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TO EXAMINE EMERGING TECHNOLOGIES THAT SUPPORT URBAN RESILIENCE PLANNING

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Chapter 2. Literature Review

2.1. Introduction

This chapter gives an overview of the impacts and importance of resilience in the urban planning. The focus is on the technologies available to support urban resilience planning.

2.2. Overview

McKibben (2012) provides a detailed discussion on why planning is important for the stability and future development of the major cities. In his article, McKibben (2012) discusses the values of the main factors that may affect the stability of any city, which are temperature, carbon dioxide, and oil reserves. Thus, he concludes that many of the negative impacts and consequences that cities are confronting are the result of human activity. The latter is to become a more valid argument over time as the United Nations (2015) estimates that the number of urban residents will increase from the current 2.9 billion to around 3.0 billion by 2030. The implications of this shift in the population distribution will result in an unprecedented situation that more people will be living in urban areas than outside them. Just as a comparison, in 1913 only 1 in 10 persons was living in cities (UN, 2015).

Desouza & Flanery (2013) mention that half of the people already live in a city. But by 2050 around 75% of the population will live in cities. The fact that half of the world's inhabitants now live in cities and that in the next twenty years the number of urban dwellers will swell to an estimated five billion people, will increase the pressure on the already inefficient transportation systems and poorly designed buildings. Thus, many cities (especially in the United States) will increase the quantity of fossil fuels burned and the amount of greenhouse gases emitted. But the planet has a finite amount of carbon-based fuels that have powered urban growth for centuries and it does not seem easy to curb neither the fossil fuel consumption nor the greenhouse gas emissions.

This situation raises the question:

Are the world's cities headed for an inevitable collapse?

This is the goal of intelligent planning and visionary leadership to help cities meet the impending crises, and look to existing initiatives in cities around the world. A philosophical perspective is to respond with hope and not with fear. First, the present situation of the use of oil and the contribution to climate change is described and then four possible outcomes for the cities are produced:

1. Collapse
2. Ruralised
3. Divided
4. Resilient

In response to these scenarios, it should be possible to develop a new *sustainable urbanism* that could replace the present *carbon-consuming urbanism*. A detailed example addresses how new transportation systems and buildings can be feasibly developed to replace the present low efficiency systems.

Madisch (2015) discusses how resilience, just like sustainability, represents an abstract concept. Therefore, it can be difficult to determine specific ways to plan for resilience. Resilience is a thought for more strategy about planning, building and running the cities. This ensures that the systems are working for all citizens. Spending fortunes of money rebuilding and repairing after emergencies will never allow advancement in any of the other goals such as disease outbreaks, social inequities or unemployment. It is critical that resilience is seen not just as something useful after a shock, but as something actively pursued by governments, private enterprises, and citizens, all together in the moments of need and in the calm times, not just for the benefit of one city, but for all cities. A response to vulnerabilities is not a new concept and, through history, it has been a big concern for cities. There is a long record of these responses such as the aqueduct systems and some of the greatest innovations like the underground subways. Today though, the global community is experiencing these shocks and disruptions on a near weekly basis. Some cities - examples are Boston (USA), Istanbul (Turkey), San Jose (Costa Rica), Athens (Greece), Budapest (Hungary), Colorado Springs (USA). All those cities are from different regions, with different demographics, geographic terrains, and political systems. But they all share one thing in common: in the last year they have experienced at least one major disruption:

- Bombings
- Violent protests
- Earthquake
- Financial ruin
- Unprecedented flooding

- Devastating wildfires

2.3. Increased Shocks and Major Disruptions

It is not possible to predict when or where the next shock will hit. But it is a fact that those shocks will come and that they will likely only continue to increase in frequency, intensity, and impact for at least three reasons:

1. Urbanization
2. Globalization
3. Climate change

These factors add pressure on both urbanization and globalization challenges. In fact, when these three factors are together, they are the greatest threats and disruptions. All cities deal differently with these shocks.

2.4. Resilience: Terminology

Resilience is defined as:

> "The capacity of individuals, communities and systems to survive, adapt and grow in the face of changes, even catastrophic incidents."

In other words, building resilience is about making people, communities and systems better prepared to withstand catastrophic events, either natural, climate change-driven, or man-made, and be able to bounce back more quickly and sometimes even emerge stronger from those shocks and stresses. At the same time that the term of resilience is presented, it is helpful to discuss what resilience is not about. It is not a solution to the last problem.

> "What the last problem looked like; you know it very well. In a span of less than 215 days, we endured Hurricane Sandy, a

> horrific shooting at Sandy Hook Elementary School, bombings at the Boston Marathon, a massive fertilizer factory explosion in Texas, and severe flooding and tornadoes in various parts of the country." (Judith Rockefeller foundation president)

Resilience is not just about climate change or weird weather. It is about the shock and awe of the unknown and about what to do before and after those disruptive events. Resilience is also not a trait people are born with. While the recovery of New Jersey versus the recovery of New Orleans after Hurricane Katrina should give the elements to reflect, there is a natural question:

Are certain communities and people inherently better at managing shocks and interruptions than others?

The answer to this question rests on the fact that any skill can be learned. Thus, it is possible to teach people to recover, persist, and thrive during a disorder. That is, the learning of how to be resilient in the lulls between the shocks. As an example, after 9/11, property owners were so worried about attacks from air that they buried their generators underground, where they were submerged by storm surge during Sandy. It is not an innate human quality that bubbles up in times of stress as it is often talked about, for example, after the Boston bombings. And it is not an emergency response after a disaster has hit.

