City Resilience Index

Research Report Volume 1
Desk Study

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Jo da Silva

Director

Arup International Development

On behalf of Arup International Development's study team: Jo da Silva, Braulio Eduardo Morera, Samantha Stratton-Short, Andrea Fernandez, Stephen Cook, Sam Kernaghan, Flora Tonking, Sachin Bhoite, Sandra Diaz, Geoffrey Morgan, Vicky Evans, Elizabeth Parker, Laura Frost, Kieran Birtill, Ashlee Loiacono.

Graphics Design: Michel Haessler, Charlotte Svensson

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(Front cover)

Rio de Janeiro: View from the favelas

Introduction

As the 21st century unfolds, an increasing majority of the world's population will live in cities, where their wellbeing relies on a complex web of institutions, infrastructure and information. Cities must be able to survive and thrive despite numerous pressures that pose a challenge to urban living. These include food, water or energy security; climate change; disease pandemics; economic fluctuations; rapid urbanisation; social conflict; and terrorism, among others. Risk assessments and measures to reduce specific foreseeable risks will continue to play an important role, but pressures are still likely to develop and unforeseeable events may occur. Unless our cities are resilient, a range of shocks and stresses may cause decay or collapse, affecting millions of people with far reaching economic consequences.

In order to plan for the future, cities need a means to determine whether their development trajectories will enhance or undermine their resilience. This is particularly true for rapidly growing cities in developing countries. If governments, donors, investors, policy makers, and the private sector are to foster more resilient cities, they need to understand the factors that contribute positively (or negatively) to resilience at a city scale. They need to identify where action and investment will be most effective. They also need to understand the dynamic networks of control and influence which reach beyond a city's administrative boundary, and influence their ability to take appropriate action. Yet, at present there is no common definition of city resilience, or a framework to guide decision making.

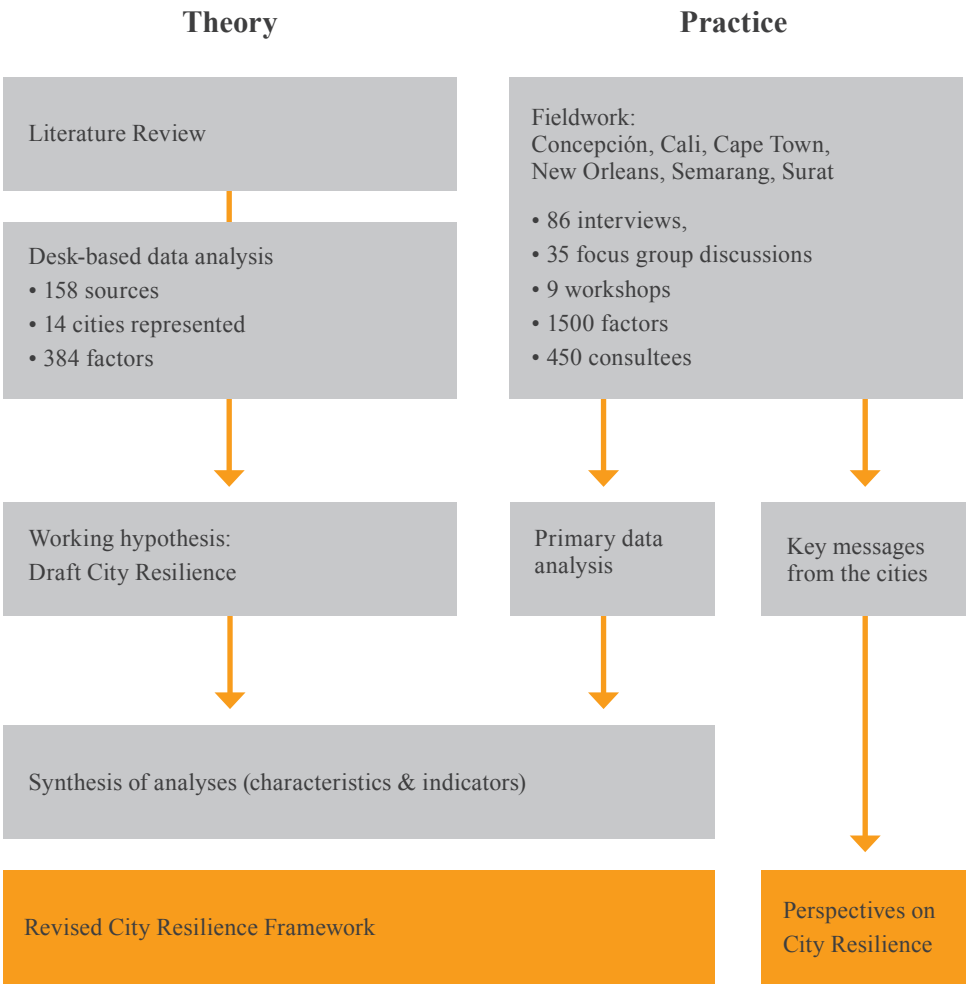
The City Resilience Index (CRI) is the result of an intensive 18 month research project undertaken by Arup with support from the Rockefeller Foundation. Its aim is to create an accessible, evidence-based articulation of city resilience that will ultimately provide a robust basis for measuring resilience at the city scale. Its purpose is to inform urban planning practice and investment patterns, to better enable urban communities - particularly poor communities - to survive and thrive following significant social, environmental, or economic stress and disruption.

This report - "City Resilience Index: Research Report Volume I: Desk Study" - summarises the desk-based research carried out between May and October 2013, which led to a preliminary definition of city resilience. This definition will be further refined based on primary data collected from six cities (Cali, Concepción, New Orleans, Surat, Semarang and Cape Town) between October-December 2013. The analysis of the primary data is summarised in "City Resilience Index: Research Report Volume II".

(Image Opposite)

View of Lower Manhattan from New Jersey showing the 9/11 Memorial

Figure 1: Research methodology and outputs.



How the report is organised

Chapter 2 discusses the key themes emerging from the initial phase of the literature review, focusing on resilience and, more specifically, urban resilience. It provides a synthesis of the qualities of resilient urban systems and the possible functions of resilient cities.

Chapter 3 summarises a further stage of desk-based data analysis undertaken to explore the evidence collected from others' research on resilience. This was examined on the basis of how resilience can be recognised in the performance of a city (rather than in the assets or systems that make up a city). This resulted in the proposal of a performance-based articulation of city resilience based on eight functions.

The final chapter (Chapter 4) briefly summarises the report and the next steps which it informs.

This report is also supplemented by a series of appendices, containing further details of qualities of resilient systems; a set of brief case studies of city failure; and a bibliography of materials and references cited.

Executive summary

The City Resilience Index (CRI) is the result of an 18 month research project undertaken by Arup with support from the Rockefeller Foundation. Its aim is to create an accessible, evidence-based articulation of city resilience that will ultimately provide a robust basis for measuring resilience at the city scale. This report – "City Resilience Index: Research Report Volume I: Desk Study" – summarises the desk-based research undertaken to inform the CRI. This was the first stage of an intensive process of research and development. The Desk Study led to a preliminary definition of city resilience (the 'City Resilience Framework'). In the next stage, the analysis of primary data collected from six cities was used to challenge this definition (see "City Resilience Index: Research Report Volume II").

The Desk Study highlighted important insights about resilience, which informed the development of a draft City Resilience Framework.

Evolutionary resilience | Resilience is defined differently by different theorists, according to their discipline or context. 'Evolutionary resilience' recognises that systems constantly shift between states of equilibrium. Under changing conditions, continual adaptation is required. This definition is particularly relevant to cities undergoing growth and/or contraction.

Different from deterministic risk management | Resilience is different from the 'predict and prevent' approach that characterises traditional disaster risk reduction. Rather than focusing on individual risks, resilience recognises the need for a multi-faceted approach that manages change and uncertainty in a more integrated way.

Performance-based approach | A number of approaches have been taken to enable practical application and assessment of resilience. In the context of cities, an asset-based approach takes into account the resilience of individual infrastructure components, but neglects the role that these components play in city systems. A system-based approach overcomes this criticism, but does not consider the interdependencies between different systems at different scales, nor the governing structures that influence the way systems work. A performance-based approach defines resilience in terms of a city's ability to fulfil and sustain its core functions. This recognises that a city's functions are achieved by multiple city assets, systems and actors simultaneously, and therefore begins to address questions of interdependency and power dynamics.

(Image Opposite)

Residential buildings in Hong Kong

Qualities of resilient systems

Eight qualities can be identified in physical and non-physical systems, which if present mean that a city is likely to be more resilient. A resilient system will be accepting of uncertainty and change; reflective; adaptive; robust; resourceful/efficient; integrated; diverse; and inclusive.

Based on the initial literature review, a draft hypothesis was developed, which proposed that urban resilience could be articulated in terms of seven critical functions of a city. The draft hypothesis was tested through a desk-based analysis of the 'factors of resilience' identified from more than 300 secondary accounts of cities experiencing shocks or stresses, together with recent guidance on urban resilience. As a result of this work, the hypothesis was refined and amended to include eight functions.

The analysis suggested that a city's ability to perform specific functions would lead to either resilience or failure in the physical, social and economic dimensions of the city. Failure would be identified by poor health, conflict or deprivation among the city's population, while resilience could be perceived from good health, social harmony and prosperity. The three dimensions of resilient cities provide the framework in which a city's functions play out.

Eight functions of a resilient city

A resilient city…

1. …. Delivers basic needs

Most urban inhabitants are engaged in economic activities and are not directly involved in producing their food, water, energy, medicine and shelter. These things are provided by the city. Large populations live in dense concentrations, where the demand for basic materials is very high and the supply can often fluctuate. A resilient city provides for its people continuously, despite stresses and shocks.

To continuously enable life, a city must rely on multiples sources of water, food and energy in case a single source is compromised in a shock or stress event. On these occasions, having stockpiles of provisions like food, medicines, clothing, and emergency shelter is helpful. Promoting sustainable practices like solar passive energy, water harvesting and domestic food production can ameliorate the build-up of stresses caused by a lack of energy, water and food respectively.

2. .... Safeguards human life

Urban communities are vulnerable to threats such as fire, diseases, floods, pollution and terror attacks. People do not always have the means to react to these threats at an individual level. Cities need the capacity to protect their inhabitants from threats by raising awareness, undertaking direct planning

measures and ensuring that adequate resources are available to deal with the effects of specific shocks and stresses. In times of stress and shock, cities need to react in order to save lives.

Resilient cities keep their citizens safe by having special measures in place, like an emergency evacuation strategy and sufficient numbers of health workers trained with relevant skills. They also put preventive measures in place to minimise exposure to threats by planning/zoning areas that are prone to hazards.

3. …. Protects, maintains and enhances assets

Cities are an assemblage of physical assets that are used and often owned collectively. Assets may be man-made - including buildings, bridges, transport networks and energy plants - or they may be natural systems, such as rivers, forests, mangroves, soil and ground water. These form a line of defence to protect the city from hazards like flooding, landslides and pollution. They can also be the city's lifeline due to their provision of water, energy and food. Cities need to protect these assets to maintain their functionality and protect populations that may be severely affected if assets fail.

A resilient city protects its natural and man-made assets to reduce the likelihood of shocks and stresses and to continue providing critical services during shock and stress events. Coastal cities may maintain mangroves and restore wetlands to defend themselves from floods, while hill cities might build dams to control flooding and landslides downstream.

4. …. Facilitates human relationships and identity

Cities are powered by people. People of different races, genders, classes, religions, cultural identities and affiliations live in close spatial proximity in cities. City dwellers experience vibrancy of place through differences in cultures, cuisines and shared histories. They can also experience feelings of isolation, anxiety and discontent. Social cohesion can be a major advantage to a city undergoing a shock or stress event. Social networks can facilitate access to assets and provide psychological support to those experiencing a shock or stress.

The ability of a city to ensure a peaceful and stable society and to prevent societal breakdown during shocks and stresses is a characteristic of resilience. Cities do this by promoting active and engaged civil society networks that include communities in the decision making process. In many cities, religious and faith-based institutions play an important role in this regard. NGOs and human rights organisations assist in raising awareness and reaching out to marginalised communities.

5. …. Promotes knowledge, education and innovation

Cities have always been hubs of knowledge and innovation, and magnets for creative and educated people. The kind of knowledge in cities ranges from scientific research and information, to awareness of local weather patterns and forecasting potential natural disasters. Cities constantly need to raise their levels of awareness. Knowledge plays a crucial role in a city's ability to absorb shocks and stresses, and also assists in the city's quick recovery. Being able to communicate during a shock or stress event plays an important role in the short term recovery process and long term learning. For example, a higher level of literacy within a city allows external agencies to coordinate evacuation and rescue operations more effectively.

Resilient cities understand the power of knowledge and can harness it to their advantage to increase understanding of shock or stress events, and to learn from past experiences. Institutions that research and monitor risks have an important part to play. Cities improve their resilience by putting in place back-up systems for communications run by trained and prepared crisis communication teams.

6. …. Defends the rule of law, justice and equity

Cities have a need to influence human behaviour and ensure they are accountable to their citizens and administrators. They need to promote justice and equity in order to protect the rights and freedoms of their citizens. Cities do this passively through policies and laws that deter iniquitousness by individuals and groups. They also control businesses through government and legal systems. During shock events like riots, violent demonstrations and natural disasters, police presence is vital to a peaceful recovery. Having faith in the justice system makes people feel secure. Failure to uphold the rule of law can have cascading negative impacts on a city, allowing new stresses and shocks to emerge that can have a more lasting impact on the city than the shock event itself.

Being resilient involves defending the rule of law, justice and equity, to foster an effective and fair system that promotes accountability and maintains peace. An adequately resourced and trained police force that works within a transparent and non-corrupt political system can curb the escalation of lawlessness during stress or shock events. The policies that a city puts in place should be equitable, while protecting marginalised communities.

7. …. Supports livelihoods

Cities are hives of economic activity with complex divisions of labour. City dwellers are involved in supporting services like manufacturing, retail, government, and infrastructure management. By doing so, city dwellers provide needed services and goods to the city, and also generate income to support themselves and their dependents. A city's failure to provide and support livelihoods can itself become a source of stress in a city, which can escalate with rising unemployment. Failures in urban planning or critical infrastructure networks can have a knock-on effect for city dwellers, for example inhibiting access to places of work.

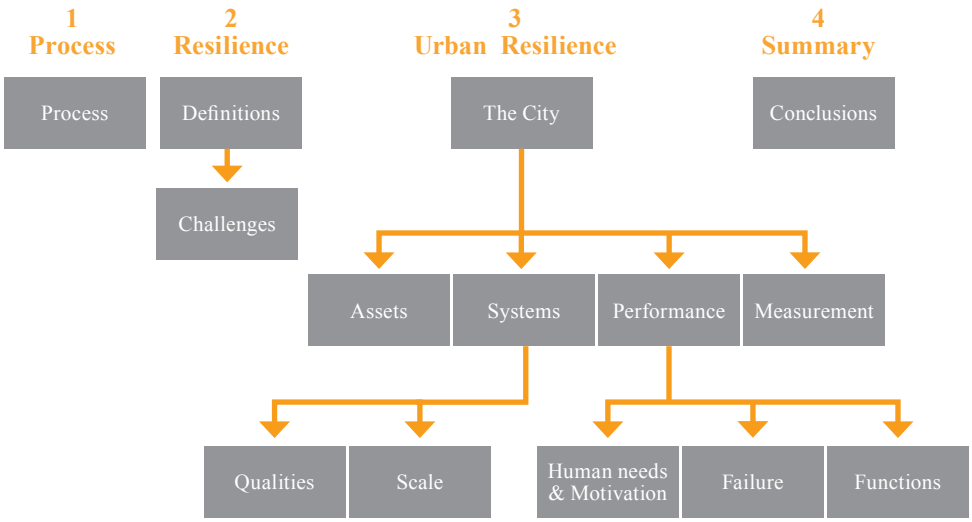
A resilient city supports livelihoods by improving access to income-generating activities and providing support for businesses during shocks and stresses. Cities need to promote entrepreneurship, encourage household savings, and provide micro finance institutions and affordable transport systems that improve access to jobs. This is even more relevant during shock or stress events, which present additional challenges to livelihoods.

8. …. Stimulates economic prosperity

Cities are sites of industry, trade, production and investment. The concentration of economic activities in urban areas not only promotes competition internally but also supports inter-city competition. To facilitate economic prosperity, cities need to operate at a macro level to regulate trade within cities as well as economic activities beyond their borders. This is delivered by a form of infrastructure made up of stock markets, monetary organisations, financial institutions and trade unions, which support business continuity. A city's inability to create a strong business environment can lead to loss of competitiveness, stagnation and even closure of vital industries. Shock and stress phenomena like economic crises and large scale unemployment are a result of such failures.

Cities stimulate economic prosperity by strengthening competitiveness, diversifying the economic base and promoting a healthy business environment. Corporate business continuity planning is encouraged by resilient cities, which should also have a proactive chamber of commerce. National governments often support cities financially during times of economic downturn to stabilise their markets and maintain competitive advantage within the wider economy.

Figure 2: Literature review structure and key concepts identified.



Conceptualising resilience:

Literature review

Process

Literature was collected using a series of keyword-based database searches, using sites such as JSTOR, journal publishers' catalogues, and Google Scholar. No limits were applied to dates of publication. Documents returned by the searches were examined, and included in the full review if they were deemed relevant to the CRI project's objectives[1]. Keyword terms used in the searches included:

- Resilience
- Urban resilience
- Cities + resilience
- Urban systems + resilience
- Resilience + performance
- City functions
- Systems + city functions

The use of the above search terms allowed collation of a series of books, journal articles, and popular press articles which related to three core thematic areas: **resilience, urban resilience and conceptualising cities**[2]. Several documents were also reviewed that did not link to these core areas, but instead related to the fields of ecology and human needs. These documents were reviewed as they provided insights into the development of many broader ideas which have been incorporated into the three core areas; such as 'resilience' itself, originally a term drawn from ecology.

For the purposes of the CRI project, resilience is understood as an outcome (i.e. a scenario that could be achieved), rather than a process (i.e. a continuous series of actions). Therefore, the literature review focused on resources that also view resilience as an outcome. The review gathered information about how urban resilience is articulated, i.e. what 'things' might be observable in a city which is considered to be resilient, rather than the processes of resilience building (as examined by authors such as Mark Pelling (2003), and bodies such as UNDP, who study the transformative processes of resilience).

(1) Arup (2013) Resilient Cities Index: Project Plan.

(2) 87% of documents referenced in this research paper are focused on one or more of these three core thematic areas.

Resilience

Defining resilience

The literature highlights the varying ways in which resilience has been articulated as a concept.

Emerging from the field of ecology in the 1970s, 'resilience' was understood as the capacity of a system or agent[3] to maintain or recover functionality in the event of disruption or disturbance. Dalziell & McManus (2004: no page numbers) further recognise resilience as "the overarching goal of a system to continue to function to the fullest possible extent in the face of stress to achieve its purpose, where resilience is a function of both the vulnerability of the system and its adaptive capacity."

The concept of resilience is commonly applied to systems rather than individual units. This is due to the term having its origins in ecology; a discipline which is concerned with the study of interaction of organisms and the environments in which they exist; rather than the study of the individual organisms themselves.

One school of thought focuses on a system's process of returning to an equilibrium state, following disturbance (as explored by Davoudi, 2012). In literature which promotes a concept of 'engineering resilience', this return was to the previous equilibrium state, i.e. restoration of business as usual (Holling, 1973). In contrast, concepts of 'ecological resilience' (also described by Holling, 1973) recognise that a return to equilibrium should not automatically mean a return to a previous state. Instead, ecological resilience proposes that, in restoring functionality within a system, a new equilibrium can be established, which in turn renders the system better able to manage disruption in the future.

'Evolutionary resilience' recognises that systems are constantly shifting between states of equilibrium, with risks arising both within the system and from outside.

Other conceptualisations of resilience have challenged these equilibrium-based theories, instead viewing resilience as a process of evolution or transformation and recognising that systems are in a state of permanent change, even when they are not challenged by disturbances and exogenous events (Sheffer, 2009). Folke (2006) terms this 'socio-ecological resilience', while Davoudi (2012) calls this third conceptualisation 'evolutionary resilience'. Such views of resilience as a transformative process accept uncertainty and change as a behavioural feature of systems and environments, rather than promoting the prediction and prevention of hazard events (da Silva, 2012).

(3) "a person or thing that takes an active role or produces a specified effect" (Oxford English Dictionary)

Articulated in this way, resilience goes beyond the traditional practices of disaster risk reduction. While disaster risk reduction is based on a deterministic (predict and prevent) approach, resilience focuses on the ability of a system to function and evolve in the face of a wide variety of stresses and shocks. Uncertainty and change is understood as originating within systems and environments (endogenous), as well as outside them (exogenous). The concept of evolutionary resilience recognises the complexity of resilience in systems, as well as their continual adaptation. As Davoudi (2012: 304) states "[e]volutionary resilience promotes the understanding of places not as units of analysis or neutral containers, but as complex, interconnected socio-spatial systems with extensive and unpredictable feedback processes which operate at multiple scales and timeframes."

Resilience should not be viewed as an antonym of 'vulnerability'.

The concept of resilience has also been associated with that of 'vulnerability'. In some cases resilience is even offered as an antonym of vulnerability (Folke et al, 2002). Dalziell & McManus (2004: no page number) define vulnerability as "the human product of any physical exposure to a disaster that results in some degree of loss, combined with human capacity to withstand, prepare for and recover from the same event." Given its human focus, the concept of vulnerability can help in considering resilience in urban settings, i.e. places with a concentration of people and social systems. Vulnerability also lends a further aspect to understanding urban resilience, as it highlights how different social groups (for example, ethnicities, ages, classes, genders, castes etc.) which cluster in cities experience risk and resilience differently (Lucini, 2013).

Utilising resilience as an antonym of vulnerability, the following formula is often cited as a method of understanding the relationship between resilience and hazards:

This method of evaluating resilience applies a deterministic approach, which defines resilience as a narrower concept consistent with traditional theories of hazard-specific risk management. It is considered only in terms of what thing is resilient (i.e. a particular asset or system) to what specific – and hence, foreseeable – hazard or threat (e.g. flooding, heatwaves or earthquakes).

Challenges of resilience

The literature highlights the varying ways in which resilience has been defined three main challenges are discussed in the literature reviewed.

Resilience is difficult to implement and measure.

Firstly, it is noted that the concept of resilience does not translate easily into practice (Wilkinson, 2012), evidenced by the often noted challenges of measuring resilience, and the usage of proxy indicators of resilience (Béné et al, 2012; Arup/IFRC, 2011). As Martin-Breen & Andries (2011: 52) state "[r] esilience is not visible; it is a theoretical construct, a dispositional property that relates to an individual's or system's response to future events. In order to get a grip on it, one must be able to relate resilience to other properties that one has some means of ascertaining, through observation, directly or mediated by additional theory."

Existing articulations of resilience fail to account for power dynamics.

The second limitation is that the concept of resilience fails to adequately describe and examine social dynamics within systems (Béné et al, 2012; Levine et al, 2012). This is understandable within ecological resilience, but it is important that power relations are considered when applying resilience to cities. The decisions made by city stakeholders are driven by very particular motivations and human needs. While many of these motivations may be common to all human beings, others are mediated by power dynamics (i.e. extents of control and influence) and unique structures of authority within particular cities (da Silva et al, 2012).

Resilience and poor urban communities

Irrespective of power dynamics, resilience is not commonly recognised as a pro-poor concept (Béné et al, 2012), This is significant when applying the concept to cities in the developing world, but also more widely since cities are places where poverty concentrates (Hardoy & Romero Lankao, 2011). Béné et al (2012) provide the following example which illustrates the trade-offs that poor individuals may have to make, regarding their resilience. Imagine a poor household is attempting to build its economic resilience (through increasing its disposable income, i.e. financial assets) by moving to an area of a city where housing is cheaper. In doing so, the family's outgoing costs are lowered and it has greater potential to save money for times when it may experience a shock, i.e. if a family member loses a job. However, housing may be cheaper in this new area because it is a place in which there are higher crime rates. The household therefore makes a sacrifice in terms of its security and wellbeing (i.e. its social resilience) to improve its economic resilience.

(3) "a person or thing that takes an active role or produces a specified effect" (Oxford English Dictionary)

Resilience plays out at multiple scales and through a series of interdependent systems.

Thirdly, activities which aim to build resilience may have unexpected knock-on effects, such as reducing resilience in other places or at other scales (Ali & Jones, 2013). This is perhaps a consequence of understanding resilience as the inverse of vulnerability and not considering that the interdependency between systems means that interventions attempting to build resilience in one place may have feedback implications in other places. For example, Brown & Kernaghan (2011) provide an example from Quy Non, Vietnam, where elevated roads were constructed following severe floods in 2009 to avoid future inundations and protect houses and strategic infrastructure. However, the knock-on or 'ripple' effects across the wider urban systems within the city were not universally positive. These elevated roads created increased flooding in other areas of the city by disrupting established run-off routes. Strengthening resilience at smaller scales too may have unintended effects, such as the reprioritisation of household spending outlined above, which, in turn, can affect the wellbeing of individuals.

