Environmental Industry Letters
https://ijitis.org/index.php/EIL
ISSN: 2806-2965
Volume 1, Issue 1
DOI: ***https://doi.org/10.15157/EIL.2023.1.1.46-63***
Received: 14.02.2023, Accepted: 13.03.2023

Smart Dashboard of Water Distribution Network Operation: A Case Study of Tehran

Amirhossein Kiyan[1], Mohammad Gheibi[2,3]*, Reza Moezzi[2,3], Kourosh Behzadian[4]
[1]Department of Engineering, Azad Islamic University, Karaj branch, Karaj, Iran
[2]Association of Talent under Liberty in Technology (TULTECH), Tallinn, Estonia
[3]Institute for Nanomaterials, Advanced Technologies and Innovation, Technical University of Liberec, Czech Republic
[4]School of Computing and Engineering, University of West London, London, UK
*** Mohammad.Gheibi@tultech.eu**

Abstract
Numerous water supply utilities around the world face challenges in successfully distributing water in distribution networks due to increased urbanization, population growth, and climate change. The age of the water supply facilities is a particular issue, which is aggravated by their inadequate maintenance and operation. Due of this, many water utilities have recently adopted integrated and intelligent water supply solutions that leverage information technology, artificial intelligence, big data, and IOT (Internet of Things) to handle water supply system issues. In this study, a smart dashboard of water distribution network operation was developed to improve the effectiveness of Tehran, Iran's water delivery system. In order to properly manage water resources, the article proposes adopting knowledge management systems in Tehran's municipal water distribution and transmission networks.

Keywords: *Water distribution networks; Knowledge management; Decision support system; Multiple Criteria Decision Making; Hydraulic model*

INTRODUCTION

The water supply and distribution network are an essential component of modern cities, and the effective management of these systems is crucial for ensuring the sustainability, reliability, and quality of water supply. According to the World Bank, around 2.2 billion people lack access to safe drinking water, and around 4.2 billion people lack access to safely managed sanitation services [1]. One of the most significant challenges in the water industry is the management, maintenance, repairs, and control of facilities related to urban water supply networks. Effective management of urban water supply systems is necessary for ensuring the reliability, sustainability, and quality of water supply [2]. Therefore, knowledge management systems [3-5] play a critical role in improving the efficiency and effectiveness of water distribution networks. In the water and sewage industry, hydraulic and quantitative issues are given priority over qualitative factors. However, it is essential to note that these two factors are interdependent, underscoring the need to study them simultaneously [6]. To overcome this issue, knowledge management mechanisms are implemented in urban water distribution and transmission. Knowledge management is the process of developing and transferring technical knowledge and experience of individuals within the system to future generations [7]. The transfer of experience and knowledge through various methods, such as interviews and questionnaires, is one of the essential pillars of knowledge management. Moreover, a proposal system section allows the system to update and modify previous methods to address challenges effectively. Knowledge management systems help water distribution networks deal with data and information challenges in decision-making processes. These systems also provide timely and accurate information for risk management and crisis prevention, such as water shortages, contamination, or natural disasters [8]. One of the critical characteristics of knowledge management is the ability to analyse problems with maximum accuracy in minimal time to provide appropriate solutions. This approach ensures prompt actions during emergencies, reducing the negative impacts of crises on water supply systems. Knowledge management systems can optimize water supply network operations, reduce water loss, and improve water quality and reliability [9]. In conclusion, a decision-making support system with a smart dashboard capable of reading, analysing, and providing solutions with the highest accuracy in the shortest possible time is crucial for efficient management of urban water supply networks, especially in highly populated cities such as Tehran. While Tehran's water and sewage companies have a team of expert and experienced professionals in urban water management and supply, not all experts will be available during massive and urgent crises due to retirement, leave, or transfer to another city. Therefore, this study aims to address this issue by implementing knowledge management systems in Tehran's urban water distribution and transmission networks to manage water resources effectively.

RESEARCH BACKGROUND

In recent years, there has been significant focus on improving the urban water distribution network, with particular emphasis on the design and operation of the system for enhancing its efficiency and effectiveness. The growing capacity to collect data has led to a greater demand for quick and accurate analysis of this information. To facilitate decision-making based on data, scientific and standardized methods, as well as insights from prior experiences within the system, it has become essential to develop decision support systems (DSS) that can effectively process and present information to operators. The development of a decision support system (DSS) is a critical component of smart dashboard systems for managing treatment plants. In the following, we will examine research conducted to create a DSS system specifically for water systems. Marques et al. in [8] conducted research on a multi-criteria decision-making analysis system that serves as a tool to support decision-makers during a crisis [10]. Effective management of water distribution networks requires addressing conflicts of interest and collaborating with stakeholders. To address these complex needs, methods such as Multiple Criteria Decision Making (MCDM) [11], [12] can be used to identify the most flexible solutions that consider all aspects and requirements. MCDM typically involves three main steps, as illustrated in Fig. 1.