Resilience is what is built in those moments between catastrophe and the next big disruption, a skill that can be learned, and a quality that can be adapted, from toughening up building codes in San Francisco to withstand the shocks of the next earthquake to the creation of *Evacuspots* in New Orleans to ensure a speedy evacuation of residents ahead of future storms. And building resilience is critical to protect the most vulnerable population, those who typically live in the most easily impacted areas and who are least likely to have savings stashed away or insurance to protect them in case of disaster. This kind of situation is present in the developing countries, where already overcrowded slums will nearly double in population to 2 billion, putting strains on already fragile ecosystems and hindering the ability of these areas to respond to shocks and recover from them.

Krings (2015), from the German Federal Office of Disaster Assistance, focused her presentation on the major adaptation strategies Germany is putting into action against the climate change. Natural disasters, human failures and others (terrorism, war and crime) are the major factors the agency is concerned with. Krings (2015) concludes her presentation explaining the concept of *prioritization*:

> “Which situation is tolerable and which not?” and “what are the minimum services to be provided when the population is under risk?”

The Merriam-Webster definition of resilience is “the ability to recover from or adjust easily to misfortune or change” (Merriam-Webster, 2013). The definition of resilience is the quality of being able to resume its original shape, or the ability to recover quickly.

> “Resilience is the capacity of a system to continually change and adapt yet remain within critical thresholds.” –(Stockholm Resilience Centre, 2015).

Resilience reflects the ability to persevere in the face of emergency, to continue its core mission despite daunting challenges, and is as appropriate to discussions about Venice's rising tides as Medellin's corruption, Detroit's unemployment, and Budapest's floods.

Resilience provides a practical framework to identify climate sensitivities and prioritize opportunities to promote resilience. "It is our deep conviction that we should be preparing for disasters before they happen, rather than responding after the fact" (Langeveld, 2013). Resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption of some sort.

> “Resilience is the amount of change the system can undergo and still retain the same controls on function and structure, the degree to which the system is capable of self-organization and the ability to build and increase the capacity for learning and adaptation.”

Resilience is an important tool to evaluate the capacity of the systems (Brand & Jax, 2007; Folke *et al.*, 2002), including cities (Evans, 2011), to adapt to change. Resilience is therefore also a key to understanding the ability of a system to satisfy the social norms embodied in the sustainability goals (Ernstson *et al.*, 2010). Resilience as a term may be approached as a compelling metaphor, like sustainability, having important political and social connotations (Brand & Jax, 2007). Sustainability is a set of socially derived goals, combining social equity, economic viability, while resilience is a key concept for operationalizing sustainability, and resilience is used as a non-normative conceptual scientific model for the processes underlying sustainability. Resilience is a conceptual and modelling framework that indicates the phenomena that facilitate or inhibit the achievement of normative sustainability goals (Childers *et al.,* 2014) and ecological integrity (Curwell *et al.*, 2005; Jenks & Jones, 2010), to recognize sustainability as a set of socially constructed, normative goals, emphasizing process rather than stasis. Resilience is not simply an emergency response; it is how people survive and get stronger even when things are very tough. (AbdulMatin, 2014).

> “Resilience is the ability to withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life and without a large amount of assistance from outside the community’’ (Mileti, 1999).
>
> “Resilience is the amount of disturbance that a system can absorb while still remaining within the same state or domain of attraction, and it is the degree to which the system is capable of self-organization (versus lack of organization or organization forced by external factors); and is the degree to which the system can build and increase its capacity for learning and adaptation.’’
>
> “Resilience is not a destination, is a journey. It is about doing it all the time and all together” (Basili, 2015). In more reductionist terms these three levels reflect: Systemic integrity, Coordination, Self-improvement (The Herald, 2013).

2.5 Urban Resilience

Desouza & Flanery (2013) propose that “our future is an urban future that is resilient”. As of 2010, half of the world’s population dwell in urbanized areas, and of those 3.5 billion people, 38%, live in large urban agglomerations or mega-cities. From 2005 to 2010 the world’s urban population increased at a rate of 1.9% (United Nations, 2011). Rapid urbanization and growing mega-cities point to a need for smarter and more resilient cities that possess the capacity to withstand the shocks of population growth, world economic crises, rapid demographic shifts in population, and environmental catastrophes. In addition, resilience must also be displayed in terms of events that have a more long-term horizon such as when the cities are in decline. Resilience in terms of cities generally refers to the ability to absorb, adapt and respond to changes in an urban system as well as shares other three key contemporary urban goals:

1. Sustainability
2. Governance (Tompkins & Hurlston, 2012)
3. Economic development.

Each of these issues is viewed through the lens of an urban system’s ability to transmit information and resources (Changizi & Destefano, 2009). Indeed, when information and resources are seen as *signals* transmitted through time and space. Because resilience, like sustainability, represents an abstract concept, determining specific ways to plan for resilience can be difficult.

Urban resilience is to adapt and respond to changes in an urban system. 100 Resilient Cities has a unique and broad view of how urban resilience is defined: the capacities of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kind of chronic stresses and acute shocks they experience.