Urban resilience

The concept of resilience can be applied to cities.

Relating the concept to cities, Campanella (2006: 141) defines urban resilience simply as "the capacity of a city to rebound from destruction". Literature which attempts to identify the presence of resilience in cities has traditionally focused on measuring or evaluating urban assets or systems (da Silva et al, 2012; Tierney & Bruneau, 2007; O'Rourke, 2007). Systems are typically comprised of assets, while assets rely on systems for their existence and maintenance. Assets – both physical (like buildings) and non-physical (such as skills or social relationships) – may be defined by their qualities or contribution to an urban system. Systems are defined by the particular role which they help the city to perform. For example, an asset such as an early warning alert is a key feature of a disaster management system; a system which, in turn, helps to protect buildings, infrastructure, and the wellbeing and security of citizens.

Urban resilience: Assets

The study of urban resilience often focuses on a city's assets.

The presence and quality of assets influences exposure and vulnerability to risk (Arup/IFRC, 2011). Assets can influence both behaviour and the availability of resources to reduce or mitigate losses (i.e. disaster risk reduction). For a city to prosper, assets – particularly physical assets – must be maintained and enhanced (or replaced).

Assets can be physical and non-physical.

Various works on resilience in relation to livelihoods have identified a range of different asset types (sometimes referred to as 'capitals', for example by DfID, 1999, 2000, 2001 and Mayunga, 2007), both physical and intangible. Typically, assets are categorised as:

- **Human** (Sanderson, 2000; Lowe & Shilderman, 2001; McLeod, 2001; Mayunga, 2007): assets held at the individual or household level, such as health or knowledge[4].
- **Social** (Sanderson, 2000; Lowe & Shilderman, 2001; McLeod, 2001; Mayunga, 2007): assets which are linked to people, but held collectively rather than by the individual. Examples include social norms, community spirit, and education.
- **Political** (McLeod, 2001): institutional assets which correspond to multiple scales of political activity. Political assets include codes and standards, laws and policies.

(4) Sometimes knowledge assets have been separated out as a further unique category, as suggested by McLeod, 2001.

- **Economic** (Mayunga, 2007) or Financial (Sanderson, 2000; Lowe & Shilderman, 2001; McLeod, 2001): financial assets from household level up to city level (and beyond). Examples include jobs and incomes, municipal budgets and investments, and banks and lending schemes.
- **Physical** (Sanderson, 2000; Lowe & Shilderman, 2001; McLeod, 2001; Mayunga, 2007): typically man-made tangible or 'hard' assets, such as infrastructure, buildings, and technology or machinery. Such assets tend to operate within networks, which may be present in particular communities or districts, or stretching throughout (or beyond) an entire city.
- **Natural** (Lowe & Shilderman, 2001; Mayunga, 2007) or Environmental (McLeod, 2001): again, tangible or 'hard' assets, but natural rather than man-made. These natural assets tend to exist within ecosystems. Examples include water (i.e. rivers, reservoirs etc.), air, and environmental habitats (including trees and vegetation, and topographical features).

These different assets support resilience by influencing different things within the city – from behaviour of individuals during a disruption (human and social assets), through to the ability of the municipality to provide services and protection for its citizens (physical and environmental assets).

A city's assets are located both inside and outside of the city's boundary.

There are three key shortcomings of asset-focused approaches to resilience. The first is that assets are typically located within the city's physical or administrative boundary, yet they exist as networked components within wider systems which often extend or are influenced by factors outside the city. Satterthwaite (2013) explains this issue using the example of urban flood risk management via watershed management that may occur at some distance from the city. Similarly, city assets can be affected by feedback loops or transmission of failure through networked systems outside of the city. Attempting to understand urban resilience by focusing on assets alone does not allow examination of the relationship between the city and its hinterland, or the exogenous factors (i.e. external shocks and stresses) which influence a city.

Assets are the building blocks of a city's systems.

Secondly, discussing assets as interdependent components within depoliticised 'networks' fails to account for the power dynamics that control and govern the existence, maintenance and quality of assets. It is straight-forward to identify the assets that help particular systems to function, but much harder to understand how well they support systems, or how some assets may undermine a system. In the politically complex context of cities, the presence and quality of assets alone offers an incomplete view of a city's ability to perform its functions.

Both physical and non-physical assets are essential for resilience.

To conceive a city merely as a collection of assets overlooks the fact that a city is a social, economic and political construction as well as a physical one; this is recognised even by the recent, infrastructure-focused Toolkit for Resilient Cities (Siemens/Arup /RPA, 2013). Many non-physical assets within cities are often overlooked due to difficulties of identification and measurement. Yet cities are built on social assets as much as the physical assets of buildings and roads. The relationship between physical and social networks is instrumental to understanding how physical assets may contribute to city resilience.

Urban resilience: systems

An alternative method of understanding city resilience is through city systems.

Each city is uniquely shaped by its geographical characteristics, its population, and its history. No city develops in isolation, and each city is a product not only of its own characteristics but also those of the surrounding areas (Harris & Ullman, 1945; Alexander, 1954). However, the systems within cities typically perform similar services; providing food and water to citizens, supplying power and other utilities, facilitating trade of goods and services, creating and enforcing legislation, among other things. Urban systems are therefore easier to compare in terms of their characteristics or qualities of resilience than cities.

Based on the urban resilience literature, it appears more common to examine the resilience of specific urban systems rather than the resilience of 'the city' as a system in itself. The practice of conceiving the city as a set of systems – both human and physical – rather than simply a geographical unit dates back almost 100 years (Geddes, 1915). More recently, Godschalk (2003) has described cities as complex meta-systems, or 'systems of systems'.

An approach which recognises interdependent systems and the services they provide could support a paradigm shift in practice towards resilience and away from traditional 'predict and prevent' approaches to risk management in cities (Allan & Bryant, 2011; Brown & Kernaghan, 2011; da Silva, 2012). Supporting a systems approach to understanding city resilience, Chelleri (2012:209) asserts that: "The systemic vision (dealing with complex systems theories) grants resilience the relevance for a debate on the city and illuminates many short-comings of urban planning."

Da Silva et al (2012) divide a city's systems into three categories, which reflect these institutional, human and physical groupings: institutional networks; knowledge networks; and networked infrastructures. These three categories of systems are broken down further by da Silva et al in previously unpublished work, as shown by Table 1 below.

Table 1: Categories of urban systems

Category	System type	Example types
Networked infrastructure	Basic Infrastructure	Food
		Water
		Shelter
		Sanitation
		Waste management
	Community wellbeing infrastructure	Education
		Health
		Power supply
	Advanced infrastructure	Acute health care
		Further education
		Manufacturing and processing (factories, industrial units)
		Service industries (banking, offices, others)
	Enabling infrastructure	Public transport - local level
		Transport - regional and global levels
		Transport of goods (freight, ports)
		Communications
Knowledge networks	Information flows	Systems for the dissemination of information (e.g. radio stations, the internet, others)
	Technology	Networks to develop and access technology (e.g. research and development centres)
	Education	Institutions for education and knowledge generation (e.g. schools, universities)
Institutional networks	Governance	Systems for governing and decision making (e.g. government structures, community associations, business associations) and rules and practices supporting interaction (e.g. justice, tenure & rights, markets)
	Social systems	Systems of social relationships, hierarchy, status, power, exchange, social reproduction
	Culture	Systems for interpretation, including issues of faith, myth and user behaviour (e.g. religious beliefs and ethical positions)
	Economic systems	Systems regulating production, exchange, and finance (e.g. markets, labour conditions, funding tools)

The systems approach recognises physical and non-physical components of cities.

The systems that comprise a city meta-system have been categorised in varying ways. Most categorisations acknowledge that cities contain a range of human and physical systems. Human systems include cultural, social and/or economic systems (UNISDR, 2012; Tierney & Bruneau, 2007; Moench et al, 2011). Assets within human systems may be harder to quantify or define due to their less tangible nature. Examples include social networks which enable social relationships and individual communications and cultural heritage systems which support use and understanding of languages, faiths, and social behaviour in cities.

The importance of human systems

Human systems have been particularly important during shock or stress events, and have been noted to prevent major crises. For example, in 1947 a smallpox outbreak threatened to affect millions in New York City. The city authorities issued advice to the general public to prevent the spread of the disease and, within a fortnight, millions were vaccinated. This successful vaccination drive was fuelled by social networks within the city, rather than the authority of the city government. By including community leaders, teachers and church leaders within the mobilisation effort, greater numbers of citizens were vaccinated than expected. The advice was disseminated by word of mouth between neighbours, with the message reinforced by announcements on public radio. The proximity of this event to the end of the Second World War may have influenced the extent of the public mobilisation, since people had become accustomed to working together and helping their neighbours (Rosner, 1995; Wallace & Wallace, 2008).

Physical systems relate to a city's infrastructure and built environment – often referred to as 'hard' or technical systems – as well as environmental or ecosystems (Tierney & Bruneau, 2007; Moench et al, 2011; da Silva et al, 2012; UNISDR, 2012). Common examples of physical systems include transport, utilities (such as electricity or gas), housing and other buildings. Bridging the gap between human and physical systems are institutional systems (Tierney & Bruneau, 2007; Moench et al, 2011). that influence human and physical systems. They comprise both intangible assets (such as information and data, and decision-making processes) and some physical assets (such as the strategic transport network). These systems enable organisations to function, from the local level up to the whole city.

Qualities

Eight qualities can be identified in physical and non-physical systems, which if present mean that a city is likely to be more resilient.

Much literature refers to characteristics or qualities of resilient urban systems, which broadly fall into three typologies:

1. Asset-based characteristics (for example, a resilient city has "buildings… constructed or retrofitted to meet code standards based on hazard threats", Godschalk, 2003:137)

2. Practices or process-based characteristics (for example, a resilient urban system has "community involvement and the appropriation of local knowledge in any resilience-building projects", Béné et al, 2012: 20).

3. Attributes or qualities (for example, a resilient urban system has "Flexibility: The ability to change, evolve and adopt alternative strategies", da Silva et al, 2012: 134)

Drawing on the literature, eight qualities of resilient urban systems have been assembled[5] (see below). These qualities are discussed in further detail in Appendix A, together with a series of case studies illustrating them in practice.

1. Accepting of uncertainty and change

Cities are so complex that planning for every eventuality is near impossible. In building resilience, there must be acceptance that changes will happen but that they may not necessarily be predicted or prepared for (Chelleri, 2012). Accepting the inherent, and ever-increasing, uncertainty and change within today's world requires a shift in the mind-set of urban system designers and managers (Beck, 1992; Béné et al, 2012; Berkes & Seixas, 2005).

2. Reflective

As well as considering an uncertain future, resilient urban systems also examine their past experiences, and learn from them. '[M]anaging resilience requires understanding how historical system dynamics have shaped the current system.' (Resilience Alliance, 2007: 22), and also how past mistakes can be avoided in the future (da Silva et al, 2012; Moench et al, 2011).

3. Adaptive

Resilient urban systems are adaptive to changing conditions, becoming stronger and more effective. The process of adaptation makes peace with alternative futures or circumstances rather than striving to maintain the status quo (da Silva et al, 2012). For systems to be truly adaptive they also have to be innovative, but this does not mean simply making use of new technology (Walker & Salt, 2006; Moench et al, 2011). It also means considering and incorporating indigenous or traditional knowledge and practices in new ways or sectors (IRWG, 2012).

4. Robust

Often used in reference to physical systems, robustness refers to the strength within systems that allows them to continue functioning during a disruption. O'Rourke (2007: 25) defines this as "the inherent strength or resistance in a system to withstand external demands without degradation or loss of functionality". Technically, systems may be considered as robust if they are governed by standards or codes which promote structural integrity. In application of this quality to institutional or human systems, robustness can be evidenced by communities which are prepared for disruption and have skilled personnel able to respond in case of an emergency (O'Rourke, 2007).

(5) 16 documents were identified, which referenced characteristics or qualities of resilience. A long list of qualities was created, relating to multiple scales or systems within cities. Assets and practices were removed from the list because they were not considered to be qualities. A coding process was used to group qualities into similar ideas in order to develop a final short list.

5. Resourceful/Efficient

From household level (Arup/IFRC, 2011; Arup/IFRC, 2013) to entire city-wide infrastructure systems (Tierney & Bruneau, 2007), the efficient management of resources (physical, financial, human etc.) is central to urban resilience. Systems themselves should be designed with redundancy, to ensure back-up capabilities exist when systems fail (Brown & Kernaghan, 2011). This could take the form of buffer stocks, spare capacity in terms of material or human resources or multiple options for the supply of critical assets or infrastructure (Moench et al, 2011; Campanella, 2006). Systems which make efficient use of resources and contain redundancy, are also better able to fail safely, without transmitting disruption from one system to another (Moench et al, 2011; da Silva et al, 2012).

6. Integrated

A fragmented or 'silo-ed' approach to resilience exists in practice as well as in theory, and is particularly unsuitable for attempting to engage with a multi-disciplinary concept like resilience in cities; i.e. a concept which in practice requires multiple interventions and actors to contribute to its development (Chelleri, 2012). Integration is therefore proposed between urban systems which contribute to building resilience; particularly within any systems that require information exchange to function effectively. Integration encourages the use of multiple mechanisms or systems working to build resilience at and across different scales (Béné et al, 2012; DfID, 2011; IRWG, 2012).

7. Diverse

Diversity can be understood in terms of function, i.e. multiple ways of meeting a given need (Berkes & Seixas, 2005, Martin-Breen & Andries, 2011). Diversity can also be understood in terms of space (Moench et al, 2011). For example, spatial diversity ensures that not all assets or urban systems are affected by a single geographical event such as a flood, by distributing assets across a city, or even beyond the city. Diversity and Integration are highly compatible with one another.

8. Inclusive[6]

It is universally recognised that the socially marginalised – particularly within urban areas – typically suffer worse impacts of disasters or crises; often due to their limited possession of assets, disposable income and/or access to public services. To ensure systems are truly resilient, the voices of these marginalised groups must be included in decision-making processes. Inclusivity may refer not only to the inclusion of the most vulnerable groups or stakeholders within urban environments, but also to the engagement of a wide range of stakeholders, particularly within governance structures (Dalziell & McManus, 2004; IRWG, 2012).

(6) The inclusion of this eighth quality aims to explicitly address one of the criticisms of many conceptualisations of resilience discussed below; that resilience struggles to recognise or explain power dynamics and social structures. Also this quality attempts to respond to claims that resilience is not typically viewed as a pro-poor concept.

Scale

The literature demonstrates the importance of scale as a framework for understanding city systems and the interdependencies between them.

Urban systems operate at the city level down to community/neighbourhood, household and individual levels. Frequently systems stretch beyond the city itself (da Silva et al, 2012). Interdependencies and feedback mechanisms exist across different scales (Béné et al, 2012; DfID, 2011; IRWG, 2012), which allow the impact of a disturbance, or the effect of a resilience building intervention, to be transmitted across scales, as well as from one system to another.

While urban systems operate at multiple scales, these scales do not fit neatly into a linear hierarchy. The relationships between scales are more complex and variable. Gunderson & Holling (2002) use the term 'panarchy' to describe a structure of systems which functions as a series of nested adaptive cycles; in contrast to a hierarchical structure. In panarchy, some systems may be stable while other related systems are in flux simultaneously. This is a useful concept for understanding urban systems and the dynamic relationships between them, as well as "the complex cross-scale effects between neighbourhoods, suburbs and the metropolitan region" (Chelleri, 2012: 205).

Understanding the relationships between systems and scales is important when planning interventions which aim to build city resilience. Scale must be understood to ensure that the benefits of the intervention are maximised through positive feedback across scales, and that negative impacts are minimised at different scales. Allan & Bryant (2011: 43) consider the relevance of scale to the practice of building urban resilience, particularly post-disaster:

"When we have...[an understanding of different scales and how they interrelate], the resilience attributes operate as tools that can suggest how, where and on what scale to intervene to achieve maximum benefit for minimum input...resilience is based on the shifting relationship between scales, and between autonomy on the one hand and connectivity on the other."

A comprehensive approach to city resilience must recognise the issue of scale and take into account the interdependencies that influence urban systems.

Urban resilience: performance

A performance-based approach to resilience may provide a more holistic perspective of the city's ability to fulfil its essential functions.

The 'performance' of a city refers to the key functions that a city exists to fulfil, and the effectiveness with which those functions are served. A performance-based approach relies on an understanding of assets and

systems, but takes a higher level view of the ways in which they contribute to a city's success.

Urban geography studies have shifted over time from morphological to functional approaches; away from examining how cities develop to why they develop (Moriwaki, 1963). Much literature examining the conceptualisation of cities defines the functions or roles of a city in purely economic terms. Cities are characterised as sites of agglomeration of economic activities and trade (Moriwaki, 1963); more specifically, as sites of production for leading service industries, and of servicing and financing for international trade, investment and HQ operations, particularly in the context of increasing globalisation (Sassen, 1996). Many of these economic functions rely on the performance of further specialised networks; for example, the provision of transport and communications networks (Moriwaki, 1963).

Broader definitions of cities and their functions recognise additional elements alongside those which contribute directly to economic performance. Frey & Zimmer (2001) acknowledge some of the functional elements that distinguish urban areas from rural areas. They identify an ecological element, which is concerned with the process of human settlement, including population distribution, density and size. They also note that urban areas have a different 'social character' to rural areas, including different patterns of behaviour, attitudes, and ways in which people relate to one another. Finally, Frey & Zimmer highlight the differences between urban and rural livelihoods, and the diversification of cities away from agricultural production as the major livelihood option.

Duhl (1986) notes that if a city, and its population, is to be considered 'healthy' it should be recognised that the city comprises organic life, and is not merely an economic entity. A 'healthy' (and functioning) city, Duhl asserts, has the following functional characteristics:

1. The ability to provide the developmental needs; encompassing basic needs, creative and recreational needs (referred to as 'functional and aesthetic needs'), communications and networks, infrastructure, and 'ecological considerations'.

2. The ability to cope with breakdown, to change and modify (or, in other words, to be resilient).

3. The ability to perform its educational role.

A resilient city will be ready and able to perform its functions under normal conditions and during periods of stress or shock.

Motivations of people and human needs theory

Urban functions can be identified by considering the basic needs of city dwellers. While much urban geography literature on the role of cities appears to focus on the economic activities enabled by cities, there is clearly a need to examine the social functions performed by cities; recognising that the city supports human wellbeing as well as economic growth (da Silva et al, 2012). Consideration needs to be given to the perspectives of both the users of services (households, businesses etc.) and the providers of services (businesses, but also governments).

At the smallest social scale, the functions of a city can be considered from the perspective of individual citizens; in terms of how cities enable residents to survive and thrive. The literature review looked at human needs theory as a way to better understand the social functions that a city performs.

The 'Hierarchy of Needs' theory of human motivation conceived by Maslow (1943) describes five sets of prioritised needs common to all people (see Table 2 below). These reflect an understanding that different human needs "arrange themselves in hierarchies of pre-potency. That is to say, the appearance of one need usually rests of the prior satisfaction of another, more pre-potent need." (Maslow, 1943: 370) Maslow notes that the physiological needs – i.e. satisfying hunger, tiredness, thirst etc. – are of greatest priority to the individual, as meeting these needs will keep a person alive at the most basic level.

Table 2: Maslow's Hierarchy of Needs

Needs	Satisfied by…
Physiological	Breathing, food, water, sex, sleep, homeostasis, excretion
Safety	Security of: the body, employment, resources, morality, the family, health, property
Love	Friendship, family, sexual intimacy
Esteem	Self-esteem, confidence, achievement, respect of others, respect by others
Self-actualisation	Morality, creativity, spontaneity, problem solving, lack of prejudice, acceptance of facts

Although sometimes visually depicted as a pyramid (with the physiological needs at the base) to show a predetermined prioritisation, in reality the significance of different needs may change during certain time periods. Applied to larger groups of individuals, it is reasonable to assume that this prioritisation may differ from city to city, or between different social groups of citizens.

Almost fifty years later, Max-Neef[7] developed a broader set of fundamental human needs, which apply to individuals living anywhere; including cities (see Table 3 below). Max-Neef (1991) identified nine fundamental

human needs as well as a series of 'satisfiers'. These satisfiers represent the "individual and collective human potential" which serve as a counterpoint to the deprivation of needs (ibid: 30). The satisfiers can take the form of being, having, doing and interacting, in relation to structural norms within society[8].

Table 3: Max-Neef's categorisation of fundamental human needs (1987)

	Satisfiers			
Fundamental human need	**Being ('qualities')**	**Having ('assets')**	**Doing ('practices or processes')**	**Interacting (i.e. where this need can be satisfied)**
subsistence	physical and mental health	food, shelter, work	feed, clothe, rest, work	living environment, social setting
protection	care, adaptability, autonomy	social security, health systems, work	co-operate, plan, take care of, help	social environment, dwelling
affection	respect, sense of humour, generosity, sensuality	friendships, family, relationships with nature	share, take care of, make love, express emotions	privacy, intimate spaces of togetherness
understanding	critical capacity, curiosity, intuition	literature, teachers, policies, educational	analyse, study, meditate, investigate,	schools, families, universities, communities,
participation	receptiveness, dedication, sense of humour	responsibilities, duties, work, rights	cooperate, dissent, express opinions	associations, parties, churches, neighbourhoods
leisure or 'idleness'	imagination, tranquillity, spontaneity	games, parties, peace of mind	day-dream, remember, relax, have fun	landscapes, intimate spaces, places to be alone
creation	imagination, boldness, inventiveness, curiosity	abilities, skills, work, techniques	invent, build, design, work, compose, interpret	spaces for expression, workshops, audiences
identity	sense of belonging, self-esteem, consistency	language, religions, work, customs, values, norms	get to know oneself, grow, commit oneself	places one belongs to, everyday settings
freedom	autonomy, passion, self-esteem, open-mindedness	equal rights	dissent, choose, run risks, develop awareness	anywhere

If the human needs above are not satisfied, an individual's wellbeing will be reduced. In cities where multiple individuals' needs go unmet the effect upon wellbeing affects entire households, neighbourhoods and even city districts. For example, a food shortage will initially affect those who cannot pay more for their food, as shortage of supply drives up the cost. As supplies run down and more people fail to meet their subsistence needs, hunger and then starvation will spread from a few households through entire neighbourhoods, and across a city unless the food supply can be restored. The inability of a city to provide food for its citizens, and prevent starvation, is a clear example of systemic failure. Thus city resilience can be understood in terms of how and why the urban systems that enable human needs to be satisfied might fail, as a path to considering how to minimise the likelihood of disruption and failure.

(7) Max-Neef, M. (1991) Human scale development: Conception, application and further reflections. New York City: Apex

(8) Three of these four categories correspond to the three typologies of factors of resilience that wereoutlined earlier. 'Being' is aligned with the qualities or characteristics which support resilience

Understanding failure

Performance can be understood based on what 'failure' would look like. Failure of a city to perform one or several of its functions is a demonstration of the resilience, or lack thereof, of the city. The ability of a city to perform its functions and avoid collapse/failure (i.e. resilience) is determined by the operation (and evolution) of systems and the assets they comprise. If assets and systems within a city can be examined to understand resilience, it should also be possible to examine them to understand how and why they might fail.

Firstly, we can identify the type of system which fails, or is likely to fail; i.e. how failure occurs. Revisiting da Silva et al's (2012) categories and types of system, failures are apt to be linked to either the absence of particular systems or the inadequacy of systems that do exist. The same is true for assets – which contribute to resilience through both their presence and quality (table 1). For example, da Silva et al view food systems as part of 'basic infrastructure' systems. Should there be no food system within a city, or should the existing system be unable to adequately meet the needs of the city's population, failure will occur evidenced by hunger, malnutrition and starvation.

Returning to the eight qualities of resilient systems proposed above, a set of qualities may be deduced which suggest lack of resilience (and propensity for failure) in a system.

Table 4: Qualities of a resilient system

A resilient system is…	A system susceptible to failure is…
…accepting of uncertainty and change	…focussed only on current status and past experience, not prepared for future change
…reflective	…unable to internalise learning from past experience
…adaptive	…rigid/inflexible
…robust	…weak
…resourceful/efficient	…inefficient
…integrated	…siloed/uncoordinated
…diverse	…limited
…inclusive	…exclusive

It could be assumed that if a system demonstrates qualities of a system susceptible to failure, it will not demonstrate urban resilience. As systems are disrupted by shocks or stresses, those susceptible to failure will likely be unable to function, and will, therefore, fail to help the city perform its urban functions.

