for Near-Term Development in the EDZ is located in Weiyang District, Xi'an, covering an area of 2.89 km2. The unit's overall characteristics include an appropriate scale for the residential area, a dominance of high-rise housing, a favorable green environment, a good commercial service environment, and balanced public services. However, challenges persist, including high building density and Floor Area Ratio (FAR), concentrated population, challenges related to building facade materials and thermal insulation energy consumption, issues regarding the reasonable proportion and site selection of public service facilities, and carbon emissions resulting from resident travel behaviors. Although the unit scores highly for overall livability, there remains room for enhancing carbon reduction effectiveness and potential. A key advantage is its potential to achieve an internal carbon balance across "production–consumption–sequestration."

1. Carbon Reduction Strategy: Establishing a Carbon-Inclusive Platform and Deploying Photovoltaic Systems

(1) Establishing a carbon-inclusive platform

With government support, neighborhood committees and surrounding local businesses will establish community-level carbon-inclusive platforms. The carbon-inclusive mechanism will be promoted through public messaging in community grid networks and public spaces to raise residents' low-carbon awareness. The development and popularization rate of rooftop and balcony greenery will be intensified, and the amount of ecological green space and shaded corridors will be increased.

(2) Deploying photovoltaic systems

Photovoltaic systems will be prioritized for deployment on public buildings and schools within the community. Through incentive-based communication, consensus will be achieved among "government-enterprises-communities-residents" to enable the deployment of PV systems on residential buildings.

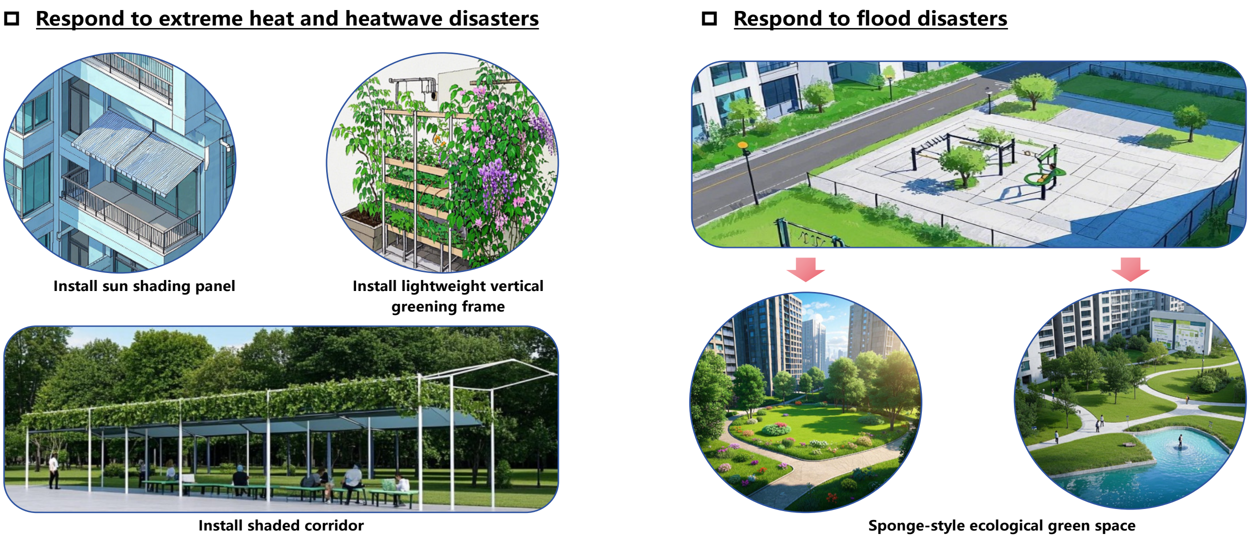

Figure 10: Residential Unit — Near-Term Development Unit Carbon Reduction Strategy Conceptual Diagram
Source: Prepared by author

2. Resilience Enhancement Strategy: Building a Resilience System and Refining Resilience Facilities

(1) Build a resilience system

Based on existing research, the residential area's dual-purpose (peacetime and emergency) resilient public spaces are defined as: open spaces within the 5-minute living circle; kindergartens and local markets within the 10-minute living circle; and primary schools and parks within the 15-minute living circle.

