Smart Urban Resilience:
Enabling Citizen Action in Disaster Risk Reduction and Emergency Response
(ESRC/CONACyT ES/S006583/1)

Academic Literature Review: Smart cities and digital technologies in DRR

Working Paper 1; Work Package 1

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1. INTRODUCTION

This paper presents a critical appraisal of current debates and proposals that elaborate and discuss the role of digital and smart urban technologies in disaster risk reduction (DRR) and emergency response. In particular, it focuses on how the relationships between technology, nature, people (either as individuals or collectives), the state, private stakeholders and the city are imagined and produced across different disciplines. In doing so, we engage not only with disciplinary boundaries, debates and positions. We also ask how various concepts of technology, nature, citizenship, agency are mobilised and analyse what kind of work they do in describing and theorising the relations between these and other objects, subjects, processes and practices. Through this discussion, our aim is both to map these debates and proposals, and to establish a research agenda that can advance current knowledge about this emerging field. This agenda draws on critical perspectives on smart urbanism, digital technologies, digital humanitarianism and disaster governance and seeks to advance the debates by asking what is specific about the intersection between the urban, DRR and emergency response, and smart and digital technologies.

The remainder of the review is organised into two broad sections. The first provides background to the specific debate around smart and digital urban technologies. We do this by looking at current debates on the relationships between DRR, emergency response and technology. Here we focus primarily on how international instruments, in particular the Sendai Framework, imagine these relationships, and how academics and practitioners elaborate their guidelines and objectives. We highlight how these debates imagine technology as a problem-solving tool, guided by science and enabling efficient and effective action, although we introduce some critical counterpoints to this debate. In this section, we also discuss how the adoption of the Sendai Framework deepened the shift from a hazard approach to a vulnerability approach to disasters and emergencies (Gaillard and Mercer 2013).

While the former focuses on the event as rupture and response as the best action, the latter takes into account how previously existing inequalities, both social and spatial, affect the disaster and its effects. We argue that this shift sets the stage for technological developments that focus on prevention and preparedness rather than response, although we are cautious and do not assume that this discursive shift has necessarily been reflected in practice, or that the stark difference between the two approaches necessarily holds empirically.

The second section first explores the issue of digital and smart urban technologies and their relationship to DRR and emergency response in depth. We do this through a two-level discussion. The first presents the different technologies that are involved in current proposals and debates. In a field dominated by problem-solving approaches, led by engineering concepts, imaginaries and practices, these technologies often duplicate debates. That is, when discussing how the Internet of Things (IoT), artificial intelligence (AI) or remote sensing can improve DRR and emergency response, technologies are more than mediators or tools, they are the main stakeholders to enable significant changes in the way emergencies and disasters are known, managed, and governed.

The second layer of this discussion looks at how a number of more abstract debates emerge from the practical arguments and propositions that characterise the problem-solving approach of DRR, emergency, and smart and digital urban technologies. A summary of these technologies and debates is presented in Table 1. Importantly, we argue that most of these technologies, even when focused on prevention or preparedness, mobilise a hazard-centric approach to disasters and emergencies. Finally, we argue that these approaches already lay the groundwork for critical analyses that problematise the classic divisions between emergency and normality, nature and society, and human and non-human, a task we undertake in section three.

Technologies	**Debates**
Social Media	Improved information and communication flows
Mapping and geospatial technologies	
Applications	Exploring disaster-related cultures and behaviours
Drones and robots	Collect, store, and use accurate data
Games and visualization	
Detection and IoT	
Integrated platforms	
Critical approaches	
Smart cities and smart urbanism	
Exploring disaster ontologies, politics, and inequalities	
Digital humanitarianism	

Table 1. Digital and Smart Urban Technologies in DRR and Emergency Response

The final part of the second section presents a range of critical approaches that address digital and smart urban technologies and their relationship to DRR and disasters in a variety of ways. We open that section by focusing on work by scholars who approach the issue of smart cities and smart urbanism from a variety of critical perspectives (Hollands 2008, Hollands 2015, Marvin, Luque-Ayala and McFarlane 2016). We focus in particular on how issues of emergency and governance have been analysed (Luque-Ayala and Marvin 2016), arguing that, despite these contributions, more work is needed in this regard. Following this discussion, we analyse various contributions that address the issue of digital technologies and DRR and the emergency response to technosolutionist discourses and proposals.

