Research on Urban Water Infrastructure Optimization Based on Artificial Intelligent

Lei Chen [1] and Junfeng Fu [1*]

[1] School of Electric Power Engineering, Kunming University of Science and Technology, Kunming, China

* Corresponding author's e-mail address: 2631524@qq.com

Abstract. At present, the city water system has been utilized in numerous countries and continuously changed by the city's appearance or development requirements. However, existing cities' water infrastructures are established with low requirements and construction structure conditions, which cannot satisfy the current expand amount of population water supply and may decrease the region's economic growth. In this paper, the related concepts and evaluation indicators for water infrastructure and traditional structures of urban water infrastructure are initially introduced. Subsequently, the existing artificial intelligent neural network to train a novel urban water infrastructure optimization model is utilized, which can enhance the water supply effectiveness and avoid system faults. From our extensive simulation results, it can be concluded that the proposed model can achieve the optimization of urban water infrastructure for certain evaluation indicators with reasonable costs.

Keywords: Urban water infrastructure, Optimization model, Neural network, Artificial intelligence.

1 Introduction

The city water system is an essential part of any urban area. It is responsible for providing clean, safe drinking water to the citizens of the city. It also helps to maintain the health of the environment by controlling the number of pollutants that enter the water supply [1]. The city water system is made up of a variety of components, including water treatment plants, reservoirs, pumps, and distribution networks. This system is designed to ensure that the water is safe for consumption and that it meets all applicable regulations. In addition, the city water system is responsible for providing water for firefighting, irrigation, and other uses. This article will provide an overview of the components of the city water system and how they work together to provide clean, safe drinking water [2].

Urban water infrastructure is a complex system with the component of pipes, pumps, and other equipment that is utilized to deliver clean water to individuals and organizations. It is responsible for providing safe drinking water, wastewater treatment, and storm-water management. Urban water infrastructure is essential for the

D. Li et al. (eds.), *Proceedings of the 2023 9th International Conference on Architectural, Civil and Hydraulic Engineering (ICACHE 2023)*, Advances in Engineering Research 228,
https://doi.org/10.2991/978-94-6463-336-8_5

health and social life of citizens, as well as for the economic development of cities. It is also a major factor in the sustainability of urban areas, as it assists to reduce water pollution and conserve water resources [3]. Urban water infrastructure is a critical component of any city infrastructure, and its maintenance and improvement are essential for the long-term health of the city.

Water infrastructure optimization is the process of improving the efficiency and effectiveness of water infrastructure systems. This includes the use of advanced technologies, such as sensors, automation, and data analysis, to monitor and manage water resources. Optimization of water infrastructure can help reduce water losses, improve water quality, and reduce energy consumption [4]. It can also help to reduce the cost of water delivery and wastewater treatment, as well as improve the reliability of the water supply. Optimization of water infrastructure is essential for the sustainability of cities and towns, as it helps to ensure that water resources are used efficiently and effectively [5].

Artificial intelligent water infrastructure is a system of technologies that use artificial intelligence to monitor the structure of the water system and manage water resources. Artificial intelligent-based water infrastructure systems can be utilized to detect and predict water-related problems including leaks, contamination, and water shortages [6]. Artificial intelligent-based systems can also be utilized to optimize water delivery and wastewater treatment, as well as to improve the efficiency of water infrastructure. Artificial intelligent-based water infrastructure systems are becoming increasingly important for the sustainability of cities and towns, as they can assist to reduce water losses, improve water quality, and conserve water resources [7].

The remainder of this paper will be arranged as the introduction about related concepts and urban water infrastructure evaluation indicators is shown in Section 2. Indeed, Section 3 will demonstrate the framework of the proposed neural network and optimization targets calculation process. Section 4 consists of the simulation results and analysis for the proposed model. Finally, Section 5 concludes the general proposed model and provides the future improvement methods of the optimization model.

2 Preliminaries

2.1 Concepts about urban water infrastructure

Urban water conservancy infrastructure refers to the collective term for facilities and their supporting and ancillary facilities and their supporting and ancillary facilities to control and allocate surface water and groundwater in nature, to eliminate harm and profit. It provides water sources for the city, urban logistics and the transportation of people, the regulation of floods in the river basin, agricultural irrigation in suburban counties, ecological construction, ornamental tourism, water entertainment activities, urban microclimate improvement, replenishment of underground water sources, direct provision of industrial cooling water sources and the final recipient of urban surface runoff and sewage, etc. [8] Urban water infrastructure is an important part of the city, the survival and development of human society are inseparable from the support of urban water conservancy infrastructure [9-10].