Critical functions of a resilient city

Seven critical urban functions can be determined, which relate to the economic, ecological and social parameters of a city. If these functions can be fulfilled and sustained, a city is more likely to survive and thrive. Based on common perspectives proposed by the literature, seven functions of a resilient city can be determined.

1. Protection of human life

Cities protect human life in two ways. Firstly they enable their citizens to meet their basic needs, via the provision of food, water, and shelter (Maslow, 1943; Duhl, 1986; Max-Neef, 1987). Secondly, life is safeguarded via the provision of healthcare to maintain physical and mental health (Maslow, 1943; Max-Neef, 1987; da Silva et al, 2012); efforts to control disease and sources of pollution (Dodman et al, 2011); and emergency services, disaster and contingency systems and plans which are critical in times of shock or stress.

2. Support of livelihoods

As well as protecting the lives of its citizens, the city safeguards their livelihoods. A livelihood comprises the capabilities, assets, and activities required for a means of living.(Chambers & Conway, 1992; DfID, 1999, 2000, 2001). This particular role of the city refers to subsistence or micro-economics, rather than the macro-economy of the city. Systems which support this role include access to raw materials, (micro-)credit and banking systems, as well as places of work such as markets or offices. Related systems help to support livelihoods such as the public transport systems which help citizens travel around the city for work, and power and communications systems which allow businesses (from self-employed individuals to Small- and Medium-sized Enterprises[9] and large corporations) to operate (UNISDR, 2013).

3. Protection of assets

Assets within cities exist from individual and household levels (i.e. houses, savings, lighting, vehicles – some of which may be used to earn livelihoods (Arup/IFRC, 2011; Arup/IFRC, 2013)) up to wider organisation and city levels (Tierney & Bruneau, 2007). Higher level assets can include complete infrastructure systems such as energy and transport networks (Siemens/Arup/RPA, 2013). Cities act to protect, maintain and enhance assets at all levels, both physically (by building and maintaining protective mechanisms such as flood defence structures), and also via legal measures, such as land tenure and property laws.

(9) Small and medium enterprises

4. Facilitation of human relationships and identity creation

Recognising the importance to human wellbeing of non-physical, intangible assets - such as a sense of belonging, shared languages and meaning systems, and social networks - the city also enables the maintenance of human relationships and formation of a sense of identity (Duhl, 1986). These are maintained by enabling methods of communication and providing space in which people can meet and socialise. The city is a site of civic behaviours and social norms, which support feelings of belonging (Max-Neef, 1991) and citizenship.

5. Information, education and innovation

Cities contain education systems and assets (such as schools, training centres and universities), as well as research and development systems; often supported by policies and economic systems. These contribute to the development and dissemination of information to citizens within – and potentially beyond - the city. Cities foster thought and creativity, and promote innovation. This role contributes to the fulfilment of citizens' self-actualisation and esteem needs, as well as creativity and understanding (Maslow, 1943; Duhl, 1986; Max-Neef, 1991).

6. Upholding the rule of law and promoting justice and equity

Cities need to protect the rights and freedoms of citizens, in order to fulfil their wellbeing and livelihood needs (Max-Neef, 1991). Urban areas have a role to play in promoting justice and equity (Harvey, 1973). The city government performs many of the functions that the central government performs at national level, via the development and promotion of city-level policies and laws. Key systems which support this role include government systems, legal systems, social welfare and (where they exist) human rights systems (da Silva et al, 2012). In the context of resilience, this function responds to the critique about failure of resilience building efforts to benefit multiple actors equally (Béné et al, 2012; Ali & Jones, 2013).

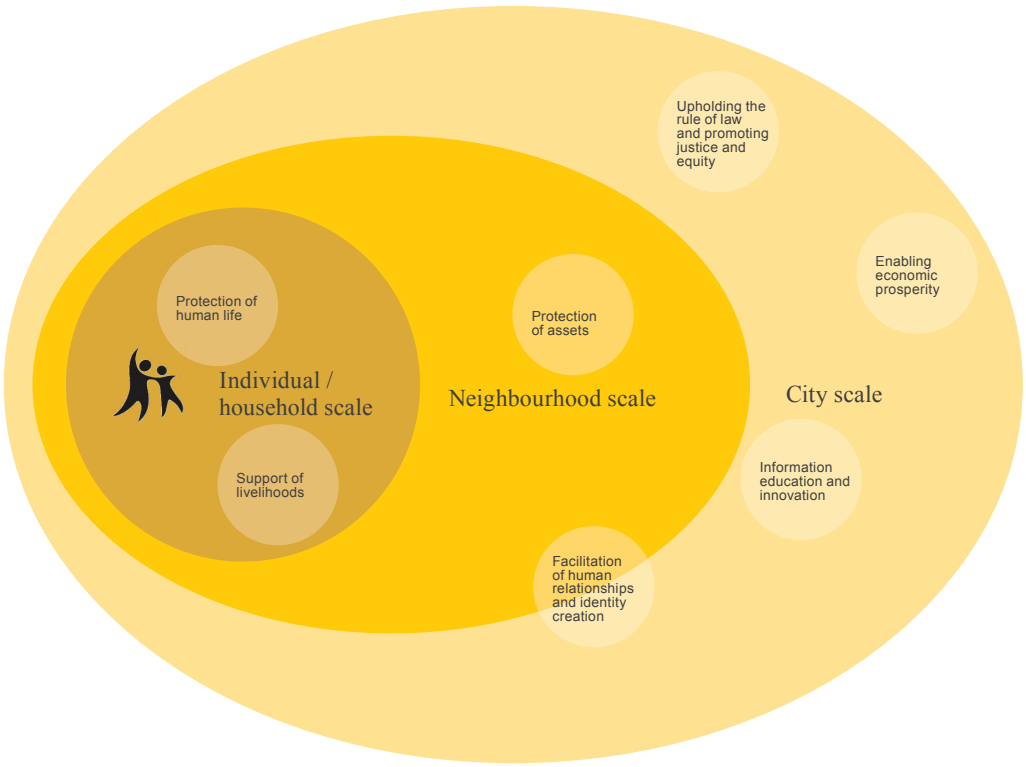
7. Enabling economic prosperity

Cities facilitate economic activities – from those undertaken by small private enterprises to those undertaken by large companies and businesses. This includes commercial organisations which may have their headquarters within the city but with operations in multiple sites beyond the city boundary (Friedmann, 1986; Sassen, 1996). This role of the city is linked into economics at a macro-scale, rather than micro-scale livelihoods. Cities are sites of industry, production, trade and investment (Moriwaki, 1963). Investment is critical for the development of many assets within the city, such as roads, telecommunications technology, hospitals etc. The concentration of economic activities in urban areas (and their enabling environments) allows cities to support collective efficiencies, business continuity and consumption

practices. This can result in "agglomerative economies…a concentration of economic functions that operate external to a particular firm but make it advantageous for a firm to locate there." (Frey & Zimmer, 2001: 26).

As suggested by the descriptions above, these functions play out at different levels – from the individual or household level up to the city-wide scale (see Figure 3 below). The impact of a failure to perform these functions can occur at different scales too[10].

Figure 3: Performance of city roles at scale



As with the human needs identified by Maslow and Max Neef, each urban role has an implicit level of importance, which varies from city to city; or even between different actors within a single city. Likewise, priority functions may also shift over time or following a shock or stress. In the event of a catastrophic event, for example, enabling economic wealth creation may not be seen as a high priority for a city. Instead a much greater importance may be placed on the meeting of basic needs, i.e. provision of food, shelter and water. It is therefore useful to consider not just the different functions of a city, but also how they are prioritised by urban actors. This prioritisation can enable a more effective consideration of how resilience should be measured within cities.

(10) Appendix B provides several examples of seven cities' failure to perform their functions, and the impact and demonstration of a lack of urban resilience..

Urban resilience: Measurement

The literature confirms that urban resilience is difficult to measure, and difficult to implement in practice.

The challenge of measuring resilience, and thus being able to make a case for considering resilience in planning, long-term development and disaster recovery, still remains insufficiently addressed[11].

While the application of a systems approach to the resilience field has provided useful insights and ideas about urban systems, there is a lack of tools that allow resilience to be integrated in the practices of urban planning and governance (Chelleri, 2012). Similarly, there are few tools that support the measurement of progress in resilience-building efforts. Currently, tools range from risk reduction frameworks (such as the UNISDR's 2012 Making Cities Resilient framework) to sets of indicators (sometimes formally compiled within an index), which allow estimation and measurement of resilience in practice (Berkes & Seixas, 2005).

Since resilience cannot be measured readily, proxy indicators (often deemed to reflect 'characteristics of resilience') are often used to reflect the qualities of the systems (and their assets) that result in resilient behaviour or performance. Examination of the relationships between different systems and assets is also important to fully understand not only what factors affect resilience, but how they have these effects.

The literature also proposes 'surrogates' of resilience, which are similar to indicators but use proxy measurements or variables to represent resilience. Surrogates differ from indicators by measuring likely or plausible future states rather the current or past states (Berkes & Seixas, 2005; Carpenter et al, 2005); i.e. they are considered as 'leading' rather than 'lagging' measures. Surrogates are sometimes regarded as more appropriate than indicators when considering resilience, given the concept's inherent need to accept greater uncertainty in the future to effectively build resilience in urban areas (Berkes & Seixas, 2005).

The use or development of both indicators and surrogates is dependent on the availability of relevant data, at appropriate temporal and spatial scales. As resilience is a relatively new concept in its application to cities, this data may not commonly be found in all cities around the world.

(11) Arup has further examined measurement of city resilience in the accompanying CRI research report, "Urban Measurement".

Summary

This literature review has revealed that there are many definitions of 'resilience' currently in use. The 'evolutionary' approach appears to be the most relevant for cities. This approach views resilience as a process of evolution or transformation, recognising that systems are in a state of permanent change even when not subjected to disruption. The evolutionary approach was considered relevant due to the dynamics of growth and change in cities, especially the increasing urbanisation of the global population. Cities must be able to accept uncertainty and change in order to continually build their resilience and safeguard the lives and livelihoods of citizens.

Many previous approaches to urban resilience have focused either on a city's assets or its systems; both of which have been seen as measurable and a useful way to monitor progress in building resilience. However, considering assets or systems alone when examining city resilience limits understanding. Such approaches fail to account for the complexity of cities or the complexity of resilience itself. The identification of linkages and interdependencies between systems is useful to extend understanding of resilience. It is also necessary to understand the feedback loops between systems, , including how and why they affect city operations, across a range of scales; from household level up to city level.

The power dynamics controlling assets and systems are insufficiently addressed within the existing literature on resilience. Multiple groups of people –including government, business and civil society[12] – live and work within cities. Each of these actors makes decisions that affect both individual and collective resilience. The decisions they make are often driven by very particular motivations and human needs, some of which may be shared across interest groups while others are mediated by power dynamics and unique structures of authority within particular cities. Power dynamics are an important consideration for any articulation of urban resilience.

The measurement of resilience using appropriate indicators presents particular challenges for those aiming to operationalise the concept in cities. Alongside the failure to account for the complexity of cities and the socio-political power dynamics that affect resilience, approaches to measurement do not sufficiently articulate the minimum performance – or 'functions' - that cities need to achieve in order to be considered resilient.

The literature review explored what these functions might be, based on theories of functional urban geography and fundamental human needs. This analysis enabled an understanding about the minimum performance of a city at different scales (individual, household, community, city).

(12) As recognised by UNESCAP (2012) 'What is Good Governance?' Bangkok: UNESCAP

The review identified a gap in the conceptualisation of urban resilience; there does not yet appear to be a holistic and comprehensive approach, or framework, which can be used to both articulate and measure urban resilience. The CRI will aim to fill this gap.

Based on the literature, the development of the CRI will commence with the hypothesis that a city's performance hinges on its ability to fulfil seven critical city functions:

1. Protection of human life
2. Support of livelihoods
3. Protection of assets
4. Facilitation of human relationships and identity creation
5. Information, education and innovation
6. Upholding the rule of law and promoting justice and equity
7. Enabling economic prosperity

The following section of this report will test this hypothesis using a desk-based analysis of urban resilience evidenced through secondary case studies and reports.

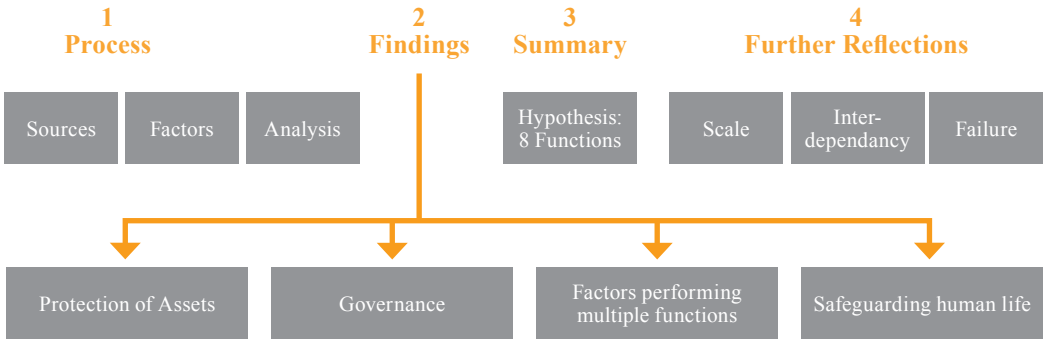
(Picture right)

Waterfront dwelling in Can Tho, Vietnam

(Picture above)

Workshop with tsunami-affected community in Sri Lanka

Figure 4: Data analysis structure and key findings identified.



Examining evidence from the literature:

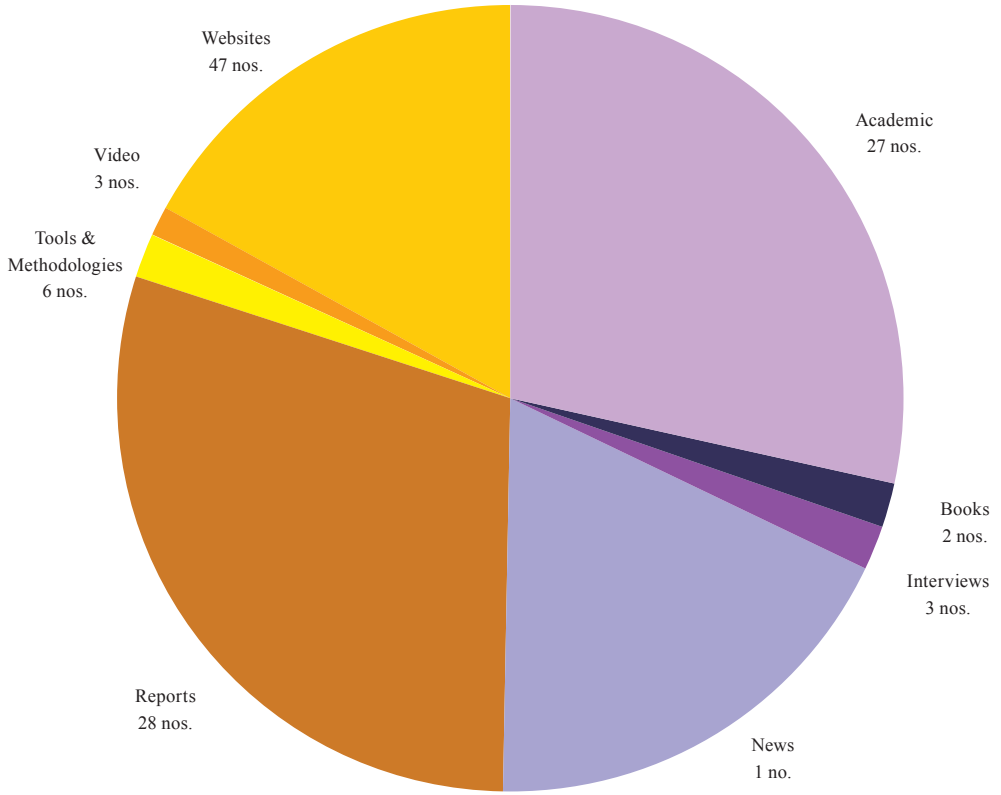
Desk-based data analysis

Process

Sources

More than 150 sources were reviewed to understand the range of challenges faced by cities, and the ways in which cities have responded to stresses and shocks. These sources were made up of city specific studies and more general guidance documents on urban resilience. Figure 5 summarises the types of sources used in this review.

Figure 5: Types of references used for the desk-based analysis.



City-specific sources

From the available literature, 14 cities were selected that included those with low, middle and high GDP per capita, located in the following geographic regions: North America, South America, Middle East, Sub-Saharan Africa, East Asia, and Southeast Asia (as outlined in Table 5). The shocks and stresses faced by these cities vary in nature and include natural disasters, violence, terrorism, health epidemics, food scarcity, economic decline, fires and resource inadequacies. The cities were also selected based on their experiences of shocks or stresses within the last 15 years.

Table 5: List of cities covered by the city specific sources and the shocks/ stresses studied

City	Country	Shock / Stress
Bangkok	Thailand	Political Protests (2008-2010)
Brazzaville	Republic of the Congo	Munitions Depot Explosion (2012)
Chengdu	China	8.0 Wenchuan Earthquake (2008)
Detroit	United States of America	Declining Economy and Bankruptcy
Doha	Qatar	Food Security
Hong Kong	China	SARS Epidemic (2003)
Kampala	Uganda	Market Fires (2009-2013)
New York	United States of America	Terrorist Attack (2001)
Seattle	United States of America	Wind Storm (2006)
Dar es Salaam	Tanzania	Flooding (2011)
Ho Chi Minh City	Vietnam	Flooding
Lima	Peru	Water Scarcity
Quito	Ecuador	Volcanic Eruption (2002)
Rio de Janeiro	Brazil	Lack of Security

Guidance documents

In addition to the city-specific sources, six guidance documents were reviewed, which directly address the concept of urban resilience (Table 6). These documents cover research on urban resilience within research organisations, businesses and private sector practices. This provided insights into contemporary research and perspectives on urban resilience. It is possible to see how the documents are influenced by the author's role and remit, such as technology, climate change and urbanism. By considering a range of such documents, the interests of authors from different sectors could be balanced to avoid bias.

Table 6: Guidance documents used in desk-based research

Publications	Key objectives
Resilience indicators developed for the Asian Cities Climate Change Resilience Network (ACCCRN) based on experiences in 10 Asian cities (ISET, 2014)13	Challenges faced by cities that are undergoing a combination of rapid urbanisation and climate change
Arup, RPA & Siemens (2013). *Toolkit for Resilient Cities*, London: Siemens	Strategies adopted by cities to combine technology solutions and enabling actions to deliver resilient infrastructure
Arup (2011). *C40 Cities Report Climate Action in MegaCities*, London: C40 Cities climate action group	Actions taken by cities to counter major risks arising from floods, heat stress and water stress, among others.
Carbon Disclosure Project (2013). *Wealthier, Healthier Cities,* London: Carbon Disclosure Project, AECOM & C40	Co-benefits of taking actions on climate change in cities e.g. Improving efficiency and attracting new business
Martin-Breen, P. & Andries, J. M. (2011). *Resilience: A Literature Review*, New York: The Rockefeller Foundation	Literature review of the theory and application of resilience across related disciplines like engineering, psychology, complex adaptive systems and economics
UNISDR (2012a). *City Resilience in Africa: 10 Essentials Pilot*, New York: UNISDR	Checklist and toolkits to building disaster risk reduction in cities

(13) This refers to the Excel spreadsheet of indicators developed by the Institute for Social and Environmental Transition (ISET) that were shared with ACCCRN partners, in addition to Developing Indicators of Climate Change Resilience - Working Paper 3 (ISET, 2014) .

Factors

Factors of resilience were identified from the various sources, using the definition below. This process resulted in a long list of 384 factors.

Definition of factors: Assets, systems, practice or procedures - that contributed positively (or negatively) to the city's ability to prepare, recover and adapt in the face shocks or stresses.

The assets, systems, practices or procedures identified were considered to have assisted in either recovery from shocks and stresses, or avoidance of future disruption in the city (e.g. riots, floods, epidemics).

For example, in Chengdu, China, the emergency following the earthquake in 2008 forced local authorities to work with NGOs – in several cases for the first time – in order to access isolated communities. Subsequently, Chinese policy makers recognised the importance of civil society in responding to crisis and reduced the regulatory bottlenecks constraining NGOS and charitable foundations. Here, the emergence of formally recognised NGOs and the policy context that encouraged them were factors that evidently helped to increase resilience in Chengdu.

(Picture Below)

Cheng Du: NGO efforts bringing aid to disaster areas after the earthquake

Qualities

The qualities of resilient urban systems (identified in the preceding chapter) were used to help in identifying factors.

For example, in São Paulo, automation and remote monitoring stations installed along water supply networks helped the city to forecast demands and avoid the risk of water shortages. The adaptive quality of the network was a result of specific technical measures that were put in place.

Performance-based approach

The selection of factors focused on items that made a direct contribution to resilience, rather than interventions that were directed towards other agendas like liveability, sustainability or economic development.

The factors were extracted based on evidence of performance failure, and therefore comprised only items that clearly contributed to failure or would help to avoid future failure. . This led to a clear distinction between factors needed for a well-functioning city (day to day) versus factors needed for a resilient city (in the long-term).

Proactive and reactive factors

Two types of factors could be observed: proactive and reactive factors.

Proactive factors are items that cities put in place before a shock occurs or before stresses become severe. They help to reduce the probability of disruption or the severity of its impact.

For example, building codes that account for the risk and magnitude of earthquakes greatly reduce the damage that an earthquake may cause to a city.

Reactive factors are things that help cities respond to a disruption, for example, distribution of food packets to flood victims.

Since a few of the cities studied for this analysis had experienced recent shocks and stresses, they had not fully demonstrated their ability to recover from and avoid similar failures. It was therefore important to take note of factors that negatively affected the city's experience. These factors were rephrased positively, assuming that a reversal of circumstances would help to improve city resilience.

For example, during the SARS outbreak in Hong Kong in 2003, lack of communication between the Department of Health and the hospital authority led to a 10 day delay in action to stop the spread of disease. A strong link between public and private health practitioners is therefore a factor of resilience that would improve response times and reduce the spread of infectious diseases in a city.

Figure 5: An example of the coloured sticky notes used to represent factors of resilience in the desk-based analysis

Analysis

'Post-it' sticky notes were used to record the factors. The use of post-its enabled a complete picture of the data-set and facilitated an easy iterative analysis. The factors were coded with different types of information. Colour-coded notes were used to record the original source of each factor, such that the original evidence could be traced and any predispositions of the author could be recalled. Each note was annotated to identify whether the factor referred to a physical or non-physical item.

Mapping factors against functions

The main purpose at this stage was to test the relationship of the factors against the seven functions of a city, as identified in the literature review. The factors were mapped to the most appropriate function. Within the function, multiple factors were grouped where they appeared to contribute to a common outcome.

For example, a common consequence of integrated water policy, watershed protection and reforestation could be 'protection and control of floods', which in turn contributes to the protection of assets – one of the seven functions.

At a later stage, the mapping was transferred from a physical to digital format to facilitate further analysis, verification and presentation of the findings.

Iterative reviews

A series of internal review workshops were held to bring in various perspectives on how the factors aligned with the functions and whether there were any gaps in the findings of the literature review. Reviews with various technical and strategic experts within Arup were also carried out. Specialists with backgrounds in engineering, masterplanning, social sciences and economics participated in an iterative process of analysis and review of these factors and the themes emerging from factor groups, in order to challenge, develop and re-shape the seven functions identified by the literature review.

Findings

The following describes the key findings of the analysis, and the decisions taken to develop the initial performance-based urban resilience framework that emerged from the literature review.

Protection of assets: resilience specific factors

The factors relating to 'protection of assets' comprise both the man-made and natural assets of a city, which need to be protected from shocks and stresses. Assets include canals, highways, and buildings, as well as wetlands, forests and mangroves. Regardless of their natural or man-made typology, both asset categories contribute to similar outcomes, such as flood management. The fundamental interaction between natural and man-made assets can also be observed when, for example, man-made infrastructure like weirs and dams are put in place to increase the utility and/or capacity of natural systems; neither type of infrastructure acts in isolation of the other. These observations implied that natural and man-made assets should be included within a single function, as the literature review suggested.

Governance: an overarching theme

A significant number of factors relate to some aspect of management, oversight, or the act of governing, which suggest that an additional function of a resilient city may relate to governance. For example, several factors relate to multi-stakeholder engagement. After consideration by the research team, it was agreed that 'governance' was too broad to be a stand-alone function, and most of these factors could be interpreted as assisting other functions.