- Shocks are typically considered *single event* disasters: fire, earthquakes and floods.
- Stresses are factors that pressure a city on a daily or a reoccurring basis: chronic food and water shortages, an overtaxed transportation system, or a high unemployment rate.

Defining urban resilience: Recognising that *resilience* is an increasingly common term, but is rarely defined in context (Davoudi, 2012; O'Hare & White, 2013; Shaw, 2012; Wilkinson, 2012), the research first sought to establish a working definition of resilience in order to understand what gives rise to resilience in an urban environment. The concept of resilience was first discussed in relation to science and engineering in the 1970s (Plodinec, 2009), with early definitions being applied to the fields of ecology, physics and psychology. While definitions differ, there are similarities across disciplines. Many refer to the ability to resist shock, the need for a flexibility in absorbing shocks without compromising function, or speed with which the system can 'bounce back', that is, regain effective functionality or return to an equilibrium state if the shock has caused disruption or disturbance. Davoudi (2012) calls this *engineering resilience*. More recent publications (Davoudi, 2012; Roberts, 2009; Shaw, 2012) advocate a definition that incorporates the ability to *bounce forward*, transform or adapt to a new stable state as more appropriate in a planning context that needs to consider complex interconnected socio-spatial systems.

The severity of a future breakdown can be constrained or diminished by making the technologies, economic, and social systems more resilient to unexpected shocks (Homer-Dixon, 2006).

In order to function effectively, the city system and component systems need to have certain characteristics, while the changing environment refers to short-term and long-term change, that is, both shocks and stresses, which may be caused by a wide range of hazards, threats and trends. This definition recognises that the urban environment is intrinsically changeable and allows for the city system to transform in order to function effectively in the face of uncertainty. Using this definition as a starting point, the research identified the following five fundamental elements that would form the basis of the five fundamental elements proposed in the resilient cities framework.

2.6. Five fundamental Elements: Proposed Resilience Framework

The following are five fundamental elements:

1. Systems and interconnectivity
2. Breaking down the system – for analysis and action
3. Hazards, threats and trends
4. Characteristics of resilience
5. Responses: building in resilience (tomorrow's cities in a framework to assess urban resilience).

When Mike Gillooly became the first Chief Resilience Officer of Christchurch, New Zealand, he made a breakthrough. His vision for urban resilience involves:

- Working side-by-side with members of the community as equals
- Taking advantage of cutting-edge technology, and
- Promoting the tools and tactics used in Christchurch with other cities across New Zealand

- Empower students to become knowledge brokers who are fluent in the use of cutting-edge analytical methods and who feel at ease in the world of urban investment and policy making.

2.7. Urban Resilience: Challenges

There is a big challenge between urban and environmental economists' way of thinking that a collision between climate change and urbanisation is in fact unavoidable if governments continue to take no action. The root of the problem is simple: the world's cities account for 70% of the emissions; however they cover 2% of the planet's land mass. It is estimated that 59% of the world's population will be living in urban areas by 2030 coupled with the fact that every year the number of people who live in urban areas grows by 67 million with developing countries accounting for 91% of this trend. The extreme densities of these areas create vulnerable consequences from an increase in the intensity of frequent warm spells, heat waves and extremely high sea levels. Urban areas are naturally energy-intensive due to the increased transport use, heating and cooling and economic activity to generate income. However, it is because of these dependencies that future populations will be stripped of their assets and livelihoods due to future climates changes affecting water supply, physical infrastructure, transport, ecosystem goods and services, energy provision.

The top five shocks are:

1. Coastal and rainfall flooding,
2. Earthquakes,
3. Tropical storms including hurricanes and typhoons,
4. Heat waves, and

5. Landslides.

All were most concerned with the threat of flooding, which accounted for over a third of all shocks mentioned.

From the stresses:

- endemic crime,
- chronic food shortages, and
- monolithic economies

The top five stresses mentioned were:

1. Aging infrastructure,
2. Drought and water shortage,
3. Environmental degradation,
4. An overtaxed/underdeveloped/underfunded public transportation system, and
5. Sea level and coastal erosion.

There is a challenge shared by many that resilience may not live up to its promise for a variety of reasons including

1. The potential for narrow interpretations
2. A selective or limited understanding of what can be a relatively abstract concept, but also because of a what some have identified as
3. A lack of quantifiable metrics for evaluation purposes

Therefore to address challenges imposed by disasters in modern cities and to exploit possibilities emerging as a result of recent technological advances, the following steps need to be taken:

- Advance the use of data management, geographic information, computerbased modeling and simulation, and visualization of complex urban dynamics so that decisions can be more effectively based on the best available knowledge,

- Conduct research that leads to better policy related to urban climate change mitigation and adaptation,
- Engage the research and practitioner communities in dialog so both sides truly learn from each other about processing power, transmission systems (e.g. high bandwidth wireless technologies) and real-time location tracking and data collection.

In Luca Alinova's (Alinova, 2015) plenary presentation, he spoke of the very real threat of resilience being adopted and applied in name only, and there is a real risk that in the rush to measure resilience and develop quantitative metrics for comparative purposes, what is actually measured may represent the same things that have long been monitored and measured but are now being packaged in the language of resilience to meet the demand. The fact remains however, that resilience will and already is, being measured. This will be a big challenge to think about it.