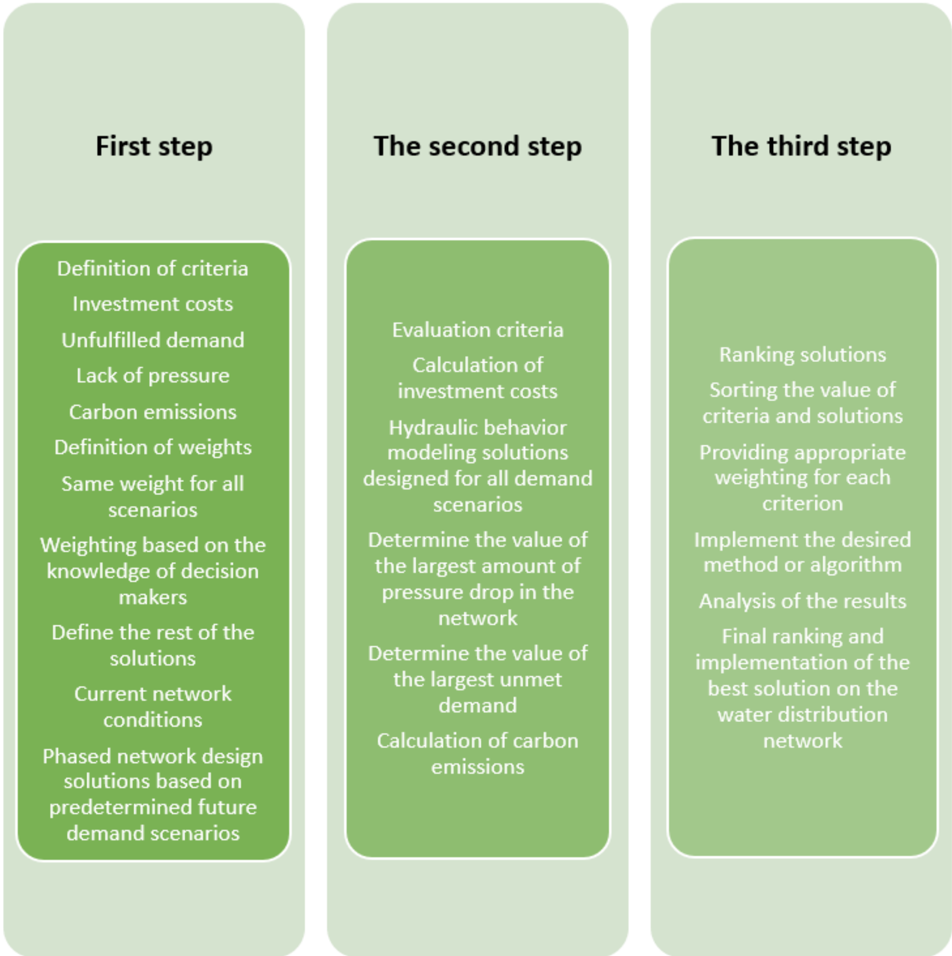

Fig. 1. Three steps for Multi Criteria Decision Making analysis [13], [14]

In [9] Zhang et al. conducted research on various methods of partitioning and proposed a multi-criteria optimization method for partitioning based on hydraulic, water quality, and economic indicators. They subsequently developed a final solution for managing the amount of leakage based on segmentation, utilizing the Non-dominated Sorting Genetic Algorithm (NSGA-II) method. The study was conducted using one of the EPANET benchmarks as a case study [15]. In their research, they proposed a new framework named Burst Location Identification Framework (BLIFF), which utilizes the FL-DensNet software to accurately determine the location of one or more potential pipe breaks in a given area. The BLIFF3 framework leverages hydraulic models of the water distribution network to simulate pipe bursts and then trains the FL-DenseNet software. Moreover, the framework has the ability to predict future potential burst points by collecting new pressure data in the network and feeding it to the software. The study applies the framework to two pre-existing case studies, achieving successful identification of the location of 57 out of 58 bursts. A general diagram of the design is shown in Fig. 2 [16].

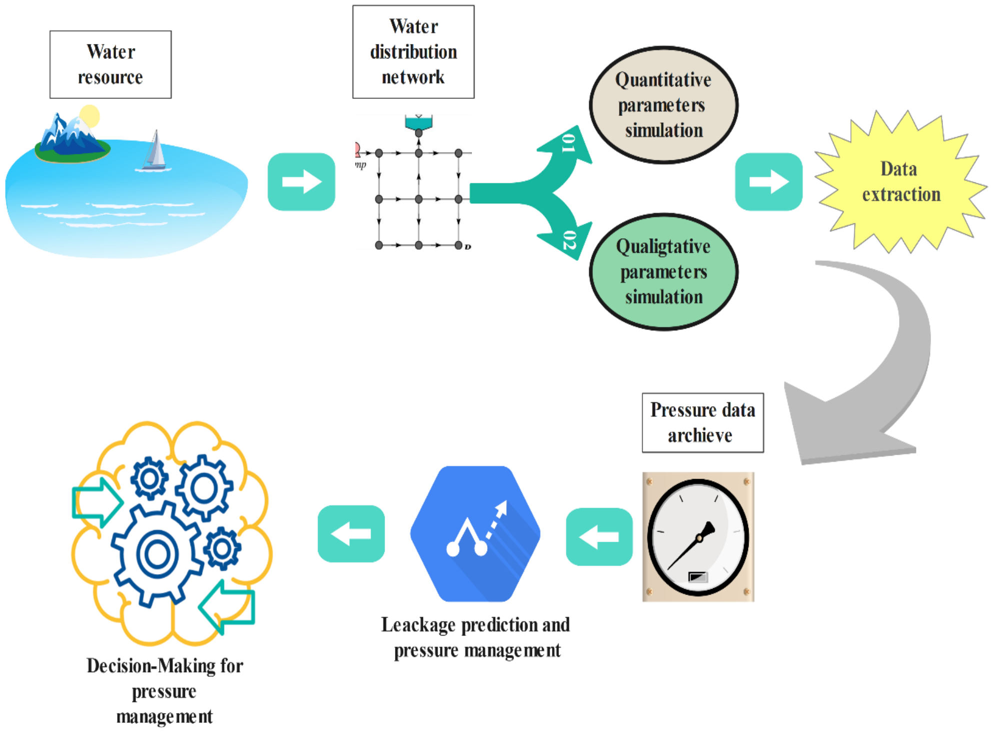

Fig. 2. How the model works

Other studies proposed a pollutant leak detection method to improve the control of water quantity and quality in water distribution networks by employing machine learning methods [17-19] such as Gaussian Process Regression (GPR) for modeling and Generalized Likelihood Ratio Test (GLRT) for pollutant and leak detection. The study's results show positive outcomes in all neural network and Support Vector Regression (SVR) methods used for modeling, indicating the effectiveness of the proposed innovative approach [20]. In the following, Table 1 listed the studies use DSS for water distribution networks.

