Duško Laković [40]
Ministry of the Interior of the Republic of Serbia, Subotica/Serbia

CLIMATE CHANGE AND CITY WATERWORKS

DOI: 10.5937/PIM25163L

Abstract:
The scarcity of water and the population increase on the planet are global problems that will become more and more pronounced in the coming decades. Water is a necessary resource for life and is often taken for granted. At the local level, the city's waterworks supply the population with clean drinking water 24/7. Their complex value chain as well as problems existing in primary activities, require efficient and effective management. With climate changes, as well as trends in the consolidation of cities, the business of city waterworks is under increasing pressure. In this paper, we will deal with some aspects of climate change that affect the city's waterworks and make their operations even more difficult..
Keywords: *City waterworks, Value chain, Climate change, Water scarcity*

Introduction

Without water and air, there are no conditions for life on earth. There is a huge disparity between the water surfaces that make up 70% of our planet and the small fraction of clean water of 0.5% that can be used for drinking. About 2.3 billion people on the planet live in water scarcity and that number is expected to grow. The urbanization process and concentration of people living in points is unstoppable at the global level with 55% in favor of the population living in urban areas. According to United Nations research, predictions are that about 70% of the world's population will live in cities by 2050 [1]. The global fight for clean water began a long time ago.

The role of infrastructure is multiple. Some authors with reason state that it is a materialized condition for the existence and development of basic human activities in an organized space [2]. Social infrastructure consists of standard facilities in the domain of health, education, social care, culture, administration, etc. The technical and economic infrastructure consists of networks and facilities: traffic, water management, energy, communications, etc..

[40] duskolakovic1@gmail.com, ORCiD: 0000-0001-9984-9669

Water utilities provide water to the population and they can usually be organized at the city or regional level. They are part of the narrowest infrastructure, which is often called critical infrastructure, due to its importance, and they carry out their business through a set of complex, intertwined business processes, which extend from taking raw water from the source, processing it through a technological process, and then distributing drinking water to the end consumers who use it. After using the water, it goes into the sewage system, where it is taken away from the consumer, and after treatment, it ends up in waterways. Business requirements in city waterworks are usually such that they need to provide each citizen with a sufficient amount of water 24 hours a day, 7 days a week, while the values of important parameters such as pressure and flow should be within the prescribed limits. Not all waterworks have the ability to provide drinking water for their citizens, but some of them do just that. This means that drinking water, in addition to pressure and flow, must meet the physical, chemical, biological and microbiological prescribed values of various parameters, which are determined by the standard and in accordance with health regulations. Because of this, the pressure on the operation of city waterworks is constantly increasing and can be seen as a multifactor optimization problem.

Water and city waterworks are inextricably linked to climate change. Droughts, rising sea levels, occurrence of floods, fires, reduction of ice fields and other trends of change in natural phenomena directly affect the operation of city waterworks. This paper aims to analyze the mentioned phenomena and their impact on waterworks operations.

Business Model of City Waterworks

In general, a model is a simplification and an idealized image of reality, which allows us to face the real world in a simplified way, avoiding its complexity and irreversibility, as well as all the dangers that can arise from an experiment on the real system itself [3]. Water companies have a complex business, and in order to present it in a simpler way, a value chain model can be used. A value chain is a series of related activities that add value to an organization's products or services [4]. There are two types of activities: primary activities and support activities. Primary activities directly affect the production and distribution of the firm's products and services. The value chain of water utilities has been proposed by OFWAT [5], the regulatory body of England and Wales consisting of water sources, raw water distribution, water treatment, potable water distribution, sales, sewage collection, sewage treatment, sludge treatment and sludge disposal.

The value chain starts with water sources, which serve to supply raw water. At the same time, water sources can be underground or above ground. Urbanization trends are such that the number of inhabitants in cities is increasing, and therefore the need for water is greater, i.e. new sources of raw water.

In the process of distributing raw water, it is transported from the source to the water treatment plant. The accompanying infrastructural elements that make this possible are pipes, valves and pumping stations.

Plants for water processing carry out the technological process of processing raw water into drinking water. Depending on the quality of the water available at the source itself, the number of technological stages, the economy of the procedure and its overall complexity, the process of obtaining raw water can differ.