(2) Refining resilience facilities

Community public space renewal: The strategy involves constructing a "node–hub–emergency flow" resilience network by utilizing open spaces as nodes, establishing markets (such as Baihualin Market) and schools (such as Jingkai No. 6 Middle School) as hubs, and employing the transportation system as the emergency flow corridor.

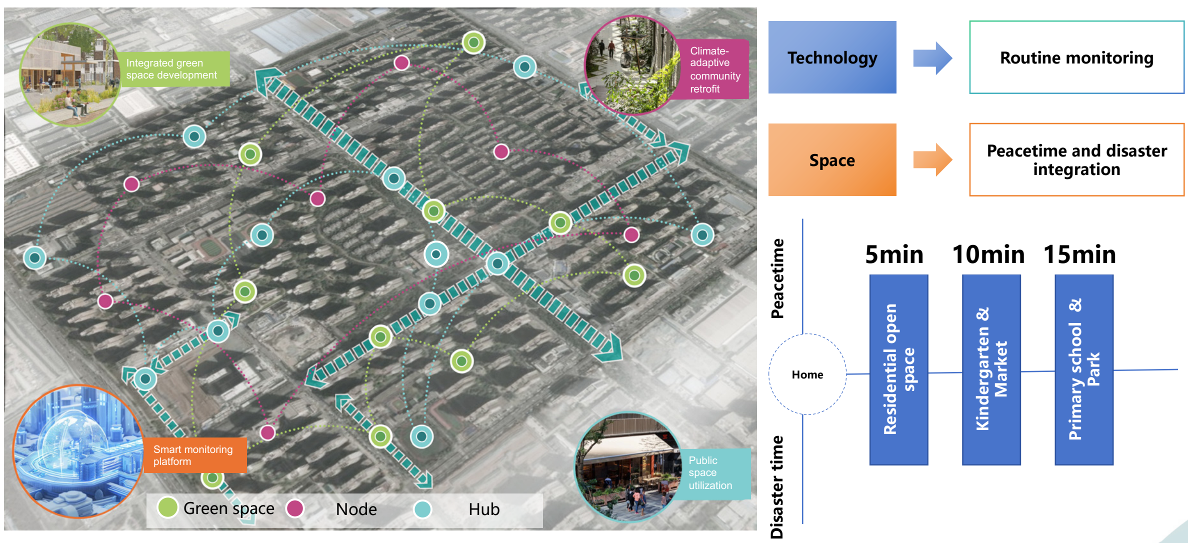

Figure 11: Residential Unit — Near-Term Development Unit Community Resilience Network Conceptual Diagram
Source: Prepared by author

Improving elder-care facilities: Elder-care facilities will be refined through three methods: new construction, functional integration, and functional reallocation. Functional integration and reallocation will utilize residential-unit spaces and street-front shops to create a multi-module community elder-care system covering daily care, medical care, cultural/recreational activities, and psychological support services. For instance, the Baihualin Community will develop cultural and recreational elder-care facilities through functional integration with the community committee and the community clubhouse.

