

# Typology, Spatial System, and Planning Priorities of Urban Routine-Emergency Dual-Use Public Infrastructure

RAN Jing, JIANG Xiaohui, HE Lei, XU Yiqing, ZHANG Peng, YAN Xiangqi

**Abstract:** To support systematic planning and strengthen disaster-prevention benefits, this study clarifies the conceptual scope, typology, spatial system, and planning and construction methods of routine-emergency dual-use public infrastructure through a review of the literature and a comparison of policy documents. Conceptually, such infrastructure is defined as the functional integration of social infrastructure and emergency-service facilities, with the primary objective of enhancing emergency-service capacity. Typologically, an eight-category system is proposed to cover emergency-service needs comprehensively. Spatially, a three-tier hierarchy - provincial, municipal/county, and central urban area - is established within the territorial spatial planning framework. For facility layout, a three-stage approach of existing-condition assessment, demand analysis, and site selection is proposed, guided by safety, equity, and efficiency. The study concludes that planning for dual-use public infrastructure should prioritize the completeness of both its typology and spatial system, thereby enabling these facilities to contribute systematically to emergency services and urban resilience.

**Keywords:** routine-emergency dual-use public infrastructure; comprehensive disaster-prevention planning; urban resilience; routine-emergency conversion

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Climate and environmental change may expose cities to more frequent extreme disasters and security incidents, and this high level of uncertainty places growing pressure on the response capacity of urban disaster-prevention facilities. Where urban facilities and land are scarce, facilities designed for both routine and emergency use provide an effective means of strengthening urban resilience. During the COVID-19 pandemic, for example, stadiums, exhibition centers, schools, and hotels were converted into shelters and isolation spaces [1-2]. During the catastrophic rainstorm in Henan, libraries and schools served as temporary accommodation for affected residents. In the United States and Japan, convenience stores, food markets, and supermarkets have been incorporated into community emergency-supply networks [3], while parks, schools, and stadiums have been used as evacuation shelters [4-7]. The multifunctional use of urban space and facilities is therefore a key expression of urban resilience. Routine-emergency functional integration improves both the continuity and functional resilience of facilities under normal conditions, while flexible conversion enhances their agility in responding to risk.

In 2023, the State Council issued the Guiding Opinions on Actively and Steadily Advancing the Construction of "Routine-Emergency Dual-Use" Public Infrastructure in Megacities and Large Cities,

launching pilot construction in selected cities [8]. In 2024, the Ministry of Natural Resources issued the Planning and Land-Policy Guidelines for Resilient Cities with Integrated Routine and Emergency Functions [9], which set out planning requirements for dual-use public infrastructure within the territorial spatial planning framework and called for resilient cities with integrated routine and emergency functions. However, large-scale construction before the typology and spatial system are clearly defined may result in narrow emergency functions, duplicated facility types, redundant investment, and irrational spatial distribution. It is therefore necessary to examine the typology, spatial system, and construction priorities of urban dual-use public infrastructure within the territorial spatial planning system, so that such facilities can be planned systematically and coordinated effectively with comprehensive territorial disaster-prevention planning.

## **1 Conceptual Scope and Typology of Routine-Emergency Dual-Use Public Infrastructure**

### **1.1 Concepts of Dual-Use Facilities and Dual-Use Public Infrastructure**

Dual-use facilities generally refer to facilities that function as urban infrastructure under normal conditions and can be used as disaster-prevention facilities during disasters or emergencies. Whether the "routine-emergency dual-use public infrastructure" currently promoted in China is equivalent to this broader concept must be clarified before identifying and classifying the relevant planning objects within the territorial spatial planning system. Accordingly, this study first distinguishes among dual-use public infrastructure, urban disaster-prevention facilities, and urban infrastructure (Table 1).

Under current Chinese standards, urban disaster-prevention facilities are construction works and supporting facilities required for disaster control, defense, and emergency response [10], whereas urban infrastructure comprises the engineering and social infrastructure necessary for urban survival and development [11]. In theory, the intersection of these two systems - facilities capable of performing both sets of functions - may be regarded as dual-use facilities in the broad sense: they maintain routine urban functions under normal conditions and activate or convert their functions during public emergencies. The Guiding Opinions define dual-use public infrastructure as important emergency-support facilities integrating isolation, emergency medical care, and material support. Under normal conditions, they may support tourism, health and wellness, and leisure; during emergencies, they can be mobilized and converted into isolation sites to meet needs for emergency isolation, temporary accommodation, and material support [8]. In substance, this category combines social infrastructure with emergency-service facilities. It excludes engineering infrastructure within the urban infrastructure system and emergency-support infrastructure within the disaster-prevention system, and instead refers specifically to emergency-service facilities. Thus, dual-use facilities have a broader scope, whereas the current construction of dual-use public infrastructure focuses on supplementing and improving emergency-service facilities.

