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Urban Resilience: considering technical and social infrastructures in complex human environments

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"What makes a city resilient? What enables a devastated metropolis to rebuild its physical fabric and recover its social fabric and cultural identity?"[1]

1 Introduction

The urban space has always been one where opportunities and challenges are abundant. Layers of infrastructure, people, and economic interests create a complex fabric of interests and vulnerability, often referred to as the 'built environment'. Cities are one of the clearest examples in modern societies where people must always interact with technical structures when going about their daily lives. This fundamental interaction raises important issues for managing vulnerability and resilience in urban spaces.

Today, continually increasing population densities[2] within urban areas are compounding social and infrastructural complexity. At the same time issues such as global economic interdependence and environmental change are creating or exacerbating vulnerabilities that sit along a broad spectrum of risks and threats, which can be concentrated or diffuse, fast or slow-moving. In the face of such shifts, the role of establishing, enhancing or maintaining resilience in the urban space has become an exceedingly important, though difficult task.

On the one hand, cities are often referred to as a 'system of systems' – a mixture of socio-technical entities where production, supply and consumption chains that sustain urban functions are supported not only by social institutions and governance networks, but also by the built environment. The built environment includes buildings, neighborhoods, complex transportation and telecommunication lines, electrical networks, *etc.* As Alberti et al. (2003) aptly note, cities "have rich spatial and temporal heterogeneity—a complex mosaic of biological and physical patches in a matrix of infrastructure, human organizations, and social institutions."[3] Unpacking and understanding this complexity is challenging, let alone defining or understanding its resilience, particularly because complex socio-technical systems represent constantly evolving and dynamic spaces that cannot be simply understood as the sum of their parts. Indeed, resilience can and does mean different things to different parts of a complex system, thus invoking such questions as: Resilience of what and to what? Resilience for whom and against what?[4] Along this line, Giroux and Prior (2013) debated whether "resilience was about returning to a pre-disturbance state quickly? Or does resilience also involve change and transformation, which might result from experiential learning and the development of adaptive capacities?"[5] Indeed, answering such questions in the context or urban systems is not straightforward and requires a nuanced understanding and appreciation of the socio-technical system.

While the built environment, made up of critical infrastructures, enables the circulation of goods, knowledge, meaning and people within the urban space, it can also raise challenges. On the one hand, urban systems can be challenged by their innate and systemic complexity, particularly in relation to the various issues that impact cities' vulnerability. These issues include increased and changing demands on services, meaning of infrastructure (for social systems) and its deterioration (often caused by ageing), and the effects of various hazards from social unrest and terrorism to climate change and extreme weather events, to name a few. Consequently, Coaffee (2013) aptly describes how resilience has "come to symbolize the response to a range of environmental crises and economic recessionary 'shocks'."[6]

In the 2013 CSS study "Preparing for Disasters in Global Cities: An International Comparison"[7], Prior and Roth addressed the topic of urban resilience by examining the management of disasters in cities around the world. Related to this study, we continue our examination of resilience in the urban space, but divert by focusing on critical infrastructure resilience and uniquely draw out its interdependent relationship with critical social infrastructures (CSI), which include services such as health services, insurance, relief organizations, etc., that often help communities cope with the impact of CI disruptions. Together, critical *technical* infrastructures and critical *social* infrastructures represent two fundamental elements in socio-technical systems. CSIs are important assets with important functions that can be placed within a discussion on urban resilience, and connected to the way

1 Campanella, T.J. (2006): Urban Resilience and the Recovery of New Orleans, Journal of the American Planning Association, 72(2), p. 141.

2 More than half of the world's populations live in cities, with over 1 million people migrating to such areas each week. Kilcullen, D.J. (2012): The City as a System: Future Conflict and Urban Resilience, The Fletcher Forum of World Affairs, 36(2), p. 22.

3 Alberti, M. et al (2003): Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. BioScience 53(12), p. 1171.

4 Hassler, U. & Kohler, N. (2014): Resilience in the built environment. Building Research & Information, 42(2), p. 122.

5 Giroux, J. & Prior, T. (2013): Expressions of Resilience: From 'Bounce Back' to Adaptation. Factsheet, Risk & Resilience Team, Center for Security Studies, ETH Zurich, p. 4.