2.8. Technologies

Technologies can play a critical role in addressing shortcomings of existing disaster response operations. The recent technological advancements are:

- In hardware: e.g. miniaturization, increased processing power,
- Transmission systems: e.g. high bandwidth wireless technologies
- Real-time location tracking and data collection systems, which have enabled new possibilities for effectively meeting challenges imposed by man-made and natural

disasters. Peña-Mora *et al.* (2004) present that the future resilient city will have lots of data points and technology will be embedded into every major system. AbdulMatinm (2013) proposes to use UV filters in every home, solar water heaters on every building eliminating the need for oil and gas alternatives, and complex storm water management systems that mimic salt marshes to reduce the need for storm walls at the coastline of cities.

Current uses are the following:

- Geographical Information Systems (GIS) for Disaster Response
- Building Black Box
- RFID/Mobile Ad-hoc Networks for building assessment
- Reconstruction during or post disaster built environment using real-time images or video stream data from disaster site
- Building Information Modeling BIM
- Augmented Reality techniques for Disaster Visualization
- 3D laser scanning
- Robust Wireless Communication Networks
- Big Data

Geographical Information Systems (GIS) for Disaster Response

Geographical Information Systems (GIS) plays a critical role in spatial analysis to help develop high levels of situation awareness and facilitate critical decision making. GIS can be used during all four phases of disasters including preparedness, response, recovery, and mitigation. During the preparedness phase, spatial data and geospatial analysis services are to be prepared and deployed. Real-time data collection, integration, and analysis can be performed based on GIS during the response phase, while during the recovery phase large scale spatial planning and progress monitoring for repair of infrastructure and housing can be executed. During the mitigation phase, simulation models and cost analysis can be studied through visualization and comparison in GIS to have alternative disaster mitigation plans for future disasters. Prior to disasters, resources, facility locations, and road network data are geo-coded into geospatial databases. After the disaster, the application takes destinations and traffic conditions as inputs, and analyzes the updated road network data for optimal allocation routes and resource distribution decisions. The application is automated for easy and efficient use under stressful and complex conditions. Moreover, different optimization models can be plugged into the system for different scenarios for resource allocation. Firstly, spatial data critical to disaster response is prepared prior disasters. During disasters, graphical representation of collected spatial information, traffic conditions and disaster sites, is done using GIS. Also, GIS facilitates critical decision making and emergency response planning through services such as facility location selection and emergency route finding for optimal resource allocation.

RFID/Mobile Ad-hoc Networks for building assessment

Building assessment is one of the key tasks undertaken by the engineering workforce during Urban Search and Rescue operations (US&R) during disaster response and recovery operations (McGuigan, 2002). The next generation disaster resilient Radio Frequency Identification (RFID) technology was employed to support an assessment of building conditions and the status of rescue operations.

The rationale of tracking building conditions during Urban Search and

Rescue operations is twofold. Firstly, responders entering buildings need to know which parts of building are structurally safe and are free of hazardous materials. Secondly, identifying buildings that are safe for re-occupancy can reduce an overall chaos and allow staging areas for people displaced from their houses. Apart from the structural assessment markings, building assessments also include information like potential victim location and number of victims rescued. In the existing practice, building assessment information is posted on buildings with the help of spray paints. Recording assessment information using spray paints has many limitations including poor visibility in foggy/smoky conditions. Also, this information is not recorded in computers resulting in lack of overall situation awareness about the search and rescue process. Forms containing critical building assessment information are submitted only towards the end of an operation cycle causing delays in communication. However, for an optimal resource allocation, it is imperative that the decision makers are made aware of site conditions as quickly as possible. During disasters such real-time access is often made difficult because of a failure of pre-existing infrastructures such as telecommunication networks.

Building Black Box

Building black-boxes are ruggedized and serve as disaster resistant information storage hubs which are embedded in buildings to support building assessment during disaster response operations. Building black boxes serve to achieve two pronged objectives: first, to store static building information such as building information model, building drawings, historical maintenance and operations data. Second, to provide dynamic building information through disaster resilient sensors such as temperature, humidity, stress/strain in structural elements as well as visual sensors locating personnel/victim locations inside a building. System testing was done to meet disaster resilience, secure communications and resilience requirements. Regular backups of information stored in building black boxes was done at secure data mirroring centers and emergency offices in order to ensure building information availability during an incident response. In cases where regular communication infrastructure is not available after disaster events, engineers can access information stored in the black box using mobile ad hoc networks or through a satellite up-link.

Reconstruction during or post disaster built environment using real-time images or video stream data from a disaster site

Visualization of built environment using photographs and videos allows first responders and decision makers - regardless of their level of knowledge and expertise - understand spatial constraints of the disaster site and explore the rescue and recovery operation alternatives. In addition, during disaster response and recovery operation, there is a very limited time for assessing the stability of the disaster site. Therefore, reconstruction of the scene based on images could become a good source for during- and post-disaster site stability assessment and act as a good communication tool among first responders. Knowing camera pose (location, orientation, and field of view) allows disaster site photographs be placed into common 3D coordinates and consequently disaster responders will be able to virtually explore the scene by moving in 3D scene from one image to another, while the special configuration of the images within the 3D scene are preserved. The camera pose information could be retrieved either by GIS or wireless location tracking techniques (Behzadan *et al.*, 2008) or could be recovered by Image-based

Modelling (IBM) techniques wherein three-dimensional models are reconstructed from a collection of input images based on Structure from motion (SfM) techniques (Pollefeys *et al.*, 2004; Hartley & Zisserman 2004). This visual dataset allows photographs and video stream images of the post-disaster scene to be posed in locations where images were taken.

