A Resilience Framework for Smart Cities

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ABOUT THE PAPER

Resilience is receiving growing attention as a tool for improving the capacity of urban or regional systems to respond to the variety of challenges they face. This paper illustrates a nine-box resilience framework which can be used by cities to review and enhance the resilience of the systems they manage. It is also part of a forthcoming book on Smart Cities which will be published by College Publications (London).

KEYWORDS

Resilience; smart cities; nine-box framework.

A Resilience Framework for Smart Cities

"Resilience, in short, is largely about learning how to change in order not to be changed. Certainty is impossible. The point is to build systems that will be safe when they fail, not to try to build fail-safe systems."

Brian Walker (2013)

Introduction

Resilience is receiving growing attention as a tool for improving the capacity of urban or regional systems to respond to the variety of challenges they face. Given the difficulty in translating an abstract concept such as resilience to practical action on the ground, the ambition should be to bridge the conceptual and the practical without overly compromising either: Resilience requires deep systemic understanding, while governments require visible and impactful interventions. In this paper we present a framework that could be used to achieve both these objectives. We illustrate each of the aspects of the framework and describe how it applies in concrete cases.

This framework was developed over two years from 2012–14, when nine multinational companies collaborated to deepen their understanding of what role they might play in building the resilience of the socio-economic systems they provide goods and services to. Would their offerings need to be different? Would the nature of their relationships change? Would this require the acquisition of new competencies? Prompted by a series of CEO conversations at the World Economic Forum, the project led to a final report titled *Turbulence* (Kupers, 2014) before dissolving. The tools and insights generated continue to be applied by the companies themselves. They have also been applied more widely, for example by the Rockefeller Foundation's 100 Resilient Cities initiative.

What is resilience?

There are varying definitions of resilience but we choose to emphasise two particular aspects. We find this distinction helpful in developing practical interventions.

The first aspect is the ability of a system to bounce back from stress. The stresses a city faces can be different in nature: they may be chronic or acute, exogenous or endogenous, natural or social, knowable or unknowable. The system can be a bungee cord, someone's body, a company or a city, etc. Bouncing back is important, but if it were only that, it would be mere robustness. Robustness is building ever higher dikes to protect cities against floods, like in New Orleans or Amsterdam; or to make buildings earthquake-proof like in Tokyo.

The magic of resilience comes with learning — this is the second aspect. This is when the system becomes smarter and more resistant through friction with the external world; just like a child's immune system which becomes smarter when injected with weakened bacteria. This is crucial to the adaptive capacities of cities. At a resilience workshop in 2014, the chief resilience officer of New York City David Zarilli said that they were trying to understand social resilience by focusing on what was unique about communities that self-organised best in the aftermath of Hurricane Sandy. Boosting the capacity of communities to learn and self-organise is harder, but cheaper, than just building more infrastructure. The former also builds more resilience. This second aspect also holds the key to transformation: learning enables the system to transform and stay in a new state, especially when it is not desirable for the system to return to its original state.

That said, we may not always want to maximise resilience. Some systems are too resilient, such as those of organised crime or even a benign social structure where change is overdue. In those cases resilience must be reduced, so as to create new options and possibilities. In organisations, reducing undesired but resilient cultural norms is frequently done through departmental reorganisation and movement of key personnel. For cities, participatory tools such as open space technology, appreciative inquiry, citizen juries and deliberative polling have been used to frame and structure conversations which seek to break resilient but dysfunctional or outdated structures and mental models.

Resilience is a property of a complex adaptive system. It emerges as a result of many interactions within the system (Colander and Kupers, 2014). As such it is a global property, but it does not equate to the sum of its parts. A collection of very resilient cities does not necessarily make a resilient country, just as a collection of great sports people does not automatically make a great team. Hence we should be cautious when designing resilience metrics. There is natural interest in developing resilience metrics, but it can be counter-productive. This is because "measuring and monitoring a narrow set of indicators or reducing resilience to a single unit of measurement may block the deeper understanding of system

dynamics needed to apply resilience thinking and inform management actions" (Quinlan, 2015). Focus on achieving one of the metrics may inadvertently lead to suboptimal outcomes at the broader systemic level. In most cases, a qualitative discussion about resilience measures should take priority over a detailed set of quantitative resilience metrics.

Another point to note is that efficiency often comes at the expense of resilience. It is difficult and unpopular to argue against efficiency. Yet many losses in resilience come about through relentless optimisation drives. The reverse does not hold; not all efficiency reduces resilience. Wasting food is clearly inefficient and does nothing to build resilience. On the other hand, the relentless focus on efficiency in agricultural systems has brought great benefits but also reduced resilience with the loss of biodiversity, erosion of soil quality and loss of livelihoods. The trade-offs between resilience and efficiency constitute one of the more challenging and impactful aspects of applying a resilience frame.