Table 1. DSS systems used in different studies

No.	Specifications	The measured parameters	Applied techniques and tools	Reference
1	A case study in Barcelona, Novayacaria region	Placement of sensors based on flow pressure analysis	A case study in Barcelona, Novayacaria region	[21]
2	A case study of a small town in China	Scenario-based vulnerability assessment of water distribution network considering uncertainty in different collapse modes	A case study of a small town in China	[22]

3	A case study in the southern parts of Chile	Evaluation of network sensitivity and reliability	A case study in the southern parts of Chile	[23]
4	Benchmark available on EPANET for Milan (Italy)	Functional analysis of leakage parameters by leakage performance index (LPI)	Benchmark available on EPANET for Milan (Italy)	[24]
5	A case study of Zarqa (Oman), Sanaa (Yemen), and Wanza (Tanzania)	Assessing the actual water loss and checking its accuracy and uncertainty	A case study of Zarqa (Oman), Sanaa (Yemen), and Wanza (Tanzania)	[25]
6	Case study of Ikaria (Barcelona), Limassol (Cairo), and Hanoi (Vietnam)	Leakage modeling and minimization	Case study of Ikaria (Barcelona), Limassol (Cairo), and Hanoi (Vietnam)	[26]
7	A case study of Hanoi (Vietnam)	Minimize network cost	A case study of Hanoi (Vietnam)	[27]
8	A case study of Calžanapoca (Romania)	Analysis of priority selection based on network renewal	A case study of Calžanapoca (Romania)	[28]
9	A case study of Hanoi (Vietnam) and Limassol (Cairo)	Using the hybrid feature selection algorithm	A case study of Hanoi (Vietnam) and Limassol (Cairo)	[29]
10	SMaRT-Online project on the water distribution network	A tool for tolerability and online safety management - pollutant transport modeling	SMaRT-Online project on the water distribution network	[30]
11	EPANET benchmark model	Create a schedule for pumping in the distribution system	EPANET benchmark model	[31]
12	EPANET2 benchmark	Management and quick response in the water distribution network and estimation of pressure and flow effects	EPANET2 benchmark	[32]

PROBLEM STATEMENT

Tehran metropolis

Tehran, the capital of Iran, is a sprawling metropolis with an urban area spanning 720 square kilometers. With a population of 8,693,706 people according to the Iran Statistics Center's

2016 census, it is the most heavily populated region in the country. As such, providing essential services to its residents is a critical task in enhancing the quality of public life. Services essential to the well-being of Tehran's population include energy supply, security, public transportation, water purification, sewage collection, and public health. Among these, the provision of clean, purified water is particularly crucial, as it plays a significant role in safeguarding the health of citizens. Tehran province's water distribution network spans an impressive 14,893 kilometers, with pipes ranging in diameter from 80 to 800 mm. The network's pipes are constructed using a variety of materials, including steel, concrete, ductile, cast iron, asbestos, and polyethylene. The Water and Sewerage Company of Tehran province operates through approximately 1.5 million active branches, which equates to roughly 3.23 million units. Of these branches, around 1.31 million are equivalent to 274,000 household units, with the remainder serving non-domestic purposes. To maintain water pressure and store drinking water, the company has commissioned 265 reservoir units across Tehran province, with a combined volume of 24.2 million cubic meters. The province's distribution network comprises over 12,1940 valves, with an additional 683 pressure relief valves installed to regulate water flow.

Water distribution network

The water distribution network is a crucial component of urban water supply systems, responsible for delivering safe and clean water to consumers. In most cities, the cost of constructing and maintaining the water distribution network accounts for between 50 and 90 percent of the total expenses of the water supply facilities.

Since replacing pipes in the network after a few years of operation can be expensive, engineers and planners base their calculations on estimates of population growth for the next 25 to 40 years. This approach ensures that the network is designed to meet the anticipated demand for water and can adapt to changing population patterns over time.

In terms of the water distribution system, the piping network can be designed in three ways:

1. Branch networks are the simplest type of water distribution networks, resembling trees in their structure. The water flow in these networks is unidirectional, flowing from larger branches to smaller branches. While the calculation of branch networks is straightforward, a significant drawback is that if a pipe part is damaged, all the sections downstream will lose water pressure. Additionally, water may become stagnant at the ends of the branches due to low consumption, which does not affect water quality. However, the constant unidirectional flow and slow speed in these networks can result in increased sedimentation in sub-branches.

2. Ring networks are formed by connecting the ends of branch networks, resulting in a closed loop. Water flow in ring networks changes direction based on consumption, and each area can receive water supply from two or more directions. Compared to branch networks, ring networks do not suffer from the issue of water loss in case of a pipe break. However, their construction costs are higher, and their calculation is more complex due to the changing flow direction in the pipes, which must be carefully analyzed.