These contributions are characterised by their plurality, ranging from empirical assessments of the role of social media in disaster situations (Ferris et al. 2016), to theoretical analyses that question how detectors and sensors are reshaping citizens' performances today (Gabrys, 2016). Finally, we turn our attention to how these issues have been discussed in the rich field of critical approaches to digital humanitarianism (Duffield, 2019). We highlight how these contributions foreground questions of power, inequality, and the particular forms of domination and difference enabled by digital and smart technologies, while analytically challenging the notion of humanitarianism. We conclude this paper by summarising the main findings present in contemporary debates, and by posing some generative questions that might be useful for querying the particularities of urban form, experience, and processes in relation to digital and smart technologies and DRR and emergency response.

2. BACKGROUND

This section focuses on two interrelated questions. First, we ask how technology is imagined and conceptualised in current DRR and emergency response policy, practice and research. We argue that dominant views of technology in disaster and emergency situations see it as an unqualified good that promises improved decision-making and reduced economic loss and damage to human life, property and infrastructure. Second, we investigate how disasters and emergencies are conceptualised, and how their relationships to technology and action are elaborated in these dominant views. Following Gaillard and Mercer (2013), we posit that there has been a significant shift in such conceptualisations, marking a shift from a risk paradigm that focuses on the event as rupture and individual behaviour, to a vulnerability paradigm that highlights how pre-existing social and spatial inequalities shape how disasters unfold and are experienced.

To explore these claims, we look at the Sendai Framework, an international mechanism that seeks to inform, shape, and regulate DRR policy around the world. We also look at various contributions that bring together practitioners and academics to explore the implications of the Sendai Framework for technology and science policy, often offering recommendations and proposing ways forward for governments, non-governmental organisations, experts, and other stakeholders.

In contrast to these arguments, we introduce some critical considerations before moving on to a more in-depth analysis of digital and smart urban technologies. We note analyses that problematise the direct relationship between technology and improved disaster risk reduction and emergency response (Easthope and Mort, 2014). We also consider contributions that challenge the supposedly direct links between knowledge and action that are often assumed in mainstream discussions of DRR, science and technology (Gaillard and Mercer 2013).

Finally, we analyse critiques of resilience that problematise the role of technology, highlighting the unequal power relations in the changing face of contemporary DRR and emergency response (Derickson 2016, Duffield 2016, Davoudi 2018, Jon 2019). In doing so, we seek to problematise dominant narratives about the role of technology in DRR, as well as introduce critical tools that will be needed when analysing the specificities of digital and smart urban interventions and relations.

2.1. TECHNOLOGY IN THE SENDAI FRAMEWORK

2.1.1. INTRODUCTION

The Sendai Framework 2015-2030 is a voluntary, non-binding international agreement that seeks to shape DRR policy worldwide. It postulates that the state is primarily responsible for disaster risk reduction, but also recognises the role that other stakeholders, such as local government, private parties, and civil society organisations, could play in this task – this is defined as a 'whole of society' approach (UNISDR, 2015, 13).

The Sendai Framework has a 15-year time frame and follows the 10-year strategy proposed by the Hyogo Framework for Action 2005-2015. Both instruments, and the previous guideline, the Yokohama Strategy (1994), aim to reduce the potential losses that disasters can cause to economic growth, development goals, the environment, human lives, and livelihoods. Its implementation is supervised and supported by the United Nations Office for Disaster Risk Reduction (UNDRR), formerly known as the United Nations International Strategy for Disaster Reduction (UNISDR).

The Sendai Framework places special emphasis on disaster risk reduction. While the Hyogo Framework sought to reduce disaster losses as its main outcome[1], Sendai seeks 'the substantial reduction of disaster risk and losses in lives, livelihoods and health, and in the economic, physical, social, cultural and environmental assets of people, businesses, communities and countries' (UNISDR, 2015, 12). The emphasis on disaster risk and not simply disasters shows a shift in the way DRR is conceptualised and operationalised.

In particular, it suggests that there is growing concern and interest in acting before disaster strikes, recognising that the impacts felt after disaster are associated with different and unequal social, economic and environmental contexts. Poverty, inequality, climate change, unplanned urbanization and weak institutional arrangements are some of the drivers of disaster risk that the Sendai Framework takes into account.[2] Taking disaster risk as its primary concern, the Sendai Framework aims to prevent and reduce existing disaster risk through an integrated

[1] In 2005, the Hyogo Framework set the desired outcome as 'The substantial reduction of disaster losses, in lives and in the social, economic and environmental assets of communities and countries' (UNISDR, 2005, 3).