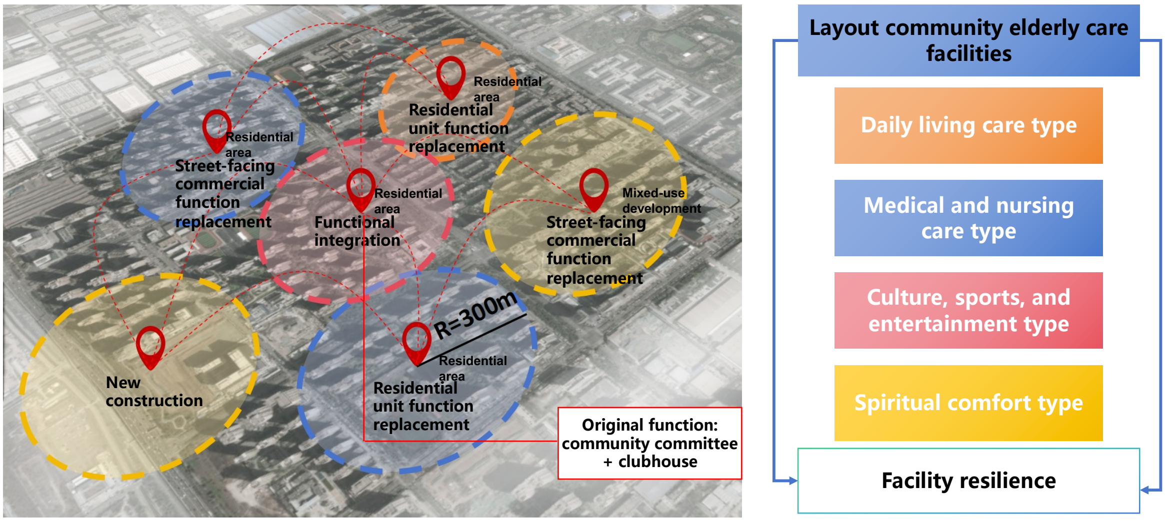

Figure 12: Residential Unit – Near-Term Development Unit Elder-Care Facility Layout Conceptual Diagram
Source: Prepared by author

7.4 Renewal Unit – Sanxue Street Historic District

The BL-03 Renewal Unit, encompassing the Sanxue Street Historic District, is located in the Weiyang and Beilin districts of Xi'an. It is a high-density area characterized by high clustering, primarily driven by cultural tourism and leisure commerce, and serves as a core node within Xi'an's "Ancient Capital Core Functional Zone." Current challenges include heavy traffic volume, narrow roads, high detour rates, and elevated carbon emissions. Issues also include the presence of heavy vehicle access during daytime hours; parking facilities require further optimization; and the prevalence of hardscape paving on certain plots results in a lack of public green space. Furthermore, there is a need to enhance the cultural characteristic elements of the historic district and upgrade the spatial environmental quality. Given its importance as both a crucial spatial carrier for Xi'an's cultural identity and a key practice area for modern urban renewal initiatives, specifically the "Three Olds and Three Transformations" work, the unit must introduce cultural resilience in addition to ecological and spatial resilience, addressing its high-clustering and high-density characteristics.

1. Carbon Reduction Strategy: Promoting Building Energy-Saving Retrofits and Building a Green-Space System

(1) Promoting building energy-saving retrofits

Aging residential complexes such as the Future Publishing House Community and Shuyuanmen Community will undergo upgrades to improve building thermal insulation performance, thus reducing heat loss. Commercial buildings, including Xi'an Department Store, Yongningli, and Qin Fengyuan Cultural Block, will be equipped with intelligent building energy systems to adjust HVAC operations based on real-time indoor temperatures, thereby conserving electricity consumption.

