Why smart might not be resilient – The relevance of cascading effects for adapting critical urban infrastructure to climate change

1. Introduction

Cities are key players with respect to climate change. They are not only contributing to climate change, they will also be affected by expected climate change impacts such as urban floods after heavy rain events or heat stress, which will most likely occur more frequently and with increasing intensity in the future. This is why cities need to adapt on time to protect inhabitants, assets, and elements of critical infrastructures.

The relevance of climate change mitigation and adaptation is also highlighted in the Global Risks Report 2017 based on perspectives from about 750 experts on the perceived impact and likelihood of 30 prevalent global risks as well as 13 underlying trends and their interconnections. Based on the World Economic Forum Global Risks Perception Survey 2016, climate change was on second place. And for the first time, all five environmental risks (extreme weather events, natural disasters, failure of climate change mitigation and adaptation, biodiversity loss and ecosystem collapse, man-made environmental disasters) in the survey were ranked both high-risk and high-likelihood, with extreme weather events emerging as the single most prominent global risk.

At the same time, cities and regions all over the world are increasingly trying to become smarter. Therefore also urban critical infrastructure need to be smarter in a sense that they are more intelligent and interconnected in order to integrate multiple information as well as new information and communication technologies (ICT) to manage city's assets. Smart cities are often seen as a city model both enabling long term economic growth and well-being of citizens. However, they mostly focus only on making infrastructure smart in normal operation and everyday use, whereby longer periods of dysfunctioning are often not considered.

The main research questions we discuss in our paper are as follows: i) will current smart city infrastructure elements still be smart and resilient when they are exposed to external shocks like climate change impacts? Are smart cities by definition also resilient cities? Or will smart cities finally be even more vulnerable due to the growing complexity of critical infrastructure and their multiple dependencies?

2. Methodology and preliminary results

Based on a review of past as well as possible future climate change induced cascading effects, our current study analyses where critical interdependencies of different components exist and how they interact with other critical infrastructure sectors or elements. Thereby the specific relevance of cascading effects for critical infrastructure will be highlighted at the background of smart cities and their dependency on energy supply.

In general, critical infrastructure describes assets that are essential to maintain vital societal functions. Therefore, failures or functional impairments can have immediate and high impacts on several sectors as well as to the whole society. On a national level in Germany, for example, average total outage costs are expected to be around 430 Mio €/h, peaking at 750 Mio €/h on a Monday in December between 1 p.m. and 2 p.m. A missing gigawatt hour creates average outage costs of about 7.6 Mio €. Also on a regional level, electricity blackouts as a consequence of a failure in the power supply can cause significant economic losses. If electricity supply would decrease by one GWh, Berlin is expected to suffer losses of around 12 Mio € on average. Furthermore, interactions between critical infrastructure in different sectors like communication, information technology, water supply, wastewater treatment, transportation, healthcare and public health as well as emergency services have become a growing phenomenon as they are not only one point of potential vulnerability but may also compound existing vulnerabilities and carry them across multiple infrastructure sectors and elements.

Critical infrastructure is exposed to various kinds of threats. There are man-made or technical (terrorism, sabotage, software failures etc.) and natural threats. The latter differ from geological (mass movements, earthquakes etc.) to hydro-meteorological hazards (climate change impacts), whereby in particular climate change induced extreme weather events are a main trigger of cascading effects related to critical infrastructure.

Cascading effects in general are the dynamics present in disasters, in which the impact of a physical event or the development of an initial technological or human failure generates a sequence of events in human subsystems that result in physical, social or economic disruption. Thus, an initial impact can trigger other phenomena that lead to consequences with significant magnitudes. Cascading effects are complex and multi-dimensional and evolve constantly over time.

Within our paper we focus on the relevance of climate change impacts for critical infrastructure and cascading effects. Thereby we make an important contribution to a growing literature in this field that, however, currently is mostly based on analyses regarding other causes for cascading effects like cyberattacks, human failures or terrorism.

Our study is based on how current developments like smart grids or smart cities are rapidly shaking up the formerly to a greater extend existing interdependent set of critical physical infrastructure networks on which regions and cities depend.

This growing interlinking of infrastructure elements is leading both to opportunities for innovation, but also complex, specific and rather novel risks. Furthermore, the economic value of physical infrastructure networks in cities increases with its scope. For instance regarding information and communication technology, the more people a network connects, the more useful it becomes. For supply infrastructures like energy and water, the connection of more people is in theory often expected to lead to more resilience and leverage necessary economies of scale. Furthermore a greater connectivity of, for example energy infrastructure, is thereby expected to lead to more intrinsic resilience, because electricity networks with more supply points, would be less prone to failure.

However, as different infrastructure networks become more interdependent, there is also a growing – and currently often still underrated – scope for systemic failures to cascade across networks and affect society in multiple ways.