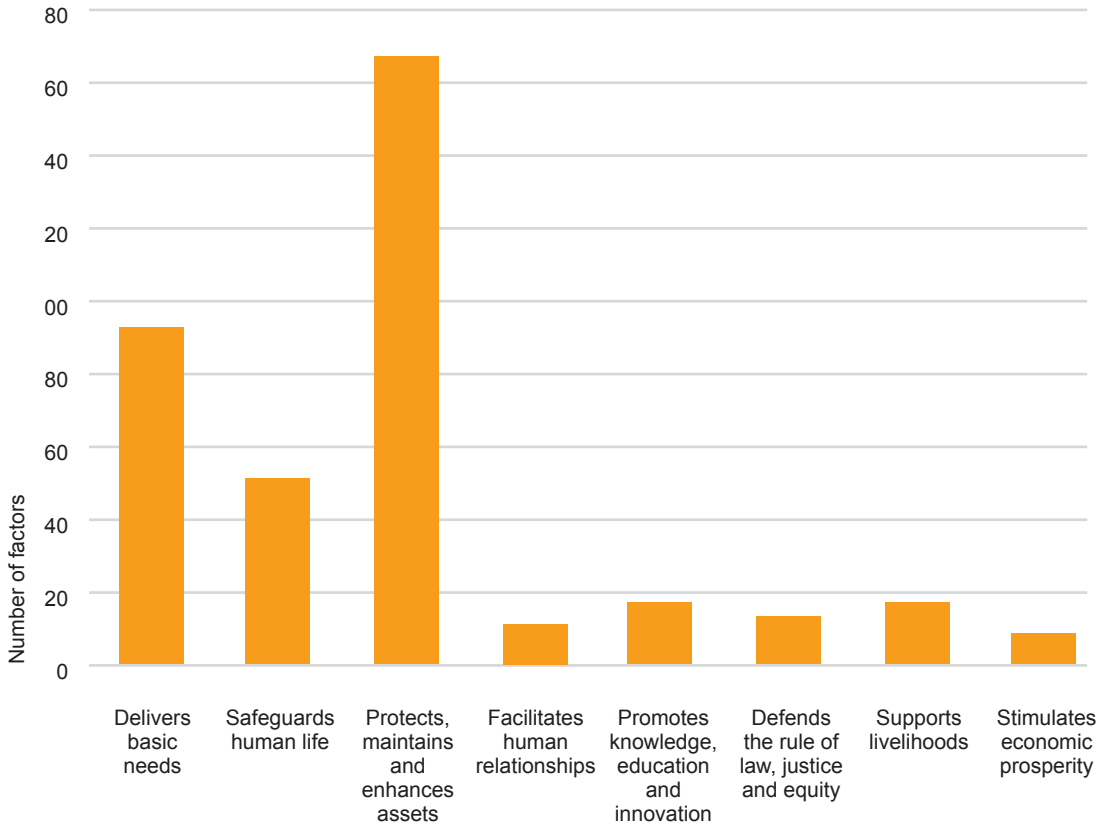
Factors performing multiple functions

Demonstrating the interdependency between urban systems, a number of factors could be deemed to perform several functions in a resilient city. For example, factors relating to urban transport required a more detailed analysis. Transport systems are made up of physical assets that need to be built, maintained and protected. Transport modes are essential in post disaster recovery and rescue operation, therefore- safeguarding lives. They also connect places of residence to places of work, thus supporting livelihoods. Investments in urban transport are seen to have a direct positive contribution to the economic prosperity of a city. This finding supports the adoption of a more holistic approach to resilience than focusing on assets alone.

Safeguarding human life: serving vs. protecting

The factors that accumulated under the function ‘protection of human life’ show a clear distinction between those that relate to everyday basic needs, compared to those that relate to safeguarding human life. For example delivering food to urban citizens is a basic need, whereas emergency services like disease control and fire brigades are operationalised only after shocks with the sole purpose of protecting lives. ‘Meeting basic needs’ emerged as a separate urban function that includes specific urban services that, according to the sources, are essential for urban living (e.g. food, water, healthcare).

Figure 6: Factors mapped against the eight functions of a resilient city



Revised hypothesis:

Eight functions of a resilient city

As a result of the analyses and reviews, eight functions are proposed as the foundation of a measurable framework for city resilience. The number of functions increased from seven to eight and the phasing of the functions was modified to reflect the analysis.

The new functions are as follows:

A resilient city…

1. …**delivers basic needs** by providing access to water, energy, food, shelter and waste management, despite on-going stresses and occasional shocks. (New)
2. …**safeguards human life** from threats by raising awareness, undertaking direct planning measures and ensuring adequate resources are available to deal with the effects of the shocks and stresses.
3. …**protects, maintains and enhances assets** to reduce the likelihood and impacts of shocks and stresses, and continues to provide critical services during shock/stress events.
4. …**facilitates human relationships** and identity to ensure a stable and peaceful society and to prevent societal breakdown aftershocks or during stresses.
5. …**promotes knowledge, education and innovation** that increases understanding of threats, improves management of shock/stress events and creates an ability to learn from past experience.
6. …**defends the rule of law, justice and equity** by maintaining an effective justice system that holds people and institutions accountable to preserve the peace.
7. …**supports livelihoods** by improving access to income generating activities and support for business during shocks and stresses.
8. …**stimulates economic prosperity** by strengthening competitiveness, diversifying the city's economic base and promoting a healthy business environment.

This performance-based approach to urban resilience will be further tested by the primary data collected in the fieldwork of six cities[14].

(14) See Arup, Research Report Volume 2: Fieldwork and Primary Data Analysis.

Figure 7: Diagrammatic representation of scales at which each of the functions operates

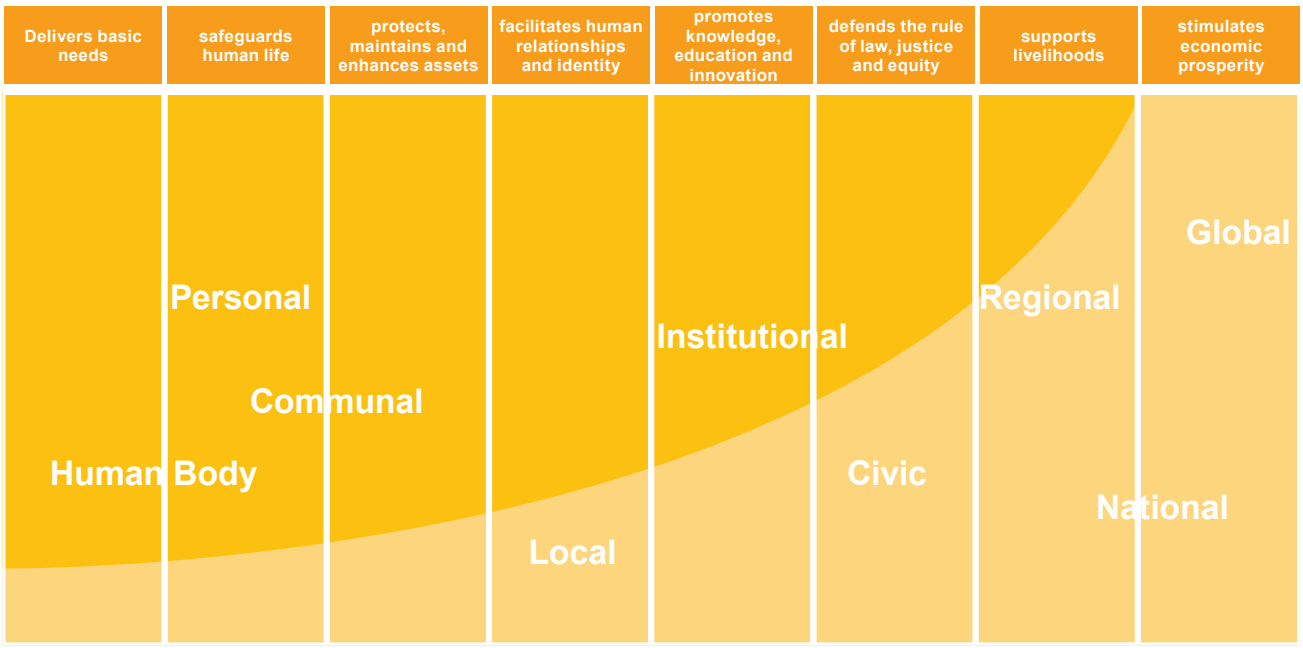
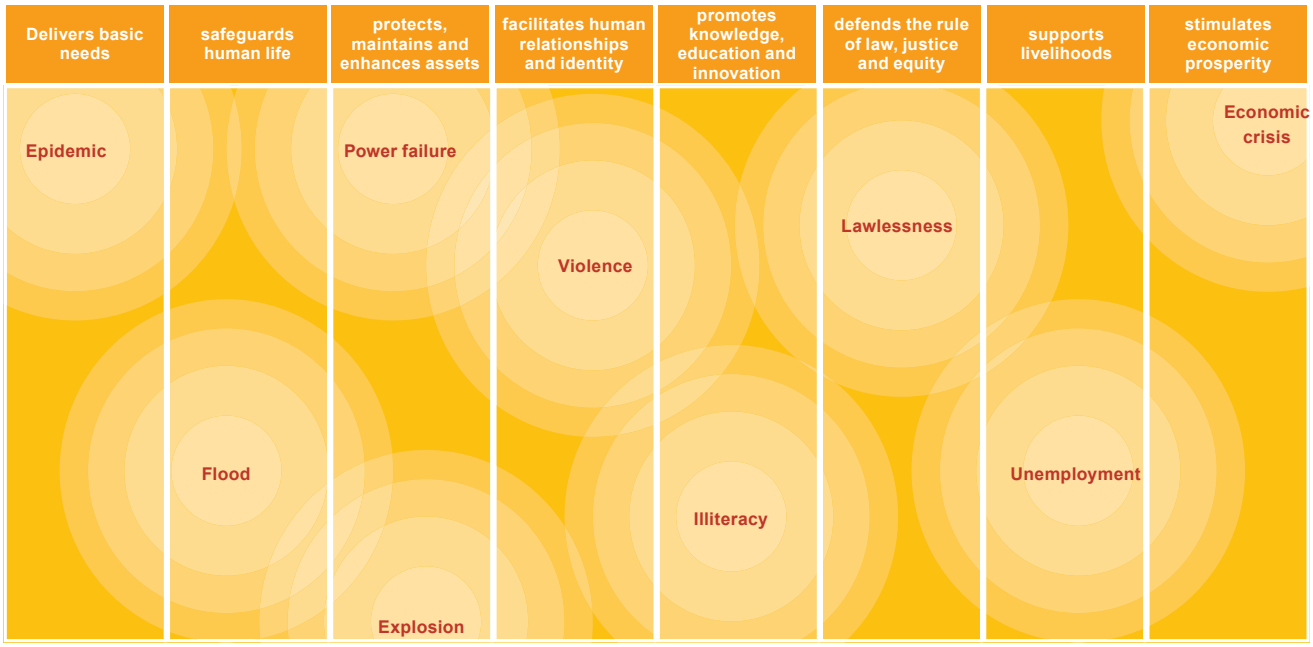


Figure 8: Diagrammatic representation of ripple effect of shocks and stresses across eight functions



Further reflections:

This section highlights some of the additional observations emerging from the desk-based analysis, which relate to the key issues emerging from the literature review.

Scale

The factors range in scale with respect to control and influence. Some factors serve the direct needs of individuals or families, such as water and food. Others solve challenges that emerge within larger complex societies, such as having good coordination between state authorities and media during emergencies. Institutions, such as criminal courts and police forces to defend the rule of law, are applicable to the entire city.

To illustrate this, the eight functions of a resilient city were organised in order of increasing scale. Figure 7 illustrates how the eight functions encompass the range of scales from individual through intermediate collective scales based on place (neighbourhood) or social groups (community) to the city scale, and beyond.

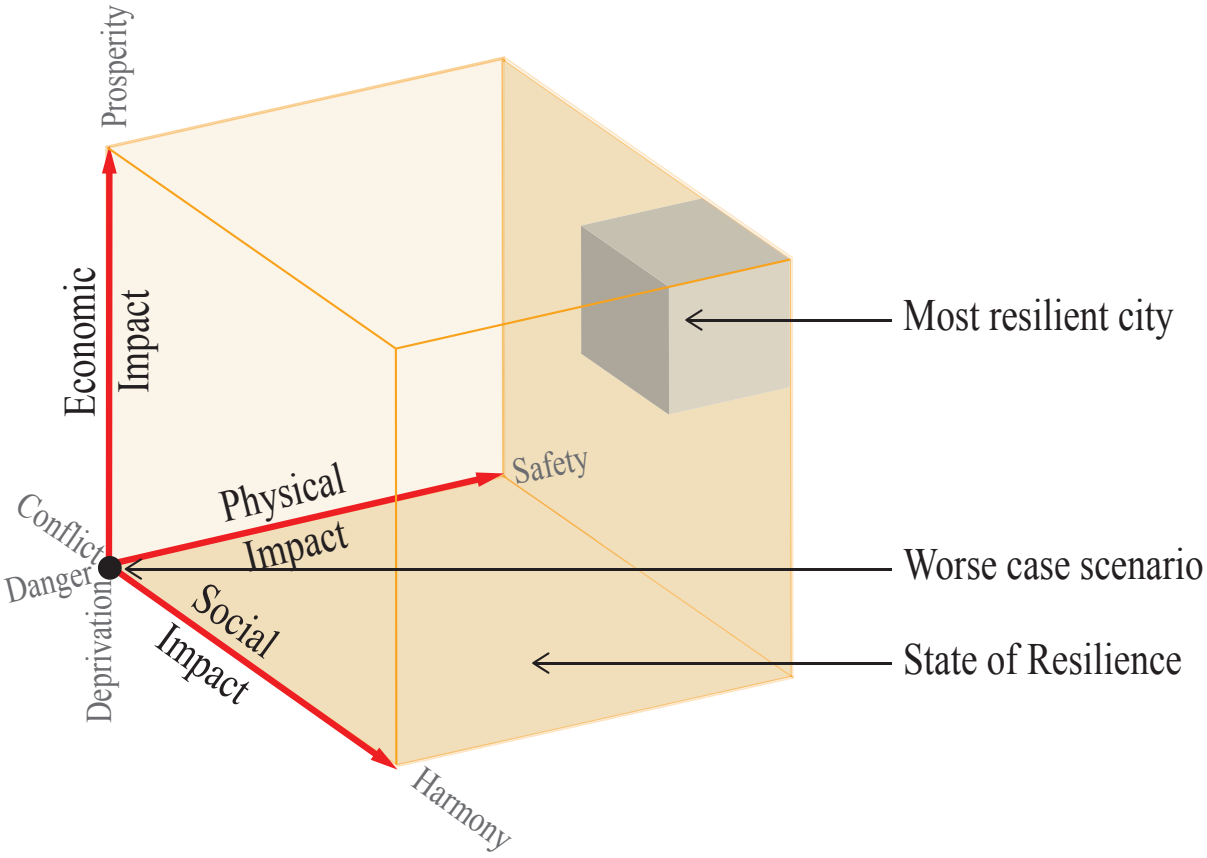
Although illustrated as function 7, the function of 'supporting livelihoods' also plays out at an individual or community scale when discussing micro-finance or street-trading.

Interdependency

Studying cities with respect to their shocks and stresses highlights that failure in one system may hamper the functioning of other systems in the city. For example, lack of affordable urban transport can have a detrimental effect on communities that cannot access employment, which in turn affects their ability to meet basic needs. Although disruptions may be caused by a lapse in particular functions of a resilient city, the effects are not confined to these functions. The impacts of shocks and stresses have knock-on (or, 'cascading') effects. Failure in one 'function' can reduce performance in other functions.

For example, in Brazzaville, Republic of the Congo, several powerful explosions at a munitions depot in 2012 resulted in 282 deaths and contaminated the surrounding area. This led to disease outbreaks due to the failure of water and sanitation services. The destruction of schools disrupted education of children, leading to children loitering and social unrest.

Figure 9: Relationship of the 3 dimensions to the types of impacts in a city



Dimensions of failure

The analysis suggests that the inability of a city to perform specific functions would contribute to failure of different types. For example, inability to deliver basic needs or protect, maintain and enhance assets ultimately would contribute to creating an environment that is dangerous. Similarly, lack of livelihood support or inability to stimulate the economy of a city would eventually deprive citizens. These failure mechanisms can be broadly classified as physical, social or economic.

Conversely, the inter-linkages in the city cannot be ignored, as shock or stress in any one domain can have an impact in all three domains. For example, severe flooding might cause damage to infrastructure as well as loss of life or injury (physical), result in looting in some neighbourhoods (social), and affect business continuity (economic). These can be described as three 'dimensions of resilience'.

Each dimension is defined by a worst case scenario representing collapse or failure (danger, conflict, deprivation) and a best case scenario representing a resilient city (health, social harmony, prosperity). Shocks and stresses threaten to push the city towards the worst case scenario, while they strive to develop and maintain a healthy, harmonious and prosperous place.

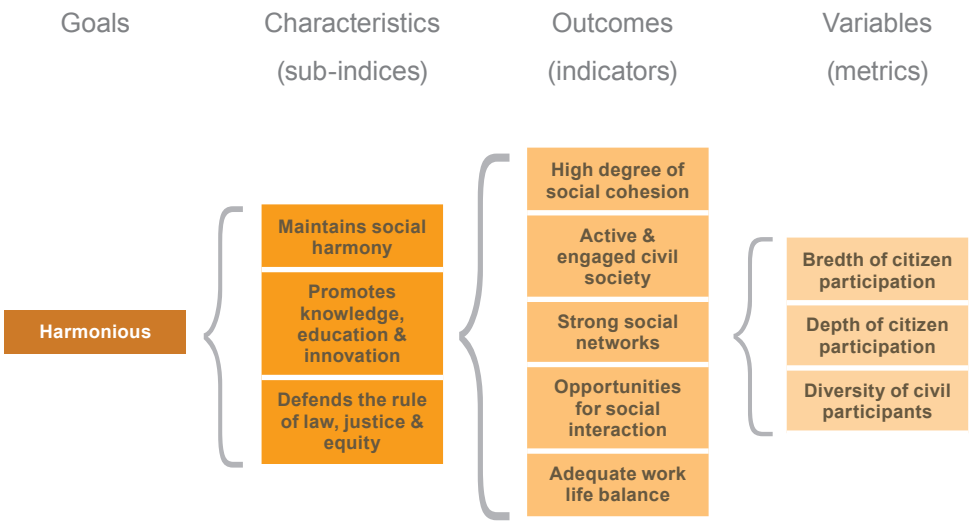
Prior to the earthquake in 2010, Port au Prince, Haiti was an example of a city that was not resilient. It was characterised by poor quality infrastructure that proved dangerous in an earthquake. The ability of Port au Prince to recover has been further hampered by social conflict and economic deprivation.

Cities are made up of interlinked systems which respond and interact in different ways to a shock or stress, and may exhibit varying levels of resilience. These systems are constantly working to move the state of a city along these three dimensions:

- On the physical dimension, from a worst case scenario of danger to being safe
- On the social dimension, from a worst case scenario of conflict to harmony
- On the economic dimension, from a worst case scenario of deprivation to prosperity

Figure 9 represents the 3 dimensions as 3 axes in cartographic space defining a cube. The black dot represents the worst case scenario of total collapse while the yellow dot is the best case scenario that resilient cities strive towards.

Figure 10: Operationalising city resilience – how the City Resilience Framework provides a structure for measurement.



Conclusions

This desk study identifies some of the key challenges surrounding resilience in the context of cities; including the mix of physical and social dimensions, understanding inter-relationships, incorporating power dynamics, and measurement. It confirms the need for a clear articulation of city resilience, which considers economic, physical and social disruption at a city scale, while also embracing human behaviour and physical aspects. As current approaches focus on specific risks, or are limited to consideration of assets or specific systems (usually physical systems) within cities, an holistic approach could not be identified which adequately meets this need.

As a result of further literature review and desk-based analysis, a performance-based approach to resilience is proposed. This approach describes - and will ultimately be used to measure - city resilience in terms of the ability of the city to function. This approach is more holistic because it recognises the cross-cutting nature of assets and systems, which contribute to multiple city functions simultaneously. The performance-based approach also embraces actions taken by a wide range of agents (government, business and civil society) at different scales of city operation (individual, household, city, etc.). This goes some way towards addressing the challenges of resilience, outlined in the literature review.

This report proposes eight functions and three dimensions that combine to create a City Resilience Framework. This hypothesis will be tested, using primary data from fieldwork in six cities. Further testing will ensure that the final articulation of a City Resilience Framework is evidence-based and comprehensive, reflecting a range of experiences and contexts. Ultimately, by identifying measurable indicators to accompany each function, the Framework might form the basis of a City Resilience Index.

Revised functions of a resilient city

To deliver basic needs

Most urban inhabitants are engaged in secondary and tertiary economic activities and are not directly involved in producing their food, water, energy, medicine and shelter. These things are obtained by the city instead. Large populations live in dense concentrations, where the demand for basic materials is very high and the supply can often fluctuate. A resilient city provides for its people continuously, despite stresses and shocks.

To continuously enable life, a city must rely on multiples sources of water, food and energy in case a single one is compromised in a shock or stress event. On these occasions, having stockpiles of provisions like food, medicines, clothing, and emergency shelter is helpful. Promoting sustainable practices like solar passive energy, water harvesting and domestic food production can ameliorate the build-up of stresses caused by a lack of energy, water and food respectively.

Example: Due to rapid demographic growth in the State of Qatar, food demand has outstripped domestic levels of agriculture production. Since more than 90%of this food supply is imported at a great cost, urban populations are extremely vulnerable to effects of political, biological and economic shocks. In response to this, the country has started an initiative to increase agriculture production to reach 40% of its demand within the next 12 years. To ensure this, they are implementing innovative techniques like desalination, hydroponics, soil enrichment and water efficiency techniques.

To safeguard human life

Urban communities are vulnerable to threats including fire, diseases, floods, pollution and terror attacks. People do not always have the means to react at an individual level to these threats. Cities need the capacity to protect their inhabitants from threats by raising awareness, undertaking direct planning measures and ensuring that adequate resources are available to deal with the effects of specific shocks and stresses. In times of stress and shock, cities need to react in order to save lives.

Resilient cities keep their citizens safe by having special measures in place, like an emergency evacuation strategy and sufficient numbers of health workers trained with relevant skills. They also put preventive measures in place to minimise exposure to threats by planning/zoning areas that are prone to calamities like floods and landslides.

Example: In ***Chengdu***, the disaster management and mitigation that the Chinese Central Authority had put in place prepared it to react better to a 7.9 magnitude earthquake that hit the city in 2008. This was due to learning from a previous snow storm which paralysed the national transport system in China. Chinese policy makers have also realised the importance of including civil society in responding to crises and they have reduced regulatory bottlenecks.

To protect, maintain and enhance assets

Cities are an assemblage of physical assets that are used and often owned collectively. Assets may be man-made - including buildings, bridges, transport networks and energy plants - or they may be natural systems, such as rivers, forests, mangroves, soil and ground water. These protect the city from hazards like flooding, landslides and pollution. They can also be the city's lifeline due to their provision of water, energy and food.

Cities need to value these assets, as they form a line of defence from stresses and shocks. They need to protect these assets to maintain their functionality as well as to protect populations that may be severely affected if the assets fail. For example, a dam may hold potable water for the city to utilise. If the structure of the dam fails, it will lose not only this functionality, but also cause floods.

A resilient city protects its natural and man-made assets to reduce the likelihood of shocks and stresses and to continue to provide critical services during shock and stress event. Coastal cities may maintain mangroves and restore wetlands to defend themselves from floods while hill cities might build dams to control flooding and landslides downstream.

*Example: In **Dar es Salaam**, after a massive flood in 2011, a city-wide action plan for upgrading unplanned and unserviced settlements by 2020 contributes to building resilience through improving infrastructure and services taking into account the potential of future shocks.*

To facilitate human relationships and identity

Cities are powered by people. People of different races, genders classes, religions, cultural identities and affiliations live in close spatial proximity in cities. This characteristic is a pre-requisite of urbanity, since most cities have historically grown out of regional, national and international migration. City dwellers experience vibrancy of place through differences in cultures, cuisines and shared histories. They can also experience feelings of isolation, anxiety and discontent. Social cohesion can be a major advantage to a city undergoing a shock or stress event. Social networks can facilitate access to assets and provide psychological support to those experiencing a shock or stress.

The ability of a city to ensure a peaceful and stable society and to prevent societal breakdown during shocks and stresses is a characteristic of resilience. It does it by promoting active and engaged civil society networks that include communities in the decision making process. In many cities, religious and faith-based institutions play an important role in this regard. NGOs and human rights organisations assist in raising awareness and reaching out to marginalised communities.

*Example: In 2008, **Bangkok** experienced a political crisis that increased tension in the city and culminated in massive violence claiming lives and livelihoods. In the aftermath of the violence, religious services and activities were used as a means to build psychological resilience at an individual level, as part of the rehabilitation process. Also, Bangkok changed the curriculum of 435 schools to enable students to become better citizens by teaching them how to act properly and patriotically when displaying political dissensions.*

To promote knowledge, education and innovation

Cities have always been hubs of knowledge and innovation and magnets for creative and educated people. The kind of knowledge in cities ranges from awareness of local weather patterns and reading tell-tale signs of a potential natural disaster to accessing scientific research and information. Cities constantly need to raise their levels of awareness. Knowledge can not only play a crucial role in a city's ability to avert shocks, but also assist in its quick recovery. Being able to communicate during a shock or stress event plays an important role in the short term recovery process and long term learning. For example a higher level of literacy within a city allows external agencies to coordinate evacuation and rescue operations more effectively.