Table 1. Comparison of routine-emergency dual-use public infrastructure, urban disaster-prevention facilities, and urban infrastructure

| Item                 | Routine-emergency dual-use public infrastructure                                                                                                                                                                                                                                                                                                     | Urban disaster-prevention facilities                                                                                                                                                           | Urban infrastructure                                                                                                                                                |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Concept              | Important emergency-support facilities integrating isolation, emergency medical care, and material support. Under routine conditions they may support tourism, health and wellness, and leisure; during emergencies they can be converted into isolation sites to meet needs for emergency isolation, temporary accommodation, and material support. | Construction works and supporting facilities required in an urban disaster-prevention system for disaster control, defense, and emergency response.                                            | Engineering and social infrastructure required for urban survival and development.                                                                                  |
| Basis                | Guiding Opinions on Actively and Steadily Advancing the Construction of "Routine-Emergency Dual-Use" Public Infrastructure in Megacities and Large Cities.                                                                                                                                                                                           | Technical Specification for Comprehensive Disaster-Prevention Planning in Territorial Space (TD/T 1086-2023); Standard for Comprehensive Urban Disaster-Prevention Planning (GB/T 51327-2018). | Urban Infrastructure Management (GB/T 32555-2016).                                                                                                                  |
| System composition   | Not yet established.                                                                                                                                                                                                                                                                                                                                 | Disaster monitoring and early-warning facilities; disaster-defense facilities; basic emergency-support infrastructure; emergency-service facilities.                                           | Engineering infrastructure: energy, water supply and drainage, transportation, etc. Social infrastructure: culture and education, health care, social welfare, etc. |
| Objectives and tasks | Maintain routine urban functions and convert during emergencies to support rescue, disaster response, evacuation, and sheltering.                                                                                                                                                                                                                    | Maintain essential urban functions under abnormal conditions such as disasters and reduce disaster losses.                                                                                     | Ensure the efficient operation of routine urban functions.                                                                                                          |

## **1.2 Typology of Routine-Emergency Dual-Use Public Infrastructure**

For dual-use facilities to remedy weaknesses in urban disaster prevention and improve urban resilience, a complete typology must first be established so that planning and construction do not become narrowly focused or omit essential functions. Drawing on the 2023 Guidelines for Land and Sea-Use Classification in Territorial Spatial Survey, Planning, and Use Regulation (Trial) and the Technical Specification for Comprehensive Disaster-Prevention Planning in Territorial Space, this study clarifies the types of urban infrastructure and disaster-prevention facilities. It then identifies compatible relationships between the two systems on the basis of documented disaster-response practices and relevant government policies, and develops a comprehensive typology of dual-use public infrastructure within the broader framework of dual-use facilities.

Past disaster-response practices demonstrate the wide range of compatibility between urban infrastructure and disaster-prevention facilities (Figure 1). For disaster-defense functions, squares, green spaces, elevated structures, and underground parking facilities have been retrofitted as dual-use stormwater-storage facilities [12]. For emergency-support infrastructure, water-supply vehicles, storage tanks, and wells have been used to provide emergency water [13]. The largest body of practice concerns the conversion of infrastructure into emergency-service facilities. Schools, large stadiums, convention and exhibition centers, cultural and sports venues, hotels, parks, green spaces, squares, and welfare institutions have been converted into shelters [13-15]. Hospitals, hotels, and social housing have served as centralized isolation sites, while large exhibition centers and stadiums have been transformed into temporary hospitals [15-16]. Airports, railways, and highways have been used as emergency logistics hubs, and selected urban expressways and arterial roads as emergency corridors [15]. Retail stores, convenience stores [17-18], food markets, supermarkets, community micro-warehouses, and delivery or pickup stations have been used for emergency storage and distribution [19], while libraries have served as emergency shelters and temporary command posts [20].