[2] The full list is as follows: 'disaster risk drivers, such as the consequences of poverty and inequality, climate change and variability, rapid and unplanned urbanization, poor land management and aggravating factors such as demographic change, weak institutional arrangements, risk-informed policies, lack of regulation and incentives for private investment in disaster risk reduction, complex supply chains, limited availability of technology, unsustainable uses of natural resources, declining ecosystems, pandemics and epidemics.' (UNISDR, 2015, 10)

approach to reduce vulnerability, reduce exposure to hazards and increase preparedness for response and recovery, thereby strengthening resilience.[3]

2.1.2. *Locating Technology*

Technology, in the Sendai Framework, functions primarily as a tool that mediates two sets of relationships. The first is that which takes place within its 'whole of society' approach. This means that technology can be useful for states to plan, prepare, respond, and try to build back better after a disaster. At the same time, it can be used by local governments, civil society organisations, academics and experts, and private stakeholders to participate in such DRR and emergency response moments. The second set of relationships that technology seeks to mediate in the Sendai framework are those between natural disasters (and nature in general) and society. It does so by presenting a range of scientific and technological tools and measures that could enable a better understanding of disasters and their drivers. These include early warning systems (EWS), geospatial information technologies, risk maps, disaster risk databases, and digitally enabled measurement and analysis technologies, among others. Thus, technology is useful throughout the entire life cycle of a disaster. Finally, a central concern in the Sendai Framework is the need to increase technological and scientific cooperation between countries in an effort to develop DRR capacity.[4]

There are three key elements to keep in mind when looking at how technology is implemented and imagined in the Sendai Framework, and how its relationships to disaster and action are conceptualised and mobilised. The first is that technology is seen as a fundamental tool for strengthening DRR measures with a whole-of-society approach. This means that technology should not only be used by governments and states, even if the responsibility lies primarily with them. Civil society organisations, potentially affected individuals and communities, academics, scientists, and the private sector are also part of the development and use of these technological tools. The second is that technology is useful in various phases related to disasters, whether in relation to preparedness, response, recovery, or mitigation. Thus, technology is a flexible set of tools that can be used by as many users as possible

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[3] This objective is stated as: 'To prevent new and reduce existing disaster risks through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce exposure to hazards and vulnerability to disasters, increase preparedness for response and recovery, and thereby strengthen resilience'. (UNISDR, 2015, 12)

[4] There are many conceptualizations of these cycles. Here we consider it to be composed of the following phases: prevention, preparedness, response, relief, rehabilitation, and recovery (see Khan et al., 2008; Coetzee and Van Niekerk, 2012). Technologies relate to these in different ways in the Sendai Framework. For example: early warning systems can be useful to improve preparedness; disaster and disaster risk databases can provide relevant information for authorities and potentially affected groups and individuals to better prevent disaster risk; real-time access to data could improve response and relief efforts; and promoting the resilience of critical infrastructure, including water, electricity, or telecommunications, can be useful now, but also in recovery and reconstruction (UNISDR, 2015, 21).

in various spaces and time periods in a disaster environment. Finally, there is a concern to level technology development across the world through cooperation, as there is a recognition of the inequality in development in this regard. This emphasises the role that scientists, academics and professionals who are in contact with these areas can play.

2.2. Disaster, Technology, and Policy Debates

The notions of technology and disaster embodied in the Sendai Framework remain necessarily abstract. This is due to the scope and goal of the document, an international instrument that seeks to shape policy and action worldwide. However, the Framework also functions as a starting point for numerous reflections and proposals on science-technology-policy linkages. Discussions on how various technologies could be developed, how knowledge and technology transfer networks could function, or how local communities can use technology in the context of disasters are the subject of contributions brought by practitioners, government experts, non-governmental organisations and academics.

In the following, we analyse two sets of contributions. The first, which seeks precisely to discuss and operationalise the goals, objectives, and outcomes of the Sendai Framework. These contributions share a vision of technology as a mediating tool of action and knowledge to achieve more efficient disaster management actions, often inextricably linked to science. They also work through a notion of disaster informed by the vulnerability paradigm mentioned above, as does the Sendai Framework. At the same time, we also look at critical contributions that focus on how technologies are reshaped as disaster unfolds, challenging dominant notions of technology as a mediator and a non-problematic tool.

