Making a Step Forward Towards Urban Resilience. The Contribution of Digital Innovation

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Abstract. Starting from 'wicked problem' theory as the landmark for framing disaster events in terms of policy issue for city governments, this paper highlights the contribution provided by Big Data analytics and digital innovation in dealing with disaster risks. The research aims at answering the following question: *what is the role that 'smart technologies' play in strengthening urban resilience to disaster risks?*

To answer the question, the study devotes attention to some applications of data analytics for enhancing cities resilience towards disaster risk reduction.

Exploiting the transformative power of digital innovation for the enhancement of city 'smartness' could be a valuable path for boosting urban resilience facing 'wicked problems. However, it is debatable whether cities can effectively overcome these problems without a clear understanding of the need to merge smartness and resilience in a broad policy framework and to apply these principles into consistent operational disaster risk reduction plans.

Keywords: Smart cities · Resilience · Disaster risk reduction · Big data analytics · Smart technologies

1 Introduction

Enhancing the 'smartness' of cities and boosting the 'resilience' of their communities in the face of 'wicked problems' are key contemporary challenges for local governments that ask for, adaptive, collaborative, and long-term oriented policy approaches.

These challenges drawn the attention of both academic and politicians, arriving at the fore of the agenda of UN Institutions, national, local Governments, and NGOs, in light of the pivotal relevance they assume for the achievement of Sustainable Development Goals. A major concern of the Agenda, in fact, is to "*ensure responsive, inclusive, participatory and representative decision-making at all levels*". Likewise, the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) have strongly emphasized the need for "*strengthening disaster*

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risk governance and coordination across relevant institutions and sectors and the full and meaningful participation of relevant stakeholders at appropriate levels".

For 2018, the UN 'High-Level Political Forum on Sustainable Development' (HLPF) will focus on transformation towards sustainable and resilient societies, with a major attention, among others, to SDG 11 named "Make cities and human settlements inclusive, safe, resilient and sustainable", confirming the pivotal role played by Cities, Local and Regional Governments in pursuing sustainability and disaster risk reduction challenges.

Adopting a 'smart approach' that "*makes use of opportunities from digitalization, clean energy and technologies, as well as innovative transport technologies, thus providing options for inhabitants to make more environmentally friendly choices and boost sustainable economic growth and enabling cities to improve their service delivery"* is a basic principle of the UN New Urban Agenda.

City transformation processes must therefore be rethought to mitigate the effects of extreme events on the vital functions of cities and communities.

In light of these challenges the paper debates on how the dissemination of 'smart technologies' strengthens urban resilience to disaster risks.

The remainder of the research is structured as follows: Sect. 2 presents the literature review which embraces two major strands of research: public policy and ICT management; Sect. 3 briefly describes method and discusses preliminary findings; Sect. 4 highlights conclusion and limitations of the study.

2 Framing Cities in the Era of Complexity and Vulnerability to Disaster Risk. A Literature Review

The public governance literature has illustrated how organizations and communities could deal with the dynamic complexity that characterizes today's societies [1–6].

From the perspective of public policy issues, 'wicked problems' [7] are those unpredictable, complex, undefined, open-ended and non-linear problem [8, 9], that 'have no technical solution, involve multiple stakeholders, and create ripple effects' [10].

In their pivotal work, Rittel and Webber [7] listed ten properties of wicked problems[1], whose essence has been effectively summarized by Head [11]: complexity, uncertainty and divergence.

Looking at these features, which are cumulative and mutually reinforcing, disasters can be easily labeled as 'wicked problems' due to their wide nature (storms,

[1] For every WP: 1. There is no definitive formulation of a wicked problem. 2. They have no stopping rule. 3. Solutions to wicked problems are not true/false, but good/bad. 4. There is no immediate and no ultimate test of a solution to a wicked problem. 5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly. 6. They do not have an enumerable (or exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan. 7. Every wicked problem is essentially unique. 8. Every wicked problem can be considered a symptom of another wicked problem. 9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's solution. 10. The designer has no right to be wrong.

earthquakes, volcanoes, heat waves, droughts, epidemic, floods, landslides, wildfire, collision, terrorist attack, nuclear accident, etc.), causes (natural vs. man-made, mixed), scale (local, national, super-national), and to the variety of interpretative criteria applicable to these catastrophic events (technical, social, economic etc.), [12–15].

The frequency and intensity of disasters and extreme weather events occurred in the last decade posed critical issues that forced policy makers to prioritize disaster risk management and community resilience in the policy agenda [16–18], defining effective strategies that might spread a common sense of preparedness, adaptation and awareness through the communities.

From an urban governance perspective, disasters determine devastating effects to critical infrastructure and basic service disruptions, generating mistrust and insecurity through the community.

Moreover, the whole disaster risk management cycle poses problems in terms of scales of governance, decentralization of tasks and resources, legitimacy, collaboration paths between public and private organizations [19–21].

As for Harding et al. [22], these problems 'involve complex interconnected systems linked by social processes, with little certainty as to where they begin and end, leading to difficulty in knowing where and how constructive interventions should be made and where problem boundaries lie'.