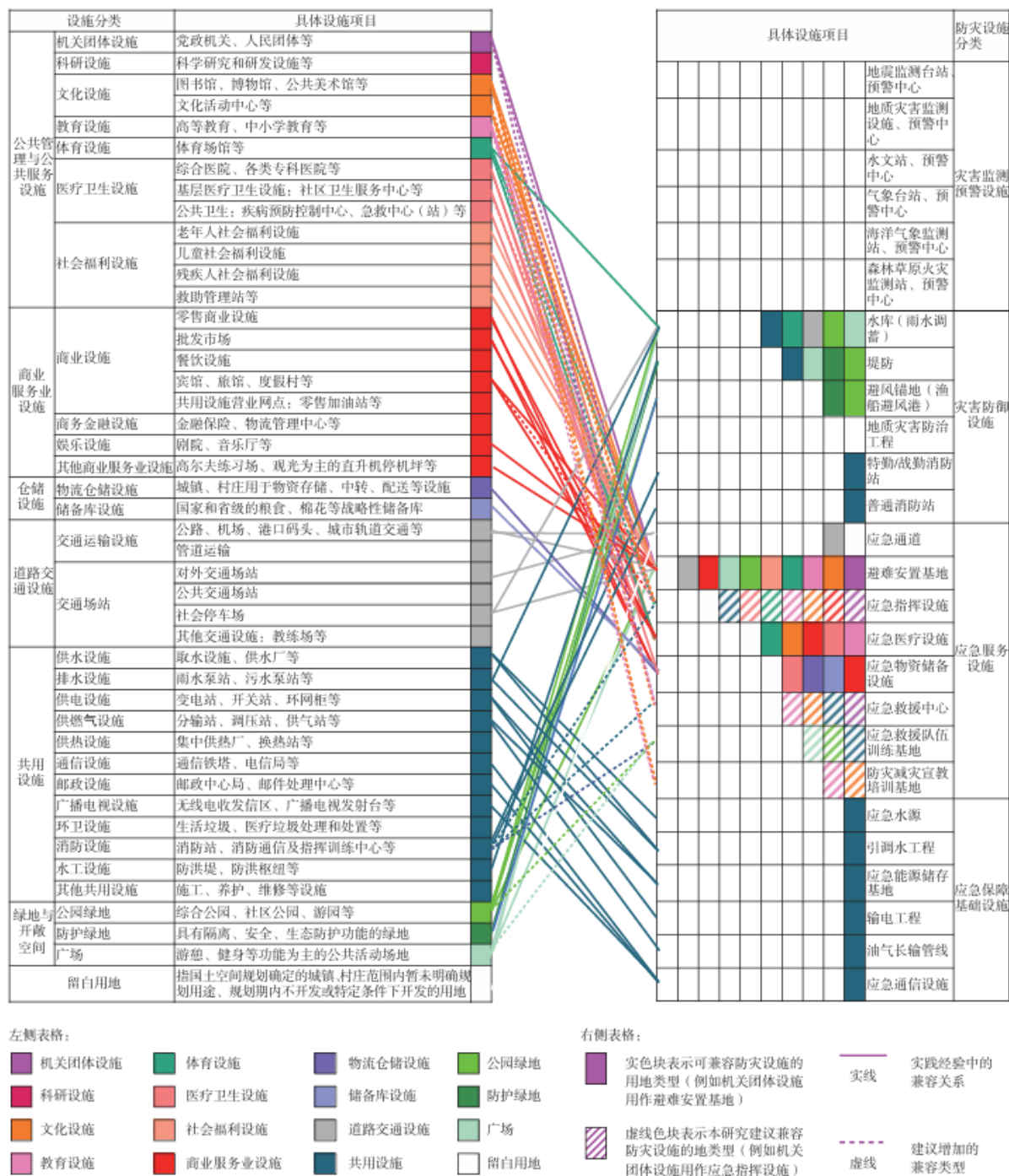


Figure 1. Compatibility between urban infrastructure and disaster-prevention facilities

Among the four categories of disaster-prevention facilities identified in the Technical Specification for Comprehensive Disaster-Prevention Planning in Territorial Space, disaster-defense facilities, emergency-service facilities, and basic emergency-support facilities can all be matched with urban infrastructure that has disaster-prevention and risk-reduction potential; monitoring and early-warning facilities are less compatible with routine urban functions. Of the three compatible categories, emergency-service facilities have been converted from urban infrastructure most extensively and most frequently. This explains why current Chinese policy on dual-use public infrastructure emphasizes emergency-service functions. Planning and construction should therefore establish a complete typology based on the detailed categories of emergency services.

More specifically, future deployment should expand the four currently emphasized emergency-service functions - emergency transportation, shelter and accommodation, emergency medical care, and emergency-supply storage and distribution - by adding emergency command facilities,

emergency rescue centers, emergency rescue-team training bases, and disaster-prevention and risk-reduction education and training bases. The proposed additional compatibility relationships are indicated by dashed lines in Figure 1, and together form the typology shown in Table 2. First, under the Standard for Comprehensive Urban Disaster-Prevention Planning [10] and the Specification for Emergency Command Communications Support Capacity [21], emergency command facilities must meet seismic-resistance and emergency-communications requirements and be readily accessible. Government and institutional buildings, large hotels, and major stadiums often contain communications equipment, offices, data centers, and meeting spaces and can therefore serve as temporary emergency command facilities. Second, the siting of emergency rescue centers should account for geographic accessibility, available rescue forces, a relatively complete emergency medical-rescue system, and theoretical, practical, and experiential capacity [22]. Government institutions, universities, research institutes, hospitals, and fire stations can rapidly assemble rescue teams and combine them with on-site equipment to form temporary emergency rescue centers. Third, rescue training requires sufficient space for drills and the storage of training equipment; large fire stations, parks, green spaces, and squares can provide reserve bases for practical simulation exercises. Fourth, in line with the emergency public-education projects proposed in the 14th Five-Year Plan for the National Emergency-Management System [23], theme parks, science and technology museums, museums, educational facilities, and cultural activity centers developed from former industrial sites or abandoned mines are closely connected to the public, offer diverse forms of display and interaction, and can reach broad audiences; they are therefore suitable as disaster-prevention and risk-reduction education and training bases.

Different types of dual-use public infrastructure should also be configured according to the requirements of comprehensive disaster prevention. Facilities compatible with emergency medical care, for example, should distinguish between general emergency medical services and infectious-disease emergency medical services. The following sections examine the spatial system and planning and construction priorities of the dual-use public infrastructure currently being promoted in China.

Table 2. Proposed typology of routine-emergency dual-use public infrastructure

| Category                        | Subcategory               | Territorial spatial planning land-use / facility types    | Routine function                             | Emergency-service function                                                                                                                  |
|---------------------------------|---------------------------|-----------------------------------------------------------|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Emergency transportation        | Emergency routes          | Railways, highways, urban rail transit, etc.              | Passenger and freight transport              | Transport of personnel and emergency supplies                                                                                               |
| Emergency transportation        | Emergency transport nodes | Railway stations, airports, ports, wharves, etc.          | Public transport nodes                       | Transport of personnel and emergency supplies                                                                                               |
| Shelter and accommodation bases | Central shelters          | Large parks and green spaces; squares                     | Ecological landscape; leisure and recreation | Integrated functions including rescue command, material storage and distribution, medical and health rescue, and stationing of rescue teams |
| Shelter and accommodation bases | Central shelters          | Large stadiums                                            | Sporting events and fitness                  | Integrated functions including rescue command, material storage and distribution, medical and health rescue, and stationing of rescue teams |
| Shelter and accommodation bases | Central shelters          | Higher education institutions                             | Education services                           | Integrated functions including rescue command, material storage and distribution, medical and health rescue, and stationing of rescue teams |
| Shelter and accommodation bases | Central shelters          | Convention and exhibition centers                         | Conferences, trade fairs, and exhibitions    | Integrated functions including rescue command, material storage and distribution, medical and health rescue, and stationing of rescue teams |
| Shelter and accommodation       | Central shelters          | Cultural centers, activity centers, public theaters, etc. | Leisure and entertainment                    | Integrated functions including rescue command, material                                                                                     |