We do so by focusing on six debates. We do not argue that these are the only ones that hold on the relationships between technology and disasters. Our aim is simply to explore the field and provide relevant background for the following discussion on digital and smart urban technologies. These debates address the following topics:

1. Linking knowledge and action;
2. Capacity building and promotion of DRR networks;
3. Develop and improve access to reliable data;
4. Prevention and preparedness technologies;
5. Recovery technologies; and
6. Resilience and technology;

2.2.1. Linking knowledge and action

A central concern for scholars and practitioners working on the policy implications of the Sendai Framework is how to link knowledge to action. Numerous contributions question how the findings and technological developments emerging from the work of experts and international initiatives can be implemented. A crucial space in which these debates have taken place is the Science and Technology Advisory Group (STAG) of the United Nations Office for Disaster Risk Reduction (UNDRR - and formerly UNISDR). The STAG was established in 2016, following a conference on the role of science and technology in DRR and the implications of the Sendai Framework. An agenda emerged from that meeting, drafted by experts working in international and governmental institutions in various countries and academics (Aitsi-Selmi et al. 2016b). This particular conjunction of backgrounds, areas of activity and concerns is well reflected in the document, which relates to several of the debates we discuss here, including that of linking knowledge to action.

The STAG is particularly concerned with supporting governments 'in capturing and using scientific knowledge, including technological innovations' (Aitsi-Selmi et al. 2016b, 14), a key lesson identified from the implementation of the Hyogo Framework. For Sendai to succeed, they suggest, this support must be provided in a number of ways. These include, for example, the development and sharing of new ways of recording, organising, storing and analysing data using geospatial technologies. They also advocate closer cooperation between developed countries and those that do not have the budget or expertise to conduct research or implement technological solutions. Beyond the specific measures to be taken, they assume a close relationship between science and technology, where the former often follows the correct application of the latter. Even when these technologies are developed at the local level, the question for these authors who are interested in linking knowledge to action as a policy issue is how to scale up local initiatives, and not so much questioning how they work and how they might challenge the assumed links between technology and science.

The question of how policy and technological developments consider local knowledge and action is relevant. Although the Sendai Framework (and to a lesser extent the Hyogo Framework) has promoted a vulnerability approach to disaster management, DRR and emergency response, this conceptualisation does not easily translate into policy action at national and local levels. There, as Gaillard and Mercer (2013) argue, hazard-focused approaches that assert 'that disasters are the result of extreme and rare natural hazards, and that affected people fail to "adapt" because their perception of the risk associated with these natural events is insufficient' (p. 93) have dominated (p. 93).

This means that, even if it is recognised that 'disasters primarily affect those who are marginalised in everyday life and lack access to resources and means of protection that are available to others with more power' (p. 93), ways of tipping the scales of power and dynamics to better adapt, use and implement local ways of knowing and doing have not been developed. That is, even if Sendai develops a preventative and all-hazards approach for the whole society (Aitsi-Selmi, Blanchard, and Murray

2016a), ways to foster, promote, and empower local actions, technologies, and stakeholders have not been developed.

Considering this imbalance, it follows that the task of linking policy and action in DRR is not simply a technical issue, but also a political one. One proposal that links theory and practice is put forward by the aforementioned Gaillard and Mercer (2013), who investigate the roles of the set of stakeholders that exist between international institutions, be they governmental, private and non-governmental, and local and community-based stakeholders and grassroots actions. They proceed by suggesting a reconciliation between different forms of knowledge and action, integrating different scales and reconciling bottom-up and top-down approaches (p. 94). This proposal, shown in Figure 1,[5] has numerous implications that go beyond the question of technology and deserve further discussion. However, as far as technology and its relationship to knowledge, science and power imbalances between local, state, and international stakeholders are concerned, the authors offer some critical considerations that are useful for understanding how DRR policies and actions operate in different spaces and moments.