Building Information Modeling, BIM

BIM can play a crucial role in releasing the bottleneck that often stops designers' smart ideas from reaching clients. Construction 2025 sets a range of targets including the reduction of costs by 33%, cutting delivery times by 50% and reducing the greenhouse gas emissions by half. BIM could improve procurement practices and opportunities for architects and other suppliers to contribute to innovation in construction. (Wilding, 2013). A BIM carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of "smart objects". For example, an air conditioning unit within a BIM would also contain data about its supplier, operation and maintenance procedures, flow rates and clearance requirements (CRC Construction Innovation, 2007) including 3D Architectural Model, Integrated Structural and MEP Model , Site Logistic Planning Model, Quantity Estimates. A building information model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule. This model can be used to demonstrate the entire building life cycle (Bazjanac, 2006). As a result, quantities and shared properties of materials can be readily extracted. Scopes of work can be easily isolated and defined. Systems, assemblies, and sequences can be shown in a relative scale with the entire facility or group of facilities. The construction documents such as drawings, procurement details, submittal processes and other specifications can be easily interrelated (Khemlani *et al.,* 2006**).**

The BIM model retrieved from the Black box allows the pre-disaster situation to be known. Superimposing the reconstructed scene on the pre-disaster virtual model environment, allows the photographs and video snapshots to be registered within the virtual environment. Within such registered environment, images could be analyzed using image processing techniques (Brilakis *et al.,* 2006; Varma & Zisserman, 2005), and the severity of disaster incident could be assessed. Also within the registered environment, the structural deviations between pre-disaster and post-disaster conditions could be measured and reported to disaster responders.

Augmented Reality techniques for Disaster Visualization

Once the camera pose is known for each image, the video stream or each photograph would be registered with the 3D model. This in turn creates an Augmented Reality environment wherein the pre-disaster virtual model is superimposed with post-disaster images. Using an Augmented Reality model (Golparvar-Fard *et al.*, 2008) with US Homeland Security Advisory System color coding scheme, different structural or hazardous conditions are visualized. The augmented photographs provide a consistent platform for representing pre-disaster, post-disaster and structural discrepancies information and facilitate communication and reporting processes among first responders.

3D laser scanning

During the rescue operations, always there is little time for a rigorous structural analysis and a limited time to decide the remaining stability of the building and/or the temporally shoring measures required (McGuigan, 2002).The large variety in structural typologies and different levels of damage make it difficult to model simple patterns for building behaviour. LIDAR (Light Detection and Ranging) techniques could provide a quick way to gather building data from the disaster scenario and tools to improve a building assessment. Laser technologies serve as a valuable tool to gather real-time information in the response phase of an extreme event.

Robust Wireless Communication Networks

The ways to improve collaboration and coordination in a disaster response effort have been highlighted in various studies. Also various pitfalls related to collaboration, such as lack of trust, information sharing, communication and coordination, have been well documented. In the hours and even days following a major disaster, communication is often limited because the existing infrastructure may be destroyed or the event may have occurred in an area without infrastructure. Voice service may be severely restricted. Challenges imposed by disasters emphasize that the collaboration medium provide attributes such as high availability, improved transmission capability, and appropriate information dissemination. To achieve these goals, a reliable and transparent Mobile Ad-hoc Space for Collaboration (MASC) was developed to support collaboration among first response organizations and leverage civil engineers' role during disaster response and recovery operations (Aldunate *et al.,* 2005). MASC was tested through software simulations in a search and rescue exercise at the Illinois Fire Service Institute. The results obtained showed that it was possible to build a system for traditional teams of first responders exhibiting 98% of availability in square areas where the side length is about three times the wireless communication range. Furthermore, the search and rescue exercise allowed the research to confirm results found through simulation runs about availability and to demonstrate that MASC is also portable among different devices, transparent to first responders, and able to adequately manage and disseminate information in disaster scenarios. Such results demonstrate appropriateness of Mobile Ad-hoc Space for Collaboration. Currently, the ways to scale up MASC for a large set of response teams is being explored with the tools such as Mobile Communication Bridges (Peña-Mora *et al.,* 2004) that would allow responders to communicate reliably and securely.

Big Data

There are 7 principles for Big Data when managing a resilience project. These seven core principles serve to guide data projects to ensure they are socially just, encourage local wealth- and skill-creation, require informed consent, and be maintainable over long timeframes.

1. Open Source Data Tools - Wherever possible, data analytics and manipulation tools should be open source, architecture independent and broadly prevalent (R, python, etc.). Open source, hackable tools are generative, and building generative capacity is an important element of resilience. Data tools that are closed prevent end-users from customizing and localizing them freely. This creates dependency on external experts which is a major point of vulnerability. Open source tools generate a large user base and typically have a wider open knowledge base. Open source solutions are also more affordable and by definition more transparent.

Open Data Tools should be highly accessible and intuitive to use by non-technical users and those with limited technology access in order to maximize the number of participants who can independently use and analyze Big Data.