The nine-box framework

To help practitioners understand and discuss these aspects of resilience, a nine-box frame has been developed. The frame has been tested through urban and corporate cases in various cities and regions. The resilience aspects are organised in groups of three and described below.

Structural Resilience	Integrative Resilience	Transformative Resilience
Redundancy	Multi-scalar interactions	Distributed governance
Modularity	Thresholds	Foresight capacity
Requisite diversity	Social cohesion	Innovation & experimentation

The Nine-Box Resilience Framework

Structural resilience — the systemic, infrastructure-related aspects of resilience; i.e., redundancy, modularity and requisite diversity.

1 — Redundancy refers to spare capacity or 'fat' in the system. This is often the most straightforward but also most costly way of building resilience. Sometimes it may not be politically or financially feasible. Examples of redundancy include: the spare tyre of a car, additional staff to deal with unexpected peaks, spare capacity in a power grid.

An interesting phenomenon in recent years is the rise of the sharing economy that is challenging the notion that redundancy is costly. Companies such as Airbnb and ridesharing BlaBlaCar have enabled cities to boost their short-term capacity in rooms, cars, courier services etc. relatively quickly and inexpensively. However, when the sharing economy simply translates hidden spare capacity into production, it is increasing the efficiency — but doing nothing for resilience. It is the dynamic tapping of spare capacity that is enabled in the sharing economy that builds resilience.

2 — Modularity refers to loosely-coupled components. When one part of the system is affected, the components can be separated and recombined to continue operations. Well-designed modularity means that the system can be re-combined in many ways to respond to changes in the environment. For example, the shipping container is designed with fixings and dimensions that can work well across multiple modes of transport — road, rail and sea. However, one needs to be careful of "fake modularity". The 2008–9 Financial Crisis demonstrated "fake modularity" as financial companies and institutions were much more strongly connected than previously perceived. When the crisis hit, it became clear that they had behaved in a similar fashion, without fundamentally diversified risks.

3 — Requisite diversity: Diversity reduces business risks. Workforce diversity also enables different responses in times of crisis. However, increasing diversity may reduce efficiency in the short term. Rather than diversity for its own sake, it is important to consider what types of diversity are relevant for particular circumstances, hence *requisite* diversity. Examples include the effort by the public service to include more diversity in thinking through mid-career recruitment, secondments and cross-postings. Another example is the mixing of commercial, residential and recreational facilities in urban planning to build neighbourhood character and avoid the problem of deserted streets in the central business district in the evenings.

Singapore's water story — From vulnerability to strategic advantage

While Singapore is surrounded by seawater, it is water-scarce because of its limited land to store rainwater. The World Resources Institute ranks Singapore as an "extremely high water stress" country in its assessment of 180 countries, ahead of Saudi Arabia and Kuwait (Reig *et al.*, 2013).

To cope with Singapore's water vulnerability, PUB, Singapore's National Water Agency has been testing and using new water technologies since the 1970s. PUB, which manages the whole water loop in Singapore, pursues three key strategies: It collects every drop of water, reuses water endlessly and desalinates more seawater.

Two-thirds of the city-state serves as water catchment and the rainwater collected is stored in 17 reservoirs. The city-state also imports water from neighbouring Malaysian state Johor under a 1962 water agreement. To further increase its water supply, Singapore desalinates seawater into drinking water. Used water from the system is also reclaimed and purified into high-grade water of drinking-water standards known to Singaporeans as NEWater. The different sources — local catchment water, imported water, NEWater and desalinated water — make up Singapore's **Four National Taps**.

Singapore's diversified supply of water reduces its reliance on any one source of water. In particular, NEWater and desalination build modularity into the system by decoupling water supply from freshwater availability. That said, desalination uses more energy than conventional water treatment and PUB is continually researching ways to improve the energy efficiency of desalination. NEWater creates a multiplier effect in water yield, as the bulk of the water supply is used and re-used. The current NEWater process turns 75% of feed water (i.e., treated used water) into NEWater and PUB is studying ways to improve this water recovery rate. To make the water supply more sustainable, PUB has been relentless in promoting water conservation and minimising water leakage. At 5% of total water production, Singapore's 'unaccounted for water' (or, water lost in the pipelines during transmission) is one of the lowest in the world.

Nevertheless, at 151 litres per day, domestic water consumption per capita remains higher than desired. Recent efforts to reduce water consumption include mandatory submission of water efficiency management plans by large non-domestic water users and the study of behavioural insights to reduce demand for water. Saving water amounts to a 'fifth tap', adding further diversity.