3. Combined networks are a practical solution to the high construction costs of ring networks, making them uneconomical in certain areas. As such, a combination of both branch and ring networks is often used in urban water distribution systems. This hybrid approach offers a balance between cost-effectiveness and efficiency, allowing for a more adaptable and versatile network design that can meet the varying demands of different areas.

Fig. 3 shows a simple design of the connection process and return of settled water, where unused water is re-entered into the cycle.

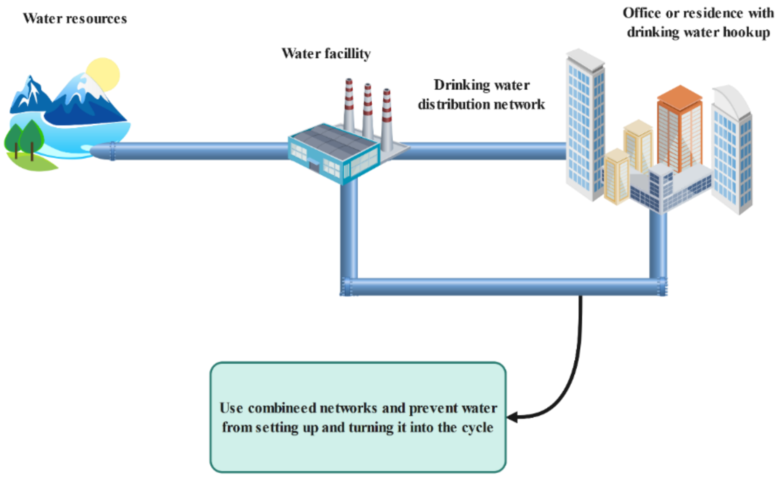

Fig. 3. Water treatment plant and water distribution network

The types of influential parameters of water distribution networks can be divided into the following 2 general categories:

1. Piping method: (Division of the distribution network in terms of piping)

In this division, the distribution network is separated into 3 categories: branched, circular, and mixed.

2. Pressure supply system: (Division of distribution network in terms of pressure supply system)

In creating water flow and ensuring adequate pressure in a distribution network, the force of gravity is often utilized whenever possible. Gravity networks are preferred due to their simple design, which results in greater reliability during operation. However, in cases where gravity networks cannot be established, pressure in the water distribution network can be provided through the use of pumping stations.

Distribution networks are classified into various types based on their pressure supply, including:

1. Gravitational network of the first type:

If the studied area has a small area and there is a sufficient height difference, the pressure of the entire area is provided by one or more tanks with the same height.

2. Gravity network of the second type:

If the area being studied is relatively large, with significant changes in elevation, the use of one or more reservoirs with the same height level may not be feasible. In such cases, it becomes necessary to install either reservoir-type or mechanical pressure reduction facilities, such as pressure relief valves, to divide the city into different pressure zones. This allows for the delivery of water at optimal pressures for each zone while ensuring efficient use of resources.

3. Composite gravity network:

In areas surrounded by natural heights on several sides, additional reservoirs can be constructed at lower elevations compared to the primary reservoir. With this approach, during peak consumption hours, all tanks are connected to the distribution network and included in the operating circuit. During periods of low consumption, some tanks are excluded from the circuit to avoid water overflow in the lower tanks. To prevent overflow, flow control facilities, such as flow control valves at the entrance of tanks, must be installed. This system offers several advantages, including a reduction in the diameter of the main pipes required for the distribution network compared to simple gravity mode, resulting in lower operational costs.

Gravity pumping:

In cases where the water supply location is downstream of the city and the distribution network is located at a higher elevation than the supply location, pumping is required to move water to the distribution network. Pumped water is stored in storage tanks during low consumption hours, and during peak consumption hours, the pumping station and storage tanks work together to supply water to the distribution network.

Direct pumping:

In cases where there is not enough elevation difference in the region, water distribution and supply are achieved through direct pumping of water to the distribution network. However, this system can be associated with several issues, such as pressure fluctuations during different usage hours. Therefore, it is generally used in special conditions and for small-scale projects.

The primary objective in creating a hydraulic model of a water distribution system is to achieve a comprehensive understanding of the system's various states to enhance its design and operation both quantitatively and qualitatively. The model and its simulation results in a distribution system can generally be summarized as follows:

- System design in connection with modification and development: the hydraulic model provides designers with a useful tool to evaluate proposed and existing water distribution networks, identify defects, evaluate proposed solutions, and make modifications and developments to the system.

- Training of users: the hydraulic model can be used as an educational tool to train and help users understand the system and the effects of applying different policies and operating methods on its efficiency.

- Designing optimal exploitation strategies: experts can use the hydraulic model to analyze the existing system and develop optimal exploitation strategies and methods, leading to the establishment of useful rules and guidelines.

- Evaluation of system operation and results: the hydraulic model provides valuable information about the impact of different operation policies on the system's efficiency.

- System maintenance: The hydraulic model can provide a comprehensive understanding of the water distribution system, which enables experts to identify potential issues and plan for preventative maintenance. This allows for a systematic and long-term plan for supply and maintenance based on prediction and prevention, reducing downtime and maximizing efficiency.

• Optimizing the system in emergencies: The hydraulic model can identify situations that occur when a part of the network is out of order and the load is transferred from one part to another part. This allows for appropriate measures to be taken to minimize water loss and maintain supply to affected areas during emergencies, such as natural disasters or system failures.

• Existing situation: The hydraulic model can provide facilities needed for water supply in different stages of the city's development according to the available and needed water resources. This helps in the planning and development of water distribution systems to ensure adequate and reliable supply to meet current and future demand.