Distribution of drinking water aims to deliver drinking water from the water treatment plant to the final consumers. It is a complex hydraulic system composed of pipes, valves, pumps, hydro towers and tanks. If the city is located on hilly terrain, then pumping stations are used to push the water to the appropriate height from where it is distributed to consumers by gravity.

Consumers use water, which is charged in the sales process. The water used is calculated on the basis of two independent readings of the measuring device, the water meter, in different periods of time. The difference between the two readings is the amount of water used, which is measured in cubic meters (m3).

The used water is sent through the hydraulic elements to the sewage system, which, in addition to wastewater, also collects atmospheric water. The collected water is taken to the wastewater treatment plant.

After delivery to the processing plant, processing of atmospheric and wastewater is carried out and its negative effect on the environment is reduced.

Sewage sludge is a by-product which results from the treatment of municipal wastewater. Sludge treatment refers to various treatment processes before transporting the treated sludge to a collection point for recycling or disposal.

After processing, the sludge is disposed of or recycled. There are a number of ways to carry out the procedure: recycling by spreading on agricultural land, where it is used as a soil enhancer and fertilizer, then disposal by incineration and disposal in landfills. With this set of activities, the value chain ends, as a business model of city waterworks.

Problems in the Value Chain of City Waterworks

The operation of city waterworks is complex and there are many problems in the primary activities of the value chain. Although in practice there is a much larger number of problems [6], for the purposes of this paper, we will focus on: the problem of contamination and the problem of non-revenue water.

The problem of contamination includes contamination problems of water at the source and contamination of potable water. The raw water used by the waterworks as the main raw material is taken from the source of the water and it has certain values in terms of physical, chemical, biological and microbiological parameters. Depending on whether it is an underground or an above-ground source, the values of the parameters can vary significantly, because the action of numerous other factors on the sources largely determines the mentioned values. Therefore, in most waterworks, continuous sampling of raw water is carried out, their quality is checked, and if there is a risk of contamination, adequate actions are taken to prevent such raw water from entering a predefined technological process. In addition, the economic aspect is not negligible either, because the parameter values affect how profitable the processing process will be. Source contamination is a major health and safety problem for every city and state, and for this reason, constant independent controls are carried out at the state level. The usual practice is that sampling is carried out in a manual way, where later each sample is checked with a series of necessary analyses and it is determined whether the values of all relevant parameters are satisfied. A similar principle applies to drinking water that needs to meet some other set of parameters. Both activities mentioned here aim to prevent health disasters and to enable the long-term supply of resources necessary for life.

The problem of non-revenue water is a global problem of all waterworks and refers to drinking water from which the company cannot generate income, it is composed of a set of problems, where some relate to leakage in the distribution network of the water supply system, then to the reading of the water meters themselves, theft of water, etc. The mentioned set of problems leads to the fact that there are losses of produced water delivered to the distribution network, which have been increasing for years. Losses of drinking water are extremely high and, according to the initial extensive research, they amount to about 32% in the Republic of Serbia and have an increasing trend [7]. In the Republic of Serbia, the losses are higher than in the countries of the European Union, and the areas with the greatest losses are the Raška and Kolubara regions with over 50%. Among the cities, Novi Pazar stands out with losses of 72%, Lajkovac with 66% and Bojnik with even 82%. Water balance is used for a detailed understanding of the structure of water losses [8]. Solving the mentioned problem requires an integral approach of a number of organizational units, which rarely happens in the practice of city waterworks.

Table 1: *Water balance*

<table>
<tr><td rowspan="10">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="6">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility’s Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Source: [8]

Effects of Climate Change on the Operation of City Waterworks

Climate change is a long-term change in the average climate patterns that have defined the local, regional and global climate of the Earth [9]. Climate change and water are closely related either directly or indirectly. Afermentioned changes such as changing precipitation patterns, droughts, shrinking ice sheets, and rising sea levels affect water. The increase in temperature disrupts precipitation patterns, as well as the entire water cycle, thus worsening water shortages, as well as water-related hazards such as floods and droughts [10]. The authors indicate a strong connection between the UN Sustainable Development Goals and water infrastructure components, where some impacts on water infrastructure are given directly and indirectly [11]. Some of the challenges, which also relate to the operation of city waterworks, are: reduced access to clean, safe and accessible water, which leads to a decrease in water quality and threats to the ecosystem; jeopardizing freshwater ecosystems and their services due to increased risk of droughts and floods; obstacles to the efficient use of natural water resources due to water shortages, flood damage and inadequate wastewater management; increased inadequate and unsafe basic water services, leading to increased deaths or affected populations related to water-related disasters.

