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Overhauls in water supply systems in Ukraine: A hydro-economic model of socially responsible planning and cost management

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A R T I C L E I N F O

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A B S T R A C T

The poor technical conditions of the water supply systems complicate the quality of urban population life and create a burden on public budgets. We examine the water supply system factors in Ukraine and identify the main parameters that restrain their development. This study examines the development of overhaul planning in water supply systems in Ukraine, taking into account the network equipment-aging factor. We employ a mathematical technique for optimizing the planned costs for overhauls in water supply networks by engaging latent-semantic analysis (LSA). The LSA provides a novel approach to sustainable planning of several economic factors in water supply. The exhibited results underline prominent technical and economic similarities in Ukrainian water supply systems. These results allow us to reveal an unsustainable usage of public funding for overhauls. In addition, the overhaul planning model engaged, improves the Ukrainian water supply sector. It helps the country to abandon the current reactive water management approach and aims towards proactive and sustainable water management. This innovative approach could redefine the public managerial profile, calibrating it towards a socially responsible one, significantly raising the quality of the urban population's living standards.

1. Introduction

Water supply systems (WSS) in Ukrainian cities face a plethora of technical and economic issues primarily due to: i) high levels of water supply networks and equipment depreciation; ii) lack of financing, leading to water pipe failures and iii) high energy consumption and waste of drinking water in WSS (Burak and Yurchenko, 2015). These issues cause a shortage of valuable drinking water resources of an average of 35–40% and excessive power consumption to 4.5 billion kWh or 3.9% of the total power consumption in Ukraine (Pokutsa, 2015). Specifically, Ukrainian water supply networks have the following average lifetime and percentage of the total WSS supply, as follows: i) more than 90 years at a percentage of 35.1%; ii) 75–90 years at a percentage of 19.5% and iii) more than 50 years at a percentage of 22.1% (Statistics JKG portal, 2013). All Ukrainian enterprises use chlorination for water disinfection. In addition, the type of coagulants used can be different: aluminum-containing or iron-containing. It is noteworthy that water treatment equipment is worn-out and in need of repair. All of the above economic and technical factors have a negative effect on the living standards in major Ukrainian cities (Vitale, 2012). Consequently, reactive treatment to repairs, overhauls, replacements or renewals in water supply networks signify unsustainable practices and development (Gazzola et al., 2014). Therefore, the introduction of new hydro-economic models of planning overhauls and cost allocation for the fixed-assets improvement in WSS should reveal a socially responsible profile (Chandler, 2016) for all municipal and other public organizations in Ukraine.

The aim of this study is to explore the cost management and socially responsible planning of the water supply network in Ukraine, using the latent-semantic analysis (LSA) (Landauer and Dumais, 1997).

The first research objective is to identify the optimum frequencies of overhauls in WSS. This objective takes into account the failure rate growth factor of the single-repaired equipment. Current

Abbreviations: LSA, latent-semantic analysis; WSS, water supply system; GRI, global reporting initiative.

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managerial planning overlooks this sustainability factor, and it does not embed unpredictable future costs in the WSS budget (Mays, 2011; Zhang et al., 2008). It is also a compound factor to analyze, as every municipal water supply company in Ukraine has its own technical and economic variables as well as autonomous overhaul planning. Unfortunately, lack of proactive repair-management in water supply networks, in accordance with budgeted time schedules, is essential as the reactive managerial approach bears the danger of insufficient financial and technical allocation of resources to emergency overhauls (Draper et al., 2003). Proactive allocation management of water supply resources and network maintenance is necessary to enable and forecast the expected number of networks and corresponding costs of failures (Gurung and Sharma, 2014). Thus, the resolution of the optimum overhaul frequencies' factor empowers a socially responsible managerial approach, which is critical for sustainable management to further advance the financial planning of WSS.

The second research objective is the realization of a failure analysis in WSS. It is a critical planning factor to predict future occurrences of failure in water supply networks and the corresponding financial costs of their elimination (Kleiner and Rajani, 2001). This is a significant factor, not only for the context of sustainability reporting, but also for cost-effective and efficient goal-setting of water management in WSS planning as well as within their strategies for developing tighter relations with their municipal stakeholders (Mascarenhas et al., 2015).

Finally, the third research objective is to establish sustainable public standards for socially responsible management in emergencies (Lambooy, 2011) by tackling improper planning of overhauls in WSS.

Among the most important findings revealed are: i) overhaul planning and financing has some significant defects and does not satisfy sustainable and socially responsible goals and objectives (Papagiannis, 2017) of WSS fixed assets reproduction; ii) lack of funding for planned overhauls; iii) embryonic functions and sustainability reporting of predicting failures and planning overhauls in WSS; and iv) fragmented information reporting of the water supply networks status. Redesigning the forecast of the number of failures and the necessary costs for their liquidation could upgrade Ukrainian water management and increase the socially responsible profile of the country (Jonkman et al., 2008).