• Solving issues and problems raised in hot seasons and times of water scarcity and crisis: The hydraulic model can simulate and predict the effects of different operating policies and methods on the efficiency of the system during times of high demand or water scarcity. This allows for the development of effective strategies and solutions to mitigate issues and ensure an adequate supply of water during critical periods.

• Studies related to urban water losses: the model can be used to study and identify areas with high water losses, and to develop strategies to reduce these losses, which can have significant economic and environmental benefits.

• Studying, checking, and evaluating the system, simultaneously with the operation: the model can be used to continuously monitor and evaluate the performance of the water distribution system in real-time, identifying potential problems before they become critical.

• Studies related to energy management in the distribution network: the model can be used to analyze energy consumption in the distribution network, and to develop energy-efficient strategies that can help to reduce operating costs and carbon emissions.

• Studies and economic evaluation of the distribution system: the model can be used to evaluate the economic efficiency of the distribution system, taking into account factors such as construction costs, operating costs, and environmental impacts.

• Carrying out qualitative studies and trending in the qualitative mode of the network: the model can be used to conduct qualitative studies of the water distribution network, such as water quality analysis and monitoring, and to identify trends and patterns in the system that can help to optimize performance.

• Determining the size and type of required facilities such as tanks and pumping stations: the model can be used to determine the optimal size and type of tanks and pumping stations needed to meet the demand of the water distribution system, and to optimize their location for maximum efficiency.

• Determining the location of various facilities in the distribution network: The model can help identify optimal locations for various facilities, such as pumping stations, treatment plants, and storage tanks, based on factors such as population density, water demand, and available resources.

• Determining the size, type, and location of valves: Valves are critical components of the distribution network, and the model can help determine the optimal size, type, and location of valves based on factors such as pipe diameter, water pressure, and flow rate.

• Determining the appropriate size of the pipes: The model can help determine the optimal size of pipes based on factors such as water demand, pressure, and flow rate, to ensure that the system operates efficiently and effectively.

• Determining the volume required for firefighting: The model can help determine the volume of water required for firefighting and ensure that the distribution network is capable of providing the necessary water supply.

• Determining different pressure areas and analyzing the specific issues of each area: The model can help identify different pressure zones within the distribution network and analyze specific issues, such as pressure drops, leaks, and water quality problems, in each area.

• Determining water needs and network capacity at different points and times: The model can help determine the water demand and network capacity at different points and times, which is critical for ensuring that the system can meet the water needs of the community.

• Determining the amount of incoming load to neighboring networks and adjusting the load: The model can help determine the amount of incoming load to neighboring networks and adjust the load to ensure that the system operates efficiently and effectively.

Preparation of hydraulic model of water distribution network

Over the past two decades, there has been significant growth in the industry and advancements in methods for collecting, processing, and storing statistical information. These advancements have led to the development of techniques for simulating current situations and predicting future scenarios, which are critical for the management of water distribution networks. As a result, water distribution network analysis methods have become widely accepted as important and efficient tools for understanding hydraulic and qualitative behavior, evaluating development plans, and improving overall performance. Despite the fact that there are still some uncertainties in describing the basic relationships that show the influence of process parameters in water networks, these models are effective and appropriate tools for quantitative and qualitative estimations of process variables. Overall, the use of these models has opened up new perspectives for experts in the field of water management and has enabled them to make better-informed decisions based on the simulation and prediction of various scenarios.

Water distribution network modeling steps

a) Definition of the topic:

The first step in preparing a model is to identify the subject matter. This principle applies to the modeling of water distribution networks as well. The following are the general topics on which a model for water distribution networks can be based:

- Studying comprehensive water plans
- Evaluating and monitoring water quality
- Estimating the efficiency of the water distribution network
- Conducting studies related to energy management of water distribution networks
- Developing plans for modifying and repairing the water distribution network

- Establishing communication with nearby networks
- Designing new water distribution networks
- Utilizing the water distribution network efficiently

b) Model selection

When selecting a model, numerous factors should be considered, and the ability of the models to meet the needs will depend on these factors. The selection of the model entails asking various questions, and if answered, the desired software is chosen and utilized. Some of the questions that arise during model selection include:

- How detailed is the model?
- Does it simulate all pipes within the distribution network?
- Does it simulate all valves, pumps, tanks, and other control systems?
- How detailed are the usage and patterns that it should simulate?

c) Model calibration

- Dynamic calibration (dynamic)
- Simple calibration (stable)

d) The type of simulation required

- Permanent or static
- Expanded or dynamic
- Qualitative
- How to connect the model with other applications such as GIS, CAD, databases, etc.
- Hardware requirements
- Software requirements
- Technical and economic considerations

e) Collecting and organizing information

The information required in distribution network models is divided into two categories, quantitative and qualitative.

Quantitative information:

In the water distribution network, quantitative information includes the following:

• Information related to the network (topography, geographic conditions, map, and location of piping routes)

• Information related to consumption (domestic, commercial, industrial consumption statistics, etc.)

Qualitative information:

If preparing a water quality model in a network is considered, information on water quality analysis and quality criteria and goals of the network is required.