2. Transparent Data Infrastructure - Infrastructure for data collection and storage should operate based on transparent standards to maximize the number of users that can interact with the infrastructure. Data infrastructure should strive for built-in documentation, be extensive and provide easy access. Data is only as useful to the data scientist as her/his understanding of its collection is correct. This is critical for projects to be maintained over time, regardless of team membership, otherwise projects will collapse when key members leave. To allow for continuity, the infrastructure has to be transparent and clear to a broad set of analysts – independent of the tools they bring to bear. Solutions such as hadoop, JSON formats and the use of clouds are potentially suitable.

3. Develop and Maintain Local Skills - Make "data literacy" more widespread. Leverage local data labor and build on existing skills. The key and most constraint ingredient to effective data solutions remains human skill/knowledge and needs to be retained locally. In doing so, consider cultural issues and language. Catalyze the next generation of data scientists and generate new required skills in the cities where the data is being collected. Provide members of local communities with hands-on experience; people who can draw on local understanding and socio-cultural context. Longevity of Big Data for Resilience projects depends on the continuity of local data science teams that maintain an active knowledge and skills base that can be passed on to other local groups. This means hiring local researchers and data scientists and getting them to build teams of the best

established talent, as well as up-and-coming developers and designers. Risks emerge when non-resident companies are asked to spearhead data programs that are connected to local communities. They bring in their own employees, do not foster local talent over the long-term, and extract value from the data and the learning algorithms that are kept by the company rather than the local community.

4. Local Data Ownership - Use Creative Commons and licenses that state that data is not to be used for commercial purposes.

The community directly owns the data it generates, along with the learning algorithms (machine learning classifiers) and derivatives. Strong data protection protocols need to be in place to protect identities and personally identifying information. Only the “Principle of Do No Harm” can trump consent, as explicitly stated by the International Committee of the Red Cross’s Data Protection Protocols (ICRC, 2013). While the ICRC’s data protection standards are geared towards humanitarian professionals, their core protocols are equally applicable to the use of Big Data in resilience projects. Time limits on how long the data can be used for should be transparently stated. Shorter frameworks should always be preferred, unless there are compelling reasons to do otherwise. People can give consent for how their data might be used in the short to medium term, but after that, the possibilities for data analytics, predictive modelling and de-anonymization will have advanced to a state that cannot at this stage be predicted, let alone consented to

5. Ethical Data Sharing - Adopt existing data sharing protocols like the ICRC’s (2013). Permission for sharing is essential. How the data will be used should be clearly articulated. An opt in approach should be the preference wherever possible,

and the ability for individuals to remove themselves from a data set after it has been collected must always be an option. Projects should always explicitly state which third parties will get access to data, if any, so that it is clear who will be able to access and use the data. Sharing with NGOs, academics and humanitarian agencies should be carefully negotiated, and only shared with for-profit companies when there are clear and urgent reasons to do so. In that case, clear data protection policies must be in place that will bind those third parties in the same way as the initial data gatherers. Transparency here is key: communities should be able to see where their data goes, and a complete list of who has access to it and why.

6. Right Not To Be Sensed - Local communities have a right not to be sensed. Large scale city sensing projects must have a clear framework for how people are able to be involved or choose not to participate. All too often, sensing projects are established without any ethical framework or any commitment to informed consent. It is essential that the collection of any sensitive data, from social and mobile data to video and photographic records of houses, streets and individuals, is done with full public knowledge, community discussion, and the ability to opt out. In essence, this principle seeks to place “Data Philanthropy” in the hands of local communities and in particular individuals. Creating clear informed consent mechanisms is a requisite for data philanthropy.

7. Learning from Mistakes - Big Data and Resilience projects need to be open to face, report, and discuss failures. Big Data technology is still very much in a learning phase. Failure and the learning and insights resulting from it should be accepted and appreciated. Without admitting what does not work the community is

not learning effectively. Quality control and assessment for data-driven solutions is notably harder than comparable efforts in other technology fields. The uncertainty about quality of the solution is created by the uncertainty inherent in data. Even good data scientist are struggling to assess the upside potential of incremental efforts on the quality of a solution. The correct analogy is more one a craft rather a science. Similar to traditional crafts, the most effective way is to excellence is to learn from ones mistakes under the guidance of a mentor with a collective knowledge of experiences of both failure and success (Pena-Mora, 2004).

2.9. Assessments

Urbanisation is one of the great driving forces of the twenty-first century. Cities generate both productivity and creativity, and the benefits offered by high-density living and working contributes to sustainability. Cities comprise multiple components, forming both static and dynamic systems that are interconnected directly and indirectly on a number of levels. Bringing together large numbers of people within a complex system can lead to vulnerability from a wide range of hazards, threats and trends. The key to reducing this vulnerability is the identification of critical systems and determination of the implications of their failure and their interconnectivities with other systems. One emerging approach to these challenges focuses on building resilience – defined here as the degree to which a system can continue to function effectively in a changing environment. In addition to urbanisation trends, which mean for the first time that more than 50% of people live in urban environments globally, the climate is changing. While both trends are being recognised and projected, the inherent uncertainty of their impacts is putting immense pressure on cities and their critical role in sustaining the lives and livelihoods of their citizens, their economies and environments (da Silva *et al.*, 2010).