| Category                        | Subcategory      | Territorial spatial planning land-use / facility types                      | Routine function                                   | Emergency-service function                                                                                                                  |
|---------------------------------|------------------|-----------------------------------------------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| bases                           |                  |                                                                             |                                                    | storage and distribution, medical and health rescue, and stationing of rescue teams                                                         |
| Shelter and accommodation bases | Central shelters | Reserved land                                                               | Undetermined                                       | Integrated functions including rescue command, material storage and distribution, medical and health rescue, and stationing of rescue teams |
| Shelter and accommodation bases | Fixed shelters   | Medium-to-large parks and green spaces; squares                             | Ecological landscape; leisure and recreation       | Fixed shelter for affected populations and centralized rescue                                                                               |
| Shelter and accommodation bases | Fixed shelters   | Higher education institutions; primary and secondary schools                | Education services                                 | Fixed shelter for affected populations and centralized rescue                                                                               |
| Shelter and accommodation bases | Fixed shelters   | Stadiums; public fitness centers                                            | Mass sports activities                             | Fixed shelter for affected populations and centralized rescue                                                                               |
| Shelter and accommodation bases | Fixed shelters   | Public libraries, museums, exhibition halls, cultural centers, etc.         | Cultural exhibitions and leisure activities        | Fixed shelter for affected populations and centralized rescue                                                                               |
| Shelter and accommodation bases | Fixed shelters   | Nursing homes, child welfare institutions, rescue-management stations, etc. | Low-cost care, accommodation, and related services | Fixed shelter for affected populations and centralized rescue                                                                               |
| Shelter and accommodation bases | Fixed shelters   | Hotels, inns, guesthouses, and resorts with lodging                         | Tourist accommodation                              | Fixed shelter for affected populations and centralized rescue                                                                               |

| Category                        | Subcategory        | Territorial spatial planning land-use / facility types                                                      | Routine function                             | Emergency-service function                                                                                                |
|---------------------------------|--------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Shelter and accommodation bases | Emergency shelters | Transport hubs: passenger/freight railway stations, intercity bus terminals, expressway service areas, etc. | Public transport nodes                       | Immediate refuge and temporary shelter nearby; transitional gathering and transfer                                        |
| Shelter and accommodation bases | Emergency shelters | Gardens, squares, green spaces, vacant land, etc.                                                           | Ecological landscape; leisure and recreation | Immediate refuge and temporary shelter nearby; transitional gathering and transfer                                        |
| Shelter and accommodation bases | Emergency shelters | Primary and secondary schools; kindergartens                                                                | Education services                           | Immediate refuge and temporary shelter nearby; transitional gathering and transfer                                        |
| Shelter and accommodation bases | Emergency shelters | Cinemas and theaters                                                                                        | Leisure and entertainment                    | Immediate refuge and temporary shelter nearby; transitional gathering and transfer                                        |
| Emergency command facilities    | -                  | Party and government agencies, people's organizations, and affiliated institutions                          | Offices for public bodies                    | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency command facilities    | -                  | Convention and exhibition centers; conference centers                                                       | Conferences, trade fairs, and exhibitions    | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency command facilities    | -                  | Cultural activity centers                                                                                   | Leisure and entertainment                    | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |

| Category                     | Subcategory                                | Territorial spatial planning land-use / facility types                                                                                           | Routine function                     | Emergency-service function                                                                                                |
|------------------------------|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Emergency command facilities | -                                          | Higher education institutions                                                                                                                    | Education services                   | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency command facilities | -                                          | Stadiums                                                                                                                                         | Sporting events and fitness          | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency command facilities | -                                          | Community health service centers                                                                                                                 | Public health and basic medical care | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency command facilities | -                                          | Large hotels                                                                                                                                     | Accommodation and catering           | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency command facilities | -                                          | Fire command and training centers                                                                                                                | Routine training and patrols         | Emergency command; communications and information services; monitoring, analysis, and forecasting of incident development |
| Emergency medical facilities | Comprehensive emergency medical facilities | General hospitals, traditional Chinese medicine hospitals, integrated Chinese-Western medicine hospitals, ethnic-medicine hospitals, specialized | Medical services                     | Emergency medical treatment and support                                                                                   |

| Category                                             | Subcategory                                     | Territorial spatial planning land-use / facility types                                                                                                      | Routine function                                       | Emergency-service function                          |
|------------------------------------------------------|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------|
|                                                      |                                                 | hospitals, nursing institutions, etc.                                                                                                                       |                                                        |                                                     |
| Emergency medical facilities                         | Comprehensive emergency medical facilities      | Centers for disease control and prevention; maternal and child health hospitals; emergency medical centers/stations; blood collection and supply facilities | Medical services                                       | Emergency medical treatment and support             |
| Emergency medical facilities                         | Comprehensive emergency medical facilities      | Community health service centers; township or subdistrict health centers                                                                                    | Medical services                                       | Emergency medical treatment and support             |
| Emergency medical facilities                         | Infectious-disease emergency medical facilities | Centers for disease control and prevention                                                                                                                  | Medical services                                       | Infectious-disease treatment and sanitary isolation |
| Emergency medical facilities                         | Infectious-disease emergency medical facilities | Reserve designated treatment hospitals: general hospitals and specialized hospitals                                                                         | Medical services                                       | Infectious-disease treatment and sanitary isolation |
| Emergency medical facilities                         | Infectious-disease emergency medical facilities | Centralized isolation sites: medium-to-large stadiums, convention and exhibition centers, tourist accommodation, reserved land, social housing, etc.        | Leisure, recreation, residence, and related uses       | Infectious-disease treatment and sanitary isolation |
| Emergency-supply storage and distribution facilities | Emergency-supply storage facilities             | Comprehensive logistics hubs and large warehouse bases                                                                                                      | Goods aggregation, storage, sorting, and transshipment | Storage and provision of emergency supplies         |
| Emergency-supply storage and distribution facilities | Emergency-supply storage facilities             | Shopping malls, supermarkets, clothing and small-commodity markets, etc.                                                                                    | Retail sales                                           | Storage and provision of emergency supplies         |
| Emergency-supply storage and distribution facilities | Emergency-supply storage facilities             | Wholesale markets                                                                                                                                           | Urban consumer-goods transfer and distribution         | Storage and provision of emergency supplies         |
| Emergency-supply                                     | Emergency-supply                                | Air, sea, rail, and road logistics hubs                                                                                                                     | Urban consumer-goods                                   | Transfer and distribution of                        |

