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Socially-integrated resilience in building-level water networks using smart microgrid+net

Kemi Adeyeye[a*], Abderrahmane Bairi[b], Stephen Emmitt[a], Katherine Hyde[c]

[a]*Department of Architecture and Civil Engineering, University of Bath, Claverton Down, Bath, UK*
[b]*Thermal and Energetic Engineering Department, Université Paris Ouest, France.*
[c]*School of Construction Management and Engineering, University of Reading, UK*

Abstract

Environmental change and natural events can impact on multiple dimensions of human life; economic, social, political, physical (built) and natural (ecosystems) environments. Water distribution networks cover both the built and natural realms and are as such inherently vulnerable to accidental or deliberate physical, natural, chemical, or biological threats. An example of such threats include flooding. The damage to water networks from flooding at the building level can include disrupted supply, pipe damage, sink and sewer overflows, fittings and appliance malfunctions etc. as well as the consequential socio-economic loss and distress. It has also been highlighted that the cost of damage caused by disasters including flooding can be correlated to the warning-time given before it occurs. Therefore, contiguous and continuous preparedness is essential to sustain disaster resilience.

This paper presents an early stage review to: 1. Understand the challenges and opportunities posed by disaster risks to critical infrastructure at the building level. 2. Examine the role and importance of early warnings within the smart systems context to promote anticipatory preparedness and reduce physical, economic, environmental and social vulnerability 3. Review the opportunities provided by smart water microgrid/net to deliver such an early warning system and 4. Define the basis for a socially-integrated framework for resilience in building water networks based on smart water micro grids and micronets. The objective is to establish the theoretical approach for smart system integration for risk mitigation in water networks at the building level. Also, to explore the importance and scope integration of other social-political dimensions within such framework and associated solutions. The findings will inform further studies to address the gaps in understanding the disaster risks in micro water infrastructure e.g. flooding, and; to develop strategies and systems to strengthen disaster preparedness for effective response and anticipatory action for such risks.

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* Corresponding author. Tel.: +44 1225 38 6113.
E-mail address: k.adeyeye@bath.ac.uk

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1. Introduction

Environmental change and the resulting natural events can impact on multiple dimensions of human life; economic, social, political, physical (built) and natural (ecosystems) environments. Water distribution networks cover both the built and natural realms. As such, they are inherently vulnerable to accidental or deliberate physical, chemical, or biological threats [1].The damage to water networks from natural and environmental shocks at the building level can include disrupted supply, pipe damage, sink and sewer overflows, fittings and appliance malfunctions etc. as well as the consequential social and economic distress. It has been shown that the cost of damage caused is directly related to the warning-time given before the event occurs. Therefore, continuous preparedness over time is essential to sustain individual and collective disaster resilience [2]. However, monitoring systems remain inadequate to support the anticipatory and timely analysis of disaster events at this scale [3]. The emergency-focused risk management approach also means that risks that arise over a longer time, including hazards that occur infrequently, and which take account of dynamic factors such as climate change, population growth and socio-economic change, are overlooked. Therefore, stakeholders do not always fully understand the overall level of risks necessary to make informed resilient judgements.

Early warning systems are used to improve the efficiency of disaster preparedness and response. However, in its analysis of the technological aspects of the infrastructure, the literature has failed to carry out an investigation of early warning process for other areas [4]. This paper is concerned with the importance of early warning in mitigating the impact of physical and natural events on water distribution networks. This is because a gap has been identified in the consistent, long term approach needed to ensure the timely problem identification, preparedness and solution deploying aspects of risk mitigation in water networks.

1.1. Flood risks; challenges and opportunities

Natural events; hydrological, geomorphological or climatological has direct or indirect cause and effect attributable to current and ongoing environmental change. During the past two decades, earthquakes, storms, tsunamis, floods, landslides, volcanic eruption and wildfires have killed millions of people, adversely affected the lives of even more people and resulted in enormous economic damages. 90% of all worldwide natural events – disasters - are water related and it is through water that most of the impact of climate change are felt [5]. In the UK, nearly 1 in 6 properties are currently at risk of flooding, and this number is set to increase as the latest projections indicate the severity and frequency of rainstorms are rapidly on the rise [6]. The impacts will see the cost of flood damage rise fivefold in the UK by 2050, up to £23bn a year [7]. However, flood monitoring systems especially across urban scales remain inadequate to support the timely analysis of flood events [3]. The city system is made up of various components that act as input–output units, including positive or negative feedback loops across spatial levels (Figure 1). Consequently, flood exposure at a certain spatial level is dependent on the interventions implemented at a higher level [8]. At a lower spatial level, the system is composed of interacting parts or subsystems such as buildings, roads and a supporting social economic environment for agents to interact. This is where at-risk residents and property owners can be involved in both the problem identification, preparedness and solution deploying aspects of risk mitigation. In principle, at each spatial level, three types of measures can be put in place to reduce a system's flood vulnerability based on the type of possible responses of a system to floods. These are: reducing exposure; reducing the system's sensitivity and; mitigating the impacts (recovery).

Smart buildings, districts and neighborhoods, and by extension smart cities, is today developed as a potential answer to not just environmental challenges, but challenges created by increased urbanization. It is considered a solution for maintaining necessary supplies of water, energy, communication and transport to meet growing demands in urban centers, and in parallel a mandatory evolution of old and established city infrastructures [9]. And to mainstream climate adaptation across sectors and funding mechanisms [10]. A smart city is characterized by a pervasive use of ICT, which, in various urban domains, help cities make better use of their resources and achieve