Examining and determining criteria and limitations

In preparing the hydraulic model and presenting the exploitation scenarios, attention is always paid to the point that the pressure and flow in the pipelines are at the optimal level and also within the range of the existing criteria. In this section, the basics of the desired criteria are explained.

a) Flow rate

In general, the flow rate in the pipelines from 3 points should be taken into consideration in the preparation of the hydraulic model. Water speed in the distribution pipes should not be excessive. Because water speeds from one side based on the Darcy–Weisbach equation increase the pressure drop and, on the other hand, the pressure facility rises the height of the pumps and generally the cost of the pumps. The fixed and current pumping stations and networks are distributed. Based on the relationship between changing the amount of motion, the amount of force imported in the knees and highways due to the change and high flow rate causes the pipes to break, especially in the joints. Also, due to the possibility of a sudden closure of the cutting valves in one section, compression trauma is created in other parts that increase the chance of breaking those points, depending on the speed. The high speed of water causes the wall of the pipe to erode, especially at the opening of the pipe and at the junction of the two pipes, and if this is not considered, the useful life of the pipelines will be reduced. Given the above, the maximum selection is necessary and the minimum for water speed in the pipes and the speed constraint is usually considered as the following. The maximum water speed in pipes with a diameter of 5 mm/ s is 2 m/ s and in pipes with a diameter equal to or greater than 0.5 mm/ s. The minimum water rate in the water pipelines is taken into consideration, which is caused by the low sediment rate in the pipes, and on the other hand, water-soluble gases are bubbles that are bubbles in the water. The tall parts of the pipelines accumulate and disrupt the flow of water and also change the taste of the water. According to the world's acceptable standards, a minimum speed of 1 to 2 m / s is considered.

b) Pressure

The maximum pressure in the pipelines should be enough for the pipes to withstand the existing pressure, especially at the joints, in the worst working conditions of the pipe, i.e., static conditions. High pressure provides the risk of breaking the pipes in low points and pits, on the other hand, the pressure plays an effective role in the amount of leakage and water loss, and it also causes the class of the pipe to rise and, as a result, increase the costs of water supply facilities. Limiting the pressure in the network is important because at the time of maximum consumption and harvesting of water, the pressure should not be less than 0.3 atmospheres in any part of the city, and the addition of pressure should not cause an increase in consumption and especially water losses. Logically, the general point of view in preparing the hydraulic model of the water distribution network to reduce losses should be in such a way that, taking into account the technical and economic aspects, the pressures in the major covered levels should be the lowest possible value. The maximum pressure is raised when the risk of pipe bursting in the weak points of the network, especially at night when the water flow inside the network is very slow as a result the pressure drop reaches the minimum possible and finally, the hydraulic pressure approaches its maximum i.e. equivalent to static pressure. , and this causes the pipes, fittings, and valves to break. Therefore, according to the working pressure of the existing pipes and the proposed pipes that are made for a pressure of 6 to 12 atmospheres, and also considering the possibility of their rotting after installation, the non-responsiveness of the pressure of the pipes in practice, compared to the nominal pressure, the existence of network weakness In the connection places and the installation of pipeline accessories, and in addition, according to the water industry standard, the maximum allowable pressure of the water distribution network is determined and limited to an appropriate amount according to the water column. The minimum water pressure in the water distribution network should be enough to have the necessary pressure for the consumer in the pipe at the beginning of each branch. This pressure should provide the pressure drop in the meter and accessories, the floors and height of the building, and the minimum pressure required on the last floor of the building during the peak consumption of the hot months of the year, which is at least 20 meters' column for cities where the construction of buildings up to three floors are allowed. Water should be taken into account in preparing the hydraulic model of the water distribution network to prepare the appropriate exploitation processes that reduce water losses. The maximum pressure range between 20 and 40 meters of the water column will be observed.

Software

Smartening of urban water distribution networks requires the study of existing hydraulic software, to obtain the evaluation of the indicators required for the smartening of the network. Therefore, the hydraulic software should be reviewed according to the level of access to the program, hydraulic capability, connection with other programs, and water quality modeling, and sufficient knowledge of their characteristics should be obtained. EPANET is one of the most powerful software among hydraulic software, which is the basis of the development of much existing software. The availability of mathematical equations is one of the prominent features of smart networks. The existence of these equations requires the existence of SDK, API, or Toolkit so that it is possible to access the text of the program in a suitable mode. To use or provide hydraulic software, the needs of the urban water distribution intelligent network must be known first. The items that should be checked as network requirements include the following items.

• Pressure zone management and network isolation

To provide a solution in the field of network pressure management, pollution and incident management, and other cases, the program in question should have the ability to provide pressure zoning to isolate a subsection of the main network against pollution. Based on the limitations and according to the conditions, this work is done by the hydraulic motor and at the request of the programming algorithms.

• Access to equations

Access to the mathematical equations required by the network to provide a function to display the results in hydraulic software should be considered. The relevant software should not only be able to create the mathematical model of the network but also should be able to zone and isolate the desired parts and optimize the isolated mathematical model.

• Hydraulic solution based on pressure and leakage

Managing pressure and leakage in the network is one of the main goals of network intelligence. Therefore, the ability of the hydraulic motor to solve problems related to pressure and leakage in the urban water distribution network is vital.

• Update and extensibility

Based on the feedback from the development of knowledge, the increase in experience resulting from the operation of the network, and the events resulting from it, the smart network for the management and operation of urban water distribution should be able to improve its performance in managing and dealing with incidents and the special operating conditions can be updated and expandable in sync with their daily operation.

• Communication with other related and partner software

The smart network of urban water distribution management, due to its vastness, should be able to read, analyze and develop in other software environments such as CAD, GIS, SDI, etc. The conceptual scope and volume of data in the system show the connection of hydraulic software with other software as inevitable. Therefore, issues such as water supply management, non-revenue water management, pressure management, event management, passive defense, and quick response to water quality and quantity anomalies in the urban water distribution network should be among the functional features of the hydraulic motor system provided for the system.

Table 2. Comparison of different software according to the access level of the program.