6 Coaffee, J. (2013). Rescaling and Responsibilising the Politics of Urban Resilience: From National Security to Local Place-making. Politics 33(4), p. 241.

7 Prior T. & Roth, F. (2013). Preparing for Disasters in Global Cities: An International Comparison. Center for Security Studies (CSS), ETH Zurich. Available at: *http://www.bevoelkerungsschutz.admin.ch/internet/bs/en/home/dokumente/Unterlagen_Risiken.parsys.60231.downloadList.85825.DownloadFile.tmp/preparingdisastersglobalcities.pdf*

that social systems can be managed and develop adaptive features or capacities during crisis. In this report, we review urban resilience literature and highlight case examples that illuminate two noteworthy debates in the context of urban resilience, and particularly the role of critical social infrastructures in urban resilience. The first concerns the CI ownership debate between the public and private sectors within the context of building resilience, while the second issue examines the role that land-use and urban planning play in contributing to urban resilience. We conclude with some implications for Switzerland – a country that is experiencing growth in its urban centers and surrounding areas.

> *"Resilient Cities are constructed to be strong and flexible rather than brittle and fragile... their lifeline systems of roads, utilities and other support facilities are designed to continue functioning in the face of rising water, high winds, shaking ground and terrorist attacks."* Godschalk (2003)

2 Critical Infrastructure & Cities: Understanding Vulnerability & Resilience

The notion of socio-technical complexity, with its different implications for resilience and shifting vulnerabilities, calls for enhanced understanding of resilience in urban environments. Yet, gaining this understanding is complicated by the self-organizing nature and systemic complexity of the urban environment where risks are often endemic. In this section, we position our analysis of CI resilience by first conceptualizing CI vulnerability in the urban space and then move to a discussion of resilience. Notably, key themes in this analysis are the aspects of interconnectedness and interdependencies between different elements in the urban system, which can exacerbate or create new points of vulnerability for critical infrastructures. In addition, we highlight how urban resilience connotes a sense of 'pro-activeness' and consider how 'precautionary governance'[8] has gained currency in related policy discourse. In this respect, rather than focus on the technical components of CI resilience, which have been exhaustive, we emphasize that CI resilience within cities is better understood with an appreciation of the role that critical social infrastructures (CSI) play in helping a community cope with the immediate and adverse effects caused by disruptions or damages to the built environment. Indeed, given its emphasis on self-organization, CSI's are particularly relevant to the urban resilience discussion, because the social characteristics of a technical infrastructure (management, maintenance, design, etc.) ultimately play a considerable part in the resilience of that technical structure.

2.1 Unpacking Vulnerability

Many of the inherent aspects of the city that create vulnerabilities are closely associated with the same characteristics that make them attractive places for people to live, namely the economic, social and technical services around which they are constructed.[9] Yet, the density of people, resources, and networks that exist in urban environments creates enormous complexity that can enhance or shift vulnerabilities, making failures, if not more likely, then certainly more consequential. Based on existing literature considering CI resilience in the urban space, we delineate three dimensions of vulnerability: ecological, social and technical (which also includes virtual or cyber networks). Figure 1 illustrates and highlights the key points within each of the dimensions.

The ecological element is the first and overarching dimension of CI vulnerability in the urban space. This dimension considers how the environment impacts the vulnerability of critical infrastructures through factors such as adverse ground chemistry, surface loading (or