For engineers, planners and designers an increasingly uncertain world presents challenges for traditional modes of predicting risk based on historical data, and reducing exposure to natural hazards by designing land use and defences to ‘keep nature out’. While it is possible to make infrastructure projects themselves more durable in the face of projected changes in climate, considered en masse these investments can collectively decrease (Brown & Kernaghan, 2011) the ability of interconnected urban environments to function and meet the livelihood outcomes in the face of such uncertainty. In order to tackle these challenges at the city scale, organisations including the World Bank, Rockefeller Foundation, City of London, the C40 Cities and the Institution of Civil Engineers, are increasingly shifting to resilience-based approaches, recognising the need for adaptable strategies and processes to address a multitude of uncertainties relating to climate, the economy and demography. This means finding ways to prepare for an uncertain range of hazards and threats, and increasing the ability of urban systems to cope with the resulting shocks and stresses. Research undertaken into what makes a city resilient found that existing frameworks only consider specific trends or hazards such as climate change – for example, Tyndall Centre’s integrated assessment methodology for climate change in cities (Dawson *et al.,* 2009) and the urban resilience framework (da Silva *et al.,* 2010); for example, Thames Estuary 2100 (McBain *et al.,* 2010) and Resilient Sheffield (Arup, 2011a); or functional vulnerabilities – for example, Economy and Environment Program for Southeast Asia (EEPSEA) adaptive capacity and vulnerability frameworks (Yusuf & Francisco,

2009) and Climate Resilient Ningbo (Arup, 2011b). A new framework was needed to enable engineers, planners and designers to think about city resilience in totality, and assist with the challenge of communicating these complex issues to a wider audience.

2.10. Systems and interconnectivity

Cities are complex and rely on a large number of interdependent and interconnected systems. For example, a flood may affect a water supply and sanitation system, which may impact human health, in turn increasing pressure on the healthcare system. The importance of considering the interconnectivity of systems was demonstrated by Arup's work on Resilient Sheffield (Arup, 2011a), which assessed the city's various systems to determine the implications of their failure and their interconnectivity with other systems, leading to the identification of options for building resilience.

2.11. Hazards, threats and trends

When defining a set of possible threats and hazards to the city's aystems, some are semi-predictable (e.g. seasonal monsoon), but most are uncertain by their very nature. Impacts can result from incremental change or from sudden events.

2.12. Characteristics of Resilience

There are five characteristics that resilient systems share, in good times and in times of stress:

1. The capacity for robust feedback loops that sense and allows new options to be introduced quickly as conditions change.
2. The flexibility to change, and evolve, in the face of disaster.

3. Options for limited or “safe” failure, which prevents stressors from rippling across systems requiring islanding or de-networking at times.
4. Spare capacity, which ensures that there is a back-up or alternative available when a vital component of a system fails.
5. The ability for rapid rebound, to re-establish function quickly, and avoid long-term disruptions.

The framework is designed to aid identification of the critical systems and their interconnectivity, and consider the vulnerability of these systems to changing environments, be they gradual or instantaneous. The next step is to determine the most appropriate response. (Bahadur *et al.,* 2010; McBain *et al.,* 2010; O’Rourke, 2007; McBean & Rodgers, 2010; Barnett & Bai, 2007; da Silva *et al.,* 2012).

2.13. Responses: Built-in Resilience

Having considered the characteristics of resilient urban systems, the final step is to identify suitable ways to respond, that is, specific actions to be taken to build resilience. Increasing, or building resilience into a system, will typically be addressed by one or more of three responses.

- Mitigation: The system will be affected by a particular shock or stress at a level that is able to be mitigated (e.g. flood protection system to stop impacts).
- Adaptation: The system will adapt to a particular shock or stress (e.g. the flood overwhelms the system, but the citizens are prepared and there is little impact).
- Disaster management: The system will be heavily affected by a particular shock or stress, and disaster risk management will be required (e.g. the

system is overwhelmed, so disaster response measures are initiated).

In summary, by considering the systems that allow any particular city to function, the characteristics of resilient systems described above, and identifying potential hazards, threats and trends for that particular city, it is possible to identify vulnerabilities that undermine its resilience. On this basis, the proposed framework seeks to go beyond the existing work to define a high-level tool that can be used to identify priority systems and highlight key hazards, threats and trends for any particular city, and hence identify areas for building resilience (Collier *et al.,* 2015)

2.14. First Defences

- Live, work, learn and play places
- Buildings are the focus of commercial activity
- As assets, they represent huge economic value
- 90% of our time is spent in buildings (shelters from the storm)

2.15. Key considerations

- Location
- Micro-climate
- Design (for resource efficiency)
- Connectivity to urban services
- Green space and green infrastructure
- Affordability

2.16. Recommendations

- Upgrading existing systems,
- Rebuilding smarter,
- Replacing some systems with newer and better alternatives,

- Improving the sharing of equipment,
- Enhancing institutional coordination, and
- Improving data collection and analysis.

2.17. Approaches to Resilient Cities

- Energy and Emissions calculation and diagnosis
- Local scenarios
- Concepts (smart cities, resilient cities...)
- Observation of evolutions, tendencies
- Spotting “signals”
- GIS
- Databanks and statistical analyses
- 3D modelling

Critical infrastructures (CI) are organizational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences.

2.18. Emergency planning

Comprehensive emergency planning for prolonged and wide-ranging power outages, Core issues:

- Protective goals
- Minimum service level
- Legal framework, legal requirements
- Backup power supply concept (various levels)

- Fuel supply regulation
- Prioritization (BBK 5th Global Forum on Urban Resilience & Adaptation, 2014).

"If you want to go fast, go alone. If you want to go far, go together." African proverb (Rat-Fischer *et al.,* 2014).

