ABSTRACT

Water infrastructure forms a critical sector of our social system and provides goods and services for public health, the natural environment, economic safety, multiple businesses, and government operations. In the United States, drinking water is supplied nationally through one million miles of pipes, most of which were installed in the early to mid-20th century with a lifespan of 75 to 100 years. Along with this fact, water bills, which are rising faster than inflation, are increasing across the U.S., and communities are grappling with aging water systems, fewer water resources, and extreme weather. The federal government's share of capital investment for water infrastructure has fallen from 31 percent in 1977 to 4 percent in 2017. Regional and state expenditure has accounted for a much larger share as federal aid for water infrastructure capital needs has declined. This led that water rates are rising to cover the costs of replacing and upgrading water infrastructure in many communities across the country. They are struggling to meet them through local rates and fees.

Over the next 20 years, more than 56 million new users are expected to connect to the centralized treatment systems, and $271 billion is needed to meet current and future demands. However, the investment in critical water infrastructure is currently only meeting a fraction of the current funding need. In 2019, the total capital spending on water infrastructure at all levels was $48 billion, while investment needs totaled $129 billion, creating an $81 billion gap. As such, the most recent ASCE Infrastructure Report Card had already assigned a "D" to the drinking water infrastructure and a "D+" to the nation's wastewater infrastructure. Ineffectual and wasteful investment in the water sector causes an adverse effect on grades of the infrastructure report card for water infrastructures. Moreover, this may negatively impact water-reliant sectors and water-related infrastructures due to the economic ripple effect.

This research has developed a data-driven strategic investment decision support system to close the existing water infrastructure investment gap and reduce the vulnerability of aging water infrastructure. The first phase of this study was to determine causes affecting grades of the infrastructure report card for drinking water and wastewater infrastructure and contributing to a latent threat and prolonged risks. It uses leveraging data-driven approaches based on analysis of existing ineffective improvement methods and recommendations. It attempts to leverage a data-driven supervised statistical learning method to capture the complex relationships of new challenges and growing demand for water infrastructure needs. The ultimate outcome of this phase is a research approach to minimizing water and wastewater vulnerability and closing the investment gap to help create a paradigm shift in the current state of practice. Furthermore, improving the resiliency of and increasing investments in the water and wastewater

infrastructure will lead to a resilient, efficient, and reliable water future and protect the public health of future generations.

The second phase of this study was to predict the economic benefits of additional federal support in water infrastructure among interdependent sectors within an economic system for facilitating the federal government's share of capital investment. It conducts ripple effects analysis, which predicts the effectiveness of water infrastructure capital investment using historical economic data. It explores how federal capital investment in water infrastructure spreads economic benefits within an interdependent system. It will be conducted at the federal level using the interindustry-macro model that analyzes macroeconomic data, including over 400 sectors. Investments that will be coordinated at the federal, state, and local level will help control and stabilize rising water rates across the United States.

The third phase of this study was to conduct a benefit-cost assessment in terms of private, financial, economic, and efficiency using nominal and real terms for maximizing the benefit of investing water sector and for reducing the vulnerability of water infrastructures. In order to measure the benefit and costs of a strategy of maximizing the efficiency of limited budgets and resources, this phase conducts a benefit-cost analysis due to the investment costs for rehabilitating and improving water infrastructures using historical economic and financial data. The long-term financial framework including the deep uncertainties for decision-makers to understand the benefit of investing assets for an optimal level versus the cost of doing nothing allowing the asset to run to failure is developed using the cost-benefit assessment.

Finally, a data-driven strategic investment decision support system (DSiDS) that helps governments make water infrastructure development plans and infrastructure investment decisions in the water sector is presented. It can help them in designing a novel system or modifying existing ineffective assessment methods and recommendations aimed at minimizing the mismatch in the water infrastructure investment gap between the current spending levels and funding needs. Furthermore, minimizing risks of ineffectual and wasteful water sector investment through rehabilitating and improving water infrastructures in a rational manner will lead to improving grades of the infrastructure report card and the resiliency of interrelated infrastructures and sectors.