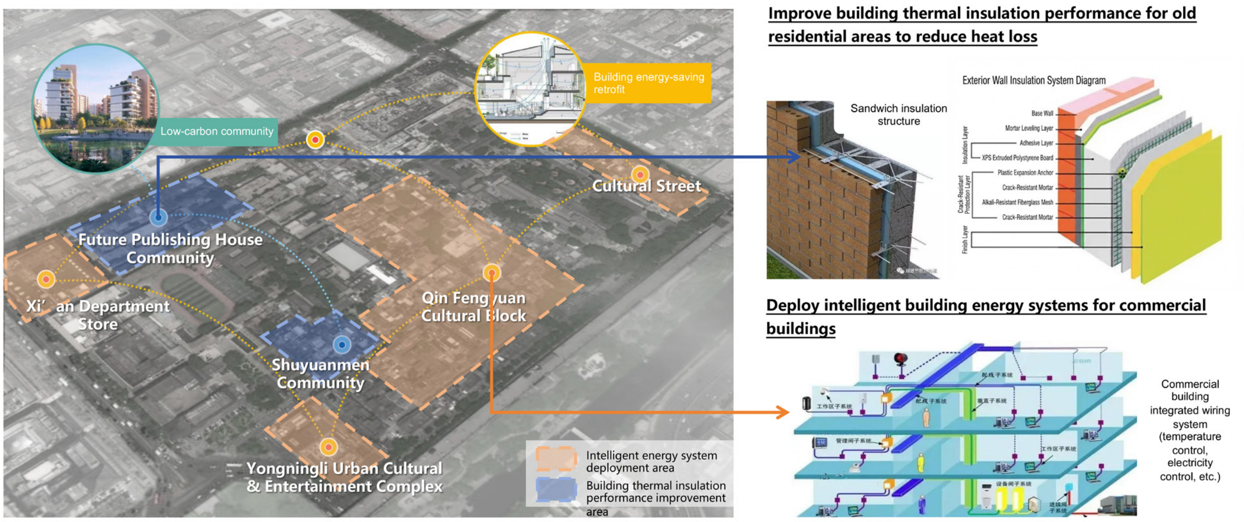

Figure 13: Renewal Unit – Sanxue Street Historic District Building Energy-Efficiency Retrofit Conceptual Diagram
Source: Prepared by author

(2) Building a green-space system

Based on the existing green space within the Sanxue Street Historic District, the plan is to develop the Dong Mu Tou Shi Green Corridor and the Beilin Museum Green Corridor. These corridors will connect the City Wall Park, the Beilin Museum, and major road-greenery spaces to form accessible, participatory, and landscaped ecological corridors. This will create an integrated "base–patch–corridor" green-space system that effectively increases carbon sequestration and reduces carbon emissions within the Sanxue Street Historic District.

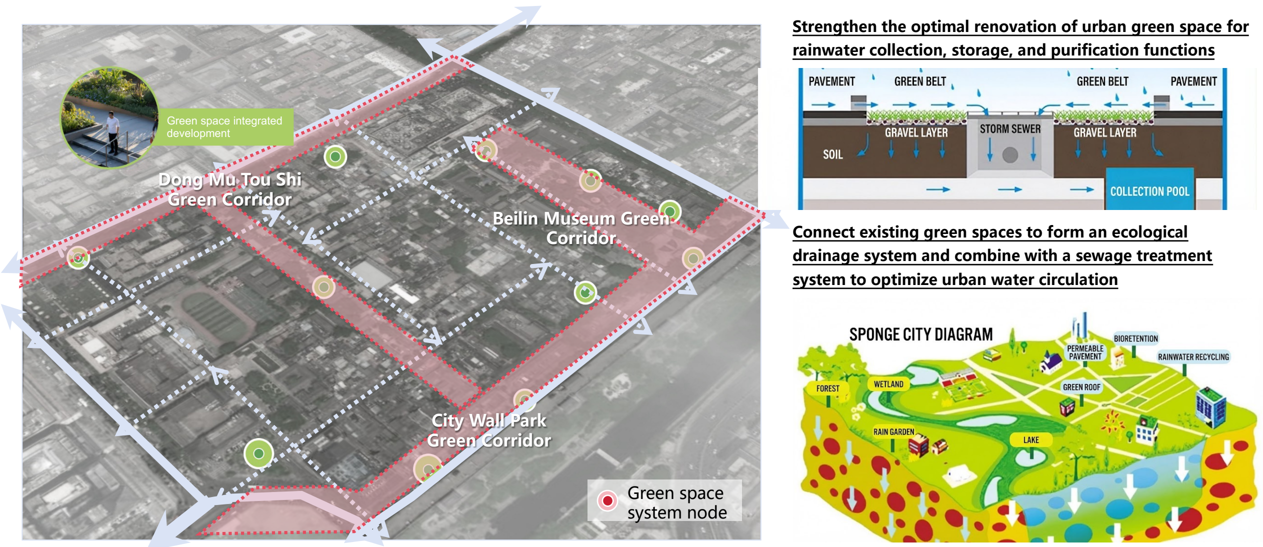

Figure 14: Renewal Unit – Sanxue Street Historic District Green-Space System Conceptual Diagram
Source: Prepared by author

2. Resilience Enhancement Strategy: Increasing the Proportion of Street-Facing Cultural Tourism Uses and Building a Disaster Evacuation Network

(1) Increasing the proportion of street-facing cultural tourism uses

The strategy involves unearthing historical and cultural elements and promoting mixed land use. By integrating with the cultural tourism industry planning, the proportion of cultural tourism uses will be increased to enhance the unit's cultural resilience. For example, the area surrounding the Xi'an Beilin Museum currently features an unwelcoming building and traffic environment, a lack of cultural tourism functions, and insufficient resting spaces. Further spatial mixed-use development, including shopping centers and cultural/leisure spaces, will be pursued to enhance the unit's spatial resilience.

