Research on Health Assessment and Improvement Strategies of County-Level Drainage Networks: A Case Study of Shou County, Anhui Province

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Abstract. This study constructs a comprehensive health assessment system for the drainage network of Shou County based on four key dimensions: structure, hydraulics, environment, and management. By integrating the AHP–entropy weight method with the TOPSIS evaluation model, the health conditions of six typical zones are systematically assessed and compared. The evaluation results indicate clear spatial differences in drainage network health. Specifically, the northern old city is classified as unhealthy, with a health index of 0.384; the southern old city, eastern old city, and northern riverside area are identified as sub-healthy, with health indices ranging from 0.412 to 0.542; the western industrial zone is assessed as basically healthy, with a health index of 0.673; and the southern new district is classified as healthy, achieving the highest health index of 0.812. Validation against historical waterlogging records demonstrates an 83% spatial overlap, confirming the reliability of the assessment results. Based on these findings, differentiated and phased improvement strategies are proposed to support more refined planning, operation, and management of the county-level drainage network.

Keywords: drainage network; health assessment; county-level city; combined weighting; waterlogging risk

1 Introduction

Extreme rainfall events are increasing[1] ,placing greater pressure on urban drainage systems and increasing the risk of urban waterlogging. Urban drainage networks are confronted with multiple challenges, including aging pipelines, low design standards, and sedimentation accumulation, all of which reduce drainage efficiency and system reliability[2-3]. In China, the total length of drainage pipelines increased from 577,000 km in 2016 to 952,000 km in 2023, reflecting the rapid expansion of urban infrastructure. However, despite this substantial growth, many drainage systems continue to face persistent problems, including aging pipelines, inadequate construction standards, and sedimentation blockages that limit their operational performance[4-5]. Therefore, introducing the concept of health assessment, which comprehensively integrates structural, functional, environmental, and managerial dimensions, is essential for evaluating the

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overall condition of drainage networks and providing scientific support for improving drainage system governance.

2 Literature Review

Scholars have increasingly adopted "health" and related concepts to describe drainage network conditions [6], with studies focusing on pipeline deterioration [7], vulnerability [8], resilience [9], and condition assessment [10]. Indicator systems typically include structural indicators from CCTV inspections (e.g., pipe material, age) [11-12] and hydraulic indicators (e.g., fullness ratio, overflow) [13-14]; some studies also incorporate vulnerability, environmental factors, and maintenance levels [15-17]. Using Shou County, Anhui, as a case study, this paper constructs a multi-source data-driven health assessment system based on actual planning data.

3 Study Area Overview and Problem Identification

Shou County is located in central Anhui Province, in the western part of Huainan City, within the Huaihe River Basin. The region has a warm temperate sub-humid monsoon climate, with an average annual rainfall of 903.2 mm, making it vulnerable to seasonal heavy rainfall and urban waterlogging. In the old town, the drainage network was constructed relatively early, and its design recurrence interval is generally less than one year. Most pipelines have relatively small diameters, ranging from d400 to d800, and many have experienced significant aging after long-term operation. Hydraulic analysis indicates that under a 3-year return period rainfall event, only 67.75% of the drainage network can satisfy the required drainage capacity. In particular, waterlogging depths at the Beidajie–Dongdajie intersection can reach 30–70 cm, causing considerable disruption to traffic and daily activities. In addition, the current management system faces several challenges, including fragmented administrative responsibilities, inadequate operation and maintenance mechanisms, and delayed updates of pipeline information, all of which reduce the overall efficiency and resilience of the urban drainage system.

4 Research Methodology and Evaluation System Construction

4.1 Drainage Subzones

Six zones (P-01 to P-06) are defined by pipe age/diameter, land use, and drainage outfalls: North Old Town (P-01), South Old Town (P-02), East Old Town (P-03), South New District (P-04), West Industrial Zone (P-05), North Riverside Zone (P-06). Table 1 shows basic data (from planning documents [18]).

Table 1. Basic characteristics

Zone ID	Zone Name	Diameter	Age(yrs)	Material	Impervious (%)	Water-logging Points
P-01	North Old Town	DN400-600	25	Concrete	65	3
P-02	South Old Town	DN300-500	22	Concrete	70	2
P-03	East Old Town	DN400-800	20	Concrete/PE	60	2
P-04	South New District	DN600-1000	8	Reinforced Concrete/PE	45	0
P-05	West Industrial Zone	DN500-800	12	Reinforced Concrete	50	1
P-06	North Riverside Zone	DN400-700	18	Concrete	55	2

4.2 Indicator System (11 Indicators)

The health assessment index system consists of four dimensions: structure, hydraulics, environment, and management. Structural indicators include pipe diameter (positive, mm), pipe age (negative, years), pipe material (positive, scored 1–5), and pipeline density (positive, km/km²), with all data obtained from planning documents and GIS databases [18]. Hydraulic indicators include drainage capacity (positive, calculated using the Manning equation based on pipe parameters), waterlogging point density (negative, points/km², derived from waterlogging records during 2018–2023), and fullness risk (positive, expert score ranging from 1 to 5). Environmental indicators consist of impervious surface ratio (negative, %, obtained from land-use data), ground elevation (positive, m, derived from topographic maps), and water system condition (positive, scored 1–5 based on planning data and field surveys). Management indicators include maintenance frequency (positive, events/km/year, based on maintenance records from 2019–2023) and data completeness (positive, %, evaluated using GIS and CCTV inspection audit results). Together, these indicators provide a comprehensive basis for assessing the health condition of the county-level drainage network.

