Research on Planning and Design of Municipal Water Supply and Drainage Systems from the Perspective of Urban Renewal

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Abstract: This paper systematically elaborates on the core value of water supply and drainage systems in optimizing spatial resource allocation, recycling water resources, and preserving historical context. It deeply analyzes the difficulties in planning and design, such as fragmented data, outdated standards, spatial constraints, and lack of coordination. Targeted measures are proposed, including building a digital pipe network platform, implementing differentiated zonal renovation, promoting technology integration and spatial composite utilization, and establishing a full-cycle collaborative management mechanism. The aim is to provide a scientific pathway for improving the quality and efficiency of water supply and drainage systems during urban renewal, thereby supporting the reshaping of urban functions and the enhancement of urban quality.

1. Introduction

Municipal water supply and drainage systems, as fundamental infrastructure ensuring urban operations, play a crucial supporting role in urban functional restructuring, spatial quality improvement, and ecological environment enhancement. Urban renewal in the new era is characterized by functional hybridization, diversified demands, and complex constraints, imposing higher requirements such as enhanced resilience, resource recycling, and smart operation and maintenance on water supply and drainage systems. The traditional planning and design model, primarily focused on incremental construction, struggles to adapt to complex scenarios like old-town renovation, industrial transformation, and historical preservation. There is an urgent need to re-examine the concepts and methods of water supply and drainage planning and design from a systemic perspective and explore technical pathways deeply integrated with urban renewal.

2. Core Significance of Planning and Design for Municipal Water Supply and Drainage Systems from the Urban Renewal Perspective

Under the background of urban renewal, the planning and design of water supply and drainage systems transcend the functional boundaries of traditional municipal engineering. They have become important carriers for reshaping urban spatial patterns, optimizing resource allocation, and preserving cultural memory. Their significance lies in transforming what was once purely infrastructure upgrading into a systemic restructuring of the urban organism. Pipeline network renewal drives the reintegration of underground space, releasing inefficiently occupied land resources for public service facilities. Rainwater and wastewater are transformed from urban burdens into utilizable water resources, shifting from the past extensive model of simple discharge to establishing a new system where water circulates and is reused multiple times within the city. Simultaneously, the renovation process respects the city's historical fabric and cultural characteristics, avoiding standardized "cookie-cutter" construction, allowing water supply and drainage facilities to become invisible links connecting the city's past and future. They serve both the functional needs of contemporary urban operation and the mission of preserving urban memory, promoting comprehensive urban revitalization beyond mere physical renewal [1].

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3. Analysis of Difficulties in Planning and Design for Municipal Water Supply and Drainage Systems from the Urban Renewal Perspective

Urban renewal projects involve multiple stakeholders and complex technical conditions, presenting numerous constraints for water supply and drainage system renovation. Key bottlenecks require in-depth analysis.

3.1Fragmented Status Quo Data Hampers Planning Accuracy

Decades of phased construction and partial renovations in old urban areas have resulted in complex underground pipeline systems. Early pipelines often only have simple schematic diagrams lacking accurate 3D spatial information. Subsequent expansions were implemented by different units, with as-built documents scattered across water, municipal, and environmental departments in inconsistent formats and not updated promptly. Numerous temporary connections and emergency reroutes lack any records. The actual alignment, burial depth, and diameter of underground pipelines often significantly deviate from drawings, especially in old residential areas and urban villages where unauthorized pipes with unclear ownership and maintenance abound. Planning designers cannot obtain complete and accurate existing data, forcing reliance on fragmented information and experience to deduce the network layout. This leads to designs disconnected from reality, frequent unexpected pipeline conflicts during construction, forced design changes, project delays, and compromised system functionality [2].