2. Literature review and research hypotheses

Historically, Shamir and Howard (1979) performed one of the first economic attempts to model pipe failures, using a regression model. In the same way, Asnaashari et al. (2013) created a predictive analysis of pipe failures. Furthermore, Weifeng et al. (2011) developed an integrated system for the detection, early warning, and control of pipeline leakage based on geographic information. Berardi et al. (2008) modeled pipe deterioration using Evolutionary Polynomial Regression. This model assists decision-support systems for pipe rehabilitation and replacement planning. Finally, failures of water pipes in urban societies compromise technical and financial abilities to meet ongoing needs for suitable water consumption (Weber, 2002). Therefore, historic economic modeling reveals that water management was, is and will remain of prominent importance for decades to come (Rusca and Schwartz, 2017).

Current sustainable designs should explicitly incorporate the ecological, social and economic perspectives. Social responsibility in water planning demands a redesign aiming towards the efficient water use (Carrasquer et al., 2017), waste elimination and decentralized controlling of the water supply systems and infrastructure. It is evident that there is little socially responsible contribution towards water usage, which results in water supply decrease while global population increases (Apul, 2010; Valentin and Bogus, 2015).

Significant economic-related modeling and investment in water infrastructure are essential to directly address the water shortage and advance beyond mere environmental ideas. Water planning and management have to emphasize sustainable cost-efficient maintenances of the existing infrastructure, rather than the construction of new water supply systems (Harou et al., 2009; Ward, 2009). Efficient management collaboration of water supplies could prevent a water crisis in the future (Uche et al., 2015). Water resources are essential to human life, vigorous environmental practices and higher living standards (Krenkel, 2012). Water is a valuable component of the natural capital, one of the five capitals of sustainable development (Gazzola and Querci, 2017). Water quality is essential for public health protection and provision of the ecosystem habitats (Gazzola et al., 2013). All these prominent factors reveal an ongoing concern to bridge main sustainability gaps, as failing water infrastructure directly affects people's lives.

Social responsibility represents the core values that define the commitment of an organization to society, economy and environment (Porter and Kramer, 2011). According to Bonn and Fischer (2011), sustainability should be considered during the strategic decision-making process as an integral part of the organizational strategy. By adopting a strategic approach to sustainability, organizations are more likely to include economic, environmental and social considerations in all aspects of their activities (Rosenberg et al., 2007; Vanderleeuw and Sides, 2014; Wong and Brown, 2009). These strategic approaches are also aligned with the ongoing and increasing levels of corporate disclosure, commitments and achievements in sustainability (Zuo et al., 2012). The hydro-economic model introduced integrates a sustainable strategy, and significantly contributes towards a socially responsible profile of Ukrainian cities.

As the main WSS of research, we considered the WSS of two Ukrainian cities: Kyiv and Kharkiv. The research motives derive from the following reasons: i) Kyiv and Kharkiv are the first and second most populated cities of Ukraine; ii) the WSS sizes in these cities are the largest in Ukraine; and iii) Kyiv and Kharkiv municipal water companies, according to the nation's history, are the oldest in Ukraine. In Kyiv, the municipal water company has operated since 1872 and in Kharkiv since 1881. Kyiv is the capital and largest city of Ukraine, located in the north central part of the country on the Dnieper River with population nearly 2.9 million people. Kyiv municipal water supply company serves more than 4000 km of water supply networks. Water pipes depreciation in Kyiv is 60–80% (Kyivvodokanal, 2017), which is a critical level for an impending failures or accidents. Water supply networks are served from 11 water supply operating services. Kyiv receives drinking water from three water sources – the rivers Dnieper and Desna, and underground sources. In the overall water supply scheme in Kyiv, the following infrastructure is involved: i) 34 water pumping stations; ii) 364 artesian wells and power supply facilities; and iii) 129 transformer substations. The total capacity of the drinking water supply in Kyiv is 2 million 100 thousand m3 per day. The main problem of the Kyiv WSS is the irrational use of financial resources and the costs for repairs in water supply networks (Kyivvodokanal, 2017).

The Kharkiv WSS, where we also propose the implementation of a planning system for failures in the water supply network with planned costs for their elimination, follows. Kharkiv is the second largest city in Ukraine. It is located in the northeast of the country and has a population of about 1.43 million people. Kharkiv WSS is the largest municipal WSS in Ukraine. It is of prominent ecological importance, as the ecological state in Kharkiv as well as the ecological states of five small rivers and Seversky Donets River depend on its operation. These water resources comprise the main