Resilient cities understand the power of knowledge and can harness it to their advantage to increase understanding of shock or stress events and to learn from past experiences. Monitoring climate data and institutions that research risks have an important part to play. Cities improve their resilience by putting

in place back-up systems for communications run by trained and prepared crisis communication teams.

*Example: **Quito** in Ecuador faces constant risks from nearby volcanic eruption. This helps to decentralise the management of DRR by preparing local governments and civil populations about the nature of risks and allows participation at an individual level.*

To defend the rule of law, justice and equity

Cities have a need to influence human behaviour and ensure they are accountable to their citizens and administrators. They need to promote justice and equity in order to protect the rights and freedoms of their citizens. Cities do this passively through policies and laws that deter iniquitousness by individuals and groups. They also control businesses through government and legal systems. During shock events like riots, violent demonstrations and aftermath of natural disasters, police presence is vital to a peaceful recovery and having faith in the justice system makes people feel secure. The failure to uphold the rule of law can have cascading negative impacts on a city, allowing new stresses and shocks to emerge that can have a more lasting impact on the city than the shock event itself.

Thus being resilient involves defending the rule of law, justice and equity- to foster an effective and fair system that promotes accountability and maintains peace. An adequately resourced and trained police force that works within a transparent and non-corrupt political system can curb the escalation of lawlessness during stress or shock events. The policies that a city puts in place should be equitable, while protecting marginalised communities.

*For example, the favelas or informal settlements of **Rio de Janeiro** began to grow in the city, from the end of the nineteenth century onwards. Following the abolition of slavery in 1888, freed slaves began flocking to Brazil's then-capital in search of work. They set up home in poorly constructed slums built on the only land that was available, usually hilltops or swamps on the city's outer limits. By 2001 favelas occupied an area of around 37 km2 in Rio, corresponding to 6.3% of its total territory. The livelihood in the favelas has been suffering the dominance of the drug gangs, influencing the opportunities for social inclusion of favela residents as well as decreasing their freedom, through the extensive use of force if the behaviour of people was considered suspicious or disloyal. Recent interventions – for example, the Favela Bairro programme– have demonstrated that it is key to not just provide infrastructure but also to combine that with social programmes allowing an increase in the quality of life within the favelas – including them within the "formal" city and enhancing social development to reduce violence.*

To support livelihoods

Cities are hives of economic activity with complex and self-regulating divisions of labour. These involve the participation of a majority of city dwellers providing supporting services like retail businesses, government officials, infrastructure operators etc. By doing so, city dwellers not only provide needed services and goods to the city, but also earn subsistence for themselves and their dependents. A city's failure to support livelihoods can itself become a source of stress in a city which can escalate with rising unemployment. Power failures and transport breakdowns can also have a knock-on effect on city dwellers in not being able to support themselves. i.e. preventing them access to places of work. This also slows down the processes of recovery.

A resilient city thus supports livelihoods by improving access to income-generating activities and support for businesses during shocks and stresses. Cities need to promote entrepreneurship, encourage household savings, and provide micro finance institutions and affordable transport systems that improve access to jobs. This is even more relevant during shock or stress events which test the agility of cities to perform its functions in a new state to keep up its economic activities.

*For example, after the earthquake and fire in **San Francisco** in 1906, the people in the city had to take solace in parks and open spaces. Although large amount of emergency supplies were deployed, a breakdown of infrastructure i.e. destruction of roads made the process very slow. In response, makeshift shop fronts were erected in wide streets encouraging a rapid resumption of commercial activity directly in front of damaged ones.*

To stimulate economic activity

Cities are sites of industry, trade, production and investment. The concentration of economic activities in urban areas not only promotes competition internally but also supports inter-city competition. To facilitate economic prosperity, cities need to operate at a macro level to regulate trade within cities as well as economic activities beyond their borders. This is delivered by a form of infrastructure made up of stock markets, monetary organisations, financial institutions and trade unions. These create a business environment, monitor markets and support business continuity. A city's inability to provide this can lead to loss of competitiveness, stagnation and even closure of vital industries. Shock and stress phenomena like economic crises and large scale unemployment are a result of such failures.

Cities stimulate economic prosperity by strengthening competitiveness, diversifying the economic base and promoting a healthy business environment. Corporate business continuity planning is encouraged by

resilient cities which should also have a proactive chamber of commerce. Governments often bail out cities in times of economic downturn to stabilise their financial markets and maintain competitive advantage within the wider economy.

*For example, the islands of the **Seychelles** have transformed in the last 20 years from being a plantation-based economy to being tourism-based one. But due to its isolated nature and its extremely high dependence on imports, the Seychelles is vulnerable to fluctuations in global prices of oil, air travel and emerging competition. In 2012, the Seychelles built a high speed fibre-optic line connected to mainland Africa to facilitate communications. This is a deliberate move to help the country to diversify its economy, with ambitions to become the knowledge and finance gateway to Africa and a hub for the emerging economies surrounding the Indian Ocean.*

City Resilience Index

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City Resilience Index

Appendix A

Examples of qualities of resilient systems

A resilient urban system is…

1. …accepting of uncertainty and change

Urban areas are so complex that planning for every eventuality is near impossible. Therefore in building resilience there must be acceptance that changes will happen but that they may not necessarily be predicted or prepared for (Chelleri, 2012). Accepting the inherent, and ever-increasing, uncertainty and change within today's world, requires a shift in the mind-set of those designing and managing urban systems (Beck, 1992; Béné et al, 2012; Berkes & Seixas, 2005). This shift is reflected in new paradigmatic concepts of resilience, such as evolutionary resilience, which are not focused on a system's return to an equilibrium point, as discussed earlier in Section 1 (Béné et al, 2012; Chelleri, 2012).

Adopting an acceptance of and openness to the possibility of change will affect the way that those involved in urban governance plan as well as act or intervene in systems (IRWG, 2012). Furthermore accepting uncertainty and change also alters how we measure and evaluate not only resilience but also our identification of success and maintenance of function within (urban) systems (IRWG, 2012). Moench et al (2011) highlight the impact which an acceptance of potentially unknown risk has on preparation for disasters or crises in urban areas. Critically, resilient preparedness measures or systems typically work to incorporate natural systems, change or risks, rather than trying to keep risk out (Béné et al, 2012).

"Planning is thus about being prepared for innovative transformation at times of change and in the face of inherent uncertainties" (Davoudi, 2012: 304). In cities this process may be challenged by land use issues and reluctance of property owners to give up land or change boundaries.

Planning systems which are accepting of uncertainty and change in Chicago, USA

Chicago is noted as one of the greenest, most innovative cities in North America, if not the world. Over its history it has continued to thrive in the face of shocks and stresses, such as the Great Chicago Fire in 1871, and reinvented itself constantly with the aim of improving the quality of life of its citizens. Recently, Chicago has made concerted efforts to embrace the uncertainty of climate change and its risks, summarised in the Chicago Climate Action Plan. One key feature of this Plan is the recognition that for future resilience, the city must act with nature and the environment, rather than acting to keep nature out.

In considering an uncertain future, Chicago has worked with future projections and plausible scenarios to imagine the state of the city in the coming years. Rather than focusing on ensuring the system is resilient in its current state, the use of forecasting – and the inherent uncertainty of such

tools – has been central to the development of the city's Climate Action Plan. Similarly, the Plan is not viewed as a fixed and final document. "Whilst based on extensive research and analysis, the Chicago Climate Action Plan represents a snapshot in time, using the best technology available today. But technology and markets change almost daily, which is why we expect the Plan to evolve over time. A strategy identified today may become obsolete, just as new technologies may emerge that weren't even considered possible when this plan was written. As a result, like Chicago itself, the Plan is dynamic and nimble." (City of Chicago, n.d.: 11).

As progress is continually monitored within the city, to examine whether Chicago is meeting the goals laid out in the action plan, these goals can also change. Revisions and adjustments can be made to targets and even indicators. This flexibility acknowledges the unexpected and the events and changes which may not be planned for, but which can have a significant impact on the resilience of Chicago.

A resilient urban system is…

2. …reflective

As well as considering an uncertain future, resilient urban systems examine their past experiences, and learn from them. "[M]anaging resilience requires understanding how historical system dynamics have shaped the current system." (Resilience Alliance, 2007: 22), and also how past mistakes can be avoided in the future (da Silva et al, 2012; Moench et al, 2011).

Studying and learning from past experiences – such as disease outbreaks, earthquakes, or widespread power failures – can help to develop scenarios to model unknown futures, to prepare for similar possible events (Wallace & Wallace, 2008). Alongside performance of infrastructure systems or governance systems, the importance of learning from social networks during disaster events has been highlighted by multiple authors. Pahl-Wostl (2006) and Leichenko (2011) have both identified the importance of 'social learning' at individual, household and local levels. The significance of learning at higher, institutional and organisational levels is also noted by the work of Fiksel (2003) and Béné et al (2012).

All urban policies and plans are the product of a particular temporal context. For reflexivity to be a core characteristic of resilient urban systems this characteristic should be demonstrated through regular and ongoing revisions and updates of plans and scheduling, based on past experience (DfID, 2011); not just reviews of current practices in the aftermath of isolated events.

Reflective land development systems in Sendai City, Japan

In March 2011 a 9.0 magnitude earthquake occurred just off the coast of Japan, in the Pacific Ocean. Shortly afterwards a tsunami hit the Japanese coastline, in the Tohuku region, destroying hundreds of thousands of buildings, killing thousands and affecting many kilometres of critical infrastructure and assets which supported the livelihoods of a significant proportion of the population in the area. The original hazard also indirectly caused one of the worst nuclear power plant accidents in recent history, extensive power failures and supply-chain disruption, particularly within electronics and technology industries. While Japan has a relatively well-embedded culture of preparedness, in response to a history of seismic hazards, the magnitude and impact of this particular shock was not anticipated. As a result of this earthquake, tsunami and ensuing nuclear disaster, a great deal of work has examined the event and extracted lessons learned.

Sendai City, Japan was particularly affected by the tsunami. Citizens suffered significant disruption to livelihood activities due to the lack of electricity. A new development area, Tagonishi, which had begun construction shortly before the earthquake and tsunami was designated a relocation area for coastal-dwelling citizens who had been particularly badly hit by the disaster. With knowledge of the disruption caused by the power failures, the developers – Kokusai Kogyo – altered their project design to ensure the site would be energy self-sufficient, and thus more resilient.

"Kokusai Kogyo thought hard about additional elements that would make their community more disaster resilient. While tsunami risk was already addressed by the inland location, Kokusai Kogyo decided that the risk for fuel shortages and stoppages to utility services, which had disrupted the livelihoods of many disaster victims over a long period in the GEJ Earthquake, needed to be addressed." The new development design therefore included micro-grid technology, and smart meters within individual homes to ensure control of energy supply through a demand-response system. Kokusai Kogyo also employs a policy of preferential sale of its commercial properties to supermarkets and retailers. This policy will hopefully ensure that these stores can operate as local supply centres in the event of future disasters. Plans are also in development to encourage stores to formalise this role via emergency agreements which would commit them to supply items to help the community meet basic needs during disasters. Had the tsunami and earthquake not struck when they had, it is doubtful whether the new Tagonishi development would have adopted these measures. In experiencing and learning from a disaster, measures were introduced to encourage local resilience.

A resilient urban system is…

3. …adaptive

Renouncing the concern with maintaining or returning to an existing equilibrium, but instead developing stronger, more resilient systems, whatever they may look like, resilient urban systems are adaptive. The process of adaptation makes peace with alternative futures or circumstances rather than striving to maintain the status quo (da Silva et al, 2012). The process of adaptation however typically involves the breaching of thresholds or reaching of tipping points. Crossing these thresholds encourages or allows development of new feedback mechanisms or functions within urban systems (Chelleri, 2012).

Sometimes thresholds may be breached as urban systems are put under far greater pressures than those for which they were originally designed; Putnam (1983) terms this phenomenon 'premature obsolescence'. For example, the sewage system in Chennai, India, designed back in the early 20th century, has been unable to cope with unforeseen levels of population growth within the city in recent years, particularly within the extensive informal settlements . Many urban systems in developing countries, like those in Chennai, are no longer fit for purpose, as the speed of urban growth has overtaken the capacity of the city to maintain and upgrade its systems and the assets they comprise.

For systems to be truly adaptive they also have to be innovative (Walker & Salt, 2006; Moench et al, 2011). Innovation in the context of adaptive urban systems does not mean simply using new technology. It also means considering and incorporating indigenous or traditional knowledge and practices in new ways or sectors (IRWG, 2012).

Successful adaptation which contributes to urban resilience is also multi-scalar (Chelleri, 2012), recognising the panarchic nature of urban systems explained in Section 2.2.1. This multi-scalar nature of adaptation requires significant cooperation and coordination by multiple actors in urban governance (Leichenko, 2011). Tight feedback loops and high levels of responsiveness are also required, including strong connections between different actors in urban governance, to ensure that actions are taken swiftly and effectively in times of stress (Wallace & Wallace, 2008).

Adaptive settlement systems in Dar es Salaam, Tanzania

Dar es Salaam is a coastal city affected by the influence of sea level rise and flooding as well as processes of coastal erosion. The city has grown rapidly over the past few decades and is also under stress from socio-economic challenges, such as the growth of informal settlements and the lack of adequate social services and provision of basic utilities such as potable water. Dodman et al (2011:8) even identify Dar es Salaam as being a city experiencing an 'adaptation deficit'. The city's infrastructure has not been upgraded or adapted to cope with the number of inhabitants currently living in Dar es Salaam.

However, the inhabitants themselves have displayed adaptive qualities within their settlement systems in response to these challenges; in some cases in partnership with local government actors and in others alone. For example, with flooding a significant concern for the city, a solid waste management initiative was launched to ensure that drainage channels could be kept clear of large amounts of rubbish produced by informal settlements. This minimised flood risk and lowered health risks by depriving malaria-carrying mosquitoes of blockages in which to breed. Community members make a small payment to municipal actors who undertake the waste collections.

Without municipal support, households have displayed adaptive capacities in modifying their homes to build resilience to floods. Some adaptations have involved physical alterations to homes, such as construction of flood defence walls outside the houses or high shelves inside on which valuables can be placed when flood waters begin to rise. Other evidence of adaptation can be found in behavioural changes of inhabitants in informal settlements. For example, residents reported responding more quickly and taking pre-emptive action when rain begins to fall, demonstrating a culture of increased awareness about risks and hazards.

A resilient urban system is…

4. …robust

Applied often to the physical systems – such as urban transport systems (Tierney & Bruneau, 2007) – robustness refers to the strength within systems that allows them to maintain function during a disruption. O'Rourke (2007: 25) defines this as "the inherent strength or resistance in a system to withstand external demands without degradation or loss of functionality". Technically systems may be considered as robust if they are governed by standards or codes which promote structural integrity. In application of this quality to institutional or human systems, robustness can be evidenced by communities which are prepared for disruption, and have skilled personnel able to respond in case of an emergency (O'Rourke, 2007).

As noted by Chelleri (2013), while the quality of robustness is commonly recognised across the literature as a feature of resilient systems, it is primarily used to refer to economic systems (Martin-Breen & Andries, 2011; Campanella, 2006) and infrastructure systems or networks (Siemens/Arup/RPA, 2013; Tierney & Bruneau, 2007). As Martin-Breen & Andries (2011) recognise it, robustness is a quality that relates to fixed systems and often a fixed set of shocks. Rarely is this quality used in relation to stresses a city faces.

Ensuring robustness is often seen as a defensive solution taken to reduce losses, rather than a longer term approach to building resilience. Indeed, as Chelleri (2013) cautions, viewing resilience as increasing robustness of urban systems – i.e. their ability to withstand or absorb shocks – alone, may mean that some unsustainable systems are perpetuated for longer than may be advisable. Instead combining robustness with flexibility and adaptability ensures that systems evolve into more appropriate forms when change occurs, rather than simply 'weathering the storm'. Martin-Breen & Andries (2011) also agree, claiming that robustness is a more static and short-term approach to building resilience than the development and support of other qualities.

Robust infrastructure systems in New York City, USA

Following Superstorm Sandy's battering of New York City in 2012, the city began a series of evaluations and reviews to fully understand the impact of the storm, and how the city could become more resilient to better manage a similar storm in the future. Following Sandy the energy system in the city was shown to be particularly ill-prepared and organised to manage such a disruption, and the city experienced extensive power-cuts for several days after the storm made land-fall.

Research undertaken by Arup on behalf of Siemens identified numerous future pathways for New York City to increase the robustness of its electrical infrastructure networks. The research recommended that New York City

work on increasing the robustness of its energy equipment in particular, via several methods including:

- *Flood and waterproofing assets such as cables and substations;*
- *Undergrounding critical overhead power lines;*
- *Ensuring that switchgear is gas insulated (which also allows it to be stored below ground, as it takes up less space when insulated in this way); and*
- *Installing fuse-saving technologies.*

Robustness in this system is intended to ensure service provision (i.e. for the benefit of consumers/citizens), and also to reduce economic costs of disruption (for the benefits of the utilities companies/service providers).

However, echoing sentiments explored above, the research did note that efforts to increase robustness effected resilience-building on a much shorter timescale than increasing the flexibility and responsiveness of urban systems.

A resilient urban system is…

5. …resourceful/efficient

From household level (Arup/IFRC, 2011; Arup/IFRC, 2013) to entire city-wide infrastructure systems (Tierney & Bruneau, 2007), the efficient management of resources (physical, financial, human, etc.) is central to urban resilience. Efficient management of natural resources in particular, such as water supplies or vegetation, can also contribute to resilience by recognising the valuable role played by ecosystems in human settlements (Arup/IFRC, 2013; da Silva et al, 2012; Arup/IFRC, 2011; Fiksel, 2003; Godschalk, 2003). "The failure of urban resilience often translates into a failure to manage ecosystems for optimal resilience." (Wallace & Wallace, 2008: no page numbers.). For example, a healthy mangrove forest can act as a natural breakwater or form of coastal defence during a storm surge event. Resourceful use of water supplies in everyday contexts can prevent water shortages during periods of drought.

Similarly, in relation to physical and financial resources in particular, the maintenance of buffer stocks (Moench et al, 2011) or reserves, such as food or cash, is noted as contributing to resilience by enabling shortfalls in demand to be addressed during times of stress, such as disasters (Fiksel, 2003). Systems themselves should be designed with redundancy, to ensure back-up capabilities exist when systems fail (Brown & Kernaghan, 2011). This could take the form of buffer stocks, spare capacity in terms of material or human resources or multiple options for the supply of critical assets or infrastructure (Moench et al, 2011; Campanella, 2006). For example, a transport system

which relies solely on a supply of oil-based fuel has less redundancy than a similar system which can be powered by oil as well as back-up batteries. In the event of supply-chain disruption and failure of oil distribution networks, the second transport system can utilise its back-up electricity power source and maintain or restore function quickly, without having to rely on restoration of the oil supply.

In turn, systems that make efficient use of resources and contain redundancy are also better able to fail safely, i.e. without transmitting disruption from one system to another (Moench et al, 2011; da Silva et al, 2012). For example, in 1977, the city of New York experienced a city-wide collapse of its power systems, triggered by a single lightning strike on one component of the electrical grid system. This initial event caused a series of shut-downs which moved across the grid, and across the city. Due to the lack of power, recovery efforts were severely hampered as there was no light by which to view damage and make repairs. Similarly, communications systems were also disrupted by the lack of power, so the general public could not be told what had happened or provided with advice on how to recover (da Silva, 2012).

Resourceful land-use systems in San Francisco, USA

By the start of the 20th century the population of San Francisco was half a million people. In 1906, a magnitude 7.7 earthquake struck the city, causing structural damage and indirectly starting a fire which swept across the city destroying thousands of homes. As thousands of citizens found themselves homeless, they took to the city's streets and open public spaces to seek shelter and re-establish their communities. These spaces became distribution points for food, water, clothing and shelter, and the sites of temporary housing camps, as well as providing a place for information exchange and collective action.

Due to the manner in which the city had been planned and land use distributed, there was plentiful public space upon which to establish camps for the internally displaced within the city. Due to the dispersion of open space across the city, those who were displaced were able to stay relatively near their own neighbourhoods, which facilitated the maintenance of social networks and support systems. Similarly the design of the city along a grid-system of roads allowed for redundancy in transport systems too. Where particular roads were blocked or damaged, people and goods could find alternative routes to their destinations, and minimise disruption to supply chains and distribution of relief items.

In this example, redundancy, in terms of transport routes and reserves of clear land on which to establish emergency shelter, was critical during the aftermath of the earthquake in allowing social systems to continue to provide support, information and meet basic needs.

A resilient urban system is…

6. …integrated

"There is such little understanding of systemic thinking in the political and governance processes that what we know about resilience and urban systems is fragmented in topics (regional economy resilience, energy production and supply resilience, water management resilience, resilience against natural risks etc.) or in the analysis of the evolution of urban pasts (through the lens of historical experiences of adaptations or transformations in evolutionary patterns)." (Chelleri, 2012: 295). This fragmented approach to resilience exists in practice as well as in theory, and is particularly unsuitable for attempting to engage with a multi-disciplinary concept like resilience in cities; i.e. a concept which in practice requires multiple interventions and actors to contribute to its development.

Integration within efforts to build resilience applies to 'soft' as well as 'hard', technical systems like infrastructure; for example, integration should occur within governance systems, stakeholder engagement processes, planning activities and decision making. Integration is of particular importance within any systems that require information exchange to function effectively. Integration of information within government departments enables cumulative action (including securing of funding) on cross-disciplinary topics such as resilience or climate change (AusAID, 2012).

At smaller scales the importance of social integration for resilience has been highlighted by Wallace and Wallace in their examination of tightly cohesive neighbourhoods and the effect of these connections upon social crises such as disease outbreaks and violent crime (Wallace et al, 1997; Wallace & Wallace, 2008). Integration should also be considered as a 'cross-scalar' characteristic, encouraging multiple mechanisms or systems working at and across different scales to build resilience (Béné et al, 2012; DfID, 2011; IRWG, 2012). Recognising that it is challenging to implement successful policy within weak institutional frameworks, integration of multiple agendas and actors can provide support for policy development and implementation. "Successful strategies are likely to be founded on robust urban planning processes that seek to reduce the dichotomy between formal governing institutions and networks of actors that provide local capacities." (Kithiia, 2011: 179)

Integrated systems should also consider the importance of modularity. Modularity refers to linkages which connect systems yet avoid cascading impacts. "A modular urban system is composed of smaller, clearly identified units that are interconnected to create a functioning whole." (Allan & Bryant, 2010: 41, citing Bolker, 2000). Modular systems contain "multiple pathways and a variety of options for service delivery; or interacting components composed of similar parts that can replace each other if one, or even many, fail." (Moench et al, 2011: 40). For example, Moench et al provide the example of an urban food system's vulnerability to disruption within the

urban energy system, due to its reliance upon power for specialised cooling and storage facilities, as well as related transportation and communication systems.

Integrated planning and land-use systems in Manizales, Colombia

The Colombian city of Manizales is located in the Andes, at a critical point along one of the country's principal highways. The topography of the surrounding area has limited development of the city, presenting a need for innovative approaches to planning and land use. Settlement on dangerous areas – notably unstable slopes – by the poor within the city is carefully discouraged by governance strategies which integrate urban planning and policy processes with locally-based efforts to reduce risks. These strategies integrate public awareness activities, hazard training, environmental management, and mitigation measures within planning and land use processes.

These strategies also involve multi-stakeholder involvement, at multiple, interconnected scales within the city, from community level up to municipal government level. This is crucial in resilience building; as Hardoy & Romero Lankao (2011: 161) describe it, "[t]he effectiveness of any local development measure is not just what a local government does but also what it encourages and supports."

For example, in tackling the risk of slope instability, government actors have worked closely with local communities, explaining the risks they face living on dangerous land, and undertaking a public awareness campaign alongside a relocation scheme. A programme entitled Guardianes de Ladera ('Slope Guardians') has also mobilised and trained over 100 women who are responsible for creating and maintaining slope stabilisation measures within their communities, and continuing to educate their neighbours on risks and adaptive measures. However, these guardians act with support from a broad range of actors drawn from NGOs such as the Colombian Red Cross, academic institutions, and technical specialists working with the municipal government. This integrated programme, engaging multiple stakeholders, has also been supported by the development of the new legislation such as the Urban Planning Law (1999), which mandates that all new urban plans must be reviewed by a multi-disciplinary Local Planning Committee; these comprise government and local institutions, academic representatives and civil society members.