Source: Singapore's National Water Agency PUB, Presentation by Chief Engineering & Technology Officer Harry Seah, June 2016

Integrative resilience emphasises the complex interconnections of the system, i.e., multi-scalar interactions, thresholds and social cohesion.

4 — Multi-scalar interactions characterise the relationships of the system under consideration with other systems at different scales around it. Scales can be geographical (e.g., neighbourhood, city, province and nation) or temporal (short, medium and long term). From empirical studies as well as theoretical insights, it appears that the ability to understand a system at multiple scales, both above and below the focal scale which one is operating in, is crucial for building resilience. This is because feedback loops operate across scales and have an impact on the focal scale. It is the quality of the links between the scales that strongly influences the resilience of the system.

5 — Thresholds are often excluded from standard policy narratives. Whether it is the Global Financial Crisis or the sudden almost universal disuse of plastic bags in Ireland in 2009 within three months after introducing a very small tax on bags; these step-changes are often unanticipated. Frequently, a system functions in a stable mode for what seems a long time then once past a threshold the system begins to work in unexpected ways. Examples include shifts in industry competitiveness, neighbourhood attractiveness, transport capacity and the impact of pollution.

Discussions and plans about the future almost always project smooth and gradual change. We rarely anticipate discontinuities that occur as a result of thresholds being crossed. Many threshold events are impossible to forecast, but that does not mean sudden change should not feature in planning. Envisaging thresholds, even unknown thresholds, can build resilience and adaptive capacity to deal with them, when they arise.

6 — Social cohesion can contribute much to resilience. As mentioned above, the city of New York studied how social cohesion helped neighbourhoods self-organise in the aftermath of Hurricane Sandy. Self-organising capabilities, social norms and trust levels within the existing system all have an impact on policy options. A key point of resilience is how to increase the self-organising capacity of societies.

Sidewalks as parks

"Public space is for living, doing business, kissing, and playing. Its value can't be measured with economics or mathematics; it must be felt with the soul."

Enrique Peñalosa, Mayor of Bogotá (1998–2001, 2016–)

Like many developing country metropolises, Bogotá was increasingly grid-locked from a rapid rise in car ownership. Mayor Peñalosa recognised that this was much more than a transportation problem, and that there was also a profound social equity issue. Rather than focusing exclusively on the traffic problem, he spotted an opportunity for addressing a number of other interconnected problems made worse by cars.

His insight is that sidewalks are much more than roads for pedestrians; they are more akin to parks than to transportation. They are a place where people meet and mingle, where social cohesion is built. In practice the few sidewalks that existed were being occupied by parked cars. In addition to the roads, the small minority of Bogotá residents who owned cars thus laid claim to a vastly disproportionate share of public space.

Reclaiming the existing sidewalks from parked cars and vastly expanding sidewalk capacity in poor neighbourhoods was a resounding success. In some neighbourhoods, it contributed to a precipitous decline in crime.

Peñalosa also pioneered the construction of pedestrian and bicycle paths on agricultural land in the immediate surroundings of the city. When the city expanded, it would develop around this new infrastructure. The lock-in to the car infrastructure often creates a huge threshold to change, which doesn't exist in greenfield expansion sites.

Source: 2011 Oxford lecture

Transformative resilience examines broader capacity issues and longer time horizons in terms of distributed governance, foresight capacity and innovation and experimentation.

7 — Distributed governance or polycentric governance is the core model for managing resilience. Centralised control is often perceived to be more efficient, but it represents a classic trade-off between resilience and efficiency. While occasionally frustrating, democratic processes, stakeholder consultation or even family meetings are all examples of the ultimate strength of a distributed model of governance. Elinor Ostrom's work (Ostrom, 2010) is the most comprehensive and well-known elaboration of this idea, and provides the conceptual foundation for public governance. In the context of building resilience, it is important to realise that overlapping competence, or what some may perceive as slightly messy forms of governance are valuable.

8 — Foresight capacity is the competence to go beyond a culture of forecasting, to include irreducible uncertainties and the plausibility of multiple futures into the planning culture of the city. Having institutional capacity to engage decision makers and help them be comfortable with multiple possible futures will build adaptive capacity for resilience. Various techniques such as Scenario Planning (Public Service Division, 2011; Wilkinson, 2014) and futures tools are available, but they all require a sustained effort to influence the governance culture. Since 1997, Singapore has conducted scenario-planning exercises every 3–5 years to refresh the government's thinking on possible futures amidst changing external conditions. A formal process ensures that these National Scenarios are incorporated by different Ministries into their strategic review exercises.