Water conservancy infrastructure in the modern sense is not only an infrastructure with a single function, but also combines landscape and water conservancy infrastructure to create a water conservancy landscape infrastructure that integrates nature, ecology, and economy, and realizes the sustainable development of human development and resources and environment [11].

Traditionally, water conservancy projects have mostly considered the demands of social economic development and rarely considered the impact of construction on river ecosystems and urban storm-water systems [12]. The construction of hydraulic buildings is used to transform and control rivers to meet individuals' various requirements including flood control and water resource utilization. When people realize that rivers are not only resources that can be developed, but also the carrier of life of river systems and pay attention not only to the resource function of rivers but also to the ecological functions of rivers [13]. The researcher starts to investigate that there are obvious defects in hydraulic engineering, that is, when meeting the needs of human society, the health and sustainability of river ecosystems are ignored. The addition of artificial means will bring irreversible damage to the natural environment, and the functions of the ecosystem will gradually deteriorate, affecting people's long-term interests.

2.2 Urban water infrastructure evaluation indicators

The evaluation indicators for urban water infrastructure include the following six items

- Water Quality: This indicator measures the quality of water delivered to citizens, including the presence of contaminants and other pollutants.
- Water Supply Reliability: This indicator measures the reliability of the water supply, including the frequency of water outages and the duration of water supply interruptions.
- Water Losses: This indicator measures the amount of water lost due to leaks, theft, and other causes.
- Energy Efficiency: This indicator measures the energy efficiency of water infrastructure, including the amount of energy used to deliver water and treat wastewater.
- Cost Efficiency: This indicator measures the cost efficiency of water infrastructure, including the cost of water delivery and wastewater treatment.
- Sustainability: This indicator measures the sustainability of water infrastructure, including the use of renewable energy sources and the conservation of water resources.

3 System framework

Above all, Figure 1 demonstrates the proposed model framework of the urban water infrastructure optimization model, which contains the input simulation of urban water infrastructure networks and the trained artificial neural network.

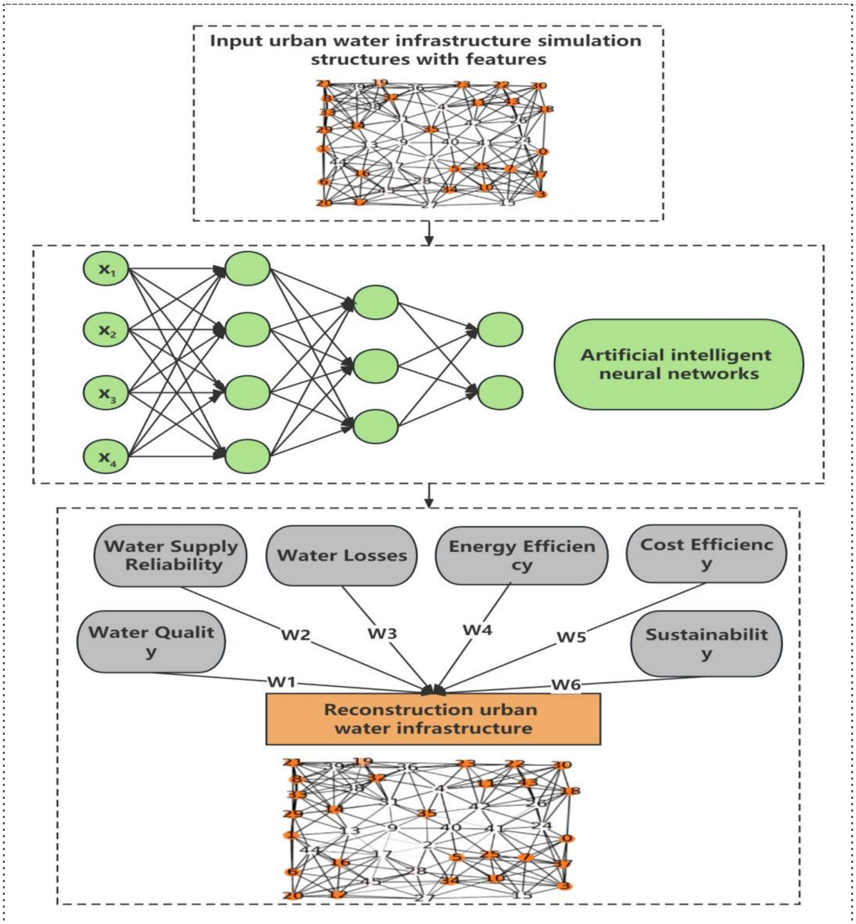

Fig. 1. A system model of urban water infrastructure optimization.