A resilient urban system is…

7. …diverse

While integration is a key characteristic of resilient systems, the additional feature of modularity also suggests a need to balance this integration with a degree of diversity. Diversity can be understood in terms of function, i.e. multiple ways of meeting a given need (Berkes & Seixas, 2005, Martin-Breen & Andries, 2011). Diversity can also be understood in terms of space (Moench et al, 2011). For example, spatial diversity ensures that not all assets or systems are affected by a single geographical event such as a flood, by distributing assets across a city, or even beyond the city. As Chelleri (2012: 297) explains, "in cities the spatial decentralisation of many essential functions can express resilience, because each element can substitute [for] another in case of need so that the whole system survives."

Diversity in economic systems is noted as making a significant contribution to resilient urban systems; from city-wide levels and institutions (Campanella, 2006) right down to individual, household and community levels (Arup/IFRC, 2011; Arup/IFRC, 2013). Economic diversity can allow actors or organisations to cope during times of financial strain; such as during a global economic crisis, times of unemployment, or following the loss of assets which support livelihoods due to the effect of natural hazards, like floods.

Fiksel (2003) notes the importance of diversity within ecosystems and social systems. A diverse, or 'bio-diverse' ecosystem contains a range of different species, each of which maintains the existence of the others via food webs. This full and diverse ecosystem is better able to withstand – or continue to function in the face of – exogenous threats, such as disease outbreaks or environmental hazards. Within social (and political) systems, Fiksel notes a correlation between resilience and high levels of ethnic, cultural, institutional and political diversity.

Diverse water systems in Singapore

Thanks to an extensive public engagement programme, citizens in the Asian city-state of Singapore are very aware of the impact that water scarcity has upon their lives and the functioning of their city. Droughts and water shortages can have an impact on businesses as well as individual households and entire neighbourhoods. With limited land resources the country does not have the space to collect and store sufficient amounts of rainwater, and is reliant on a number of diverse sources of water for residential and commercial use. The city-state has named its diverse range of water sources the 'Four National Taps'.

They are:

- *Local catchment water;*
- *Imported water;*
- *Purified, reclaimed water (referred to as 'NEWater'); and*
- *Desalinated water.*

'NEWater' is produced from an innovative wastewater recycling process, and stormwater collection and purification also contributes to the city's water supply; 'NEWater' is purified to an ultra-clean level, so much so that it is safe to drink by the end of the process. Local catchment of water is held within 17 reservoirs across Singapore, while imported water is obtained via long-term resource supply agreements with Malaysia. Desalination in Singapore occurs at one of the world's largest desalination plants. The plant produces 30 million gallons of water each day, or approximately 10% of the city-state's daily water needs. Plans are underway to increase this productivity to 25% of Singapore's total needs by 2060.

A resilient urban system is…

8. …inclusive

The inclusion of this quality explicitly addresses one of the criticisms of many conceptualisations of resilience discussed in Section 1.1; that resilience struggles to recognise or explain power dynamics and social structures. This quality also responds to claims that resilience is not typically viewed as a pro-poor concept.

Urban areas concentrate poverty and socially vulnerable groups as well as creating physical spaces in which people may be vulnerable to natural hazards. Socially vulnerable groups may be marginalised because of their wealth, religious beliefs, ethnicities, castes, gender, age, sexual orientation or disabilities. If vulnerable groups are unable to gain access to critical assets or systems during disasters, the impacts can affect them disproportionately. Often, this is due to vulnerable groups having no options to access goods or services other than those provided by the state (Moench et al, 2011; UNISDR, 2012b).

Wallace & Wallace (2008) refer to the urban poor as 'keystone populations of metropolitan regions'. Like resilience, the concept of 'keystone populations' is derived from another ecological concept – that of 'keystone species'. This term was coined by Richard Paine in the late 1960s , and identifies two key attributes of such groups. The first attribute is the crucial role which keystone species (or, in this case, groups) play "in maintaining the organization and diversity of their ecological communities" (Scott Mills et al, 1993: 219). Here we substitute the ecological community for a socio-environmental system,

to utilise this concept in an urban environment. The second attribute is the exceptionality of the role that this population or group holds in relation to the rest of the population. Critical in understanding keystone populations within urban areas is a need to recognise how they maintain diversity; in a city, the urban poor maintain economic, social, and also political diversity. Diversity, as discussed above, is another characteristic of resilient urban systems.

Diversity benefits aside, it is universally recognised that the socially marginalised – particularly within urban areas – typically suffer worse impacts of disasters or crises; often due to their limited possession of assets, disposable income and/or access to public services. To ensure systems are truly resilient, the voices of these marginalised groups must be heard in decision making processes. Only through inclusivity can interventions and policies reflect and respond to the local realities they aim to change (Béné et al, 2012). This is clearly demonstrated in the case study of Surat presented in Box 8 below.

Inclusivity may refer not only to the inclusion of the most vulnerable groups or stakeholders within urban environments, but to the engagement of a wide range of stakeholders, particularly within governance structures (Dalziell & McManus, 2004; IRWG, 2012).

Inclusive planning systems in Surat, India

Following a pattern of severe river flooding which has had both direct and indirect effects on the Indian city of Surat, state planning systems have adopted inclusive approaches to protect the most vulnerable citizens while building urban resilience. In 2006, the river Tapti rose to unprecedented levels, flooding homes, businesses and key transport infrastructure, displacing thousands of people and also raising fears of disease outbreaks. Previous floods, like a similar event in 1994, had led to outbreaks of pneumonic plague.

Cognisant of the impact of climate change upon the likelihood and intensity of flood events, the city took steps to reduce the exposure of its citizens to flood risk; focusing its attention on some of the most vulnerable groups living in informal settlements right on the river banks, directly in the line of flooding. Jawaharlal Nehru National Urban Renewal Mission (JNNURM) constructed sufficient housing for up to 19,000 families on a new site several kilometres from the river, which flows through the centre of the city. This new development provided safe and heavily subsidised housing for families in informal settlements, legal utilities and a school and space for small commercial premises. To ensure that future re-settlement could not occur along the river again, having cleared the former slums, the state government designated the hazardous land as a public space and plaza. It is currently under construction, and is being designed to withstand future floods and minimise potential loss of life.

While the desire to relocate and protect many of the city's most vulnerable residents demonstrates a commitment to building urban resilience, the process of relocation could have been more inclusive. Residents in the new development feel they have not been fully consulted on their needs, which has led to insufficient facilities being provided for the number of families living in the new blocks. Similarly, they report being confused about the financial implications of their relocation. For urban policies and planning to be truly inclusive, it is not enough to target vulnerable groups. Decision making processes and activities should include representatives of these vulnerable groups, ensuring that their voices are not only heard but understood and incorporated into resilience-building measures.

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Appendix B
Examples of urban failure

Case studies illustrating failure to perform city functions

City role	Case study example[1]
1. Protection of human life	During the SARS disease outbreak in 2003, **Hong Kong** was one of the worst affected cities in the world. The epidemic infected almost 2000 people, killing 300. Due to the disease's novelty, the city's healthcare system was unprepared for containment and treatment of SARS. Many of those infected were healthcare professionals, who also transmitted the disease across the city, due to the nature of their work, and their exposure to multiple citizens. 80% of healthcare workers in Hong Kong had received no training on infectious diseases, thus appropriate screening, testing, quarantine and treatment. Action to tackle the disease outbreak was also delayed by poor communication between the state's Department of Health and the city's hospital authority.
2. Support of livelihoods	Markets provide employment for around 5% of the labour-force in **Kampala**, Uganda, and 60% of this total works at the Owino market in the centre of the city; which provides a source of livelihoods for almost 50,000 people. In the past four years however (i.e. since 2009) the Owino market has suffered from multiple fires, some of which were recognised to have been started by arson attacks. The fire in 2009 spread quickly throughout the market, causing losses in stock for over half the market traders, and greater losses in foregone earnings as well. Security guards were reportedly absence from their posts at the market when one fire broke out, delaying response and thus allowing greater losses. Owino market has been the centre of several controversies involving leasing rights. Plans to build a new bus terminal at the Nakivubo Stadium next door to the market sparked anger among traders as many of them will lose their trading space if the development were to have proceeded as planned. One fire was thought to have been linked to this project, i.e. started within the market in an attempt to clear space for the new bus terminal.
3. Protection of assets	In December 2006 **Seattle** suffered the effects of a winter storm, experiencing high rainfall following by high wind speeds. The winds uprooted trees which blocked roads and rail tracks, caused extensive damage to the US city's power supply network, particularly by affecting 159 power substations and 85 transmission lines. The energy system in Seattle did not fail safely, causing cascading impacts which transmitted the effects of the windstorm into other systems, such as transport, communications and housing. Many citizens were without power for a week, while utilities providers worked to repair the damage; families were left without light, heat, or the means to cook at one of the coldest times of the year. Gas stations were unable to meet demands for fuel due to the power outages and also as they became cut-off from transport networks due to downed trees and blocked roads.
4. Facilitation of human relationships and identity creation	The 'favelas' or informal settlements of **Rio de Janeiro** in Brazil have been a feature of the urban landscape from the end of the 19th century onwards. However, due to the unplanned nature of these informal settlements, which are not recognised as being under control of the government, they have become the area of operations for a number of criminal gangs. Due to the control of a significant area within the city's favelas, and a reduction in access to public spaces in these areas, the citizens residing in these areas have become increasingly socially isolated. High levels of immigration to Rio's favelas have also contributed to feelings of social fragmentation, and clashes between individuals from different social groups and gangs.

5. Information, education and innovation	In the aftermath of the explosion at a central munitions depot in **Brazzaville**, Congo-Brazzaville, it was not only the damaged housing which affected the ability of the city to recover but also the damage caused to schools surrounding the depot. The explosion itself scattered munitions across a 65ha area which prevented flows of relief to the affected area and 20,000 people were left homeless. Three schools in the area surrounding the depot were also destroyed. This impact disrupted education and teaching programmes, curtailing the education of children in the area. Some of these children abandoned their education in order to start working to help support their families. Others, with nothing productive to occupy their time, took to loitering on the streets. Without the formal education system children also failed to receive much-needed psychosocial support to cope with the trauma of the explosion as well.
6. Upholds the rule of law and promotes justice and equality	Following a coup d'état in 2006, during which the democratically elected PM, Thaksin Shinawatra, was ousted from power by the military, civil unrest spread throughout the Thai city of **Bangkok**. At the core of this unrest was a clash between wealthy urban dwellers (who supported the new government), and poorer citizens, many of whom were originally from rural areas (who supported the deposed PM). Protests by both groups continued until a culmination in 2010, during which over 100,000 protesters gathered, clashing violently with the military which had been charged with controlling the protests. Many protesters invaded and occupied numerous government buildings to demonstrate their grievances. This unauthorised occupation resulted in the closure of some government services and the relocated of others. Shops and hotels closed during this period of violence to avoid being damaged during the protester-military clashes. Public transport in Bangkok was disrupted due to the government occupation and blocking of the city's road and rail networks; this affected the poorest citizens worst, as they had no other form of transport available to them.
7. Enabling economic prosperity	Following years of citizens migrating out of the city and the decline of the city's manufacturing industry, the city of **Detroit** filed for bankruptcy in the middle of 2013. The manufacturing industry which, thanks to the automotive trade, was once the backbone of the city's economy has shrunk over the past 15 years, and is now the Detroit's smallest employer. Unemployment in the city is now extremely high, and many citizens are no leaving Detroit in search of jobs elsewhere. This depopulation coupled with the collapse of the manufacturing industry has led to an insufficient economic base for the city to collect tax revenues. Investment in the city has also fallen to extremely low levels; with implications for outdated infrastructure which is no longer being maintained or upgraded, and no capacity to develop new infrastructure systems. The loss of tax revenue has also had implications for government service provision; vastly reducing the capacity of services such as the police, emergency healthcare, and even public parks management. Residents of the city report feelings of insecurity due to the reduced capacity of the police and the absence of street-lighting, and crime has risen to unprecedented levels as a result. Reductions in funding for public education have also resulted in high levels of illiteracy which, in turn, further fuels the ever-increasing levels of unemployment.

1 See City Shock Profiles (FULL REF NEEDED)

City Resilience Index

Appendix C
Factor analysis city case studies

Bangkok, Thailand

Background

Population – 14 million in the metropolitan area, 8.2 million in city centre (2010) 1

Area – 1.569 km2 1

Hazards – Flood, sea level rise, civil unrest2

Environment – Located on the coast which was previously swampland and with an average elevation of only 1.5 meters it is extremely vulnerable to flooding3.

Governance – The city government is comprised of two branches: the executive (the Bangkok Metropolitan Administration (BMA) which implements policies through the BMA civil service) and the legislative (the Bangkok City Council is comprised of councillors from each of the 38 districts)[4,5]. Thailand has recently observed decentralisation within its urban systems and is recognised as being increasingly transparent and participatory[6].

The shock – 2008-2010 Political Protests

The political crisis of 2008-2010 has its roots in the 2006 coup d'état when the royally backed military overthrew the democratically elected Prime Minister Thaksin Shinawatra because he was perceived as a threat to military and royal power[7]. Furthermore, he was considered a threat because his party, which supported the rural poor, was becoming too strong and the urban wealthy (members of the People's Alliance for Democracy – PAD or Yellow shirts) believed that they would not have an adequate voice in the government[7].

The 2007 elections saw the election of a Thaksin-affiliated party, led by Samak Sundaravej's People's Power Party (PPP). Accusing the PPP of being a proxy for Thaksin, in May 2008, PAD supporters took to the streets demanding his resignation, which occurred in September due to a court dismissal. PAD protests finally ended in December 2008 after the constitutional court dissolved the PPP and paved the way for a PAD approved Prime Minister.

Claiming that the new PAD supported Prime Minister had taken power illegitimately, as it was backed by the Thai army and the judiciary, the United Front for Democracy Against Dictatorship (UDD or Red Shirts – the rural

majority) called for the PM's resignation in April 2009 and for new elections in 2010 by holding protests both times. The protests had up to 100,000 people, leading the government to declare a state of emergency and had the military engage with the protesters which culminated in violence[8].

Impacts on the urban systems, functions and resilience

Self-actualisation

PAD laid siege to several state agencies (police headquarters and the National Broadcasting Service of Thailand) and occupied the Government House from August to December of 2008, forcing the PM to move his headquarters to a military command post[13].

PAD protesters occupied the country's main international airport in Bangkok for almost a week, stranding approximately 100,000 international outbound travellers[9]. After a few days tourists were sent to airports located in other parts of the country or to other countries via land transport at great cost[10]. It is estimated that the closure of the airport resulted in losses of $100 million from tourism, logistic, and transportation related business11.

The tourism industry, which accounts for more than 10% of Thailand's GDP, was negatively affected as tourists regarded the city and country as being unsafe. After only the first month of protest the industry's income had declined by 35%[9].

Hotels and malls were forced to close during the height of the protests and it was estimated that the political crisis cost Bangkok businesses as much as $30 million per day[12].

Over 100,000 people lost their jobs or faced bankruptcy because of the continued protests as of May 1st 2010[13].

Belonging

On-going disruption to public transport around the city created mobility challenges for the urban poor[12].

During the more violent periods of conflict the BMA incurred over $300,000 in property damages in one week and the transportation agency lost over $1 million[14].

Major transport infrastructure was disrupted by blocking roadways, hospitals, rail services, and three smaller airports in other cities for days at a time[16].

Safety

The political turmoil led to an increase in depression among Bangkok residents. To address the issue the governor of Bangkok promoted widespread religious ceremonies of healing conducted[14].

Large numbers of injured from the violent clashes put pressure on the healthcare system (85 dead, 1,378 injured)[15].

Fires set by protestors destroyed a popular shopping area owned by a powerful Thai family[15].

Lessons learned

Delicately chose the appropriate time to make sensitive political decisions. For example, the current Thai PM (Yingluck Shinawatra) wisely chose to set aside two parliamentary initiatives which if passed could have disrupted political stability and led to more protests[17].

Redundant methods for freight and human transportation can limit the amount of economic loss from the disruption of the main service.

School curriculum can help enable students to become better citizens by teaching them how to act properly and patriotically when displaying political dissension. For example, after the protests, the governor of Bangkok changed the curriculum of 435 schools to teach students what should be done to respect, preserve and act patriotically so that similar types of rioting and protesting do not occur again[14].

Religious services or activities can be used as a means to build psychosocial resilience at an individual level, as part of the rehabilitation process[14].

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Brazzaville, Republic of the Congo

Background

Population – 1,373,382 (2007)[1].

Area – 265 km^2

Hazards – Seasonal flooding[2]

Environment – Located on the northern bank of the Congo River. The city is 300 miles from the Atlantic Ocean and is at an elevation of 1000 ft. The surrounding area is savannah[3].

Governance – The Republic of the Congo is divided into 11 administrative departments, Brazzaville is one of these departments. Strong central government[4].

The shock – Mpila Military Munitions Depot Explosion

On March 4th 2012 several powerful explosions occurred at the Mpila military munitions depot in the eastern area of Brazzaville. These were triggered by an electrical short-circuit which led to a fire breaking out within the depot buildings. Given the presence of stockpiled arms and munitions within these buildings the fire triggered a series of explosions. These explosions killed 282 people, injured approximately 2,300 more and left 20,000 people homeless[4 5]. The impact zone was highly contaminated with a large number of unstable projectiles that had been scattered over an area of 65 hectares due to the explosions. The unstable projectiles posed a high risk of further explosions to the surrounding community and hindered the rescue and recovery operations. The response from the international community to work with the national and local authorities was quick and by mid-September approximately 63,850 items (94 tons) of unexploded material had been removed and destroyed[5].

This example from Brazzaville is illustrative of a number of similar shocks suffered by cities. Between January 1998 and October 2011, there were 302 instances of unplanned explosions, many of which were the result of improperly stored munitions stockpiles in densely populated urban areas[5 7].

Impacts on the urban systems, functions and resilience

Safety

Fires which were caused by the initial explosion almost spread to affect a second, larger ammunitions depot located within the city. Fortunately the progress of the fire was stopped by a team of international firefighters who took control as the local Brazzaville fire department was ill equipped in terms of knowledge, skills, and resources to tackle the blaze[8].

The explosion scattered ammunition over an area of 65 hectares which impeded the provision of humanitarian assistance and relief items and the ability of people to return to their homes following initial evacuations[4 7].

Large numbers of bodies also lay in the streets for an extended period of time, as they were unable to be collected due to the danger of further explosions. This created a health risk and added to the mental stress and anxiety of community members[9].

The city's health system was not able to cope with the large numbers of injured due to a lack of facilities, staff, and resources. Countless victims were brought to the hospitals by unmarked car, stretchers, or carried by hand by other shell-shocked residents. Furthermore, many people had to stay outside the hospitals in tents due to a shortage of beds within healthcare facilities[9].

Many people, especially children, were traumatized by the event and what they had seen in its aftermath and there were no mental healthcare services made available to them to help them cope with the stress[10].

Physiological

20,000 people were left homeless following the explosions. Many of the displaced went to live with family members, while 14,000 went to one of the three emergency IDP camps organized by Brazzaville authorities and supposed by NGOs. Several of the city's stadiums and churches were also commandeered to provide shelter for displaced citizens[10].

Poor sanitation and hygiene conditions in the camps / shelters for the displaced, as well as on-going rains, helped spread cholera1[2].

Belonging

A large number of families were separated by the blast. To help families looking for lost loved ones, pictures were posted around the city with organisations such as the Congo Red Cross working to reunite them[11].

Three schools in the immediate area were destroyed, disrupting education and teaching systems, and encouraging children to earn money doing odd jobs or simply loiter instead of attending classes[10].

Lessons learned

Advocacy on physical security within stockpile management should take place before or soon after an explosion event otherwise it can be soon forgotten by implementing organizations, donors, and the government[5]. There was a similar explosion in one of the five munitions depots within the city in 2009 and the city planned to move the munitions depot but did not act in time[5].

Urban areas are unsuitable locations for munitions depots. New depots should be built far from populated areas and existing depots should be closed down / moved where possible[5].

In addition to providing physical medical assistance to those affected by trauma, special care should be given to address psychological issues, especially children. After the explosions, children were particularly struggling to cope with the accident, some even refused to eat[10].

When planning emergency shelter camps, appropriate planning should go into water and sanitation systems, otherwise cholera and other disease outbreaks may occur, compounding a social crisis[12].

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Chengdu, China

Background

Population - 14 million[1]

Area – 12,390 km^2 [1]

Hazards – Drought, earthquake, epidemic / pandemic, flooding (river), landslides[2]

Environment – Located in a basin at the foothills of the Himalaya. Jurisdiction includes foothills and alluvial plains. There are four active fault lines in the area[3].

Governance – Chengdu is a sub-provincial city which includes within its jurisdiction nine districts, four county cities and six counties4. The central government's power is strong while the power of the civil society is quite weak though this is changing due to the emergence of a more prominent civil society after the earthquake[5].

The Shock

On May 12th 2008 Chengdu experienced a 7.9 magnitude earthquake. The entire city, especially the suburban areas closer to the epicentre, suffered heavy physical and environmental losses. In total the earthquake resulted in 69,266 fatal casualties (an additional 18,000 people are listed as missing but presumed dead6), 374,643 people injured, and 670,000 urban and rural houses damaged[7]. A statement released by the Chinese government has said that the earthquake left five million people homeless, although one official in Sichuan Province said that the number could actually have been as high as 11 million8. Approximately 15 million people in total were affected by the disaster and the direct economic loss was 98.4 billion Yuan (16 billion USD)[2]. By August 2008 over 67 billion dollars had been allocated by the Chinese government for constructing new buildings and rescuing and relocating refugees as part of the relief effort[7].

Impacts on the urban systems, functions and resilience

Safety

Artificial dams and ‘quake lakes’ in the hills on the outskirts of the city were created when landslides induced by the earthquake dammed rivers. These threatened to burst and flood surrounding areas. Over 200,000 people were evacuated (up to 1.3 million were prepared to evacuate) as a precaution, a process which was made difficult by all the landslides and road closures blocking evacuation routes[9].

Significant damage to roadways, bridges, and railways cut off the more remote districts within the sub-city jurisdiction. Helicopters became the only form of reaching victims trapped in many areas9 10. This significantly delayed relief workers and aid from arriving on site to search for survivors and build shelters.

Physiological

Some of the small towns lost 100% of their buildings, leaving the entire population without shelter[10].

Belonging

Over 7000 schoolrooms collapsed in the quake, often in poorer areas, which – due to China’s national ‘one child policy’ – meant that many families lost their only child. This created a lot of public dissention towards the government[12] as well as creating potential dependency problems for the future. Of the 90,000 people died or missing, 10,000 were children in classrooms, which accounted for about 11% of total losses[13].

The Qiang minority group lost a full 10% of their population and accounted for a third of all deaths resulting from the quake[14]. This is due to many of their population living in close proximity to the epicentre of the earthquake, and also the type of building methods (masonry and packed earth) used to construct their homes[10].

Lessons learned

Efficient crisis management is important for confidence in state legitimacy by its people. Before the earthquake the relationship between the Chinese government and civil society had been fairly tense due to corruption charges and local officials making administrative blunders and implementing controversial policies. Government officials saw the earthquake as an opportunity to improve its legitimacy and reacted swiftly by committing large amounts of resources to help the victims of the quake. Due in part to the actions of the government after the earthquake, China saw an upsurge in national pride and confidence in government[7].

As demonstrated by this case, strong centralized state crisis management can work well when the autonomy of local authorities, like provinces, is not clear-cut and sometimes enhances contradictions. This is in opposition to popular decentralised methods which are considered to yield higher efficiency and immediacy[7]. – However, this method did miss a number of smaller satellite communities which relied on support from local government or small NGOs[15].

Shocks can act as a catalyst for future disaster risk preparation across a variety of other hazards3. For example, the snowstorm which paralysed the national transport system earlier that year had directed the Chinese Central Authority to give substantial attention to disaster management and mitigation, preparing it for reacting to the earthquake[7].

Appropriate construction standards and quality control procedures are critical to the construction of schools and other pieces of key infrastructure for reducing public dissention and maintaining the function of urban systems[12].

At the local level, the earthquake forced local authorities to work with NGOs, often for the first time, and the rapid emergence of NGO networks right after the earthquake demonstrated their ability to engage in collective action with the government effectively. Subsequently, Chinese policy makers have recognized the importance of civil society in responding to crisis and have reduced the regulatory bottlenecks constraining NGOS and charitable foundations5. The local and central authority have thus learned from the disaster and changed their laws and policies which displays reflectiveness – a characteristic of resilience[5].

Rural-urban integration in planning and responding to disasters is critical for innovative and resilient development as urban systems are linked to the surrounding areas for food, water, and other important resources necessary for continued well-being[14].