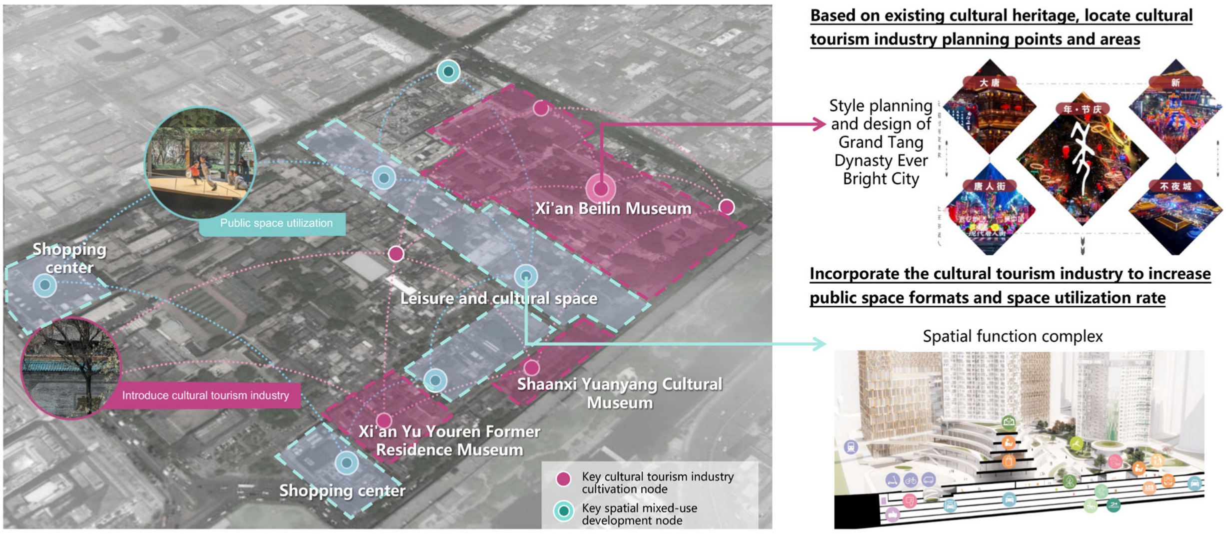

Figure 15: Renewal Unit — Sanxue Street Historic District Functional Optimization Conceptual Diagram
Source: Prepared by author

(2) Deploying the Sanxue Street Historic District Disaster Evacuation Safety Network

Key actions include road classification, network establishment, and nodal point deployment. Road traffic planning will be conducted in a stratified and phased manner to improve traffic flow efficiency. West Street, East Street, South Street, and the City Wall Ring Roads (East, West, and South) will serve as the core fast evacuation corridors. Secondary internal streets and the Inner City Ring Road will serve as the core pedestrian evacuation corridors for the area. A safety evacuation network will be established. Based on the street classification and width, appropriate evacuation routes and contingency plans will be developed to handle instantaneous pedestrian flow. Emergency shelters/refuge sites will be designated by utilizing campuses, museums, and open plazas. At key optimization nodes, pre-deployment of fire-safety infrastructure and emergency material reserves should be considered.

Disaster Prevention and Evacuation Safety Network

Site Layout	Traffic Node
Key optimization node	**Emergency refuge site**
Xi'an Bell Tower	Playground on Xi'an University Shuyuan campus
Yongningmen City Gate Tower	Xi'an Beilin Museum plaza space
Wenchangmen	Xi'an City Wall Yongningmen green space
…	…

Figure 16: Renewal Unit — Sanxue Street Historic District Disaster Evacuation Network Conceptual Diagram
Source: Prepared by author

7.5 Ecological Unit – Jingwei Confluence Scenic Overlook Park

The Jingwei Confluence Scenic Overlook is located in Gaoling District at the junction of the Jing and Wei Rivers. This linear park green space functions as both a scenic viewing platform and a popular destination. However, the unit faces several challenges: extreme summer heat inhibits prolonged stay; the park currently offers only visual amenities with no interaction between visitors and ecological and hydrological elements. Furthermore, the tree–shrub–grass composition is suboptimal: arbors are not yet fully formed and mature, grass coverage is limited, and shrub-layer carbon sequestration is low. The configuration of the plant community must be adjusted based on plant carbon-sequestration coefficients and predicted reduction amounts to maximize carbon reduction benefits.