3.2 Outdated Standards Struggle to Meet Renewal Needs

Current water supply and drainage design standards were largely developed during rapid urbanization, primarily targeting single-functional areas like residential, industrial, or commercial zones. Urban renewal, however, generates numerous mixed-use and complex spaces. Renovated old factories may combine offices, commerce, cultural/creative functions, and residences. Water usage patterns shift from uniform industrial consumption to highly fluctuating composite demand, with peak flows concentrated around meal times far exceeding original design capacities. Traditional per capita water consumption indicators fail to reflect these complex patterns. Ground-floor conversions of old residences to restaurants generate large volumes of oily wastewater, overwhelming original domestic sewage pipes not designed for grease. High-tech firms in upgraded industrial parks demand extremely high water quality stability, yet existing municipal water supply pressure fluctuates and occasionally exceeds turbidity limits. These new situations fall outside the scope of current standards, leaving designers without reliable technical guidance.

3.3 New Technology Application Severely Constrained by Space

New concepts and technologies like Sponge City and Smart Water theoretically enhance system efficiency significantly but face severe spatial constraints in old urban areas. Bioswales require continuous green belts and specific depths, yet old residential compounds often lack sufficient spacing between buildings, with limited open space used for parking or drying laundry, leaving no room for green infrastructure. Permeable paving requires adequate underlying gravel and soil layers for infiltration, but old urban undergrounds are densely crisscrossed by water, sewer, gas, electricity, and telecom lines, leaving no infiltration space. Smart water meters, pressure sensors, and flow monitors need stable power and communication, yet old buildings have cramped, dark pipe wells lacking power outlets and network ports, making installation, operation, and maintenance difficult even if attempted. These objective limitations confine many advanced technologies to the conceptual stage [3].

3.4 Lack of Multi-disciplinary Coordination Mechanism is Prominent

Water supply and drainage system renovation must be synchronized with building upgrades, road reconstruction, and landscape enhancement. However, under the current design system, different disciplines belong to separate design institutes or departments, working independently according to their own codes with little information sharing or coordination. Building design fixes indoor plumbing points without considering outdoor network connection conditions. Road design sets road elevations and cross slopes without verifying the rationality of inlet locations. Landscape design creates micro-terrain without considering its impact on surface runoff direction. Electrical duct routes often clash with water/sewer pipes without coordination for sequencing or avoidance. This siloed approach results in numerous conflicts when drawings are consolidated.

4. Optimization Measures for Planning and Design of Municipal Water Supply and Drainage Systems from the Urban Renewal Perspective

Against the backdrop of urban renewal, innovative concepts and technical methods are needed to construct a scientific and efficient solution system for water supply and drainage planning and design.

4.1 Digital Infrastructure & Dynamic Planning Model Construction

The digital transformation of water supply and drainage systems in urban renewal must first address the unclear inventory of old pipelines. Establish joint surveying teams comprising surveying units, geophysical exploration companies, and pipe network operators. Follow a sequence of "surface before subsurface, trunk lines before branches". Survey pipelines under every road in built-up areas using ground-penetrating radar (GPR) along centerlines and both sides. Verify anomalies with exploratory pits. Cross-reference survey data with as-built drawings and repair records held by water authorities. For old communities lacking data, use CCTV robotic inspection through manholes to record pipe material, deformation, and siltation. Build a database with fields like pipeline ID, start/end coordinates, depth, diameter, material, construction year, and owner. Overlay this pipeline data with topographic maps, buildings, and roads via GIS. Import this data into SWMM to build a hydraulic drainage model. Input 10 years of rainfall and water consumption data for calibration. Identify flood-prone pipe sections and nodes based on simulation results. Develop renovation plans (e.g., pipe enlargement, adding pump stations, new storage facilities). Validate renovation effectiveness by feeding plan parameters back into the model [4].