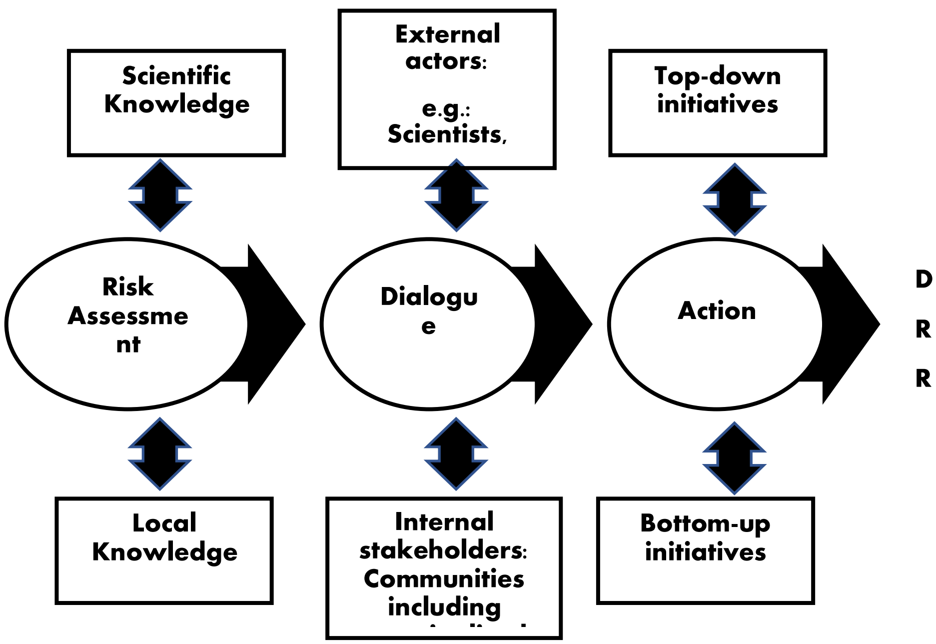

Figure 1. Roadmap for integrating knowledge, actions and stakeholders for DRR. Source: Gaillard and Mercer, 2013.

Gaillard and Mercer (2013) propose different measures for bringing together ways of knowing and doing that have often been carried out and imagined operating separately. These include questions relating particularly to the relationship between

[5] This roadmap, they argue, 'emphasizes a horizontal process that begins with an integrated assessment of disaster risk based on different forms of knowledge, then establishes a multi-stakeholder dialogue on problems and possible solutions, and finally leads to actions that combine top-down and bottom-up initiatives.' (p.95).

science, technology and action. In particular, the authors argue that even if local knowledge is increasingly recognised as having value and useful lessons for providing DRR solutions, challenging the primacy of scientific knowledge, there is still a need to bring scientists and communities together when designing DRR policies and technologies.

Another relevant case concerns the development and use of monitoring and early warning systems. The same authors argue that these may work best if they are developed in relation to community based DRR, considering locally developed technologies and localised ways of responding to and coping with hazards and disasters. In these tasks, the authors argue, a constant dialogue between scientists, experts, communities and other stakeholders is necessary, as this is where the gaps between bottom-up and top-down approaches to science, technology, knowledge and action can be bridged. Importantly, this bridge also needs to be materialised, potentially through numerous participatory practices, including mapping, which we discuss in the next section. However, technologies are not enough, as broader institutional, financial and policy changes must take place if the role of the community is to be strengthened and developed.

Finally, another well-explored concern is that of the link between science, policy and evidence (Aitsi-Selmi et al. 2016a, Aitsi-Selmi et al. 2016b, Shaw, Izumi and Shi 2016). For example, Calkins (2015) argues that there is a disconnect between science, technology, and policy, which partially explains the inadequacy of current DRR measures. As mentioned above, this posits a concept of technology as a tool that enables better knowledge of disasters and associated vulnerabilities and therefore enables better policy and action. In these conceptualisations, there is little recognition of the political issues and uneven playing fields mentioned by Gaillard and Mercer (2013).

Instead, improving DRR policies and strategies is a technical and scientific problem that can be solved through better use of evidence and data. While vulnerabilities and social inequalities are not overlooked, community-based responses and experiences are not fully integrated into this and similar approaches. This may be related to the fact that these interventions aim to intervene in the discussions taking place within the scientific and professional networks working on DRR issues, which usually operate with reference to the Hyogo and Sendai Frameworks. In this highly institutionalised space, mentions of community-based and other local approaches are often not fully engaged and developed.