The example of the relations and interactions between the water and energy sector show, that disruptions in energy supply affects water supply in a broad sense (see figure 1). Thereby, the water supply is directly affected by an electric power failure because pumps and control elements do not work without electricity. This leads to a breakdown of water supply. The missing water supply has an impact on many other public facilities such as health care and public transport. With respect to waste water treatment, the missing water supply starts a second cascading step, because the malfunction of sewerage system elements like sewerage treatment plants has a further impact on other public facilities, too. Consequently, adaptation strategies for cities need to focus on the whole system not only on single infrastructure elements.

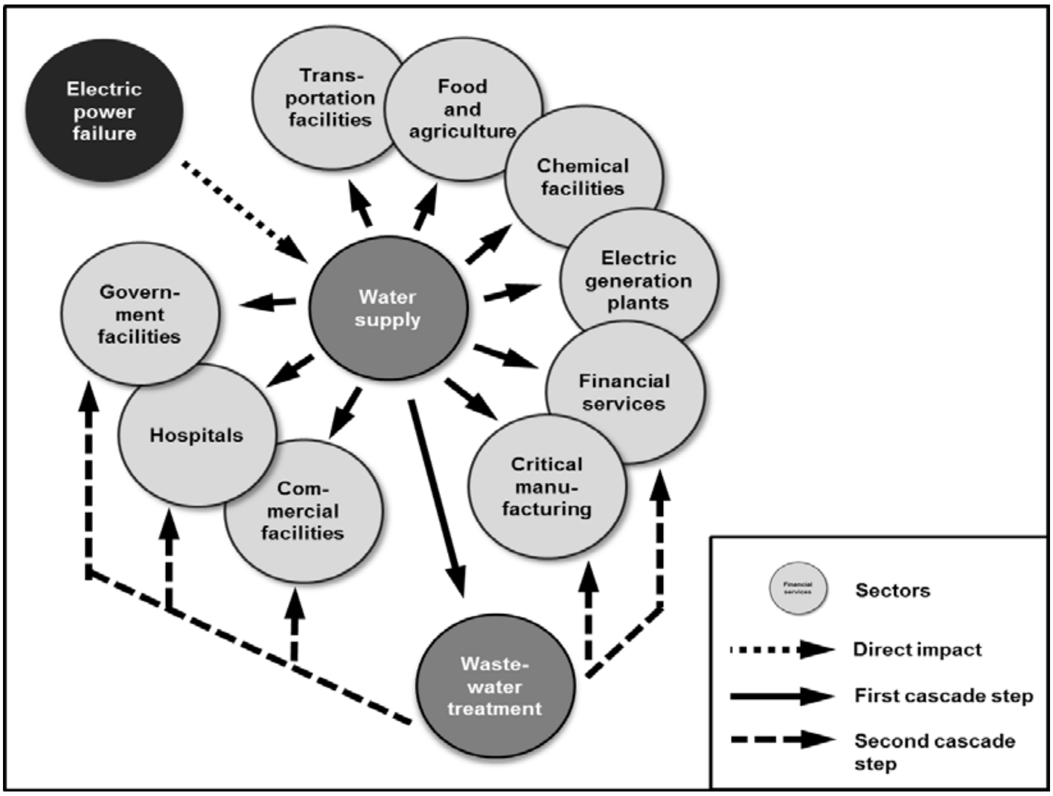

Figure 1: Cascading effects using the example of the energy-water nexus.

Hence, our study aims to prepare the ground for innovative approaches supporting cities and regions in adapting critical infrastructure to expected impacts of climate change. Therefore we outline challenges for adaptation, discuss most common approaches and argue why current adaptation strategies based on using best practice examples, databases or web portals have shortcomings and do in most cases not provide sufficient support. Based on these findings, an innovative, practice-oriented approach will be introduced that allows a flexible and customised support to adapt to expected impacts of a changing climate.

3. Conclusion and practical relevance

Climate change is already impacting and will continue to impact regions, cities and municipalities, whereby responding to climate change involves both mitigation to address the cause and adaptation as a response to the changes. Local councils are key actors when it comes to the implementation of adaptation measures in order to improve the overall resilience of local territories in various fields such as water, energy, health and transportation. Thereby, increasing cities resilience to climate change impacts is highly context specific, due to its geographical location, structure, institutions, inhabitants and operational capability.

Furthermore, cities and regions are increasingly dependent on information and communication technology networks in particular, which have their own dependencies and vulnerabilities. Within our paper, we highlight – by assessing the climate change related risks associated with a greater interdependence among different critical infrastructure networks – the need for decision makers in municipality authorities to understand risks and resilience in a whole by paying more attention to systemic risks regarding critical infrastructure and cascading effects.

Thereby, we highlight, why adapting critical infrastructure is a complex, highly context specific, multifaceted issue, especially when it comes to dealing with cascading effects between different sectors. Therefore the paper is of relevance for practical solution in order to deal with current knowledge gaps regarding how infrastructural interdependencies operate and how procedures and policies might improve the adaptation to climate change, especially focussing on making smart cities resilient – because cities not being resilient will never be smart.