| Category                                                            | Subcategory                              | Territorial spatial planning land-use / facility types                             | Routine function                                 | Emergency-service function                                   |
|---------------------------------------------------------------------|------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------|--------------------------------------------------------------|
| storage and distribution facilities                                 | distribution facilities                  |                                                                                    | transfer and distribution                        | emergency supplies                                           |
| Emergency-supply storage and distribution facilities                | Emergency-supply distribution facilities | Emergency logistics transfer centers                                               | Urban consumer-goods transfer and distribution   | Transfer and distribution of emergency supplies              |
| Emergency-supply storage and distribution facilities                | Emergency-supply distribution facilities | Express-delivery stations, community service stations, pickup lockers, etc.        | Urban consumer-goods transfer and distribution   | Transfer and distribution of emergency supplies              |
| Emergency rescue centers                                            | -                                        | Party and government agencies, people's organizations, and affiliated institutions | Offices for public bodies                        | Stationing of rescue teams and storage of emergency supplies |
| Emergency rescue centers                                            | -                                        | Large fire stations; special-service fire stations                                 | Routine training and patrols                     | Stationing of rescue teams and storage of emergency supplies |
| Emergency rescue centers                                            | -                                        | Higher education institutions                                                      | Education services                               | Stationing of rescue teams and storage of emergency supplies |
| Emergency rescue centers                                            | -                                        | Large conference or exhibition centers                                             | Conferences and exhibitions                      | Stationing of rescue teams and storage of emergency supplies |
| Emergency rescue centers                                            | -                                        | Parks, green spaces, and squares                                                   | Ecological landscape; leisure and recreation     | Stationing of rescue teams and storage of emergency supplies |
| Emergency rescue-team training bases                                | -                                        | Fire stations; fire communications and command-training centers                    | Routine training and patrols                     | Practical training for rescue teams                          |
| Disaster-prevention and risk-reduction education and training bases | -                                        | Museums, convention and exhibition centers, etc.                                   | Exhibitions                                      | Public education on disaster prevention and risk reduction   |
| Disaster-prevention and risk-reduction                              | -                                        | Cultural centers, activity centers, public theaters, etc.                          | Cultural exhibitions, leisure, and entertainment | Public education on disaster prevention and risk reduction   |

| Category                                                            | Subcategory | Territorial spatial planning land-use / facility types     | Routine function                                 | Emergency-service function                                 |
|---------------------------------------------------------------------|-------------|------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------------|
| education and training bases                                        |             |                                                            |                                                  |                                                            |
| Disaster-prevention and risk-reduction education and training bases | -           | Higher education institutions and secondary schools        | Education services                               | Public education on disaster prevention and risk reduction |
| Disaster-prevention and risk-reduction education and training bases | -           | Emergency broadcasting: radio stations, loudspeakers, etc. | Transmission of audio programming                | Public education on disaster prevention and risk reduction |
| Disaster-prevention and risk-reduction education and training bases | -           | Television stations and television broadcasting systems    | Production and distribution of video programming | Public education on disaster prevention and risk reduction |

## **2 Spatial System of Routine-Emergency Dual-Use Public Infrastructure under Territorial Spatial Planning**

To implement dual-use public infrastructure in territorial spatial plans at different levels and of different types, while coordinating it with comprehensive territorial disaster-prevention planning, the identified typology must be aligned with the spatial system of territorial planning. This alignment involves two dimensions: spatial hierarchy and spatial layout.

### **2.1 Spatial Hierarchy of Routine-Emergency Dual-Use Public Infrastructure**

Within China's five-tier territorial spatial planning system - national, provincial, municipal, county, and township - and with reference to the Technical Specification for Comprehensive Disaster-Prevention Planning in Territorial Space, this study proposes organizing the eight facility categories into three spatial levels: provincial, municipal/county, and central urban area. This framework forms a spatial system for dual-use public infrastructure (Table 3). On the basis of a complete typology, facilities should be planned and constructed systematically by scale and grade at each spatial level. In addition, dual-use facilities compatible with emergency transportation, shelter and accommodation, emergency medical care, and emergency-supply storage and distribution should be further differentiated by grade and function in accordance with comprehensive disaster-prevention planning. Shelter facilities, for example, should be organized into a graded system of central, fixed, and emergency shelters, each supported by the corresponding facilities and service standards.