1. Carbon Reduction and Resilience Enhancement Strategy: Deploying Shading Facilities Along Recreational Corridors and Low-Carbon Themed Landscapes

(1) Addressing extreme heat hazards: Deploying low-carbon shading facilities

Existing shade is insufficient, and Xi'an experiences prolonged heat waves. To better cope with extreme heat hazards while maintaining the coherence of the green space system, shading structures will be deployed along recreational corridors. These facilities can be equipped with photovoltaic panels for power generation at night and rain-harvesting systems for water storage and evaporative cooling.

(2) Addressing flood hazards: Deploying low-carbon themed landscapes

To address stormwater issues during the flood season, the park will adopt the on-site mitigation concept based on the sponge city principles of "infiltration, retention, storage, purification, use, and discharge." By utilizing local materials and capitalizing on native plants and regional climate characteristics, low-carbon themed landscapes will be deployed. This approach simultaneously enhances stormwater management and provides high-quality recreational spaces for residents.

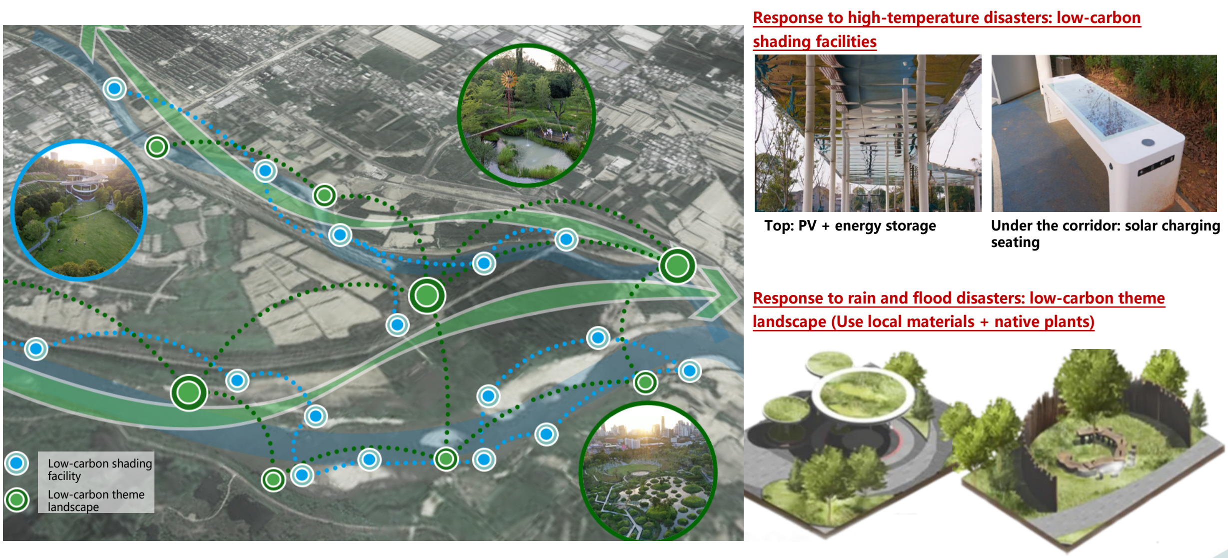

Figure 17: Conceptual Diagram of Strategies for Carbon Reduction and Resilience Enhancement in Ecological Units
Source: Prepared by author

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**Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH**

GIZ Office China

Tayuan Diplomatic Office Building
1-13-2 14 Liangmahe Nanlu,
Chaoyang District 100600 Beijing, PR China
T +86 10-8527 5180
F +86 10-8532 1405
E giz-china@giz.de
I www.giz.de/china