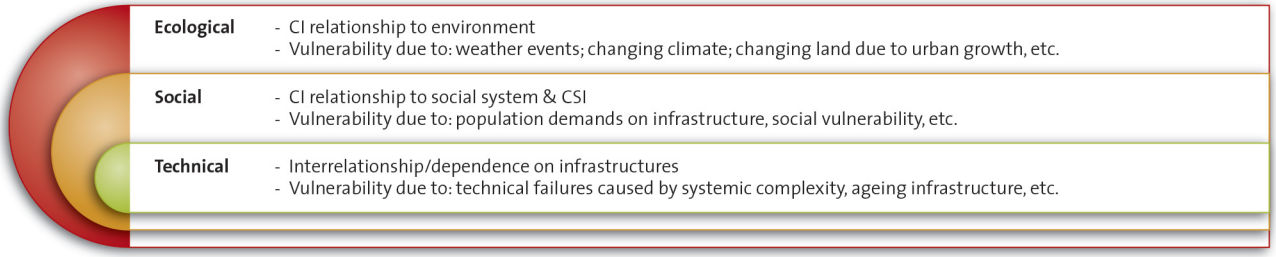

Figure 1: Interactive dimensions of vulnerability

8 Coaffee, J. (2013), p. 242.

9 Prior T. & Roth, F. (2013), p. 19.

infrastructure weight per square unit of surface, *etc.*), and extreme climate events – such as powerful storms – or gradual climatic changes.[10] For example, rising sea levels or melting glaciers are often associated with the increased threat of flooding that in turn threatens elements of the built environment or technical spaces that society relies on. However, addressing and reducing shifting vulnerabilities is no easy task, but rather one that requires a lengthy process of assessing the "implications of changing conditions on the efficacy of different approaches to planning, design, operation, management, value and governance."[11] In the last decade alone, there have been numerous examples that have shown the vulnerability of CI embedded in natural systems. Of note, the 2011 Tōhoku earthquake and tsunami in Japan not only caused major damage to the region's nuclear power plants, but has also changed the discussion of the vulnerability of nuclear infrastructure in an age of climate change. In New Zealand, many communities have been exposed to numerous events such as earthquakes of 2010 and 2011, riverine flooding and coastal erosion and storms that have put significant pressure on the built environment.[12] Consequently, city planners are looking at ways to improve the safety and sustainability of at-risk communities, which may include providing incentives to relocate people to lower-risk areas. Such portraits of vulnerability not only point to the interconnection that CI has with the ecological space, but also how vulnerability can shift over time due to changing conditions. This may result in difficult decisions about the limits of planning and design.

The second vulnerability element concerns the interactions between CI and the social dimension. Infrastructure is built to support urban functions and to serve the population's requirements. However a changing climate coupled with growing population in cities places new demands on CI, which can further impact vulnerability. Of course, the weakness or vulnerability of CI (such as aging bridges or weak levees along a coastline) can put people in harm's way just as its robustness (such as using more durable building materials for homes or burying electrical infrastructure) may positively influence a community's ability to cope and/or quickly bounce back after a crisis. Another consideration of this interrelationship concerns vulnerable populations (such as the young, disabled, etc.) who require assistance during a disaster or have limited access to critical social infrastructure (like knowledge about how or where to access disaster management resources or services).[13] Of course, during a disaster the vulnerability of the social system can shift depending on location of impact, strength of infrastructure, etc. Consequently, people rely on "social infrastructure such as health services, insurance and compensation for the loss of sources of livelihoods to help them recover."[14] Granted, many CI classifications include 'public health' or 'emergency services' as part of CI sectors; however, we use CSIs as a way to unpack these sectors and reveal the key social components and self-organizing behaviour. What's important to note here is that just as we highlighted how CI vulnerabilities can shift, social vulnerabilities can be created or exacerbated by certain weaknesses in urban development as well as disaster planning and management processes precisely because critical social infrastructures change.

Thirdly, beyond the ecological and social dimensions, the technical dimension of maintenance and adaptation of CI is a key area. Cities act as important nodes that connect local, regional, national and international networks. Therefore, the maintenance of these networks has significant implications for the vulnerability and sustainability of the city itself, as well as for other locations connected in a city's critical infrastructure network. If CIs are not maintained or developed to meet the changing needs of a city's population, social structures or environmental conditions, then technical failures are likely to become more frequent.

Woven together, identifying and understanding the aforementioned dimensions of vulnerability is a key part of the discussion on CI resilience in the urban space. However, there are two particularly important and novel points to highlight before delving more deeply into the next section on resilience: the assessment challenges that accompany a population-dense space that is characterized by uncertainty, flux, and complexity; and the relationship between CI and CSI.

Firstly, while certain hazards will continue to be key issues of concern, how these hazards are changing and what that will mean for the future creates unpredictability and uncertainty. For example, a specific type of storm that might be common to an area may determine how CI is constructed or maintained, and influence the vulnerability of certain populations in relation to their built environment. As we have alluded to, climate change presents a wild card in that its impacts on city life – many of which are predicted – is still clouded in uncertainty in terms of the actual impacts, their intensity and trajectories. Vulnerability assessments can only go so far as they are often dealing with old data in a rapidly changing

10 Leichenko, R. (2011). Climate change and urban resilience. Current Opinion in Environmental Sustainability, 3, p.164.

11 Hassler & Kohler (2014), p.121.

12 Glavovic, B.C. et al (2010). Realising the potential of land-use planning to reduce hazard risks in New Zealand. The Australasian Journal of Disaster and Trauma Studies, ISSN: 1174–4707.

