Smart Urban Water Systems

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Urban water systems comprise the infrastructures and operating controls of water supply, wastewater, stormwater, and recycled water systems. They serve the social, constructed, and natural subsystems of living cities and they connect elements of these subsystems through water uses and impacts due to linkages among natural, social, and built systems. A smart urban water system would join the constellation of other smart systems in a smart city, which use computer controls and information to collect data, use that data to improve operations, and communicate with citizens about all aspects of their lives in the cities.

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1. Smart Water Systems in Smart Cities

A smart urban water system would join the constellation of other smart systems in a smart city, which use computer controls and information to collect data, use that data to improve operations, and communicate with citizens about all aspects of their lives in the cities[1]. In a smart city, a smart integrated urban water system would feature infrastructure controls, collection of system and user information, application of the information to control water operations and to inform citizens, and it would be available for emergency management.

The concept is illustrated in **Figure 1**, which shows a system to be controlled and actuators to implement controls based on decisions informed by models and data. The data collection function informs system operators and users as well. Data from the system can be used for operations and troubleshooting. Emergency information can be sent to the actuators.

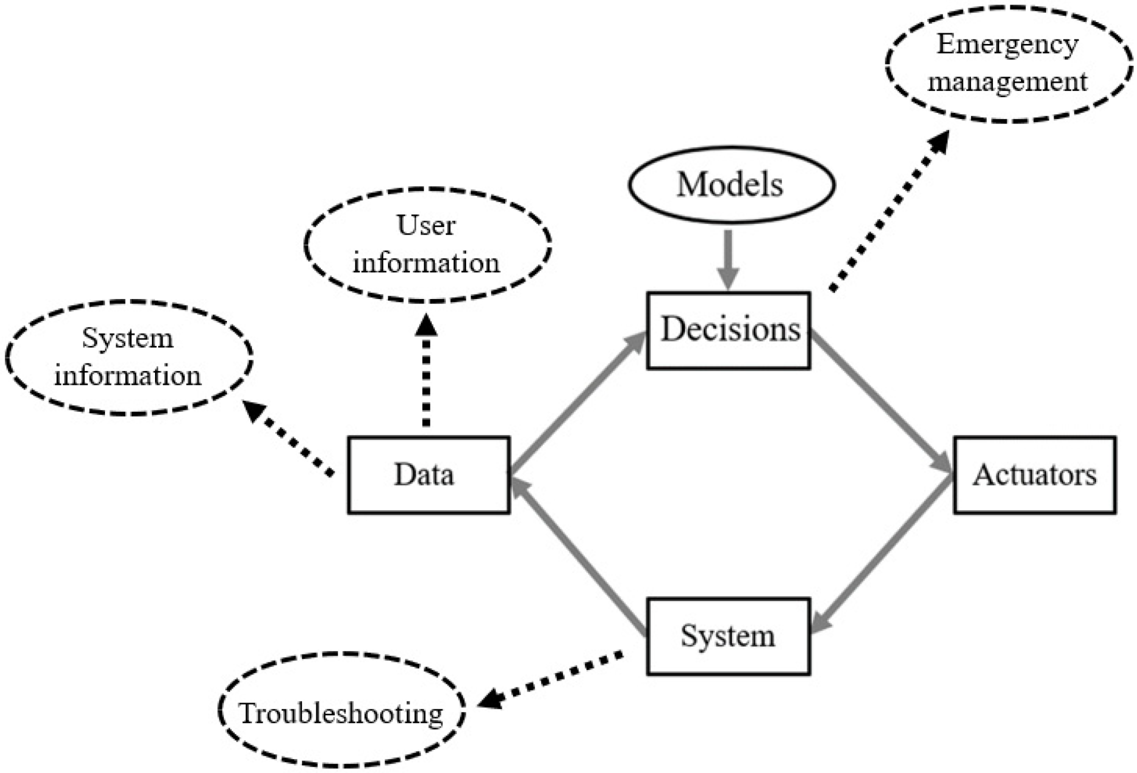

Figure 1. Systems control and information interfaces.