Urban water infrastructure optimization based on artificial intelligence is a system framework that uses AI-based algorithms to optimize the operation of urban water infrastructure. The system framework consists of four main components in the following items.

- Data Collection: This component collects data from various sources such as sensors, weather stations, and other sources. This data is used to create a comprehensive view of the urban water infrastructure.

- Modeling: This component uses artificial intelligent-based algorithms to create models of the urban water infrastructure. These models are used to identify potential areas of improvement and to optimize the operation of the infrastructure.
- This component uses the models created in the previous step to optimize the operation of the urban water infrastructure. This includes optimizing the use of resources, minimizing water losses, and improving the efficiency of the infrastructure.
- Monitoring: This component monitors the performance of the urban water infrastructure and provides feedback to the optimization component. This feedback is used to further refine the optimization process. The system framework is designed to improve the efficiency and reliability of urban water infrastructure. By using artificial intelligent-based algorithms, the system can identify areas of improvement and optimize the operation of the infrastructure. This can lead to improved water quality, reduced water losses, and improved efficiency.

Additionally, we demonstrate the inner calculation process of an artificial neural network in following Equation 1, where the symbol W is the desired weight for each training neural cell and the symbol, I is the input data with the structure of urban water infrastructure.

$$\mathrm{ANN}(I, W) = \mathrm{SUM}\ (xi * wj) \quad (1)$$

4 Experimental results and evaluation

4.1 Experimental setups

Initially, we collect the city water infrastructure from HydroSHEDS simulating as the feature of water infrastructure and generate the water infrastructure network as the input data with the collected features. Subsequently, the proposed model with the random walk optimization method (RWO) is evaluated, which includes randomly removing or adding the edge among the simulated network. Indeed, we utilize the mathematical dynamic programming method (DP) to compare the performance of the proposed model.

Compared with other algorithms, dynamic programming greatly reduces the amount of computation and enriches the results. It not only obtains the optimal value from the current state to the target state but also obtains the optimal value from the intermediate state, this is useful for many practical problems. Compared with general algorithms, dynamic programming also has some disadvantages: the space takes up too much, but for the problem of small demand for space, dynamic programming is undoubtedly the best way. Dynamic programming algorithms and greedy algorithms are common methods to construct optimal solutions.

4.2 Experimental Results and Analysis

We utilize optimization accuracy as the indicator of model performance, which is calculated as the total optimization of six weights of indicators divided by the previous sum of weights. Following Figure 2 demonstrates the experimental comparison results for the proposed model in identical simulation environment settings.

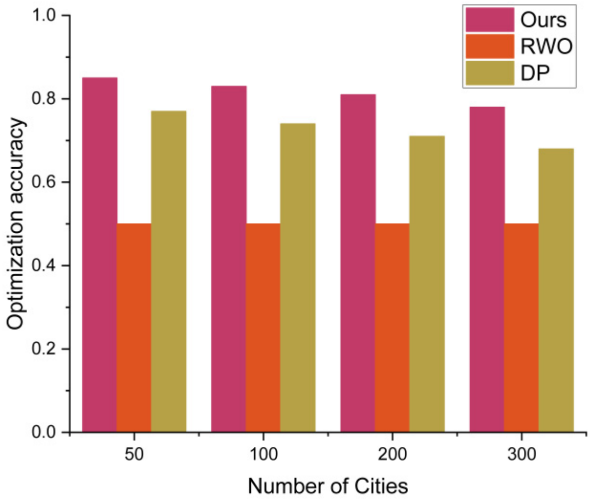

Fig. 2. Optimization accuracy of comparison results.