13 Cutter et al (2003)

14 Jamil, S. and Amul, G.G. (2013). Community resilience and critical urban infrastructure: Where adaptive capacities meet vulnerabilities. NTS Insight no. IN13-07, December. Available at: *http://www.rsis.edu.sg/nts/HTML-Newsletter/Insight/NTS-Insight-dec-1301.html*

space. In response, one approach to 'risk uncertainty' is the development and use of national 'risk registers' (inventories of hazards relevant for a country, often related to disasters and emergencies) to direct efforts and risk management resources (*e.g.* in the Netherlands and United Kingdom).[15]

Secondly, while the ecological and technical dimensions (Figure 1) are often addressed in discussions about CI vulnerability, the relationship between and vulnerability of CI and CSI within the social dimension has not factored as prominently. Granted CIs represent built (and increasingly virtual) systems, but within the framework of contemporary debates about disasters (which are often framed as 'extreme', 'historic', and 'costly') as well as urban vulnerability, CSIs play an increasingly important (but subsidiary) role in how urban systems 'bounce back' and recover. In many cases, when CIs fail due to a hazard event, CSIs can be there to cushion the fall and provide another layer of support – or, to take a term from resilience studies, a type of redundancy – until CI can be restored. For instance, during a crisis the shutdown of hospitals often results in the social system shifting health services to other spaces, such as parks or some other type of building that provides shelter, or providing mobile care. It can even mean more decentralized efforts like those expressed during Superstorm Sandy. In one example, depleted petrol supplies resulted in a huge disruption to the social system's ability to cope with the disaster. Consequently, Gas Buddy (a US online cheap fuel finder) created a "fuel shortage tracker"[16] that provided people with updates on open gas stations and fuel availability. Such efforts are not typically associated with discussions about CI, but are nevertheless notable and represent another layer of supportive social services. Building off of these considerations, we continue by looking more closely at CI resilience in the urban space, elaborating more on the risk uncertainty factor as well as the CI-CSI relationship.

> *"Resilience is a wonderful metaphor. It somehow conveys in a single word the qualities of bending without breaking, of healing after an injury, of tensile rather than brittle strength. Oak and palm trees are resilient to the power of strong winds, before which they bend and then straighten again. Resilient people pick themselves up after being knocked down, draw on their reserves of ideas and strength to deal with difficult challenges, or hunker down until the gale has blown itself away. Resilient economies bounce back, and resilient ecosystems restore themselves after the fire or the flood has passed"* Vernon, (2013)

2.2 Urban Resilience

Given the shifting vulnerabilities outlined in the previous section and the growth of the urban space, the concept of 'resilience' has become increasingly popular and important in the last decade.[17] Resilience, like vulnerability, is largely used to denote a general state of an entity like a city, or city system component, such as: this community or that infrastructure is 'resilient'; the individual's 'resilience' has decreased, etc. This rather static conception of resilience has become increasingly supplemented by a more adaptive positioning of the concept. For example, resilience is considered to encompass a process that links resources to build adaptive capacity as well as to outcomes like adaptation, readiness and response, which can reduce vulnerability.[18] Framed another way, urban resilience can be viewed as a "network of various adaptive capacities across different areas – economic development, social capital, information and communication as well as community competence."[19] Additionally, addressing the 'risk uncertainty' factor highlighted in the previous section not only means accepting the limitation of vulnerability assessments, but also building up adaptive capacities, such as robust critical social infrastructures (CSIs) which enforce the ability to plan and enact (social and structural) preparations, to mitigate exposure and reduce sensitivity to CI failures and to strengthen response capabilities.[20]

Before delving more deeply into this discussion, it is important to offer some perspective regarding the overarching resilience of the modern city. Despite increasingly complex urban systems, which are often constructed in known natural hazard areas, modern cities show an impressive capacity to rebound from catastrophic events. Since the beginning of the 19th century, virtually no modern city has been lost permanently.[21] Modern cities are rich in resources and expertise and therefore gain a degree of inherent resilience, which we argue can be attributed to three key factors:

- First, states have certain economic and political interests in keeping their cities running. They are key economic hubs as well as sources of national pride and identity;

15 Hagmann J., Cavelty M.D. (2012): National risk registers: Security scientism and the propagation of permanent insecurity. Security Dialogue, 43(1), pp. 79–96.