Disasters that occur at city level determine also transboundary effects that request collaborative approaches [23] to mitigate disaster risks, to create capacity and resilient culture [24–28] to coordinate emergency responses and provide recovery actions [29, 30].

Among public institutions, cities are those organizations that appear increasingly vulnerable: catastrophic events have seriously harmed them, their communities and the network of connections that has constituted the vital fabric on whom they are founded and developed.

As stated by Khan & Zaman [31], planning for future cities demands greater attention in coping with disaster risks and in facing the changing socio-economic and safety landscape of the urban reality.

A plethora of labels, brands and definitions of city are competing for attention in the academic debate of last decades [32].

Most of them are conceived within the ICT domain [33–36]. Digital technologies, especially with data analytics, have transformed the services and the relationship between governments and their stakeholder [37].

As noted by Kitchin [38], the development of 'smart cities' around the globe has been driven by 'technically inspired innovation, creativity and entrepreneurship. However, a technocratic focus will not necessary create more liveable and safe cities.

Some authors have properly underlined the risk connected to a short-sighted approach in considering smart cities as a merely ICT phenomenon [39–41].

None of the label here referred fully meet the idea of a city that might cope with urbanization threats, disaster risk reduction and sustainability targets.

Moreover, there are a multitude of cases where cities – supposed to be smart – have failed to plan for future threats, showing significant lack of planning and preparedness which have determined extraordinary damages and losses as results of catastrophic events [42].

3 Method and Discussion of Preliminary Results

Through a desk research, we focus on some best practices of public institutions that have applied smart technologies for the enhancement of service quality to citizens as well as to increase the level of safety and security of the communities.

Data are gathered from international reports and studies that clearly demonstrates how smart technologies for emergency significantly contributes to timely response and has reduced the number of people affected or deaths during disaster situations

In this sense, valuable examples come from Africa Region where the use of early warning systems (EWS) in flood-prone villages of Zambia allows to send alert messages to local residents, urging them to evacuate to higher ground in the event of flooding. EWS system' has helped in saving lives during annual seasonal floods and has provided governments and humanitarian agencies with information on where relief efforts are needed, thus demonstrating how ICT tools play a key role in pursuing resilience and sustainability targets.

The positive impact of ICT networks on safety and security of communities has been stressed in the literature and its effectiveness repeatedly proofed, among others, in disaster situations occurred in Mexico, Japan and among ASEAN countries where threats posed by natural disasters and extreme weather events are constantly presents.

Monitoring and communication systems, hazard mapping platforms, live crisis map are key tools of the whole disaster risk management process [43, 44].

More recently, direct participation of citizens in disaster situations via social media, videos, photos, text messages and chats (Twitter, Facebook, Instagram, Snapchat, YouTube, WhatsApp etc.), is of pivotal importance for activating emergency responses and recovery actions. These innovations have, to some extent, redesigned the process and structure of service provision. Each citizen/user is like a sensor that provides data for filling the gaps in the availability of real-time information about disasters [45, 46].

One of the main routes of innovation in enhancing cities resilience towards disaster risk reduction refers to the use of Open data innovation, Mergel [47] and Big Data as both strategic and operational tools that may bring fundamental changes to disaster risk management chain' [48, 49]. As noted by Papadopoulos et al., [50] current trends are to investigate theory using structured data to develop mathematical models [51, 52], or to use social media to study how people respond to disasters and how appropriate measures are taken to enable recovery [53–56]. There are several examples of the employment of open data infrastructure for coping with resilience and sustainability targets at local level. Maps originally produced to provide developers and planners with infrastructure and housing related information, have been updated with data on flood risk areas and critical infrastructure that are of key importance for disaster risk management and emergency plans (i.e. the Greater Manchester Open Data Infrastructure Map (https://mapinggm.org.uk/gmodin/), the Coastal Resilience projects developed in the US and the Carribean; the Cape Town Disaster Risk Management Centre etc.).

On the other hand, Big Data Analytics (BDA) enables smart cities to acquire incredible insights from immense volume of data generated via heterogeneous sources such as Internet-of-Things (IoT) integrated sensors, Radio-Frequency Identification (RFID) tags, Global Positioning Systems (GPS), smartphones, Bluetooth devices, etc. [57, 58].

Big data are here seen not as large datasets, some of which have been used for decades in climatology, but as a 'new socio-technological phenomenon resulting from the emergence and development of an ecosystem made up of the new kinds of data 'crumbs' about human behaviours and beliefs generated and collected by digital devices and services'.

The impact of Big data in boosting resilience of urban communities to disaster risk could be remarkable, providing clear and timely operational information to policy designers and ensuring prompt response during recovery actions.

Data analytics are categorized into four major strands: predictive, descriptive, prescriptive and discursive.

Predictive analytics allows understanding trends and forecasting future outcomes. Especially in natural hazard studies these data analytics are of key importance to 'enabling granular, early, and accurate weather forecasts and can increasingly predict both sudden and slow-onset disasters' [59].

Descriptive analytics refers to the exploitation of available data coming from several sources (satellite, social media etc.), in order to obtain a full comprehension of the situation. On the operational side, descriptive analytics allows to understand, monitoring and detect hazards in the pre-disaster phase, defining and coordinate timely emergency response and to assess recovery actions needed in disaster aftermaths.