The concept has evolved from the early supervisory control and data acquisition (SCADA) and control systems to today's smart concept [2]. More specifically, prior to the evolution of smart systems, the concept would have not included the transmission of data shown by the dotted lines stemming from the general flow of information and control commands. So, the ability of the smart system to provide the information for operations, customers, and emergency management comprises the most promising new feature.

These features of smart water systems have evolved from the past when information-based controls started with the advent of computers. This led to the development of the SCADA systems, and later sophisticated databases and geographical information systems were added to create technology-based platforms for system management. When personal digital assistants became available around the turn of the century, they were widely used in control and data acquisition functions.

Currently, these technologies have advanced with the development of smartphones, smart meters, and improved process controls [3]. Toward the future, more automation, advanced use of information for system management tasks such as leak detection, and more attention to cybersecurity are expected. Additionally, user information is expected to improve substantially.

2. Controls, Instruments, and Utilization of Smart Water Systems

The advancement of technologies for instrumentation and controls is driving the trend toward smart systems in different sectors of the economy. The concept of smart systems is being applied in cities, for example with smart buildings and smart transportation systems, among others. All have similar attributes based on the availability of sensors, actuators, and controls of subsystems for functions such as lighting, energy management, scheduling, and more.

Advancement in control methods follows the availability of technologies but also learning and experience about successful strategies. For example, in the case of smart water systems, some computer-based simulation models have proved to be useful and effective, while others have been developed but discarded due to lack of practical application. A possible example of this situation is the use of control methods that seem promising but have high levels of complexity and maintenance requirements that create a risk of malfunction. The use of inflatable dams placed inside of combined sewers to control overflows seems to fit this category [4][5]. These were proposed 50 years ago in San Francisco, for example, to address the expensive and perplexing problem of the aging combined sewers. However, their application has been limited.

While much of the interest in smart water systems has been driven by technologies and control methods, how customers use smart water information to help transform cities is more strategic. If the past is a guide to the future, it is expected that technologies and control methods will continue to advance incrementally, new business opportunities will be created, and experts and managers will continue to seek out new methods to experiment with them. Meanwhile, the benefits of these advances to customers and how the evolving smart systems are accepted and improve quality of life in cities remain larger questions. This issue is not limited to smart water systems, of course, because people today are confronted with a rapidly changing information environment which affects their daily lives in many ways.

3. Economic Framework of Smart Water Systems

An economic framework for smart water systems will involve the supply and demand for the public and private goods provided, their direct and indirect benefits and costs, and their linkages and impacts due to interdependences with other sectors. The organization of system management to facilitate collective action is also involved, as are social issues stemming from interactions with system customers and other stakeholders [5].

The demands for water, wastewater, stormwater, and recycled water services are different. The water supply and recycled water are commodities that can be sold like toll goods. Most explanations of water sector demands focus on them, but the demands for other services must also be assessed. Wastewater service comprises carrying unwanted used water away from properties and requires paying a portion of the treatment and disposal. Stormwater service involves draining properties and public areas and paying to prevent pollution from urban runoff. The supply of each of these services involves a combination of responding to demands and meeting mandates.

The direct and indirect benefits and costs of the services stem from the demands that are to be met. The benefits of water supply services involve applying the water for uses that range from meeting essential drinking water requirements to satisfying social needs, like health-related hygiene in the home. For wastewater, the direct benefit to customers is the removal of the unwanted residual water, and environmental protection is an indirect benefit. Stormwater services have multiple benefits, including protecting property and facilitating traffic movement in the city. Their multi-faceted attributes have made them a key part of a sustainability assessment protocol [6]. Taken together, the benefits from urban water services range across multiple categories and cannot be quantified easily.

The indirect benefits of urban water services demonstrate the connector roles of water services to various aspects of the economy and society. They stem from linkages and interdependencies with the other sectors, like employment, housing, energy supply, urban transportation, and the environment. Social impacts from water and its interactions can be considered indirect benefits and costs, and there is a substantial literature discussing how to define them [7].