Table 3. Typological and spatial system of routine-emergency dual-use public infrastructure

| Category                        | Provincial level                                                                                                                                                                                                                                                                                                                                                                                                  | Municipal/county level                                                                                                                                                                                                                                                                                                                                                                                                | Central urban area                                                                                                                                                                                                                                     |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Emergency routes                | Provincial-level and higher emergency corridors: international air routes, international freight trains, expressways, passenger-dedicated lines (including intercity railways), railway hubs, long-span bridges, airports, and ports.                                                                                                                                                                             | Disaster-relief trunk roads: expressways, national highways, provincial highways, and urban express roads. Emergency transport nodes: railway stations, airports, and ports.                                                                                                                                                                                                                                          | Primary evacuation routes: expressways and arterial roads.                                                                                                                                                                                             |
| Shelter and accommodation bases | Regional evacuation and accommodation bases: large stadiums, large parks and green spaces, squares, higher education institutions, large exhibition centers, and reserved land.                                                                                                                                                                                                                                   | Regional evacuation and accommodation bases: large parks and green spaces, squares, large stadiums, large exhibition centers, and reserved land. Regional emergency shelters: large parks and green spaces, squares, large stadiums, public fitness centers, expressway service areas, hotels, and inns.                                                                                                              | Central shelters: large parks and green spaces, squares, and large cultural activity centers. Fixed shelters: parks and green spaces, squares, schools, medium-sized stadiums, sports parks, cultural activity centers, and social welfare facilities. |
| Emergency command               | Emergency command centers: provincial agencies and organizations, large convention/exhibition centers, conference centers, higher education institutions, large stadiums, and fire command and training centers.                                                                                                                                                                                                  | Emergency command facilities: municipal/county agencies and organizations, public fitness centers, stadiums, schools, and large hotels.                                                                                                                                                                                                                                                                               | Emergency command facilities: local agencies and organizations, large hotels, cultural activity centers, and community health service centers.                                                                                                         |
| Emergency medical care          | Provincial and regional emergency medical rescue centers: general hospitals, traditional Chinese medicine hospitals, specialized hospitals, and nursing institutions. Provincial public health (clinical) centers: emergency centers, disease-control centers, and blood collection and supply institutions. Centralized isolation sites: large stadiums, temporary hospitals, convention/exhibition centers, and | Emergency medical facilities at the same level and above: general hospitals, traditional Chinese medicine hospitals, specialized hospitals, and infectious-disease treatment institutions. Public health centers at the same level and above: emergency centers, disease-control centers, and blood collection and supply institutions. Centralized isolation sites: medium-sized stadiums and tourist accommodation. | Emergency medical facilities: community health service centers and health centers. Public health centers: emergency centers and disease-control centers. Centralized isolation sites: tourist accommodation and social housing.                        |

| Category                                                            | Provincial level                                                                                                                                                                                                                                                        | Municipal/county level                                                                                                                                                                                                                                                                                                               | Central urban area                                                                                                                                                                         |
|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                     | reserved land.                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                            |
| Emergency-supply storage and distribution                           | Disaster-relief supply reserve centers: comprehensive logistics hubs and large warehouse bases; large comprehensive supermarkets. Distribution facilities: air, sea, and rail logistics hubs.                                                                           | Emergency disaster-relief supply storage: comprehensive logistics hubs and large warehouse bases, department stores, and fairs/markets. Distribution facilities: logistics transfer centers.                                                                                                                                         | Emergency disaster-relief supply storage: supermarkets, markets, wholesale markets, and grocery stores. Distribution facilities: community service stations and express-delivery stations. |
| Emergency rescue                                                    | Provincial and regional emergency rescue centers: provincial agencies and organizations, higher education institutions, and large conference or exhibition centers. Provincial and regional fire-rescue centers: large fire stations and special-service fire stations. | Emergency rescue centers at the same level and above: municipal/county agencies and organizations and schools. Land, inland-water, and maritime rescue bases at the same level and above: wharves and waterborne fire stations. Aviation emergency-service bases at the same level and above: helicopter support bases and helipads. | Emergency rescue centers: local agencies and organizations and schools.                                                                                                                    |
| Emergency rescue-team training bases                                | Large parks and green spaces, squares, fire stations, and fire communications and command-training centers.                                                                                                                                                             | Large parks and green spaces, squares, and fire stations.                                                                                                                                                                                                                                                                            | Large parks and green spaces, squares, and fire stations.                                                                                                                                  |
| Disaster-prevention and risk-reduction education and training bases | Higher education institutions, museums, and exhibition halls.                                                                                                                                                                                                           | Schools and cultural activity centers.                                                                                                                                                                                                                                                                                               | Schools and cultural activity centers.                                                                                                                                                     |

## 2.2 Spatial Layout of Routine-Emergency Dual-Use Public Infrastructure

Once the typology and spatial hierarchy have been established, a scientifically sound spatial layout becomes essential to effective emergency management. As public infrastructure, dual-use facilities must first satisfy the principle of equity [24-26]. As emergency-service facilities, their layout must also account for safety [27], efficiency [28-29], accessibility [30], effectiveness [31], and economy [32].

Drawing on these principles and on studies of safety-oriented spatial planning and facility layout [33-34], this study proposes a three-stage planning process: existing-condition assessment, demand analysis, and site selection and layout (Table 4). During existing-condition assessment, the siting and protection standards of each facility type must satisfy safety requirements and avoid hazardous areas. Emergency medical facilities should additionally avoid drinking-water source protection zones and densely populated areas and should preferably be located downwind of the prevailing annual wind direction [10]. To ensure the transmission and reception of information, emergency command centers should be located with full consideration of wartime or disaster-time functional continuity, including appropriate spacing and disaster-resistance standards. Under the principle of equity, the distribution, type, and severity of regional disaster risks and the existing disaster-prevention resources should be assessed comprehensively. A facility inventory can then be established to evaluate the disaster-prevention functions, performance, and routine-emergency conversion efficiency of existing facilities, identify gaps between facility capacity and disaster-risk requirements, and provide a basis for targeted allocation.