16 See: http://www.gasbuddy.com/sandy

17 Adgar (2006); Giroux and Prior (2013)

18 Berkes (2007)

19 Jamil, S. and Amul, G.G. (2013)

20 Prior et. al (2013)

21 Campanella (2013), p. 141.

- Second, the critical and close relationships between technical and social infrastructures attract close attention in the context of reconstruction following disturbance or damage, as well as some form of shelter during the period of reconstruction;
- Third, the increasingly complex and layered networks of urban infrastructures make the urban space complicated. The persistence of concrete foundations in the event of a disaster and the sunk costs in infrastructure almost guarantee rebuilding efforts.[22]

Yet, urban resilience goes beyond simply rebuilding destroyed and damaged CI. The performance of CSIs in relation to CIs, and the networks created by the interdependencies between these social and technical elements in the urban system define the essence and identity of a city. Urban resilience could therefore be considered as to how well the social elements and the technical elements of the system interact and support one another.

An instructive example of the importance of social infrastructure for the resilience of an urban environment lies in the danger posed by an epidemic: in such a case the built environment and technical infrastructures are left intact, but the social infrastructures are devastated, possibly including mass exodus of people, abandonment of critical infrastructures and their maintenance.[23] In the case of Hurricane Katrina, both the social fabric and physical infrastructure was damaged, leading to evacuations of large parts of the population to resettlement areas, and negative and interconnected consequences for both the technical and social infrastructure of New Orleans. Elements of both remain damaged and neglected almost a decade after the storm, attesting to the complexity of adequately recovering these interdependent urban elements. Ultimately, like vulnerability, CI resilience in the urban space must defined in a very broad sense that captures the various social, cultural, technical and economical interconnections, particularly those relating to CSI.

Of course, despite the (at least partly) autonomous development of these various systems, in order to be resilient they must be managed, organized and controlled in a distributed fashion that incorporates flexibility. As noted by numerous studies on resilience, the main factors that must be considered include the following (as illustrated in Figure 2): redundancy, flexibility, reorganization, learning and revision.

Discussion of CI resilience in cities often refers to the **redundancy** of CI systems, which is often referred to as linear and design-based concept. In our conceptualization, CI redundancy can refer to back-up power (*e.g.* generators), for example, but it can also refer to back-up CSI. For example, when power failures left half of New York City in the dark after the 2012 Superstorm Sandy, CSI

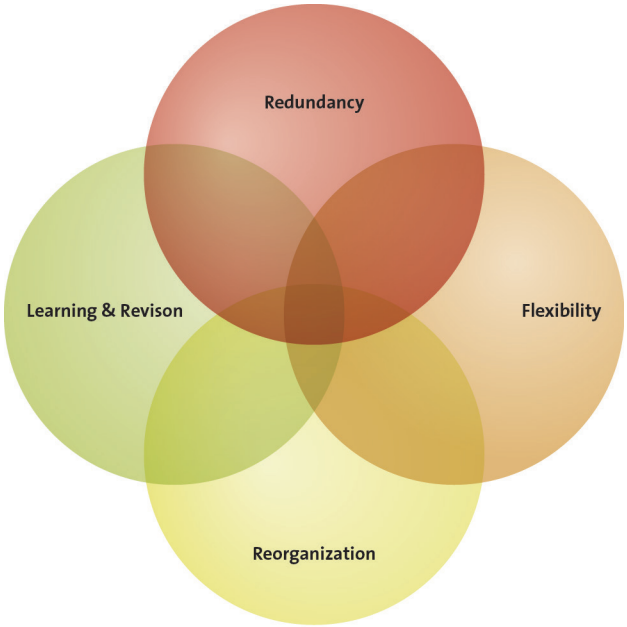

Figure 2: Four factors of an urban resilient system

services emerged to provide centers where people could gain access to electricity until traditional services were restored. Typically, redundancy measures are factored and built into the system before a crisis occurs.