Program	Developed from EPANET	Tool Kit	SDK (Software Development Kit)	API (Application Program Interface)	Source Code	Free
EPANET	-	-	+	-	+	+
AQUIS	+	-	-	-	-	-
Aquadapt	+	-	-	-	-	-
Helix delta-Q	+	-	-	-	-	-
H2ONET/H2OMAP	-	-	-	-	-	-
InfoWaterSA	-	-	-	-	-	-
IWWS	-	-	-	-	-	-
Info Water	-	-	-	-	-	-
Mike Net	+	+	+	+	-	-
OptiDesigner	+	-	-	-	-	-
Optimizer WDS	-	-	-	-	-	-
Synergi Water	-	-	-	-	-	-
STANET	+	-	-	-	-	-
Wadiso	+	-	-	-	-	-
Water CAD/Water GEMS	+	-	+	-	-	-
WatDis	+	-	-	-	-	+
Water NAM	+	-	-	-	-	-
GIS water	+	-	-	-	+	+
GIS pipe	+	-	-	-	-	+
Hydraulic CAD	+	-	-	-	-	-
WATSYS	+	-	-	-	-	-
Pipe	+	-	-	-	-	-
CEDRA-AVWATER	+	-	-	-	-	-
Urbano Hydra	+	-	-	-	-	-
Cross	-	-	-	-	-	-
Eraclito	-	-	-	-	-	-
HYDROFLO	-	-	-	-	-	-
MISER	-	-	-	-	-	-
DisNet	-	-	-	-	-	-
Pipe Flow Expert	-	-	-	-	-	-

Table 3. Comparison of different software in terms of connecting with other programs and water quality modeling

Program	Limitation	WQA (Water Quality Assessment)	GUI (Graphical User Interface)	GIS/CAD/DB
EPANET	Unlimited	+	+	-
AQUIS	-	+	+	+
Aquadapt	-	+	-	-
ENCOMS/CAPCOMS	-	-	-	-
Helix delta-Q	Unlimited	-	+	DXF files
H2ONET/H2OMAP	-	-	-	-
Info Water SA	-	-	-	-
IWWS	-	-	-	-
Info Water	-	-	-	-
Mike Net	From 250 to unlimited	-	+	DB-linked GIS-enabled
OptiDesigner	Unlimited	-	-	-
Optimizer WDS	-	-	integrated	-
Synergy Water	-	-	-	-
STANET	From 200 to unlimited	-	+	Exp-imp integrated
Wadiso	From 10000 to 16000	+	+	CAD interface GIS integrated
Water CAD/Water GEMS	From 10 to unlimited	+	+	CAD interface GIS integrated
WatDis	Unlimited	-	+	Import from Cad & GIS
Water NAM	From 50 to unlimited	+	+	integrated with GIS
GIS water	Unlimited	-	+	integrated with GIS
GIS pipe	Unlimited	+	+	Inte Auto CAD with GIS

Hydraulic CAD	Unlimited	+	+	integrated with AutoCAD
WATSYS	Up to 6000 tubes and nodes	+	+	integrated with AutoCAD
Pipe	From 250 to 20000	+	+	AutoCAD files GIS-enabled
CEDRA-AVWATER	Unlimited	+	+	Integrated with GIS
Urbano Hydra	-	-	-	Created with basicAutoCADd
Cross	Up to 10000 tubes and nodes	-	+	CAD module GIS linkable
Eraclito	From 200 to unlimited	-	+	GIS module DB module
HYDROFLO	Number of 10 sources with 9 branches and 1000 elements	-	+	-
MISER	-	-	-	-
DisNet	-	-	+	AutoCAD
Pipe Flow Expert	From 25 to unlimited	-	+	-

CONCLUSION

The water distribution network is an essential component of urban water supply systems, as it is responsible for delivering potable water to users. The establishment of a decision support system (DSS) is a vital part of smart dashboard systems for controlling the aforementioned network. This paper has been thoroughly examined with the DSS applied in several research. Then, a hydraulic model of the water distribution network, taking into account significant parameters, was discussed. Consideration is given to the pressure and flow rate as two crucial factors. Lastly, the existing hydraulic software are compared in terms of availability, SDK, API, and WQA in an effort to acquire an evaluation of the indicators necessary for network smartening. Based on intended output and distribution network facilities, the analysis revealed that EPANET is the optimal software for Tehran city.

ACKNOWLEDGMENT

The authors would like to thank the Association of Talent under Liberty in Technology (TULTECH) in Estonia for supporting this research project.

CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interests associated with this publication.