Furthermore, we compare our model and other methods' average computation cost for one city to evaluate the calculation effectiveness performance. Following Table 1 demonstrates the computation cost comparison results.

Table 1. Computation cost comparison results.

Models	Average city computation cost (second)
Ours	14.6
RWO	6.4
DP	15.3

Additionally, robustness is another essential indicator to evaluate the proposed model and verify the correctness of the proposed model in different affection environments. The following Table 2 demonstrates the robustness simulation results.

Table 2. Robustness simulation comparison results.

Models	Network robustness difference
Ours	0.23
RWO	0.31
DP	0.28

The results of the experiment are used to further refine the system and improve its performance. This process is repeated until the system is optimized and the desired results are achieved. The experimental analysis of the proposed model provides valuable insights into the effectiveness of the system. It also provides a way to evaluate the system and identify areas of improvement. This can assist to ensure that the system is optimized and the desired results are achieved. The performance of the system is monitored and evaluated. The results of the experiment are then used to refine the system and improve its performance. Finally, the system is tested again in a real-world environment.

5 Conclusion

In conclusion, the proposed optimization model is a promising solution to the challenges of water scarcity and water pollution. Artificial intelligent-based solutions can assist cities to better manage their water resources supply structures, reduce water losses and improve water quality. Artificial intelligent-based solutions can also assist cities to better predict water demand and optimize water distribution networks. As for future improvements, researchers could utilize more complex parameters and train the large-scale neural network to obtain more precise models and optimization the reconstruction water infrastructure.

References

1. Wang Yin,Qin Zhen,Hou Weidong,Storozum Michael. Water Conservancy System and Urban Layout of Yinxu, the Capital City of Shang: A GIS Approach. Land, 11(7), 2022.
2. Xu Jiayi, Dai Jiangyu, Wu Xiufeng, Wu Shiqiang, Zhang Yu, Wang Fangfang, Gao Ang, Tan Yanping. Urban rainwater utilization: A review of management modes and harvesting systems. Frontiers in Environmental Science, 2023.
3. Gao Teng, Zhang Mingye, Zhao Chunzi. An Evaluation of the Sustainability of the Urban Water Resources of Yanbian Korean Autonomous Prefecture, China. Sustainability, 15(2), 2023.
4. Xuan Liu, He Bing. A Dynamic Study on Urban Water Resources and Ecological Recreation Space in Ganjiang River Basin. International Journal of Frontiers in Engineering Technology, 4.0(6.0), 2022.
5. Darbandsari Pedram, Kerachian Reza, Malakpour-Estalaki Siamak, Khorasani Hamed. An Agent-based Conflict Resolution Model for Urban Water Resources Management. Sustainable Cities and Society, 57, 2020.
6. Ateş Kübra Tümay, Şahin Cenk, Kuvvetli Yusuf, Küren Bülent A., Uysal Aykut. Sustainable production in cement via artificial intelligence-based decision support system: A case study. Case Studies in Construction Materials, 15, 2021.
7. Tucci Mauro. Hourly Water Level Forecasting in a Hydroelectric Basin Using Spatial Interpolation and Artificial Intelligence. Sensors, 23(1), 2022.
8. Wang Chao. The Significance of Low Impact Development on Urban Water Resources. IOP Conference Series: Earth and Environmental Science, 401, 2019.

9. M. H. Giacomoni, E. Z. Berglund. Complex Adaptive Modeling Framework for Evaluating Adaptive Demand Management for Urban Water Resources Sustainability. Journal of Water Resources Planning and Management, 141(11), 2015.
10. Zhu Hong Qing, Wang Yu. Urban Water Conservancy Project Based on Engineering Construction Combined with Ecological Environment. Applied Mechanics and Materials, 700(700-700), 2014.
11. Chun Jie Ma, Gong Li Cao, Yan Ting Ma. Discussion on the Sustainable Development of Urban Water Conservancy Infrastructure Construction. Advanced Materials Research, 1601(430-432), 2012.
12. Chen Xing, Xu Qin, Cai Jing. Research on the urban water resources carrying capacity by using system dynamics simulation. Hydrology Research, 54(3), 2023.
13. Bega João Miguel Merces, Albertin Liliane Lazzari, de Oliveira Jefferson Nascimento. Development of water quality index as a tool for urban water resources management. Environmental science and pollution research international, 30(7), 2022.