2.2.2. Capacity-Building and Promotion of DRR Networks

Closely linked to the debates around interconnecting knowledge and action are a number of contributions that propose to enhance DRR through capacity building, and through fostering networks of practitioners and academics. These contributions also understand that technology is inextricably linked to science and adopt a concept of technology that does not question its politics in depth, often only analysing the large inequalities in terms of access to technology at international and national levels. For example, Calkins (2015) shows how scientists working in developing countries identify the lack of capacity to implement the Sendai Framework and national and local DRR policies as a major concern.

This involves technology transfers and innovation, but also ongoing technical support. Inequalities in DRR-related capacity, particularly in technology, are shaped by broader economic, political and historical trajectories, as well as by the differentiated impacts of disasters and climate change. This need for capacity building, between and within states is a concern that exists not only at the international level, and certainly at the national level as well (Shaw et al. 2016). In this, technology can become a particularly useful tool, particularly web-based ones, which are described as cost-effective and efficient (Kim et al. 2016).

The Sendai Framework mentions that science and technology networks could be relevant in the implementation of DRR policies worldwide. Despite these mentions, how these networks operate and what role they could play has not been fully analysed (Trogrlić et al. 2017). To that end, emerging research has identified networks, in relation to DRR, not only as groups of like-minded individuals pursuing a shared goal or interest (King 2011), but also as playing a key role in supporting 'organisations and infrastructure that enable *actionable research* actions' (Trogrlić et al.2017, 101). This can certainly include evidence-based reporting policies, as these authors mention. However, it can go beyond this. Networks can also 'assist in the implementation of the Sendai Framework, particularly by supporting the monitoring and review of the Framework's targets' (Trogrlić et al. 2017, 102), as well as work on various international agendas, including the Sustainable Development Goals or the COP21 Climate Change Agreement.

Despite the aforementioned potential Trogrlić et al. (2017) argue that more research is needed to understand how they operate in DRR, particularly at the science-policy interface, what challenges they face, and what lessons can be learned from other fields in which they play a prominent role. In this regard, Carabine (2015) suggests that international scientific partnerships, such as the Intergovernmental Panel on Climate Change (IPCC), can offer lessons to the DRR field in terms of developing scientific evidence and promoting the use of science and technology in evidence-based policy.

2.2.3. Developing and improving access to reliable data

The Sendai Framework has set, as a goal, the need to 'promote real-time access to reliable data, make use of space and in situ information, including geographic information systems (GIS), and use innovations in information and communications technology to improve measurement tools and data collection, analysis and dissemination' (UNDRR 2015, 15). Data is present in many papers investigating the role of technology in DRR. However, it is often not treated as a particular issue, but rather as an underlying concern.

For example, (Aitsi-Selmi et al. 2016a) mention that data collection is a central element of many technological developments in DRR, including early warning systems (Gaillard and Mercer 2013). Fundamentally, data collected by these systems and by other sensing devices are provided in real time. This feature, even if not developed in depth by these authors, seems crucial to improve the reliability of the data. The notion of 'real time' promises a more direct relationship between data and science, technology, and decision making. If accurate, real-time data can lead to better DRR policies and technologies.

Even if not provided in real time, increasing the availability and reliability of data is a major concern for researchers working at the science-policy interface. Whether collected by government institutions, scientific organisations, community initiatives or any individual, more data can potentially be useful for improving DRR if it is accurate and relevant. Different digital technologies can be used in this task. These include geospatial technologies, crowdsourcing initiatives, satellites and other remote sensing devices. While these technologies, which generally include a digital element, will be discussed in much more detail in the following sections, it is important to emphasise here that they are considered fundamental tools for providing better data for DRR. In turn, reliable data is presented as a possible solution for improving policies and strategies in advance planning and response to natural disasters.

This is certainly recognised by national governments and scientific organisations, which express numerous concerns regarding the accuracy, reliability, and availability of data (Calkins 2015). The concerns are varied and reflect the deep inequalities that characterise DRR policies and capacities around the world. Many countries in the Global South are concerned with their lack of capacity to collect data, to store data securely and at low cost, and with problems associated with lost data from the past.

Finally, another proposal related to data reliability is to develop standards, so that data generated in different contexts can be compared and used in the development of rigorous approaches to DRR (Aitsi-Selmi et al. 2016b). The authors argue that accurate data are 'the lifeblood' of effective disaster risk reduction policy and development policy. Crucially, they recognise that this data needs to be abstract enough to be read at an international scale, but also detailed and particular enough to make sense contextually.