Prescriptive analytics goes beyond description and inferences to examine likely scenarios by identifying causal pathways. It provides multiple forecasts developed under different scenarios to gain insight into citizen's behaviour and identify issues and optimization paths under disaster constraints situations. Table 1 summarizes the contribution that data analytics functions provide to disaster risk management.

Table 1. The role of Big data Analytics in Disaster Risk Management. Our elaboration

Disaster risk management			
Data analytics function	Pre-disaster prevention	Disaster phase	Post-disaster recovery
Predictive	Forecasting Simulating Modelling Data Assimilation		
Descriptive	Understanding Monitoring Detection Comparison	Planning Coordinate Response	Assessment Relief Rehabilitation
Prescriptive	Nudging Behavior Analysis Sensitization		

As noted by Baker [60], policy responses and efforts for boosting resilience at urban level depend on the perception of disaster risks and community awareness.

The availability of real-time data and information which can be verified from a variety of sources supports real-time decision-making process, enhances community awareness and perception of incoming threats and guarantees a timelier response in disaster situations, creating the premise for 'transforming urban governance into Smart city governance' [61, 62].

The above reflections offer interesting hints for some preliminary conclusions and for the analysis of limitations and future perspectives of the research.

4 Conclusion and limitations

Cities can be depicted as complex, dynamic and manifold organisms, which evolve, flourish and regenerate as part of a broader ecosystem. Cities worldwide are exposed to a wide range of risks; many of them are attributable to natural hazards. In facing these unprecedented threats, urban governance has to develop a deep understanding of the systems that are critical to the life of the city [63], focusing on mutual interdependencies that exist among various components of each subsystem (natural, socio-technical, economic etc.). At this stage of the analysis it can be stated that successful innovations, such as the use of digital sensors that improve controls and safety networks in smart cities, early warning systems for disaster alert, highlight the credibility and feasibility of the pursuit of certain notions of "smart" cities. Smart cities have to seek to process and manage the real-time data flowing from new digital infrastructure [64], not only for the provision of high-quality services to the community, but also as valuable tools to make working the concept of resilience into the vital fabric of the communities.

Enhancing city 'smartness' as a path for boosting the 'resilience' of their communities in the face of 'wicked problems' seems to be the right answer that urban governments have to adopt for coping with current threats posed by natural hazards, climate change and urbanization trends.

Smart city governance asks for transformative, adaptive, sustainable, collaborative, responsive and long-term oriented policy approaches where all the actors involved interact through the facilitating medium of innovative ICTs, to help to meet the challenges of urban problems.

The 'smartness' and 'resilience' are irreplaceable pillars of future cities. However, it is debatable whether cities which are now facing an endless sequence of hazardous events, can effectively overcome them without a clear understanding of the need to merge the two concepts in a broader policy framework and to apply these principles into consistent operational disaster risk reduction plan.

In the current scenario, cities have to exploit the transformative power of ICTs that might stimulate learning processes and strengthen urban resilience to disaster risks.

Big Data Analytics are of pivotal importance in boosting resilience and providing in depth and earlier understanding of natural and man-made hazards, and for knowledge enhancements about citizens' actions, behaviors and attitudes in both safe and hazardous situations.

Despite the above-mentioned 'pros' for the exploitation of digital innovation to enhance resilience to disaster risks, some limitations have to be highlighted:

- The concept of resilience has a great appeal in the academic debate and in social media. It gives us useful insights about the broader categories of activities that should be improved (learning, adaptability, awareness, collaboration,), but 'without providing any clear operative indications to policy designers' [65];
- Academics have to suggest clear and consistent directions on how to make this shift towards smart and resilient cities, highlighting how resilience can be really impactful for future cities well-being.
- While it is important that smart technologies foster innovation and resilience through the community, on the other side it is strictly needed that citizens perceive the disruptive value of this concept in an era of vulnerability, overcoming some mental biases (myopia, optimism, inertia, and amnesia, as in the s.c. 'Ostrich paradox' proposed by Kunreuther and Meyer [66], that people show when considering disaster risks.
- The desired 'cultural shift' towards urban resilience cannot be evermore "event driven"; it rather must originate from nudge initiatives and awareness from all stakeholder involved, perceiving the scope of the threats that urbanization, environmental and natural hazards pose on our heads and on those of future generations.
- The massive use of rough and unstructured data coming from a wide number of sources (social media, twitter, YouTube, snapchat, etc.) in addition to those already gathered from 'official tools' (satellite, risk platforms etc.) can lead to noises and misinformation [67];
- Strong privacy concern, security issues, and data protection, along with open data, big data, and network/ubiquitous, remind us of the importance of finding the right equilibrium/balance among these;
- Training and education in engaging with smart technologies and their limitations and potential will help bridge the gap between availability and effective adoption for urban smart governance purposes.

As the topic has great potential for further discussion, the research will benefit from a broader review of the literature, mainly focused on policy and managerial implications of digital innovation facing disasters at local level and from a well-structured comparative case study analysis.

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