REFERENCES

[1]. World Bank. (2021). Water supply and sanitation. Retrieved from https://www.worldbank.org/en/topic/water-supply-sanitation
[2]. Shu, X., & Chen, H. (2019). Study on the sustainable development of urban water supply system management. In Proceedings of the 3rd International Conference on Civil Engineering and Material Science (ICCEMS 2019) (pp. 28-32). Atlantis Press.
[3]. Easterby-Smith M, Lyles MA. The evolving field of organizational learning and knowledge management. Handbook of organizational learning and knowledge management. 2011;2:1-20.
[4]. Maier R, Hadrich T. Knowledge management systems. InEncyclopedia of Knowledge Management, Second Edition 2011 (pp. 779-790). IGI Global.
[5]. Liebowitz J, editor. Knowledge management handbook. CRC press; 1999 Feb 25.
[6]. Chen, Y., Dong, B., Zhang, H., & Gao, X. (2020). A quantitative and qualitative analysis of the urban water supply system. Journal of Physics: Conference Series, 1597, 012066. doi:10.1088/1742-6596/1597/1/012066
[7]. Alzraiee, A., Al-kaabi, S., Al-Yousufi, M., & Al-Tobi, S. (2019). Knowledge management systems in the water industry: A review. Journal of Water Process Engineering, 31, 100875. doi:10
[8]. Marques J, Cunha M, Savić D. A multicriteria approach for a phased design of water distribution networks. Procedia Engineering. 2015 Jan 1;119:1231-40.
[9]. Zhang K, Yan H, Zeng H, Xin K, Tao T. A practical multi-objective optimization sectorization method for water distribution network. Science of The Total Environment. 2019 Mar 15;656:1401-12.
[10]. Zhou, X., Tang, Z., Xu, W., Meng, F., Chu, X., Xin, K., & Fu, G. (2019). Deep learning identifies accurate burst locations in water distribution networks. Water Research, 166 doi:10.1016/j.watres.2019.115058
[11]. Zavadskas EK, Turskis Z, Kildienė S. State of art surveys of overviews on MCDM/MADM methods. Technological and economic development of economy. 2014 Jan 2;20(1):165-79.
[12]. Singh A, Malik SK. Major MCDM Techniques and their application-A Review. IOSR Journal of Engineering. 2014 May;4(5):15-25.
[13]. Parnell GS, Driscoll PJ, Henderson DL, editors. Decision making in systems engineering and management. Hoboken: Wiley; 2011 Mar 16.
[14]. Velasquez M, Hester PT. An analysis of multi-criteria decision making methods. International Journal of Operations Research. 2013 May;10(2):56-66.
[15]. Fazai R, Mansouri M, Abodayeh K, Puig V, Raouf MI, Nounou H, Nounou M. Multiscale Gaussian process regression-based generalized likelihood ratio test for fault detection in water distribution networks. Engineering Applications of Artificial Intelligence. 2019 Oct 1;85:474-91.
[16]. Sanz G, Pérez R. Comparison of demand calibration in water distribution networks using pressure and flow sensors. Procedia Engineering. 2015 Jan 1;119:771-80.
[17]. Das K, Behera RN. A survey on machine learning: concept, algorithms and applications. International Journal of Innovative Research in Computer and Communication Engineering. 2017 Feb;5(2):1301-9.
[18]. Zaidi SM, Chandola V, Allen MR, Sanyal J, Stewart RN, Bhaduri BL, McManamay RA. Machine learning for energy-water nexus: challenges and opportunities. Big Earth Data. 2018 Jul 3;2(3):228-67.
[19]. Kim YH, Im J, Ha HK, Choi JK, Ha S. Machine learning approaches to coastal water quality monitoring using GOCI satellite data. GIScience & Remote Sensing. 2014 Mar 4;51(2):158-74.
[20]. Wang F, Zheng XZ, Li N, Shen X. Systemic vulnerability assessment of urban water distribution networks considering failure scenario uncertainty. International Journal of Critical Infrastructure Protection. 2019 Sep 1;26:100299.
[21]. Jensen HA, Jerez DJ. A stochastic framework for reliability and sensitivity analysis of large scale water distribution networks. Reliability Engineering & System Safety. 2018 Aug 1;176:80-92.

[22]. Cavazzini G, Pavesi G, Ardizzon G. Optimal assets management of a water distribution network for leakage minimization based on an innovative index. Sustainable Cities and Society. 2019 Oct 14:101890.

[23]. Taha AW, Sharma S, Lupoja R, Fadhl AN, Haidera M, Kennedy M. Assessment of water losses in distribution networks: Methods, applications, uncertainties, and implications in intermittent supply. Resources, Conservation and Recycling. 2020 Jan 1;152:104515.

[24]. Soldevila A, Blesa J, Tornil-Sin S, Duviella E, Fernandez-Canti RM, Puig V. Leak localization in water distribution networks using a mixed model-based/data-driven approach. Control Engineering Practice. 2016 Oct 1;55:162-73.

[25]. Caballero JA, Ravagnani MA. Water distribution networks optimization considering unknown flow directions and pipe diameters. Computers & Chemical Engineering. 2019 Aug 4;127:41-8.

[26]. Aşchilean I, Badea G, Giurca I, Naghiu GS, Iloaie FG. Determining priorities concerning water distribution network rehabilitation. Energy Procedia. 2017 Mar 1;112:27-34.

[27]. Soldevila A, Blesa J, Tornil-Sin S, Fernandez-Canti RM, Puig V. Sensor placement for classifier-based leak localization in water distribution networks using hybrid feature selection. Computers & Chemical Engineering. 2018 Jan 4;108:152-62.

[28]. Braun M, Bernard T, Ung H, Piller O, Gilbert D. Model based investigation of transport phenomena in water distribution networks for contamination scenarios. Procedia Engineering. 2014 Jan 1;70:191-200.

[29]. Castro-Gama M, Pan Q, Lanfranchi EA, Jonoski A, Solomatine DP. Pump scheduling for a large water distribution network. Milan, Italy. Procedia Engineering. 2017 Jan 1;186:436-43.

[30]. Perelman, L., & Ostfeld, A. Topological clustering for water distribution systems analysis. Environ. Model. Softw. 2011, 26, 969-972.

[31]. Rasekh A, Brumbelow K. Machine learning approach for contamination source identification in water distribution systems. InWorld Environmental and Water Resources Congress 2012: Crossing Boundaries 2012 (pp. 3171-3177).

[32]. Rashid S, Akram U, Qaisar S, Khan SA, Felemban E. Wireless sensor network for distributed event detection based on machine learning. In2014 IEEE International Conference on Internet of Things (iThings), and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) 2014 Sep 1 (pp. 540-545). IEEE.