9 — Innovation & experimentation are obviously important for generating new ideas. However, in this context there is an additional purpose, which is to build a culture that systematically explores the edges of the system. Having people who are comfortable with ideas of radical change and experiencing the friction of very diverse concepts increases the adaptive capacity of the system and builds resilience. Google's policy of encouraging employees to dedicate a fixed percentage of their time on personal innovation projects is an example. It may yield some new ideas, but it will certainly deliver a more adaptive employee and corporate culture. Likewise, the US Department of Defense has been sponsoring the Highlands Forum since 1994 to systematically introduce new ideas to the organisation. The forum regularly convenes a wide-ranging, cross-disciplinary group of professionals and experts to discuss emerging issues that may have an impact on the Department's work.

Building transformative resilience: Netherlands flood management

One third of the Netherlands is under sea level, so flood management receives a lot of attention. After the catastrophic floods of 1953, a 50-year project was rolled out to strengthen sea defences, based on a detailed flood risk calculation and the statistical value of human lives. These two parameters allowed engineers to design new infrastructure with sufficient robustness to face down the elements, with great effectiveness.

With the completion of the original plan in the beginning of the 21st century, an extensive participatory evaluation was conducted as to the requirements for the next phase. Foresight studies had identified a shift in the nature of the surrounding system, which required a new policy approach. Risks were no longer readily quantifiable, as they increasingly became heavy-tailed. A resilience framework was adopted, which complemented traditional robustness strategies. River basins were widened, existing dikes were dismantled and flooding reservoirs such as parking garages were built with the express purpose of absorbing events that were no longer avoidable. This was a radical shift from the original strategy which sought to keep out floods entirely.

The roots of the governance of the water system can be traced back to 1120, when various towns assembled to build a dike along the Rhine. This evolved into the current polycentric system, where separate elections are held for the governance of the water boards. These boards have their own taxes, but are intertwined with provincial and city governance in various ways. While these overlapping institutional arrangements may appear messy to the casual observer, it helps to promote accountability towards the smaller communities across the water boards, preserve local knowledge in decision-making, and distribute power among key stakeholders which guards against systems failure from ineffective, top-down control. It is an example of a governance system honed over the centuries for resilience, rather than for efficiency; a well justified trade-off.

Applying the nine-box Framework: The Resilience Garage

There are different ways to apply the nine-box resilience framework. For instance, organisations can use it as an internal reference to assess the resilience of their individual projects, or use it as a tool to facilitate discussions with an external group of experts. One method which focuses on the latter is the Resilience Garage. The Resilience Garage was designed as an output of the two-year collaboration of multinational companies (Kupers, 2014), which explored how to make resilience actionable in the context of the cities and regions, while at the same time retain a deep systems perspective. The Garage has been adopted by the Rockefeller Foundation's 100 Resilient Cities Initiative as one of its core tools to engage city officials, companies and local NGOs. The first four Garages were held in Amsterdam, Delhi, Singapore and Mexico City in 2014–16. Feedback allowed the Garage to evolve to the process described here and the very positive experiences underscore the relevance and applicability across diverse cultures and challenges.

Figure 1 - Amsterdam Resilience Garage 2014

The essence of the Resilience Garage lies in its facilitated process which creates a safe platform where practitioners and scientists/researchers from across different sectors convene to challenge, learn, and hone their approaches to resilience building. During the Garage, they seek to understand resilience challenges of specific, place-based investment or development opportunities that one or more of the Garage members are considering, and suggest solutions to address these challenges.

In that way, the Resilience Garage is a form of peer review or assurance performed under non-disclosure agreements by trans-disciplinary and cross-sectoral teams of resilience experts. This improves the likelihood of success of the reviewed project. Overall, the purpose of the Resilience Garage is to accelerate the rigorous application of resilience theory in practice and the refinement of resilience theory based on practical experience and empirical evidence.

Epilogue

We have presented a resilience framework that can be used to discover and prioritise resilience interventions in the government sector and governance context. The framework provides nine different lenses on the resilience of a particular system. It is not an analytical framework in the sense that it represents an exhaustive list. Indeed that would be at odds with the complex systems perspective, where the interconnected nature of the system determines its behaviour. But it is a pragmatic and tested framework to help policy makers make sense of resilience interventions. As such it can help generate richer conversations in environments where conversations tend to be dominated by efficiency concerns.

Rethinking how governments can enhance the resilience of the systems they manage, is not about implementing a set of prescribed solutions. Rather, the idea here is to encourage policy officers to look beyond their immediate purview to the larger operating environment and think in terms of how their actions can impact other areas. From our perspective, resilience only has meaning in the context of the whole system. This is because resilience is a property of a complex system. Given that our context and operating environments are often different, the use of this framework should generate insights and policy actions that are suited to one's unique context.

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