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Dar es Salaam, Tanzania

Background

Population: 4,364,541

Area: 1,590.5 km^2 (614.1 sq mi)

Hazards: Drought, flooding, coastal erosion

Environment: Dar es Salaam is a tropical coastal city affected by El Niño

Governance: The Government values the participation of civil society in the development process but in practice the participation of non-state actors has been relatively limited (planning and budgeting is mostly done without participation of civil society). The participation by umbrella civil society is growing in policy dialogue1. The Tanzania Meteorological Agency (TMA) issues flood warnings for Dar es Salaam. It provides warnings and advisories on extreme rainfall and flooding based on daily weather monitoring

The stress - Flooding

Heavy rainfall frequently causes flooding in the city, particularly in unplanned settlements which house 70% of the city's population. These settlements are often located in high-risk flood areas (low lying areas, flat topography or valleys)[2]. 140,000 people are currently living below 10m elevation with assets worth approximately US$ 168 million, and over 30,000 of them are considered at risk. Apart from the loss of property that floods often bring, and occasional loss of life, heavy rains pose widespread health risks to poor residents by causing pit latrines to overflow due to the high water table, and sewers and drains overflow due to improper solid waste disposal practices which contaminate ground and surface water[3]. According to the 2006 municipal council records, respiratory issues (coughing, pneumonia, and tuberculosis) as well as water-borne diseases (diarrhoea, cholera and typhoid) are the most common diseases. This has some risks associated, as water pollution, dumping of solid waste and poor management contribute to ground and surface water pollution (faecal coliforms impacting the water collected in shallow wells)[4 5].

In 2011, Dar es Salaam suffered massive flooding following unprecedented downpours which started on the 20th of December. The flood waters overwhelmed the city's drainage systems (as there is not a functioning stormwater drainage system in the unplanned settlements – the ones that exists is obsolete and unable to cope with the demand as it was built in 1950s[3]), which displaced 10,000 people (2,000 families), caused 40 deaths and injured over 200 people. The total number of affected people was estimated at above 50,000 (10,000 families), including those affected by social services disruption, property damaged and direct personal injuries or deaths[6].

Impacts on the urban systems, functions and resilience

Belonging

Social services were disrupted (closing of schools during rainy season)[4].

Physiological

Houses submerged in water, people had to leave their houses and belongings behind[4].

Widespread damage to property and roads disrupting economic activities[3].

Pit latrines, doorsteps, protective walls, and building foundations get damaged in the floods. To protect them, the population elevates them which also prevents the stormwater from entering the houses[4].

To treat the contaminated drinking water, the main coping strategies used by individuals are boiling and chemical treatments[4].

To avoid the hazards created from the floods some families move away from the flood areas during the rainy season. They go to their relatives until the water levels go down[4].

Two programs have been improving infrastructure in poor areas of the city, promoting community based initiatives (the Community Infrastructural Upgrading Program (CIUP) and the Strategic Urban Development Plan (SUDP)[3].

Some of the community's methods to cope with the floodings include control of housing development and initiation of solid waste management practices[4].

Lessons learned

It is important to ensure that policy makers are aware of the impact of climatic hazards and how these impact low-income groups in particular. This awareness should inform the planning processes and the approvals of infrastructure developments. The challenge is how to include immediate and strategic responses within a wider framework[3].

Large interventions play an important part in building resilience. For example, Citywide Action Plan (a plan for upgrading unplanned and unserviced settlements in Dar es Salaam by 20207) contributes to building resilience through improving infrastructure and services (especially for the urban poor). The planning and design phase of these interventions should take into consideration potential future shocks[3].

Savings schemes are the basis for resilience in many communities in Dar es Salaam as the money they save helps them to recover from the losses that the flooding causes. Also within the community, small scale initiatives have

a considerable potential to build resilience (i.e water management strategies at scale of the communities; improving the supply of drinking water through reconnection and management of water kiosks)[3].

The activities and support from NGOs plays an important role at a community level, especially in relation to communication and implementation of projects that take into account climate change, as it allows the communities to be aware of the potential impacts of flooding so that they can plan their initiatives to mitigate them. Awareness-raising programs are needed at the community level to educate people about the need for improved sanitation practices. Greater effort needs to go into provision of improved latrines for residents[3].

Individual action to protect properties from erosion along the coastline may have harmful side-effects moving the problem of erosion to nearby areas due to the hydrodynamic and transportation systems[3].

Unblocking drains can be an effective mitigation measure (i.e: the cleaning of the Kibasila drain in Temeke resulted in a reduction of 60 cm in the level of a nearby swamp) to prevent flooding, reducing mosquito density and the size of marshy areas. This action needs to be integrated with appropriate urban planning so that is can be used as part of the malaria control programme[4].

In Dar es Salaam there is limited coordination among experts in the municipalities: the office of the Town Planner, the Engineer, and the Health Officer tend to work independently of each other. Coordination among local stakeholders is needed in order to keep all the parts informed, this could be done through different methods of coordination as regular meetings, workshops, publications, etc)[4].

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Detroit, USA

Background

Population – 3,734,090 (2010 urban area), 713,777 (2010 City Limits)[1].

Area – 3,460 km^2

Hazards – Lead poisoning in housing, declining economy, severe crime, winter storms, tornadoes, flooding[2].

Environment – Located on the coast of Lake St Clair in the centre of the United States on the border with Canada.

Governance – Mayor-council government system[3]. Civic participation is weak, 55% of the African American population in Detroit lives in communities under some form of Emergency Management which means that the authority of locally elected officials has been taken away by state government[4].

The stress and shock – Declining economy and city bankruptcy

After 60 years of the city's economy shrinking, due to the decline of the manufacturing industry and the migration of the upper and middle class to the suburbs, on July 18th 2013, the City of Detroit filed for bankruptcy with $18 billion of debt and over 100,000 creditors looking for payment[5]. The backbone of Detroit's economy was the manufacturing industry (primarily automotive) which was the city's number one employer 15 years ago, it is now the lowest[6]. Many of the factories that were located within the city have either moved to suburbs, other US states or to China and Brazil as the auto industry became global and manufacturing focused on getting faster and less expensive[7]. As the automotive industry moved away within Detroit 156,000 manufacturing jobs were lost between 2000 and 2008, a 40% drop[6]. By August 2013, that number had risen to 350,000, a 95% drop[8]. As it rapidly declined alternative industries could not grow fast enough to replace the lost jobs and GDP[6].

Impacts on the urban systems, functions and resilience

Self-actualisation

Without available jobs in the city the population has steadily been either moving to either the suburbs or to other cities entirely. Between 2000 and 2010 the population has declined 25%, which is a continuation of the trending decline in population where it has fallen 62% in the last 60 years10. Currently, around 70,000 domestic and business properties lie abandoned, including fire stations and hospitals, due to the outward migration[5].

As factories and jobs migrated out of the cities, many of the transportation links did not. This meant that members of the lower class who were unable to move or buy a car did not have access to those jobs4. As a result, a socio-economic stratification occurred where the poor lived in the city and the wealthy in the suburbs. A consequence of which was that Detroit no longer had a sufficient economic base to collect tax revenues[6].

The unemployment rate within the city is currently 18.6%; almost triple the national average and about a third of the city's residents (36.2%) are now classified as living in poverty[5]. As a method of coping with the lack of jobs, an informal economy has emerged within the local population. Some actions include: back alley auto repair shops, churches selling dinners on the streets, off the books home child care, and urban agriculture. It is also the scrappers who are repurposing the copper, weathered wood and other reusable commodities left by the abandonment of homes, stores and factories[4].

Safety

Without the tax revenues from a robust middle class the public services within the city are nearing collapse due to insufficient funds[5]

The municipal power grid is outdated and cannot handle peak power demands, resulting in power outages and brownouts across the city[11] [12].

Around 40% of the streetlamps do not work which has made many areas unsafe after dark and limits late night urban mobility[13].

Approximately 40% of the police force has been laid-off in the last 10 years[11]. Without adequate resources and staffing the police response times to 911 calls are an average of 58 minutes; compared to 11 minutes nationally[5]. Furthermore, the police department is only able to close 8.6% of its cases[11] and the murder rate is at a 40 year high (five times the national average)[5].

Emergency healthcare providers are stretched thin. Only a third of its ambulances are available due to budget cuts and disrepair[5]

Two-thirds of the city's parks have been closed down since 2008 limiting the space for recreation and relaxation for the urban population[11].

Belonging

An education system lacking sufficient resources and leadership[4] has resulted in approximately 47% of the city's residents being functionally illiterate, which makes it very difficult to get work[14]; particularly as, with high rates of unemployment, employers have significant selective control over hiring.

Lessons learned

Capital is highly mobile and has virtually no loyalty to geographic regions, nations, or cities. If it finds sufficient incentive to relocate – it will. Therefore, reliance on one type of industry for the majority of a city's employment and income generation is dangerous. Cities should have a diverse economic base with a variety of business types so that if one leaves or fails then the shock to the economy is not severe with the others supporting it.

Migration away from city centres without efficient cost-effective transportation links to the suburbs limits the flow of capital in the area. Furthermore, weak transportation links to suburban areas limits the ability of the urban poor to access jobs outside the city and reduces the city's ability to earn tax revenue.

Without jobs for the unemployed to apply for, job training programmes do not create sustainable employment opportunities. From 2007-2010 the City of Detroit spent $100,000 on job training but the majority of trainees were unable to find job after completion as there were no jobs available[8].

Local political scandals and corruption make it difficult for the city to capitalise on new investment as there is little public confidence. Without the public's confidence in the government they are less likely to spend money due to uncertainty. Furthermore, the private sector is unlikely to receive a return on their investment and thus invest again[6].

As demonstrated by Detroit, bankruptcy can be a tool used use by economically failing cities to manage their debt to help them get back on their feet.

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Doha, Qatar

Background

Population - 0.8 million (2010) [1]

Area – 132 km^2

Hazards – Haze, dust storms, sandstorms, water shortage, food shortage [2]

Environment –Desert environment with no rivers or lakes[3].

Governance – One of the seven municipalities of Qatar and has over half of the country's population. Qatar is headed by a strong central state government though it is slowly putting more power into the hands of its people[4].

The Stress – Food security

The rapid demographic growth of Qatar, Doha in particular, has outstripped domestic levels of agricultural production. The current level of cultivation is limited by access to fresh water and the national agriculture system can only produce 8% of the total food consumption needed[5]. The food supply deficit is met by a substantial volume of imports. Doha is therefore highly vulnerable to the effects of a range of political, biological and economic shocks that might affect the countries and markets supplying its food because it is out of its control6. Due to on-going population growth, in the next 10 years food imports in Qatar is expected to increase by a further 153% without intervention[7].

Impacts on the urban systems, functions and resilience

Physiological

The city is vulnerable to export bans on food from other countries, which make policy makers and companies come up with quick and creative solutions to replenish its food stocks[8]. For example, when the Saudi Arabian government placed a ban on exporting chicken to stabilise the market at home, Doha poultry shelves were bare as 70% of its poultry came from Saudi Arabia, forcing the Qatar Meat and Livestock Company to import poultry from Bulgaria for the first time[8].

Consumers are vulnerable to substantial price volatility for virtually all imported agricultural goods[9]. To cope with prices that can fluctuate up to $5 in a day, many families and restaurants shop at wholesale markets when prices are low[10].

Even though the market is quite volatile, many domestic farmers are being pushed out due to international open marker policy and the expensive price of water[11].

Doha has recently started a project to increase agricultural production to reach 40% of demand within the next 12 years through a programme of increased desalination, hydroponics, soil enrichment, and water efficiency techniques[12].

Lessons learned

Price volatility can manifest itself over long and short time periods7. The Government of Qatar, through its consumer protection body, is able to reduce food price inflation by interfering in subsidising some goods and monitoring markets[13].

In an effort to avoid the market volatility, one coping method used by Qatar businesses is to buy farms and land abroad and sell the product exclusively in Qatar[10].

A key element of a viable food security strategy is a county's ability to diversify import sources to provide buffers against political, health, weather and other disruptions, and to ensure a sustainable and reliable food supply[7].

A diverse set of food sources can also act to reduce high prices and control price volatility through competitive purchasing and greater parity relative to the market power of suppliers[7].

Appropriate technologies, such as desalination, drip irrigation, and hydroponics can help alleviate the problems of water and food shortages within the country[12].

Technology alone cannot fix the problem of water scarcity and food security. This challenge needs to be combined with legislation to help support domestic markets and increases in education and research to help facilitate the development of new sustainable options for water management and food production[11]. For example, if the food market is not properly protected from external producers then cheaper commodities from overseas can inundate the domestic market. This may force local farmers using the new desalinated water and irrigation techniques out of business, thus leaving the country in the same predicament that it was in before.

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Ho Chi Minh City, Vietnam

Background

Population: 6.4 million official population1

Area: 2,094 km2 [2]

Hazards: flooding, drought, typhoons1

Environment: Much of Ho Chi Minh City (HCMC) is located in low-lying lands that are prone to frequent flooding caused by heavy rains and, on occasion, high tides.

Governance: State administration, and thus city planning, is highly centralised. HCMC is under the Central Government administration. Flood control is under the regional planning administration and not part of the local planning department[2].

The stress – Flooding

Currently 154 of the city's 322 communes and wards, approximately 50%, have a history of regular flooding. In the last 60 years HCMC has been hit by 12 large tropical storms and within the last 10 years the impact from natural disasters has been estimated at $12.6 million and affected 971,000 people, roughly 12% of HCMC's population1. In the coming years a vast majority of the city's growing population will settle in low-lying areas. This is due to a large number of people moving to the city and driving up the price of land, which has resulted in an increase of over 500% from the 1990s. Therefore, the low-lying land is the only affordable option for poorer citizens3 which puts them at a high-risk of flooding, especially during the wet season from June to November. Nearly 70% of the city is already vulnerable to extreme flooding.

There are a number of non-climate-related factors that also contribute to the impacts of flooding, such as poor city planning. Domestic solid waste which is dumped into canals as well as poor dredging of the canals creates a very limited capacity for them to drain storm waters causing not just a worst-case scenario in terms of flooding but also creates a public health risk[1].

It has been widely documented in literature that urban flooding of HCMC is mainly caused by the following: heavy rainfall, high tides, combined rainfall with high tides, water releases from upstream reservoirs, the impact of urbanisation on runoff, and ground subsidence due to large unplanned

construction without green areas to drain the water[1].

Impacts on the urban systems, functions and resilience

Physiological:

It is the reduced drainage and storage capacity for rain water that leads to the floods ha a significant impact on transport during the rainy season, where traffic spikes are a regular occurrence as as residents try to escape the flooding[4]

Some of the measures to cope with flooding are the elevation of building sites by land filling or the construction of dikes[5]. Currently the construction of a dyke ("Dyke Project") is part of the city's flood protection plan[6].

Due to the impact that flooding has caused in HCMC, the current regional and urban development master plans (Regional Development Plan 2020, Master Plan 2025) target the problem of continuous urban expansion into lowering marshland for the first time[5].

Pollution – water from the drainage canals flooding to the surface due to poor sewerage system, dispersing the wastewater from sewerage and causing water pollution, epidemic diseases and damage to property[6].

Safety:

Higher sea levels and higher tides, due to climate change, are likely to result in the breaching of existing coastal / river defences. This will cause direct inundation of larger areas of HCMC and surcharge the existing urban drainage system if river outfalls are not protected by gates or tidal flap valves.

Salinity intrusion is an identified effect after floods in HCMC, having a direct impact on the safe water levels and in the water that needs to be discharge from the reservoirs to maintain the appropriate salinity levels at the water treatment plant[6].

Self-actualization

House prices after flooding suffer fluctuations, producing a land value loss for those leaving the low-lying areas, mostly poor people[1].

Lessons learned

In order to improve the resilience of the city and to decrease the impact of

flooding it is recommended to increase storm water storage capacity and introduce schemes to combat salinity[6].

Improve basin management - Storage of storm water in reservoirs closer to the city helps to ensure that water collected in the wet season is available for use to boost river flows in the dry season to provide security of water supply to meet peak water demands during low river flows and to insure against short term river pollution[6].

Inappropriate use of land as well as inefficient drainage systems will increase the impact of runoff. The conversion of open space to impervious surfaces, such as concrete and pavement, in residential areas without green areas reduces the infiltration and absorption of the water leading to increase the flooding in specific areas[7].

Even after implementation of its dyke project, the city will still be vulnerable to urban flooding due to rainfall and it will need a more effective drainage system. HCMC must consider how it can store flood water underground when dyke gates close and how it can convey this flood water safely to the rivers when the gates open[6].

It is highly important to develop an effective long term urban planning and land-use planning strategy[7]. Combining infrastructural measures such as construction of flood embankments, polders, sea walls, and pumped drainage are common engineering solutions in combination with eco-system based adaptation measures (i.e reforestation of the Ding Nai River basin watershed, restoration of wetlands, rehabilitation of canals and rivers)[1].

Accommodation measures minimize the vulnerability to flooding, these include raising houses on stilts, adjusting cropping patterns, and revising building codes for housing and industry[1].

Where the risks of loss of life or assets is severe, “retreating” (development is managed) as a planning option can reduce exposure to extreme events, this will be a long term strategy that involves withdrawing, reallocating or abandoning assets at-risk[1].

Strengthening institutional capacity to adapt to climate related risks - flooding needs to be considered in the context of overall water basin management and the institutional capacity to manage the resource (i.e development of an HCMC Climate Change Adaptation Plan). Coordination between different adaptation plans and planning processes carried out by different agencies is critical[1].

To implement planning restrictions as a mode of effective planning as

well as building regulations are key to the integration of managing urban development and rapid urbanization.

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Hong Kong, China

Background

Population – 7 million (2011)[1].

Area – 1, 100 km^{2} [2]

Hazards – Drought, epidemic, flood, wildfire, extreme temperature, storms[3]

Environment – Located on an island of seven million people, it is one of the most highly populated areas in the world, encouraging tall buildings and efficient utilization of space.

Governance – Hong Kong is a Special Administrative Region within China which allows it a certain level of autonomy from central control[2]. The city is subdivided into 18 geographic districts, each represented by a district council which advises the government on local matters. 405 of the 534 district council members are publically elected and listen to community stakeholders in matters of public facilities, community programmes, cultural activities, and environmental improvements[4].

The shock – 2003 SARS epidemic

Between March and June of 2003 the citizens of Hong Kong were subject to an outbreak of severe acute respiratory syndrome (SARS), a highly contagious illness with flu like symptoms. The epidemic claimed 299 lives, infected 1,755, and put 1,262 into medical isolation within Hong Kong. Though the disease spread around the world, no city was affected as much as Hong Kong with an infection rate of 0.258 per thousand inhabitants and the number of deaths accounting for more than a third of all SARS deaths[5,6,7]. SARS created international anxiety because of its novelty (i.e. people were unfamiliar with the disease, its symptoms and treatments), its ease of transmission, and the speed at which it spread globally by way of airline travel[8]. The SARS outbreak exposed the weaknesses of Hong Kong in managing a public health crisis, at an individual, community, and city level.

Impacts on the urban systems, functions and resilience

Safety

SARS differed from previous infectious disease epidemics in its explosive spread, for which the health and hospital authorities were ill-prepared[9].

Healthcare workers (HCWs) were especially at risk due to their exposure

to infected people; 405 HCWs in the city contracted the illness, which accounted for nearly 25% of those affected[6 7]. Many health workers chose to self-quarantine to prevent spreading the virus to friends and family which affected family life and stress levels within the city6. HCW were also subject to the psychological stress of attending SARS patients and had to deal with the tremendous emotional upsets of acknowledging

Physiological

Residential buildings which had dry u-traps in the bathroom floor provided a conduit for contaminated sewage droplets to enter households and infect inhabitants[5 7].

Lessons learned

Epidemics, such as the 2003 SARS outbreak, can identify gaps in the preparedness of healthcare systems; in this case over 80% of healthcare workers had no training in infectious diseases[8]. Healthcare workers and systems should have training and response plans in place to be ready to act in the event of such outbreaks.

Screening tools should be appropriate for use. Screening tools provided by international agencies did not meet local needs and resulted in misuse and incorrect diagnosis[8].

Special attention should be paid to the sanitation and drainage of buildings to limit the spread of disease from waste vaporisation[5].

Survivors of major disease outbreaks may have chronic psychological problems which need to be addressed for their future mental health10. Support systems within the healthcare system should be created to address this issue.

HCW who dealt with SARS felt that they were more prepared to deal with future epidemics such as the avian influenza pandemic[6]. This displays how reflective systems can increase their resilience by learning from their past experiences.

Inadequate epidemiological information about a disease can hamper the prompt application of effective control measures. In this case, insufficient communication with the public about the nature and treatment of SARS led to panic and thus weakened public cooperation and support8 10.

There should be procedures in place ahead of a disease outbreak for designating hospitals for the isolation and treatment of those infected to streamline the process and reduce the spread of infection9.

A lack of communication between the Department of Health and the Hospital Authority led to a 10 day delay in action to stopping the spread of the

disease[9]. These links should be strengthened to improve response times and reduce the spread of infectious diseases.

To avoid hampered decision making and delayed implementation of effective measures, communication between the Secretary (Ministry) level responsible for health policy and the management level responsible for operation of the hospitals should be clear[9].

To reduce the spread of epidemics, existing healthcare systems should aim to: reduce overcrowded wards; improve poor ventilation; have adequate isolation facilities and intensive care facilities; have staff with comfortable working environments; and create avenues to isolate and cohort patients with suspected or possible signs of the epidemic, particularly at the point of admission and immediately thereafter[9].

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Kampala, Uganda

Background

Population – 1,723,300 (2012 estimate)1

Area – 180.1 km2 1

Hazards – Seasonal urban flooding, fires, disease outbreaks, and earthquakes2 3

Environment – Located on the northern bank of Lake Victoria in the Nile basin.

Governance – The city is divided into five division, 99 parishes, and 811 sub-parishes or villages[4]. As of constitutional changes in 2010 the city is managed by the Kampala Capital City Authority (KCCA) on behalf of the Central Government[5]. The KCCA incorporate comprehensive civil and private sector participation as part of their decision and planning process[6].

The Shock – Market Fires

As in most sub-Saharan cities, markets play a key role in Kampala. They are generally located in the city centre and in the suburbs and supply the bulk of the populations' food, both fresh produce and durables, clothing and household products. Markets are also a major employer as they provide employment to about 5% of the active workforce. 60% of who are located at the Owino market, which is the largest outdoor market in Uganda (possibly the largest in East Africa) and is the place of work to nearly 50,000 traders, 70% of whom are women[7].

Between 2009 and 2013 the Owino Market has been the scene of three significant fires, the largest of which occurred in 2009; where as many as half the market's traders suffered losses[8 9]. Fires spread quickly due to the large amount of densely concentrated combustible materials[10]. The market had been the centre of several controversies involving leasing rights and there were plans to build a new bus terminal at the Nakivubo Stadium next door which sparked anger among venders as many of them will lose their space if the development had proceeded as planned. Many venders attribute the cause of the fire to arson and are accusing the bus company who wants to build the terminal on market land because it was allegedly started at a hole in the wall separating the market from the stadium[8]. The fire in 2013 was evidently started by a security guard hoping to cover his tracks from theft11. It is still unknown what caused the 2011 fire but it is believed to be arson[12].

Impacts on the urban systems, functions and resilience

Self-actualisation

Millions of dollars of goods and merchandise were lost in the market fires which families relied on for survival and meeting their basic needs[10].

Many of the traders had taken out bank loans and after the fires no longer have the means to pay back their loans or restart their businesses[13]. Some were lucky enough to have their loans cancelled by the Global Trust Bank, while others relied on friends and family to get their feet back on the ground by replenishing their stock and building new stalls[14].

Safety

During the fire fighting large amounts of goods were stolen due to a lack of security[10].

Belonging

The market had served as a meeting place and as an area for social activity. The destruction of the market forced people to change their social routine until it was rebuilt[6].

Physiological

The fires forced shoppers to go to other smaller markets outside the city centre to buy food, sometimes at a great cost and distance[6].

Lessons learned

To combat the threat of arson, security forces should be posted around the clock with proper supervision to confirm the guards are where they are supposed to be. In the case of one of the Owino fires, security guards were allegedly not around even though they were meant to be on duty and in another case a guard was possibly the arsonist[9 11].

Densely populated areas that are not up to fire safety standard are vulnerable to large fires as it is easy for them to spread. Furthermore, dense market areas make it difficult for emergency services to access fires and put them out[15]. To reduce the threat of fire, markets should be developed and/or redeveloped to minimum safety standards[6].

Centralising food sales in one location within the city is dangerous because when it is harmed or destroyed there are few other options available for consumers[6]. The development and/or redevelopment of markets in a balanced city-wide distribution, coordinated and integrated with the Public Transport system and bus stops and where possible with emergency service facilities should be sought by local government.

Quick and efficient protocols for responding to fires should be in place to reduce damages caused by fires. In one case it was over an hour and a half before fire teams arrived (even though the fire station is located down the street) which had allowed the fire to spread[8].