Increasingly, many unique response measures are emerging that are signals of adaptive capacities and **flexibility**. Examples of flexibility are often found in relief and, more *ad-hoc,* volunteer efforts that emerge during a crisis. To note, during the February 2014 flooding disaster in the United Kingdom a website was created within five hours that allowed volunteers to offer time, supplies and resources.[24] Such *ad-hoc* efforts operate alongside more traditional or formal relief efforts, such as those offered by the Salvation Army.[25] Such examples provide a portrait of critical social infrastructures that have self-organizing, emergent properties.

Indeed, examining the urban space holistically reveals an incredibly dynamic system that is able to absorb shocks in ways that avoid catastrophic failure – and in many respects this ability to avoid failure is very much a socially driven phenomenon. Individuals, and with that CSI, can be flexible during a hazard event, whereas there is less inherent flexibility and adaptability in fixed technical systems. In other words, where CI redundancy might fail during a hazard event, the partnered nature of CSI may confer the necessary flexibility to adapt the technical system to the circumstances and ensure the delivery of the essential services normally provided by CIs. For example, *ad hoc* shelters powered by generators can

22 Ibid, p.142.
23 Ibid.
24 See: http://floodvolunteers.co.uk
25 See: http://www.salvationarmy.org.uk/uki/Northwest_floodrelief

provide people with certain temporary services until power is restored.

Similarly, the ability to **reorganize** is another key component of the urban resilient system and one that is driven by the social elements of a system. An example of proactive reorganization is found in the Netherlands where a legal tool called "land re-adjustment" has been adapted to include areas that are below sea level and thus most at risk for flooding. According to Russell: "When a community is threatened, its land is re-allocated elsewhere and property lines redrawn."[26]

As such, CSIs hold the ability to **learn and revise** actions and processes based on past experiences, and to identify and address relevant problems to ensure that actions are taken on the basis of relevant information and experiences. Within the urban space this factor is applicable to both CI and CSI as separate domains, but also in relation to each other. For example, during a hazard event, certain CI vulnerabilities can be illuminated, which then lead to actions that address those vulnerabilities post-event by strengthening technical assets and implementing redundancy measures. These measures may include strengthening critical social infrastructures to help people cope during and post-crisis until CI can be restored, or to ensure CI *can* be restored.

3 Noteworthy Examples

This section turns to a more practical discussion of two examples that illustrate the themes of CI vulnerability and building resilience in the urban space. The first revisits the issue of CI ownership, where the trend toward private ownership is slowing because of growing vulnerability concerns. Recent disasters, mainly caused by extreme weather events, have led some municipalities to reconsider CI ownership due to concerns that private owners of CI do not (or cannot) make adequate investments in the CI that enhance resilience. This is particularly the case if these investments do not create profit. The second example examines the role of urban planning in resilience building. In this discussion we find that the urban space is becoming a site for adaptive planning that leverages social innovation and capital to influence the design of the built environment.

3.1 Vulnerability Concerns: Debating CI Ownership

Public private partnerships (PPP) were born out of the privatization of critical infrastructures and are one of the most commonly discussed topics in critical infrastructure protection (CIP) debates. Today a majority of CIs are privately owned, thus bringing public and private partners to the table to coordinate security and protection of such assets. However, in an age of 'risk uncertainty', some state bodies are considering whether to keep CI assets in the hands of private entities or reclaim ownership. Concerns about contemporary hazards (particularly climate change) have some government officials questioning whether private, and thus profit-motivated, owners of CI will make the same necessary investments to CI, and risk-related decisions, to reduce vulnerability and enhance resilience, especially if those actions reduce profit (or at least don't make money). Examples of the de-privatization trend are rare at this stage, but they are worth mentioning within the context of this study and the potential trajectory of this development. Within the United States in particular, two large cities, Minneapolis and New Mexico, are considering de-privatizing their private utilities, while other US states are looking into ways to de-privatize public infrastructures, or at least give municipalities the option to do so.