4.2 Zonal Differentiation Strategy & Refined Design Plan Development

For narrow, winding alleys in historical/cultural blocks, use HDPE pipes with outer diameter <200mm. Employ horizontal directional drilling (HDD) from alley entrances to exits, avoiding trenching along the alley, using mud for wall stabilization. Pull new pipes through the drilled holes. In dense heritage-conservation building areas, install decentralized integrated wastewater treatment plants (capacity: 50-100t/d, footprint: 20-30m^2), installable underground. Discharge treated water (reaching Class 1A standard) into nearby landscape water bodies. In general renewal areas combined with road widening, place concrete drainage pipes (DN800-DN1200) under vehicle lanes as mains. Place branch pipes (DN300-DN500) under sidewalks to collect road and building runoff. Install inlets every 30-50m with initial stormwater diversion chambers directing the first 15 minutes of runoff to the sewer and subsequent cleaner flow to the storm drain. In industrial transformation zones, configure water supply based on tenant types: Set up reverse osmosis water purification stations for electronics factories needing ultrapure water (<10μS/cm). Pre-treat high-concentration organic wastewater from pharmaceutical plants using anaerobic reactors before sending to the zone's advanced WWTP. Treat cleaning wastewater from food processing via grease traps and dissolved air flotation (DAF) for reuse in floor washing and irrigation [3].

4.3 Technology Integration Innovation & Spatial Sharing Mode Exploration

In land-scarce old urban areas, integrate stormwater storage functions into existing underground space retrofits. Select low-lying, flood-prone underground parking garages. Add flood barriers (60cm high) and automatic gates at entrances. Apply epoxy resin waterproof coating to garage floors. Install submersible sewage pumps and level sensors at the lowest points. Issue storm warnings in advance to move vehicles, temporarily converting the garage into a detention basin. Drain water via pumps within 48 hours post-storm to restore parking function. For new projects, require integrated design of green roofs and rainwater harvesting. Place drainage/storage boards over roof waterproofing, plant drought-tolerant species (e.g., Sedum lineare), connect overflow outlets to downpipes. Divert collected rainwater to underground PP modular tanks (configured at $3m^3$ per $100m^2$ roof area). Stored water, filtered through sand filters, is used for toilet flushing, car washing, and irrigation [5]. Install flow meters, water quality monitors, and CCTV at key junctions, pump stations, and outfalls. Transmit data to the control center in real-time via 4G/5G. Operators remotely control gates/pumps based on monitoring data and video. Implement automated control rules.

4.4 Collaborative Design Mechanism & Full-cycle Management Framework Establishment

Appoint an overall design contractor during the project initiation phase to coordinate schedules across disciplines (architecture, structure, water/drainage, roads, landscape). Develop a design interface list defining responsibilities (e.g., Architecture: water point locations/consumption; Structure: wall sleeves for pipes; Roads: elevations/gradients). Hold bi-weekly coordination meetings. Overlay discipline drawings via projection to detect clashes. Resolve issues immediately and document decisions. Use unified layer naming conventions (e.g., "W-RAIN" for storm pipes, "W-SOIL" for sewer pipes) for easy construction identification. Select low/no-maintenance equipment: Variable frequency drive (VFD) water supply units to reduce tank cleaning; Corrosion-resistant FRP septic tanks for longer life; Self-cleaning filters to minimize manual maintenance. Specify requirements on drawings. Compile O&M manuals detailing routine inspection items, maintenance cycles, fault response procedures, and spare parts lists. Provide ≥40 hours of training for O&M personnel upon handover [6].

5. Conclusion

Urban renewal presents a vital opportunity for upgrading municipal water supply and drainage systems but also unprecedented challenges. By enabling digital technology, guiding with differentiated strategies, breaking through with innovation, and ensuring collaborative mechanisms, key challenges related to data, standards, space, and coordination can be effectively overcome. This enables a fundamental transformation of water supply and drainage systems: from extensive construction to refined renovation, from single-function to multi-function, and from end-of-pipe treatment to systemic management. Future efforts should deepen theoretical research and practical exploration, continuously improving the technical system for water supply and drainage planning and design to meet the demands of urban renewal, thereby providing more reliable infrastructure support for high-quality urban development and better living standards.

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