4.3 Weights

AHP subjective weights (10 experts, all CR<0.1, avg 0.062). Entropy objective weights: $e_j = -k \sum p_{ij} ln p_{ij}\, , d_j = 1 - e_j, w_{o,j} = \frac{d_j}{\sum d_j}, W_j = \frac{w_{s,j} \times w_{o,j}}{\sum_{j=1}^{n} w_{s,j} \times w_{o,j}}$. Final comprehensive weights: Structure (0.30): diameter 0.11, age 0.09, material 0.06, density 0.04. Hydraulics (0.35): capacity 0.13, waterlogging density 0.10, fullness 0.12. Environment (0.20): imperviousness 0.07, elevation 0.05, water system 0.08. Management (0.15): maintenance 0.09, data completeness 0.06.

4.4 TOPSIS Health Index

Normalization (range method). Weighted matrix: $v_{ij} = W_j Z_{ij}$. Ideal best $A_j^+ = max v_{ij}$, worst $A_j^- = min v_{ij}$. DistanceD_i^+, D_i^-.Health index $HI_i = \frac{D_i^-}{D_i^- + D_i^+}$ Classification: Healthy (0.8-1.0), Basically healthy (0.6-0.8), Sub-healthy (0.4-0.6), Unhealthy (0-0.4).

5 Results Analysis

5.1 Health Assessment

The health assessment results for each subzone are shown in Table 2.

Table 2. Health assessment results

Zone	Structure	Hydraulics	Environment	Management	HI	Health Level
P-01	0.285	0.312	0.425	0.302	0.384	Unhealthy
P-02	0.324	0.356	0.401	0.315	0.412	Sub-healthy
P-03	0.412	0.428	0.485	0.412	0.485	Sub-healthy
P-04	0.852	0.788	0.765	0.842	0.812	Healthy
P-05	0.685	0.712	0.602	0.685	0.673	Basically healthy
P-06	0.525	0.548	0.556	0.512	0.542	Sub-healthy

5.2 Validation

To verify the reliability of the assessment results, the evaluation outcomes were overlaid with historical waterlogging records from 2018 to 2023. The comparison shows that 15 of the 18 recorded waterlogging events (83%) were concentrated in P-01, P-02, P-03, and P-06, while no waterlogging events were recorded in P-04 during the same period.

6 Improvement Strategies

Healthy (P-04):Priority 1 (1-2y): preventive maintenance (cleaning 1/yr, CCTV every 5y).Priority 2 (2-4y): integrate drainage data into city CIM platform.The improvement strategies are formulated according to the health status of each zone. For the unhealthy zone (P-01), Priority 1 (0–2 years) is to replace the main drainage pipes with diameters of ≥d1000 designed for a 3-year return period, while Priority 2 (2–3 years) is to construct additional storage facilities with a capacity of 200 m^3/km^2. Routine maintenance includes pipeline cleaning twice per year and CCTV inspection every two years.

For the sub-healthy zones (P-02, P-03, and P-06), Priority 1 (1–3 years) is to rehabilitate DN300–600 pipelines using trenchless relining technology and upgrade key sections to d800 where necessary. Priority 2 (2–4 years) focuses on installing 10 smart water-level sensors and establishing a monitoring platform to improve real-time operation and management. Maintenance measures include pipeline cleaning once per year and CCTV inspection every three years.

For the basically healthy zone (P-05), Priority 1 (1–2 years) is to implement Low Impact Development (LID) measures, including permeable pavements and bioretention facilities covering 20% of industrial plots. Priority 2 (2–3 years) is to establish a digital twin model to support intelligent management. Routine maintenance consists of pipeline cleaning once per year, while data completeness should be maintained above 90%.

For the healthy zone (P-04), Priority 1 (1–2 years) focuses on preventive maintenance, including pipeline cleaning once per year and CCTV inspection every five years. Priority 2 (2–4 years) is to integrate drainage network information into the city CIM platform, further enhancing data sharing and long-term management efficiency.

The proposed improvement strategy is implemented in three phases according to the health assessment results. Phase I (0–2 years) focuses on emergency interventions in the unhealthy and sub-healthy zones to address the most critical deficiencies and reduce waterlogging risks. Phase II (2–4 years) emphasizes the implementation of Low Impact Development (LID) measures together with digital upgrades in the basically healthy and healthy zones, aiming to further enhance drainage performance and management efficiency. Phase III (4–6 years) targets the establishment of full-network adaptive management, enabling continuous monitoring, dynamic operation, and long-term optimization of the entire drainage system.

7 Conclusions

The health assessment results reveal clear spatial variation in the condition of the drainage network. Specifically, P-01 is classified as unhealthy with a Health Index (HI) of 0.384. P-02, P-03, and P-06 are identified as sub-healthy, with HI values ranging from 0.412 to 0.542. P-05 is assessed as basically healthy, with an HI of 0.673, while P-04 achieves the highest performance and is classified as healthy, with an HI of 0.812. The validation results demonstrate that the assessment outcomes show an 83% overlap with historical waterlogging records, indicating good consistency between the evaluation model and actual drainage performance. Based on these assessment results, differentiated phased strategies are proposed to support refined county-level drainage management, providing a scientific basis for improving the operation and long-term management of the drainage network.

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