The main argument behind the de-privatization movement is that public owners of CI are more accountable to cities' inhabitants – and are ultimately responsible for societal safety and the function of critical services. In the US, as Cardwell explains, government-owned utilities "are nonprofit entities that do not answer to shareholder. They have access to tax-exempt financing for their projects, they do not pay federal income tax and they tend to pay their executives salaries that are on par with government levels, rather than higher corporate rates." In turn, "revenue is re-invested in maintenance and prevention, which can result in more reliable services and faster restorations after power failures."[27] This argument gains traction when considering the resilience of power grids during recent storms. For example, in Massachusetts, after Hurricane Irene (2011), municipally owned utilities, which employed more people to take care of power lines, were "severely affected but were able to restore power in one or two days, while investor-owned companies like NStar and National Grid took roughly a week for some customers."[28] In parts of Florida, publicly owned utility companies are using revenues to relocate

26 Parry, W. Future Disasters: 10 Lessons from Superstorm Sandy. Live Science, 28 January 2013. *http://www.livescience.com/26640-future-disasters-lessons-superstorm-sandy.html*

27 Cardwell, D. Cities Weigh Taking Over From Private Utilities. New York Times, 13 March 2013. Available at: *http://www.nytimes.com/2013/03/14/business/energy-environment/cities-weigh-taking-electricity-business-from-private-utilities.html?pagewanted=all&_r=0*

28 Ibid.

wires underground due to the region's strong storms and tendency for storm-caused power failures.

However, what seems to be missing from these discussions is any indication of whether shared ownership can lead to implementing resilience building measures. Thus far the debate continues to be dominated by PPPs, with ownership lying in the hands of private entities, or this emerging discussion about de-privatization in the face of growing complexity and shifting hazards. Clearly, from the perspective of network governance there are multiple entry points for adaptive planning and redundancy building measures that do not fall squarely in the hands of only private or public entities, but are rather shared ventures.

3.2 Building More Resilient Cities: The Role of Planning

The second noteworthy example in the discussion on CI resilience in urban spaces is the role of urban planning. In 2012, 400 delegates gathered for the third Resilient Cities 2012 workshop in Bonn, Germany, to discuss a number of issues, particularly the role that urban planning can play in reducing vulnerability. Thinking about the urban space and how that will or should change in the future brings together a diverse set of actors that can examine the various domains of urban (and thus CI) vulnerability, and identify ways to mitigate risk by enhancing the resilience of CI and, to some extent, CSI. These discussions mainly centered on new design methods that address issues of vulnerability, or even making CI flexible, as a way to enhance urban resilience. In many respects, they are not only concerned with reducing vulnerability, but also aim to tap into *revisioning* (figure 2) the future design and functionality of CIs in cities.

Another example that highlights the role of urban planning is the United Nations International Strategy for Disaster Reduction (UNISDR) guide "How to Make Cities More Resilient", which provides certain guidelines for planning that are not only structural, but also consider the need to build the critical social infrastructures that become key resources for people in strife. The accompanying handbook "Ten Essentials for Making Cities Resilient" outlines the following recommendations:[29]

1. Put in place *organization and coordination* to understand and reduce disaster risk, based on participation of citizen groups and civil society.
2. Assign a *budget* for disaster risk reduction and provide incentives for communities to invest in reducing the risks they face.
3. Maintain up-to-date data on hazards and vulnerabilities. Prepare *risk assessments* and use these as the basis for urban development plans and decisions.
4. Invest in and maintain *critical infrastructure that reduces risk,* such as flood drainage, adjusted where needed to cope with climate change.
5. Assess the *safety of all schools and health facilities* and upgrade these as necessary.
6. Apply and enforce *realistic, risk compliant building regulations and land-use planning principles.* Identify safe land for low-income citizens.
7. Ensure that education programs and *training on disaster risk reduction* are in place in schools and local communities.
8. *Protect ecosystems and natural buffers to mitigate* floods, storm surges and other hazards to which your city may be vulnerable.
9. Install *early warning systems and emergency management capacities* in your city and hold regular public preparedness drills.
10. After any disaster, ensure that the *needs of the affected population* are placed at the center of reconstruction, with support for them to design and help implement recovery measures.

In line with our previous comments about the complexity of the urban space and necessity for holistic analysis, these recommendations take into account improving CI and CSI as well as enhancing the resilience of the social system in general. However, besides these few examples, it is still unclear how extensively built environment professionals have been folded into the discussion on resilience building, and whether there is a broad understanding of the various ways to embed resilience into urban design and function. What type of capacity building is needed? What skill sets are necessary for planners to be able to effectively work with other professions such as CI professionals, business continuity experts, emergency responders, natural and social scientists, *etc.*? Regardless of these questions, in light of urban growth and the potential for disasters to hit cities, urban resilience planning will likely be a persistent topic in the foreseeable future.