As a result of major droughts, water sources will be reduced, and thus the capacity of water captured at the source. This creates a problem in water supply because the increasing concentration of people in cities generates a continuous demand for drinking water that is used for a wide variety of purposes. This puts additional pressure on the city's waterworks and their ageing infrastructure, which can contribute to an increase in non-revenue water, which in effect means that an increasing amount of clean drinking water will go unused. It is assumed that these changes will affect above-ground sources much more than underground sources, which may result in changes in the selection of sources, as well as significant additional investments in groundwater extraction if this is at all possible in a certain geographical area. If clean, drinking water is not produced enough, it opens up a whole set of problems that occur in population growth, agriculture, health, environmental pollution, etc. People may choose to use some other sources available to them, but this can be a major health threat as there is a high risk of contamination. In a certain way, the water shortage caused by the drying up of springs forces people to use other possible sources, and this can cause additional problems. An additional problem that occurs in addition to the quantity and quality of water during drought is soil subsidence. This can significantly damage the underground infrastructure predominantly represented in the city's water supply systems.

Rising sea levels can increase the process of salinization of groundwater, thereby contributing to the reduction of available water sources, especially in those regions that are close to the sea.

Floods also affect the operation of the waterworks because on the one hand, they act directly on the contamination of the soil and water sources, and on the other, they can destroy a significant part of the infrastructure and disable the distribution of water to the population. The recovery of infrastructure after a flood is very demanding and extensive, especially when it comes to the distribution of potable water to the population.

Conclusion

The city waterworks business is very complex and can be represented by a value chain model. The shortcomings and challenges in the value chain point to places where they, as the most important infrastructure, are vulnerable. Climate change affects almost every primary activity in the value chain of city waterworks because some problems are directly related to that activity, and some arise from the propagation of activities that precede them. Droughts, floods and rising sea levels increase the pressure on the operations of city waterworks, and it is necessary to look for adequate strategies in the coming years to reduce their impact.

REFERENCES

[1] United Nations. (2019). *World Urbanization Prospects 2018 - highlights*.

[2] Žegarac, Z. (1998). *Infrastruktura*. Geografski fakultet.

[3] Radenković, B., Stanojević, M., & Marković, A. (1999). *Računarska simulacija*. Fakultet organizacionih nauka, Saobraćajni fakultet.

[4] Bocij, P., Greasley, A., & Hickie, S. (2015). *Business Information Systems: Technology, Development and Management for the E-Business* (5th ed.). Pearson Education Limited.

[5] PwC. (2016). *Balance of Risk: Risk and reward across the water and sewerage value chain*.

http://www.ofwat.gov.uk/wp-content/uploads/2015/12/rpt_com201512pwcrisk.pdf

[6] Vesić, S. L. (2023). Use of Data Warehouse in Water Companies. *SETI V - International Scientific Conference SCIENCE, EDUCATION, TECHNOLOGY AND INNOVATION*.

[7] Jovanović, L., Jovanović, D., Veljković, N., Savić, A., & Stanojević, D. (2014). *Sprovođenje Protokola o vodi i zdravlju u Republici Srbiji - analiza stanja*. https://sepa.gov.rs/wp-content/uploads/2024/10/Protokol-o-vodi-i-zdravlju.pdf

[8] Babić, B. & Djukić, A. (2011). Estimation of Water Balance and Water Losses in Water Utilities-Experiences from the Belgrade Waterworks. *Water Research and Management*, *1*(4), 27–34.

[9] NASA. (n.d.). *What Is Climate Change?* Retrieved February 5, 2025, from https://science.nasa.gov/climate-change/what-is-climate-change/

[10] UNICEF. (n.d.). *Water and the global climate crisis: 10 things you should know*. Retrieved February 4, 2025, from https://www.unicef.org/stories/water-and-climate-change-10-things-you-should-know

[11] Ferdowsi, A., Piadeh, F., Behzadian, K., Mousavi, S.-F., & Ehteram, M. (2024). Urban water infrastructure: A critical review on climate change impacts and adaptation strategies. *Urban Climate*, *58*. https://doi.org/10.1016/j.uclim.2024.102132