Smart water systems will operate in the context of these interdependencies during normal and emergency times. For example, quality housing depends on meeting all water demands effectively during normal times. If there is a failure, the quality of the housing deteriorates. In the case of emergencies, the interdependencies can lead to systemic failures. For example, during flooding the failure of a stormwater system might trigger failure if the flooding shuts down a part of an electric power system.

The economic framework also involves the organization of urban water systems to facilitate effective operation and integration. The organization will depend on the structure of government and on public–private cooperation. Each of the services can be a separate utility or various degrees of consolidation and integration can be forged.

Finance is perhaps the most important issue in the economic framework of smart water systems. The management organizations can operate as utilities, but public goods are included among their services, and financing them may require subsidies along with fees for services. Each of the water services has its own financial structure. For example, water supply is like a public utility. Wastewater involves charges that are mandatory and may be offered like a utility, even if its services do not involve the distribution of a commodity. Stormwater has a unique financial structure and has been moving toward a utility model [8]. Recycled water is difficult to finance but is positioned as a utility to facilitate it [9].

By adding smart capabilities to integrated urban water systems new possibilities for effectiveness, equity, and reliability are created. Perhaps the greatest benefits are to fulfill demands more effectively and to extend services on a cost-effective basis to more people. Smart systems with their information and computing technologies should be able to promote integration through linkages for communication and controls. By sensing the status of systems and their performance, greater reliability should be fostered.

In the category of improving performance by reducing failures, smart systems can monitor environmental water quality and water in piped systems to prevent exposure of people to negative situations. Additionally, hydrometeorological sensing networks can provide advance notice of urban flood problems and warnings can be issued. Blocking cyber terrorism is another potential benefit, although the smart capability added by linking the systems may open them to new possibilities for attack [10].

Urban customers can expect more information about total benefits from water services and they can learn more about the total picture of water in cities through education programs. They can also learn about water finance and conservation with information about their bills. Subject to privacy concerns, information can be extended down to the water use of individual fixtures by using the technology of the Internet of Things (IoT).

References

1. What do we mean by a Smart City? . Ministry of Housing and Urban Affairs. . Retrieved 2023-2-16
2. Anton, Simon Duque, Fraunholz, Daniel, Lipps, Christoph, Pohl, Frederic. Zimmermann, Marc and Schotten, Hans D. Two decades of SCADA exploitation: A brief history. IEEE Conference on Application, Information and Network Security. 2017. 10.1109/AINS.2017.8270432
3. Sims, Sean. Evolving control systems are key to improved performance. Control Engineering. 2021. Available online: https://www.controleng.com/articles/evolving-control-systems-are-key-to-improved-performance/
4. Ridgway, Karen and Rabbaig, Mirza. Use of In-Line Inflatable Dams for CSO Control. 2006. Proceedings of the Water Environment Federation. 2006. 5578-5590. 10.2175/193864706783775504.
5. House-Peters, L. A., and Chang, H. Urban water demand modeling: Review of concepts, methods, and organizing principles. . *Water Resources Research* **2011**, *47*, W05401, doi:10.1029/2010WR009624.
6. Envision Sustainable Infrastructure Framework. . Institute for Sustainable Infrastructure. . Retrieved 2023-2-16
7. Cosgrove, W. J., and Loucks, D. P. Water management: Current and future challenges and research directions. . *Water Resources Research* **2015**, *51*, 4823– 4839, doi:10.1002/2014WR016869.
8. Kane, Joseph and Shivaram, Ranjitha. As flood risks intensify, stormwater utilities offer a more resilient solution. 2017. Available online: https://www.brookings.edu/blog/the-avenue/2017/09/21/as-flood-risks-intensify-stormwater-utilities-offer-a-more-resilient-solution/
9. De Paoli, Gloria and Mattheiss, Verena. Cost, pricing and financing of water reuse against natural water resources. 2016. DOI http://dx.doi.org/10.13140/RG.2.2.12270.41289
10. Clark, Robert, Panguluri, Srinivas, Nelson, Trent and Wyman, Richard. Protecting Drinking Water Utilities From Cyberthreats. . *Journal of the American Water Works Association* **2017**, *109*, 50-58,

10.5942/jawwa.2017.109.0021.