29 United Nations Office for Disaster Risk Reduction: http://www.unisdr.org/campaign/resilientcities/toolkit/essentials

4 Conclusions and Implications for Switzerland

The increasing concentration of people, industry and infrastructure in urban areas is a trend that will persist. How cities respond to and adapt to such growing pressures combined with a changing, more volatile risk terrain is an ongoing process that remains to be adequately assessed. While disasters represent a time of upheaval and loss for those affected, it also creates a space for learning and reflection. Concerning CI resilience in the urban space, we have not only learned that urban vulnerability is intertwined with the broader environment, making it difficult to unpack and separate from the broader system, but also that CSI can be viewed as an important, and often overlooked, component of the discussion. Finding ways to develop urban resilience should not simply focus on finding ways that technical services can be maintained during disruption, but it should also consider how social flexibility and adaptability contribute to the response to disruption and to supporting critical social institutions and infrastructures.

We discussed two noteworthy examples that explored the issues of vulnerability and resilience: changing patterns of CI ownership and the need to incorporate resilience thinking into urban planning. How will major disasters change the debate on the ownership of CI? Will some contexts be more susceptible to change in ownership than others? Will people eventually put more pressure on private CI owners to embed resilience into design and operation of critical infrastructures? As observed in the US, some municipalities are already making the shift back to publicly owned assets. However, such shifts are not necessarily a positive trend and do not guarantee success or immunity to risks and failures. In Switzerland, understanding how responsibility for CI resilience is ensured, either through PPP arrangements or separate service-oriented legislation, for example, will be a step towards developing resilience in urban areas.

The second example covered the important role that planning will increasingly play in enhancing urban resilience. Rampant urbanization that fails to consider the risk environment, risk exposure, and the changes that continue in both, as well as demographic changes, may create an urban future that is even more volatile and challenging. Without considered planning and foresight, urban spaces have the potential to become places where people compete for limited services, which may in turn hinder their capacity to adapt to disturbance events, and bouncing back from a disaster may become a lengthier endeavor. However, the growth of urban areas and a changing climate are relatively slow moving developments, which create opportunities for creative and proactive planning to prepare for future challenges and enhance CI (as well as CSI) resilience.

Within the context of such analysis, land and urban planning can be examined by focusing on cross-cutting and collaborative measures such as Switzerland's five-partner initiative *'Raumkonzept Schweiz'*.[30] This is an interesting example of an attempt to address some of the pressures associated with increased population density, CI pressures and competition for space that can complicate the process of achieving urban resilience. This initiative specifically addresses:

- the promotion of settlement quality and regional diversity;
- protection of natural resources; direction or coordination of population mobility;
- a strengthening of the spatial framework for a competitive and diverse economy;
- coordination of regional diversity for efficient and effective society and economy.

Such initiatives are important and could be analyzed by examining shifting vulnerability and the measures being used to enhance resilience. Indeed, while CI or CSI are not explicitly featured, they are clearly embedded in this initiative and could be analyzed in a future study.

For Switzerland specifically, more research and analysis is needed to both examine the way the nation's urban environments are changing and how CI and CSI vulnerability and resilience are factoring into this picture. For instance, within Switzerland what constitutes critical social infrastructures, and are they formal or informal? How do people, communities and institutions interact with CI, and are their examples where CSIs have mitigated CI disruptions during crises like power outages or flooding? Importantly, urban environments are composed of both social and technical elements, and understanding urban resilience is a matter of understanding how these seemingly disconnected elements interact. Critical technical infrastructures are critical exactly because of the critical service they provide to society. Yet, society (individuals, organizations and governments) must contribute to designing, maintaining and properly managing these technical infrastructures to ensure the services they provide can persist. As such, building urban resilience in Switzerland should draw on an integrated understanding and management of a broad range of factors, including the interaction between critical technical and social infrastructures, urban organization and planning, risk analysis (natural, political, technical, *etc.*), and demographic change.

30 Bundesamt für Raumentwicklung ARE: „Raumkonzept Schweiz"- Überarbeitete Fassung (2012): *http://www.are.admin.ch/themen/raumplanung/00228/00274*

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