During demand analysis, the principal regional hazard types and their maximum anticipated severity should be identified under the safety principle. The distribution of facilities in hazard-prone areas and the needs of different population groups should then be clarified, including the types and locations of demand and the expected service efficiency of facilities at different levels and of different types. This information supports scientifically grounded site selection and layout.

During site selection and layout, both candidate facilities and candidate sites must first avoid hazardous areas and meet safety requirements; facilities with high routine-emergency compatibility should be preferred. Demand-point analysis should then consider both quantity - the number and distribution of people requiring services - and quality, such as required floor area, bed capacity, or other service specifications. Facility capacity should include redundancy so that alternative facilities remain available after damage, and should meet the emergency-service demand of the population within the service area under the maximum specified disaster scenario. The Classification and Grading of Emergency Shelters, for example, specifies capacity, effective shelter area per capita, and service radius for different shelter grades [14], while the Construction Standard for Disaster-Relief Material Reserve Warehouses requires emergency reserve and distribution space of 0.12-0.15 m<sup>2</sup> per person [35]. The needs of older adults, pregnant women, and other vulnerable groups should also be addressed through dedicated shelter space and material provision. Finally, spatial optimization models or algorithms can be applied by facility type, spatial level, and hazard type to achieve full quantitative and qualitative coverage of population demand. The resulting network can improve both response speed and utilization efficiency.

Table 4. Planning framework for the spatial layout of routine-emergency dual-use public infrastructure

| Process stage                 | Safety                                                                                                                     | Equity                                                                                                                                              | Efficiency                                                                                                                                                                    |
|-------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Existing-condition assessment | Safety assessment of the site; safety assessment of facilities.                                                            | Assessment of regional hazard risks; assessment of existing disaster-prevention resources.                                                          | Assessment of existing facility types and disaster-prevention performance; assessment of routine-emergency conversion efficiency.                                             |
| Demand analysis               | Analysis of principal hazard types; analysis of locally required disaster-resistance grades.                               | Assessment of exposed elements and their distribution; assessment of population demand by facility type.                                            | Assessment of service-efficiency requirements for different facility types; assessment of service-efficiency requirements for different facility grades.                      |
| Site selection and layout     | Candidate-facility siting: avoid hazardous areas; ensure facility safety; prioritize high routine-emergency compatibility. | Demand-point analysis: consider demand quantity (population size and distribution) and demand quality (e.g., required floor area and bed capacity). | Siting optimization: allocate facilities by type and spatial level; cover all relevant hazard types; achieve full quantitative and qualitative coverage of population demand. |

### **3 Reflections on Planning and Construction**

#### **3.1 Current Planning and Construction Practices**

The preceding analysis of concepts, typology, spatial hierarchy, and layout, together with current facility-planning practices, design guidelines, and government-enterprise reserve arrangements, reveals several shortcomings in planning and construction methods and in emergency-supply reserves.

At the planning level, dual-use public infrastructure in China remains largely at the stage of policy discussion and action-plan issuance. Pilot cities have begun by screening existing resources, preparing project lists and action plans for isolation, temporary accommodation, and warehousing, and developing design standards and guidelines for new construction and retrofit projects intended to strengthen emergency capacity (Table 5). Typologically, these initiatives focus mainly on shelter and accommodation, emergency medical care, and emergency-supply storage, while command, rescue, and other functions remain underrepresented. Spatially, attention is concentrated at the municipal level, with insufficient vertical coordination from provincial to central-urban levels; a systematic dual-use public infrastructure network has not yet been established. Technically, new and retrofitted facilities designed for emergency functions currently emphasize siting, internal spatial organization, equipment indicators, and conversion plans. They focus primarily on the internal transformation of individual facilities or sites, while the alignment of service areas, capacity, and demand points has received limited attention. This may lead to simultaneous duplication, oversupply, and shortage.

Table 5. Planning and construction documents for routine-emergency dual-use public infrastructure in selected localities and their principal focus

| Type                     | Selected documents / projects                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Focus dimension | Key focus                                                                        | Spatial implication                                                                                            |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Planning                 | Draft Action Plan of Pinggu District for Further Promoting New Breakthroughs in the High-Quality Development of the Capital (2023-2025); Hangzhou First-Batch Project List for the Construction of "Routine-Emergency Dual-Use" Public Infrastructure; Nanjing Municipal Government General Office Notice on the Action Plan for Activating Existing Assets and Resources (2023-2025).                                                                                          | Focus area      | Isolation, temporary accommodation, and warehousing.                             | Municipal level; spatial layout not yet addressed.                                                             |
| Standards and guidelines | Design Specification for the Emergency-Shelter Function of Park-City Green Spaces; Hangzhou Design Guidelines for Routine-Emergency Dual-Use Medical Emergency-Service Points (Trial); Hangzhou Design Guidelines for Routine-Emergency Dual-Use Tourist Accommodation Buildings (Trial); Design Code for Dual-Use Large Public Facilities in Routine and Wartime Conditions; Hangzhou Design Guidelines for Routine-Emergency Dual-Use Suburban Large-Warehouse Bases (Trial). | Facility type   | Shelter and accommodation, emergency medical care, and emergency-supply storage. | Municipal level; emphasis on site selection, spatial organization, equipment indicators, and conversion plans. |
| Construction             | Beijing Shuguang Disaster-Prevention Education Park; Wuhan Dahua Mountain Outdoor Sports Center; Jinan Quancheng Station project; Beijing Jinhai Lake Expressway Service Area; Wuhan Yunjingshan Hospital; Beijing Jingping Integrated Logistics Hub.                                                                                                                                                                                                                           | Facility type   | Shelter and accommodation, emergency medical care, and emergency-supply storage. | Mainly individual facilities or site projects; emphasis on internal spatial organization.                      |