2.19. Challenges and Potential Collaborations

- Quality of construction
- Demonstrations needed on the district level
- Capacity building needed for Implementers
- Inefficient land use & urban sprawl
- Small and medium town development needed
- Regional cooperation is needed
- Improvement of urban finances needed
- Pollution and call for liveability
- Integrated and quality oriented planning is needed
- Multi-functionality and poly-centrality needed
- Introduction of climate-friendly technologies
- Mitigation potential in fast growing market (Werner, 2015).

2.20. Factors of Urban Resilience

Urban resilience is defined as the capacity of individuals, communities, institutions, businesses, systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience.

- Shocks are typically considered single event disasters, such as fire, earthquakes, and floods.

- Stresses are factors that pressure a city on a daily or reoccurring basis, such as
- Chronic food and water shortages,
- An overtaxed transportation system,
- High unemployment (Yanez et al., 2015).

2.21. Requirements for Building Urban Resilience

- Action
- Systemic change across all four key components of an urban system
- Infrastructure,
- Institutions,
- Knowledge, and
- Ecosystems.

2.22. Resilient Cities: The Result of Multiple Factors

- Interventions including transport and energy,
- Food security,
- Urban planning and
- Waste management;

Resilience is not location specific and is distinct from disaster risk reduction; and building resilience is a progressive and evolving process of urban development.

2.23. Summary

The following 14 points contain the summary of the chapter:

1. Are the world’s cities headed for inevitable collapse? They believe that intelligent planning and visionary leadership can help cities meet the Impending crises, and look to existing initiatives in cities around the world. Rather than responding with fear, they choose hope.

2. The amount of petroleum currently used and subsequent contribution to climate change. They then present four possible outcomes for cities: Collapse, Ruralized, Divided, and Resilient.

The chapter further describes how a new “sustainable urbanism” could replace today’s “carbon-consuming urbanism”, and how new transportation systems and buildings can be feasibly developed to replace our present low efficiency systems.

3. What the major adaptation strategies are into action against climate change. Natural disasters, human failures and others (terrorism, war and crimes) are the major factors your city is concerned with.

It should be explained the concept of *prioritization*: “Which situation is tolerable and which not?” and “what are the minimum services to be provided when the population is under risk?”

4. “Resilience is not a destination, is a journey. It is about doing it all the time and all together” (Basili, 2015).

In more reductionist terms these three levels reflect:

- Systemic integrity
- Coordination
- Self-improvement (The Herald, 2013).

5. Our future is an urban future that is resilient (Desouza & Flanery, 2013). As of

2010, half of the world's population dwell in urbanized areas, and of those 3.5 billion people, 38% live in large urban agglomerations or mega-cities. From 2005 to 2010 the world's urban population increased at a rate of 1.9% (United Nations, 2011).

First Defences:

• Living, working, learning and play places

• Buildings are the focus of commercial activity

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• 90% of our time is spent in buildings (shelters from the storm)

Key considerations:

- Location
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6. Recommendations

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- Local scenarios

- Concepts (smart cities, resilient cities...)

- Observation of evolutions, tendencies

- Spotting « signals »

- GIS

- Databanks and statistical analyses

- 3D modelling

8. Emergency planning

The core issues for the comprehensive emergency planning for prolonged and wide-ranging power outages are:

- Protective goals

- Minimum service level

- Legal framework, legal requirements

- Backup power supply concept (various levels)

- Fuel supply regulation

- Prioritization.

9. Critical infrastructures (CI) are organizational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences.

10. Challenges and Potential Collaborations

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- Multi-functionality & poly-centrality needed

- Introduction of climate-friendly technologies

- Mitigation potential in fast growing market

11. Technologies

Technologies can play a critical role in addressing short-comings of existing disaster response operations. Recent advancements in technologies, such as:

- Those in hardware (e.g. miniaturization, increased processing power),

- Transmission systems (e.g. high bandwidth wireless technologies)

- Real-time location tracking and data collection systems, which have enabled new possibilities for effectively meeting challenges imposed by man-made and natural disasters

12. The future resilient city will have lots of data points and technology will be embedded into every major system.

13. BIG Data good or bad?

Open Source Data Tools - Wherever possible, data analytics and manipulation tools should be open source, architecture independent and broadly prevalent (R, python, etc.). Open source, hackable tools are generative, and building generative capacity is an important element of resilience. Data tools that are closed prevent end-users from customizing and localizing them freely.

a. This creates dependency on external experts which is a major point of vulnerability.

b. Open source tools generate a large user base and typically have a wider open knowledge base.

c. Open source solutions are also more affordable and by definition more transparent.

d. Open Data Tools should be highly accessible and intuitive to use by non-technical users and those with limited technology access in order to maximize the number of participants who can independently use and analyze Big Data.

14. Transparent Data Infrastructure

Infrastructure for data collection and storage should operate based on transparent standards to maximize the number of users that can interact with the infrastructure. Data infrastructure should strive for built-in documentation, be extensive and provide easy access. Data is only as useful to the data scientist as her/his understanding of its collection is correct. This is critical for projects to be maintained over time, regardless of team membership, otherwise projects will collapse when key members leave. To allow for continuity, the infrastructure has to be transparent and clear to a broad set of analysts – independent of the tools they bring to bear. Solutions such as hadoop, JSON formats and the use of clouds are potentially suitable.