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Resilience of critical infrastructures: probabilistic case study of a district heating pipeline network in municipality of Latvia

Maksims Feofilovs*, Francesco Romagnoli

Institute of Energy Systems and Environment, Riga Technical University, Azenes iela 12/1, Riga, LV–1048, Latvia

Abstract

The effects of disasters on communities is a critical issue to be considered in terms of growing exposure of infrastructures to natural hazards. The significant role of the infrastructure systems – and thus their interconnections – is a key for the current urbanization development expected to increase within the next years. Thus, the role of infrastructures should guarantee the support of urban life standards to guarantee public welfare. This aim can only be designed with an enhanced level of infrastructural resilience within the field of crisis management.

The concept of infrastructure resilience is normally linked with the ability to cope with severe disruptions, guaranteeing a minimal level of a specific function of infrastructure itself. This framework provides a useful tool to enable stakeholders to effectively assess resilience strategies that are a key factor for building a resilient infrastructures. Considering this, the aim of this research is to present a resilience evaluation tool addressed to evaluate potential scenarios for enhancing the resilience of a specific infrastructure network and to further identify the most sensitivite assets of that critical infrastructure network.

The case of a real system was examined by the application of probabilistic methods applied to infrastructure network to generate statistical data for the calculation of the district heating (DH) pipeline network resilience of a municipality in Latvia. The study clarifies how resilient the district heating system is to a specific hazard and what could be the effect of specific investment scenarios aimed to enhance resilience. It will also identifies the most resilient assets of the DH network system and thus determine the main features of a DH systems that are important to ensure overall infrastructure resilience.

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Keywords: district heating system; probabilistic simulation; network modelling; case study

* Corresponding author. Tel.: +371-26733409.
E-mail address: maksims.feofilovs@edu.rtu.lv

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1. Introduction

Safe environment is a necessity for community development and critical infrastructure is vital for sustaining the 21st century community as they support most human needs. Critical infrastructure is usually considered as energy, water/sewage, telecommunication, transportation infrastructures [1–3]. Failure of any type of critical infrastructure can result in a cascade of failures in other infrastructures [4]. Unfortunately, with a growing population, urbanization, resource consumption, waste production and pollution, we keep on creating potential risks to natural and manmade disasters [5].

On this matter, the Sendai framework for disaster risk reduction 2015–2030 [6] was developed by United Nations Office for Disaster Risk Reduction and adopted in Third UN World Conference to fight disaster risks world-wide. It defines global targets like the reduction of disaster risk as an expected outcome; the goals are focused on preventing new risks, reducing existing risks, strengthening resilience, in an all-of-society and all-of-State institutions engagement. The Sendai framework introduces the goals, but solutions still must be developed step by step as the 21st century unfolds, an increasing majority of the world's population will live in cities. By 2050, the UN expects 80 % of the world's population to live in urban areas. Half of these are in small- and medium-sized cities [7].

There is an underlying assumption that resilient cities are far less vulnerable to hazards and disasters than less resilient places. But for this assumption to be validated and useful, knowledge of how resilience is determined, measured, enhanced, maintained, and reduced is vital. Specifically, it is not obvious what leads to resilience within coupled human-environment systems or what variables should be utilised to measure it. Several studies have attempted to highlight the fundamental aspects of resilience [8, 9], but because of the multi-dimensional and cross-disciplinary nature of resilience, a broad model of resilience has yet to be empirically tested at the community or city level [10, 11].

Human wellbeing in cities relies on a complex web of interconnected institutions, infrastructure and information. People are drawn to cities as centres of economic activity, opportunity and innovation. But cities are also places where disruptive events such as a disaster may result in social breakdown, physical collapse or economic deprivation. In the next decades, the major driver of the increasing damages and losses from disasters will be the growth of people and assets in harm's way, especially in urban areas [12].

Information about a city's susceptibility to disruption from hazards that is based on the status of a city's institutions, economy, and physical and social structures is already a topical issue [13]. Comparable information on cities is particularly useful, as it gives characteristics of urban development and provides confidence for policy directions that lead to better resilience [14]. This information is useful to many stakeholders, from residents and planners to national governments and international agencies.

Nevertheless, the term resilience is still indistinct as there is little regarding what it means to society, what factors are describing it and how cities might achieve greater resilience to increasing threats from natural and human induced hazards.

Findings suggest that different resilience systems have been developed of which some have been applied in real life, none of those are applicable on a regional or global scale as they are developed considering only a specific case [15–17]. A major challenge is the creation of a joint model for cities that implies identification of the metrics that can support policy action on a global scale and to develop action-relevant metrics that can be applied to hazards in cities with radically different geographical, infrastructural, economic, social, political and cultural characteristics.

The concept of infrastructure resilience is usually linked to an ability to maintain the functionality of the network through shocks and disruptions [18]. Some studies have introduced metrics for evaluation of the networked infrastructure resilience [19, 20]. In research of Leon F. G. Alanis et al. [21] a probabilistic method is carried out to evaluate the resilience of a water distribution network that is considered a critical part of infrastructure. According to Leon F. G. Alanis this method can be used for other types of networked infrastructure, like energy infrastructure. However, that study does not take into account customer based solutions for building resilience in disaster mitigation and preparedness phase [22], as for example of energy infrastructure, those would be energy efficiency measures [23, 24].

This study applies the Gay Alanis methodology to investigate a district heating (DH) system in a municipality in Latvia (i.e. Ludza). With the application of this method, the performance of the DH system can be determined under a specific damage and recovery time with respect to a well-functioning state. This information is a valuable tool for investors to find the solutions that will improve resilience of an infrastructure.