Police have cited poor or illegal electrical systems as one of the reasons for slowed response to putting out the fires because it is difficult to turn them off before entering the market to put out the fires and they fear electrocution[16]. To improve the safety of markets, electrical safety standards should be implemented and regulated through sustainable operation schemes. Alternative options can be the introduction and wide spread use of solar lamps with government support through subsidies[3].

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Lima, Peru

Background

Population: 9.7 million (2012) [1]

Area: 2,819.3 km^2 (1,088.5 sq mi) [1]

Hazards: Drought, flash mud floods, tsunamis, earthquakes[2]

Environment: the city is situated on the banks of Rimac river, near the ocean, in the coastal dessert of Peru.

Governance: Lima is divided in 2 provinces and 49 districts without any instrument of coordination and a lack of municipal planning. The water framework in Lima is centralized and it doesn't take into account a holistic view, being driven by sectorial interests[3].

The stress: water scarcity

Lima has a fast growing population and the city's water supply is scarce, unreliable, and polluted. The city has very little precipitation, and is therefore largely dependent on surface water delivered from the Andes (through precipitations) by rivers: this water is seasonally variable and is regularly affected by the lack of rainfall. Lima's rivers are also highly polluted as the majority of the water is discharged directly into the rivers and very little of the city's wastewater is treated (9% of the waste water is treated and only half of this proportion is reused). There is a strong potential for reuse of the wastewater in Lima given the water scarcity and its citizens' need for green spaces and peri-urban agriculture (around 75% of the water available is used for human consumption, 22% by agriculture in peri-urban areas and 3%on green spaces and for industrial and mining activities)[4].

Water companies have a limited budget to provide water services to the citizens(90% of the population have access to the water system while 10% get water from water tanks lories)[3] and this adds to a major demand due to the increased urban density, plus an increased in the non-human water waster use (for irrigation). To sum to these critical factors, Peruvian citizens in general do not recognize the need to pay for water services and therefore a sustainable (affordable) fee is a key factor for human consumption, this is a critical issue to manage challenging the right use of water in some other sector (i.e. industry, irrigation)[5] [6].

Impacts on the urban systems, functions and resilience:

Physiological

Some areas of the city do not have 24 hour access to water and in some others the water pressure is much lower than the quality standards[3].

Due to the sectorial treatment of the water resources and the lack of an integrated water policy, each of the water sectors work with a wide autonomy which makes it more difficult for the government to attempt an integrated management approach[3].

Currently there is instability within the supply-demand balance, the water quality, and the increase on the water demand to maintain ecosystems and activities that are not intended for human consumption (which are increasing faster than the population demand).

Unplanned urban development and the population distribution have intensified Peru's vulnerability where close to one million people don't have access to safe drinking water in Lima. The government is trying to bring water to the slums where the challenge is to supply water to slum areas alongside ever-increasing rates of migration and shortages of water where 40% of its inhabitants lack access to clean, safe drinking water and a functioning sewage system[6].

Due to the lack of water treatment the beaches are contaminated by human and industrial water increasing the rates of skin diseases[4].

Self-Actualisation

Water is unaffordable for poor people and in the other hand it is highly affordable for the rest of the city (including industry and irrigation sectors). This creates an unbalanced use and a lack of water conservation on the part of those that don't use the water for human consumption6. Private sector are taking advantages of the situation by selling water at high prices where there is not a piped water system as end users rely on them[7].

In Lima stakeholders (through a stakeholder platform) have worked to influence national legislation on wastewater reuse (for example, an Eco-Park was built as a demonstration project to expand to other projects the use of wastewater treatment and to reuse technologies through this experience)[4].

Research and innovation streams are coming from different actors in Lima as a result of the water scarcity. For example a university and an advertisement agency have built the first-ever billboard to capture air humidity and turn it into potable drinking water in Lima[7].

Two wastewater treatment plants are currently being established in Lima, this shows the commitment from Peru to adopting wastewater reuse on a large scale[4].

Lessons learned

The SWITCH project (pilot project implemented by a consortium of 32 partners and coordinated by UNESCO-IHE) carried out research and demonstrated pilot projects that evidence the importance to development an stakeholder dialogue and exchange of knowledge[8].

Through different initiatives from PAHO/CHO/CEPIS and IDRC was shown that Lima's climate and soil conditions and the shortage of water result in a need to investigate a new form of water for irrigation (being pipe water used for human consumption). Treated wastewater was offered as an alternative but Peruvian legislation doesn't promote this approach and there was not a proper institutional setting so SWITCH project aimed to lobby at national level to promote the development of a national regulatory framework and the use of wastewater in Peru[8].

Small scale initiatives can aim to proof the need of policy guidelines (if this is appropriate). As an outcome of the SWITCH project carried out by the Peruvian´s local organization and coordinated by IHE-UNESCO, the Ministry of Housing, Construction and Sanitation has approved a series of policy guidelines to support the promotion of wastewater reuse in the country for urban irrigation purposes. This has been successfully implemented due to improvement on institutional and policymaking capacities, the increased of public awareness of related issues, and the creation of appropriate financial mechanisms built on small-scale wastewater treatment initiatives in Lima[9].

Development of networks (learning alliance) of key stakeholders for dialogue and exchange of knowledge is key to implement holistic and sustainable approaches, for example, currently there are funds available to invest in water and sanitation infrastructure (like "Agua y Saneamiento para Todos programme) but when the capabilities to implement those programmes are limited (limited capacity of SEDAPAL, potable water and sewerage company of Lima , and the municipalities), through the lessons learned from previous projects funds can be efficiently implemented[5].

Promote research related to integrated analysis of existing information can be a successful way of testing in a small-scale a potential solution that can be upgraded into a bigger scale project in the long term. For example, the pilot project SWITCH showed that a multifunctional green area, irrigated with treated wastewater, can meet the needs of the surrounding population for green recreational areas, and potentially generate income for neighbours[4 8].

In relation with the water quality the different water stakeholders (MINSA, SEDAPAL and the municipalities) agreed to test the water that is sold through the private lories, and penalize to those that are not up to the quality standards[10].

The reuse of the wastewater decreases the money spent on fertilizers, and the resulting water is considered safe, since it has been treated for pathogens[9].

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New York City, USA

Background

Population – 8,336,679 (2012 estimate)[1].

Area – 1,213 km^2

Hazards – Building collapses, coastal storms & hurricanes, disease outbreaks, floods, and winter weather[2].

Environment – Located on the mouth of the Hudson River which feeds into the Atlantic Ocean. Most of New York City (NYC) is built on the three islands of Manhattan, Staten Island, and Long Island making land scarce which encourages high population density and tall buildings.

Governance – NYC is more centralised than most US cities with a strong mayor-council government system.[3] Community stakeholders are engaged in the decision making process through local community boards.

The shock – 9/11 Terrorist Attacks

The 2001 attack on the World Trade Center site, located in downtown NYC was the most destructive and deadly act of terrorism the United States has ever experienced. Alongside the physical impacts and disruptions to infrastructure systems in NYC, the 9/11 terror attacks had significant effects upon social and cultural systems, which were destabilised by the psychological shock suffered by citizens. The results of these psychological shocks include a variety of mental health issues, such as post-traumatic stress disorder (PTSD), anxiety, as well as an indication that many psychologically-affected by the attacks developed problems of substance abuse, as a method of coping with the trauma experienced4. It is estimated that 5-6 years after the attacks 43,000-88,600 New Yorkers (about 1% of the local population) still suffered from PTSD[5].

Impacts on the urban systems, functions and resilience

Safety

Stress responses among indirectly exposed individuals mirrored the psychological responses typically exhibited by individuals who are directly exposed to a traumatic event[6]. This meant a larger population were less productive and more prone to becoming ill due to heightened stress levels post disaster.

The number of physician-diagnosed health problems increased 18% over the three years post 9/11 due to post traumatic stress breaking down an individual's immune system[7]. With larger numbers of people developing health problems, health facilities were put under greater pressure to distribute budgets, resources, and staff workloads. Furthermore, the economy was burdened with a greater percentage of its workforce falling ill.

The mental health care system was unable to handle the large number of patients suffering from traumatic grief[8]. Because the system was unprepared to handle the sudden increase in stress there was a high rate of drug use relapse after the attacks where over 50% of people thought to be drug-free went back to using drugs due to fear and/or increased anxiety[4].

New Yorkers had an emotional rate of recovery on stress items about half that of others in the rest of the country, which limited their ability to operate normally in social urban systems which lowered productivity of the area[9]. This was particularly true with rescue workers where PTSD had remained persistent for about 30% of them a full nine years later[10].

New Yorkers were twice as likely to cancel an airplane trip or to take medication to calm themselves down after the attacks, thus limiting their ability to conduct regional or international business or go on holiday[9].

Professions and social groups which suffered high levels of stress after the terror attacks included fire fighters, policemen, and survivors of the attack. Construction workers assigned to "Ground Zero" for months after the attacks clearing away rubble and removing bodies, were also found to have high levels of stress and PTSD[11].

Self-actualisation

There was a severe lack of consumer confidence after the attacks which caused significant problems for the city economy, as well as repercussions throughout the global economy as a result of the attacks[12].

Belonging

After the attacks there was an increase in people's national pride and sense of belonging which resulted in large numbers of volunteers and donations made available for the reconstruction effort[9].

Lessons learned

Traumatic events can trigger PTSD and collective stress, which can have a negative impact on physical health levels as well as mental health levels for extended periods of time. Therefore, a set of guidelines and "best practices" should be created in case of emergencies to improve urban recovery rates. These should include communication and outreach programmes to patients and other treatment programmes. Furthermore, a system should be in place to meet the increased demand by creating a system for the rapid recruiting, hiring, and training of staff to help address the mental issues expediently[8,4,7].

People suffering from PTSD with previous substance abuse issues need greater access to therapeutic interventions that do not solely rely on prescription medications[4].

Workers unions are a useful avenue for providing emotional support because members will have had similar experiences and can support one another. Furthermore, there is already a system and structure concerned with their well-being and an entity administratively prepared to intervene which had on-the-ground expertise about working conditions, psychosocial reactions, and the cultural values of the workforce[11].

Studies found that women[13], minorities, low-income groups, and people in poor health had more difficulties emotionally recovering from the events of 9/11[9]. Therefore, these vulnerable groups should be given special attention after a similar event.

Firms that bounced back most quickly from the attacks were characterized by greater financial and human resources and more flexible work processes and structure. This support given to employees made the difference in how quickly the organisation rebounded[14].

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Quito, Ecuador

Background

Population: 2.2 million (2011)

Area: 324 km^2 (125 sq miles)

Hazards: earthquakes, volcanos, seasonal flooding and landslides due to steep slopes[1]

Environment: The city is located in a highly seismically active territory and surrounded by volcanoes. The urbanized portion of the Quito metropolitan area is situated in a narrow mountain valley just east of the foothills of the active volcano, Pichincha.

Governance: Quito is governed by a mayor and a 15-member city council. The mayor is elected to a four-year term and can be re-elected. Quito is subdivided into 32 parishes Ecuador has an active civil society that has got a higher influence over the governance[2].

The stress – Volcanic eruption

Quito is surrounded by eight active volcanoes with some of them having frequent eruptions such as Reventador and Guagua Pichincha (25 and 42 years respectively)[3].

Quito has grown significantly and is much more populated and concentrated than when previous earthquakes occurred (due to migrations from rural areas of the country) which has increased the adverse consequences of a potential volcano eruption. This recent growth has not been coupled with an appropriate evaluation of vulnerability for this infrastructure with respect to seismic and volcanic risk[5]. Currently construction is conducted on an informal basis without proper seismic standards in place[5] with approximately 60% of total buildings built without municipal permits[6] and inadequate localization of the population due to the weaknesses in the policies and land use planning instruments, in combination with migration towards the urban areas[1].

“El Reventador” volcano erupted in early November 2002, 90 kilometres northeast of Quito. There were repeated explosions that produced ash clouds, constant gas columns, and lava flows, affecting the population of several provinces of Ecuador[7].

Impacts on the urban systems, functions and resilience

Safety

The volcano eruption caused respiratory, ophthalmologic, digestive and dermatological problems[7].

Physiological

It also created an emergency in shortage of drinking water supply and contamination of sewerage systems[7]. Although most of the ash was rapidly cleaned by civil society and military using brooms and high pressure water. Local calculations suggest that around 300,000 tonnes of ash was shovelled

Impacts to livestock (mostly dairy cows in the study area) include: tooth abrasion due to mastication of ash; stock death and loss of condition due to ingestion of ash; and loss of grazing lands due to ash[8].

Those living closer to the volcano were highly affected by the ash, especially the land where crops were damaged, producing a food crisis in the region.

Roads and a bridge were also affected which further isolated communities.

Self-actualisation

Quito's airport and local airlines were considerably affected economically by the eruptions, due to the time needed to clean airport infrastructure (especially runways) and aircraft before normal operations could be resumed. This happened due to the lack of appropriate equipment to clean up the runways[8].

Overload is the largest telecommunication problem reported from ash fall in Quito. There were no reported physical exchange problems, but the study group had no direct contact with communications providers[8].

Most schools closed in Quito as a consequence of the volcano[8].

Lessons learned

The revision and strengthening of the land use planning system in Ecuador is essential to effectively reduce hazards impacts and related risks[9].

Despite the fact that the Metropolitan District of Quito and a few other cities have made advances in their urban regulation strategies, the country's land use planning in general has not had the legal and institutional framework needed for the consolidation of sustainable development policy and practice.[1]

In order to reduce the impact after an unexpected volcano eruption it is recommended to plan for stock transport and alternative grazing areas for the dairy industry[8].

Cleaning roads is essential for safety from three hazards: obscured road markings, direct loss of traction, and raised-dust causing nuisance and visibility reduction. Vehicles reportedly operate well in Quito in ash fall environments, but air filters require more frequent cleaning and/or replacement[8].

It is highly important to monitor volcanic activity, applying advanced technological tools for modelling and evaluation to be able to be prepared in advance[9].

Projects on environmental management and recovery of hydrographic basins have contributed to a reduction of disaster risk (one of the most notable projects was carried out by the Quito Metropolitan District through the Quito Metropolitan Sewerage and Drinking Water Company). Also if there is a need to stop water supply it needs to be noted that communities will be able to cope better if they have their own water storage and they know how to boil water as it happened in Quito, avoiding disease outbreaks that are not related to volcanos[8].

Capacity building through education and training provided to civil society needs to be planned in an on-going way to make it sustainable using different formats and languages for different audiences to ensure the highest-possible knowledge transfer. Having committed citizens is the more effective tool a city can have (citizens in Quito were actively cleaning the ashes on the streets after the volcano eruption[8]. To train the local government and civil population is essential as the nature of the system of risk management in Quito is decentralized and relies on the management of parishes, districts and provinces during a disaster[9].

Clear planning at all levels of emergency management is necessary to pre-determine the division of responsibility, and create an environment that fosters cooperation. For example when cleaning the ashes after the volcano the location for disposal needs to be planned in advance[8].

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Rio de Janeiro, Brazil

Background

Population - 15.989.9291

Size – 43.780km^2 [1]

Hazards – social violence, crime, landslides[2]

Environment – The city is located into a narrow strip of land between the coastline and a steep range of forested mountains. Rio is also still a major coastal port from where coffee, sugar, and iron ore are exported to all parts of the world.[2]

Governance – The Brazilian political system is divided in three autonomous levels (federal, state, and municipal) and as each level has its own financial resources they are not directly dependent on the other levels to function - which had a critical impact on dealing with violence in the favelas (lack of coordination-responsibility) The municipalities have autonomy to manage local issues, particularly those of an urban nature

The stress – Security crisis

The favelas or informal settlements of Rio de Janeiro began to grow in the city, from the end of the nineteenth century onwards. Following the abolition of slavery in 1888, freed slaves began flocking to Brazil's then-capital in search of work. They set up home in poorly constructed slums built on the only land that was available, usually hilltops or swamps on the city's outer limits. According to the Brazilian Institute of Geography and Statistics (IBGE), Brazil was still a predominantly rural country until the 1960s. Since then the rate of urbanisation has climbed, growing from 44.8% (1960) to 67.6% by 1980. Between 1991 and 1996, more than 12 million Brazilians moved from rural to urban Brazil, and the IBGE's 2000 census noted that over 80% of the population lived in urban Brazil by the turn of the century. The unplanned urbanization within the favelas made them ideal for drug gangs to hide from the police and set up control without any political aims.

By 2001 favelas occupied an area of around 37 km^2 in Rio, corresponding to 6.3% of its total territory. The livelihood in the favelas has been suffering the dominance of the drug gangs, influencing the opportunities for social inclusion of favela residents as well as decreasing their freedom, through the extensive use of force if the behaviour of people was considered suspicious or disloyal[3].

Impacts on the urban systems, functions and resilience:

Safety:

The explosion of urban violence and the decreased in security levels has been impacted by the large numbers of rural residents/citizens migrating to the cities without any planned urbanization in extreme conditions of poverty and exploitation, resulting in a social, economic and political crisis[4].

Controversial situation where the common belief was that the municipal government (and police) were responsible for the safety of the cities but they didn't feel they had a role to play within the favelas as according to the constitution of Brazil this was a responsibility to the provincial government (government/legal exclusion), this resulted in an increase in the violence rates due to the lack of control[5].

Child mortality rates are five times higher than in the wealthy neighbourhoods and also residents of the unplanned settlements live, on average, 13 years less than people born in southern tourist districts such as Copacabana and Ipanema (according to statistics collected by Rio's town hall).

The state's inability to produce effective social policies for such large numbers of people has helped created a parallel power where traffickers operate according to their own laws.

Safety & Belonging

The high levels of internal migration have triggered numerous social crises, putting pressure on underfunded education and healthcare systems, where schools are often obligated to close due to shoot-outs, the companies are reluctant to provide services as cables and social workers and doctors try to avoid working in those areas.

Within favelas, social violence is a significant issue (homicide, assault, grievous bodily harm, and domestic violence), while crimes against property are virtually non-existent. In the "formal" city however, property crimes (both business and homes) are more common than interpersonal violence.

Physiological

Programmes to create inclusion of the favelas such a Favela Barrio programme have had a direct quantitative impact where since 1993 approximately 600 thousand people have benefited from: 500 kilometres of water networks, 548 kilometres of sanitation networks, 1.7 million square meters of streets paved, and 600,000 square meters of leisure area. It has to be mentioned that the programme was not equal among all the favelas during the implementation due to several factors such as security risks of people delivering the systems[5].

Lessons learned

Where there is no rigid control of the use of land and the lack of accessible legal mechanisms for conflict resolution the chances of violence related to land tenure are greater. It is important to have clear expansion limits and effective control[5].

It is key to not just provide the infrastructure but also to combine that with social programmes allowing an increase in the quality of life within the favelas – including them within the "formal" city (from a governmental alignment national planning strategy) and enhancing social development to reduce violence (Favela Barrio Programme was focused on components of community and social development as well as provision of infrastructure)[5].

Integration of the favelas into the formal city development structures could provide social gains to communities (nurseries, sport centres, water and sanitation systems, primary health care, etc.) and promote the integration with the formal city[3].

An investment in social development and support, including community participation during planning and implementation phases, and educational activities related to monitoring activities and environmental conservation, is key to the integration of strategy plans to integrate the favelas. Favela-Barrio and Terra Mais Igual were including community participation since the design process adapting the designs to the community's needs[5,6].

Provide freedom to move from the favela and provide services within the favelas, allowing commercial use to enable a more dynamic urban life, organizing activities in the night periods (like capoeira) and at the same time promoting greater security and creating conditions for the realization of income generating activities, with opportunities for community work[6].

In terms of transport and as part of the urban revitalization program (PAC) a "Teleferico" (cable car/gondola) has been installed (2011) connecting residents from the favelas with the city's rail network (based on a funicular system built in similar communities in Medellin and Caracas), transporting up to 30,000 passengers a day where residents are entitled to one free round-trip a day. There are two main aims associated to this project, one is facilitating transport for resident and the second is attracting tourists that spend money in the favelas helping the local economy[7].

Building partnerships with community leaders so these act as a bridge between the communities and the government enhancing several initiatives. Train community leaders it is really important so they can do their task in an appropriate way[6].

Before establishing a programme to make sure that there is a baseline and indicators to monitor it as well as recognizing the impact of crime and violence on the programmes[6].

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Seattle, USA

Background

Population - 4 million in the metropolitan area, 0.6 million in city centre (2010)[1]

Area – 15,209 km^2 [1]

Hazards – Heavy winter storms (snow, rain, and wind), landslides, urban flooding, earthquakes, civil disorder, and fire[2]

Environment – A major coastal city, receiving a large amount of rainfall; typically receiving 37.41 inches per year[3]. The city is also located directly on top of the Seattle Fault and extremely vulnerable to significant earthquake risk[4].

Governance – Seattle is a charter city with a mayor-council form of government. The city council's jurisdiction is quite small but its urban systems extend around the Puget Sound Area5. The civil sector and private sector are both quite active in influencing policies and decision making.

The shock – Wind storms

On December 14 2006, a winter storm hit the Pacific Northwest which affected communities from northern Oregon to southern British Columbia6. The event was a mid-latitude cyclone with strong winds, of speeds which occur roughly once every 10 years. The most recent comparable storm was in January 1993; however, the damage to urban areas in terms of losses to property in 2006 was much greater7. The primary reason the damage was so severe in 2006 was that in the days leading up to the wind storm, rainfall had been extremely heavy (passing all previous records); this resulted in high soil saturation and reduced soil cohesion which made it easier for the trees to fall down7. Power outages were extensive with many customers having to wait over a week to receive power[6].

Impacts on the urban systems, functions and resilience

Physiological

Over 1.5 million people lost power[8], 159 substations were unable to provide power and 85 transmission lines – representing 45% of the total power system – were disrupted[6 8].

11 days after the storm reached Seattle, Puget Sound Energy had restored power to 95% of the outages. These outages affected business operations by forcing them to stay closed for the duration. Families were also affected as they were unable to heat their homes in the middle of winter and in many cases unable to cook food[6].

Wastewater plants lost power and dumped millions of gallons of effluent into Puget Sound which negatively impacted the environmental aquatic ecosystems[9].

With power outages and fallen trees blocking many roads, gasoline stations were unable to supply fuel or keep up with consumer demands. This lack of fuel supply had an impact not only on transport systems but also on energy and heating systems, as it was required to power thousands of generators running in homes and businesses[9]. Without power for warmth and the ability to cook, many families sheltered at malls and hotels which had generators (and were able to acquire fuel) or whose power supply was unaffected. Hotels which had power operated at full capacity to accommodate those unable to live at home during this period[9].

Safety

Having no power resulted in several people cooking indoors using charcoal grills and gasoline generators in unventilated areas. This caused eight deaths and 300 people to be treated for carbon monoxide poisoning, primarily in immigrant populations[10].

Self-actualisation

Air traffic in and out of Sea-Tac International Airport had to be curtailed when power to a critical radar system failed[9]. This prevented freight operations, passenger transport, and communications.

The Pacific Northwest has the worst coastal weather radar coverage in the USA, which meant that the population did not know the extent of the danger of the windstorm until it was too late to adequately prepare[7].

Belonging

For the first time in 70 years major news agencies in Seattle were not able to publish copies of their papers, which limited dissemination of information to the public[11]. For those who had them, portable battery operated radios were used to obtain news.

Lessons learned

Areas of recent land development (i.e. clearing trees for building construction) are more likely to have trees fall down as those trees have previously been protected from high winds by other trees. Therefore, special care should be given to protecting those areas from trees falling on power lines, houses, or other pieces or critical infrastructure[7].

Soil saturation drastically increases the risk of trees falling down in the event of a windstorm7. Government leaders, weather services, and utility providers

should be made aware of these risks so that they are able to warn their constituents and prepare in the event that these circumstances occur again.

Coastal radar can help give up to a nine hour warning window of the details of a storm[7]. These short-term forecasts are helpful if the computer generated models are wrong and can give warning to citizens so that they are adequately prepared. Furthermore, it is estimated that millions of dollars could be saved from a single storm[7].

Education on the importance of properly ventilated cooking areas should be conducted in multiple languages and through various media channels to reach at risk populations to reduce the number of carbon monoxide poisoning. Special attention should be paid to immigrant and low income groups.

Loss of power at a large scale can have a cascade failure effect on other crucial systems such as water, wastewater, health, and transport. Efforts should be made to create systems of safe failure where if one system fails it has a limited impact on others.

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Arup

13 Fitzroy Street
London W1T 4BQ
United Kingdom

Jo da Silva

Director

email: Jo.da-Silva@arup.com
tel: +44 20 7755 2010

Braulio Eduardo Morera

Associate

email: Braulio.Morera@arup.com
tel: +44 20 7755 4820

www.arup.com/cri

THE ROCKEFELLER FOUNDATION ARUP