Emergency-supply reserves are another major determinant of the service quality of dual-use facilities, and China has actively promoted the socialization of such reserves [36]. Existing reserve arrangements include direct government physical reserves, physical reserves held by contracted enterprises, production-capacity reserves held by contracted enterprises, and contractual reserves [37]. The 14th Five-Year Plan for Emergency-Supply Support, jointly issued in 2022 by the Ministry of Emergency Management, the National Development and Reform Commission, the Ministry of Finance, and the National Food and Strategic Reserves Administration, established a model based on physical reserves and supplemented by contractual and production-capacity reserves. Under the latter two arrangements, government agencies sign agreements with enterprises to secure the production and supply of emergency materials; enterprises manufacture and store materials on behalf of the government or maintain production capacity for emergency requisition [36]. Such government-enterprise arrangements can increase the government's ability to mobilize supplies and strengthen supply assurance [38]. Existing cases, however, focus mainly on physical goods, such as enterprises cooperating with the National Food and Strategic Reserves Administration to guarantee emergency grain supplies [39-40], and storage entities subject to the Zhejiang Provincial Measures for the Administration of Emergency Reserves of Important Commodities, which specifies requirements for sugar, pork, pesticides, and other goods [41]. They rarely consider reserves of space, personnel, information, services, and other dual-use resources. Moreover, most initiatives operate at the national level; government-enterprise reserve systems at provincial, municipal/county, central-urban, and community levels remain insufficiently explored.

### **3.2 Key Planning and Construction Priorities**

Dual-use public infrastructure encompasses many types, sectors, and management bodies. To address the above shortcomings and meet the overall territorial-planning requirement for integrated routine and emergency functions, planning and construction should focus on the following priorities.

First, establish a complete typology of routine-emergency dual-use public infrastructure. Territorial spatial planning relies on a unified "one-map" platform as a key basis for planning administration [42]. As an integral component of territorial spatial planning, dual-use facility planning should therefore create a complete land-use typology that explicitly accounts for routine and emergency functions. Separate land-use maps should be prepared for routine and emergency conditions to supplement and improve the disaster-prevention facility system.

Second, establish a spatial layout system coordinated across the entire jurisdiction. Facility planning must take a comprehensive view. The Planning and Land-Policy Guidelines for Resilient Cities with Integrated Routine and Emergency Functions explicitly call for jurisdiction-wide coordination of dual-use public infrastructure and for the construction of a safe urban-rural spatial pattern. Planning should therefore address not only compatible facilities in central urban areas but also coordinated deployment across other spatial levels, thereby forming an integrated spatial system for urban safety and resilience.

Third, define the conversion capacity of each facility type and improve disaster-prevention benefits precisely. Compared with conventional urban infrastructure and dedicated disaster-prevention facilities, dual-use public infrastructure places greater emphasis on functional integration and conversion. Planning standards should consider not only carrying capacity and service areas but also conversion efficiency. The greater the functional overlap between infrastructure and disaster-prevention facilities, the higher the utilization efficiency and conversion capacity; where overlap is limited, more resources are required for specialized construction. Planning should therefore assess existing facility resources and disaster-prevention needs, evaluate conversion efficiency, estimate the resources required to improve compatibility, and strengthen facility capacity selectively.

Fourth, improve emergency-reserve mechanisms. Documents such as the Measures for the Administration of Emergency Grain-Supply Enterprises and the National Standard for Comprehensive Disaster-Reduction Demonstration Communities emphasize government-enterprise cooperation, but the role of broader social actors has not yet been fully mobilized. China should refine cooperative reserve mechanisms and clarify corporate responsibilities. Beyond physical emergency supplies, government-enterprise reserve arrangements for dual-use public infrastructure should explicitly cover land, space, personnel, information, and services. Participation by markets, nonprofit organizations, and other social actors in facility construction, operation, and maintenance can activate existing infrastructure assets, stimulate market vitality, and support sustainable utilization. At the same time, government oversight must be strengthened to minimize negative externalities arising from nongovernmental involvement.

Fifth, coordinate dual-use facility planning with related support systems and strengthen routine infrastructure systems that enable emergency functions. Effective shelter operation, for example, depends on evacuation-road networks, basic electricity supply, waste-treatment systems, emergency water-supply networks, and facilities for specialized response teams. Planning should therefore address not only land provision, scale and grading, and associated material reserves, but also the full range of supporting systems required by each facility category.

#### **4 Conclusion**

Dual-use facilities are important emergency-support assets that can remedy weaknesses in urban disaster-prevention systems and strengthen urban resilience. In China, however, their precise scope and typology remain insufficiently defined, and a complete system framework has not yet been formed. After clarifying the concept of routine-emergency dual-use public infrastructure, this study develops a comprehensive eight-category typology from the perspective of integrated disaster prevention, proposes a three-tier spatial hierarchy of provincial, municipal/county, and central urban levels within the territorial spatial planning framework, and outlines the principles and methods for facility layout. On the basis of current cases, it further identifies key priorities for planning and construction. These findings provide a reference for the systematic development of routine-emergency dual-use public infrastructure in China.

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