Here, the concern about disparity of scales and contexts echoes arguments (Gaillard and Mercer 2013) about the need to link knowledge with action in DRR. While in the latter case the issue is how to integrate different stakeholders and ways of regulating DRR, in the case of data standards the problem is to produce information that can accurately convey a risk situation and that can travel between and within countries and regions. The question of how data is generated, particularly through digital and smart technologies, will be addressed in the second part of this paper.

2.2.4. Prevention and Preparedness Technologies

As stated in the Sendai Framework (2015), prevention and preparedness are key elements of DRR policies and strategies. Therefore, authors exploring ways to implement this framework have explored this issue in depth. The emphasis on prevention and preparedness is often formulated as financially and economically sound strategies, as well as ways to save the maximum number of lives in disaster contexts. The shift towards prevention and preparedness has potentially profound implications for DRR and emergency response, as anticipation and planning take precedence over discussions of how to respond once a disaster unfolds.

This approach also has an impact on the type of technologies that are imagined as relevant to DRR policy. Aitsi-Selmi et al. (2016b), reporting on the work of the UNDRR STAG, make copious references to the need to develop early warning systems for hazards, including the use of remote sensing technologies; data repositories that enable experts to understand past disaster cases; and various information technologies that help those potentially affected by a disaster to take timely action if necessary. Here too, emphasis is placed on 'cutting-edge scientific methods and technological tools [...] and fostering a network of relationships at the science-policy-practice nexus.' (2016b, 8)

In her survey of the attitudes and needs of scientists and national officials related to DRR, Julie Calkins (2015) finds that a central concern for many national DRR policymakers and researchers is the development and use of different prevention and preparedness technologies. This need is closely linked to the need for capacity building and technology transfer. Several interviewees expressed that it is not only necessary to provide them with state-of-the-art technology, but also to develop the necessary expertise to enable them to use these tools correctly. These arguments, and indeed others discussed here, see technology as a mediator between stakeholders and a tool for acquiring more accurate knowledge about disasters, nature and how people respond to them.

This often means that, even if they are aware of how technologies may operate differently on the ground, the authors rarely explore these questions empirically. Rather, their interest seems to be in the actions of experts and high-level officials, who then have the responsibility to interact with other stakeholders. An exception to this is Gaillard and Mercer's (2013) argument for a link from knowledge to action. However, empirical evidence is also in short supply. Below, we present analyses that take into account everyday uses of technology, which complicates narratives of technology use in DRR, while also presenting other stages of DRR, namely retrieval.

2.2.5. Recovery Technologies

How do people recover from a disaster? What role does technology play in this? These two questions guide (Easthope and Mort 2014) in their analysis of emergency response and recovery in the UK, particularly in the case of the South Yorkshire town of Toll Bar. The authors develop the concept of 'technologies of recovery', which are sets of documents, practices and different socio-material relations that seek to govern life in post-disaster contexts. They analyse not so much how these documents are drafted, but how they are implemented and, transformed. They show how these technologies, such as checklists, plans, protocols, etc., often fail to acknowledge the variability, unpredictability and mutability of local emergency contexts. In particular, they focus on the interactions between council workers and Toll Bar residents, and how they deployed, modified and even created new recovery technologies and, in doing so, changed the relational form of emergency response in the field.

The article shows how the interactions between recovery technologies and everyday practices, and the politics of disaster and post-disaster governance fundamentally transform the latter. 'What became visible is that, like so many other 'social technologies', recovery technologies, when appropriated by new users, were able to be 'employed in ways quite different from those originally intended.'' (2014, p. 154) This shows that 'every time retrieval technologies are used, they somehow manage to reform themselves a little. They are not on a trajectory of change generated by their own momentum, they continue to be shaped by the way they are put to work' (2014, p. 154).

This is an interesting counterpoint to more abstract narratives of technology and its role, where every imagined mechanism of collaboration is mentioned, or where information, knowledge, technology and practices are often assumed to flow relatively unimpeded. Moreover, as the authors themselves acknowledge, this outcome, where relationships between the city council, neighbours and technologies of recovery became much more horizontal, co-productive and potentially transformative, was not prescribed, but took place through the specificities of the case.

Easthope and Mort's concept of technology is broader than those explored so far. By including documents, procedures, checklists, and templates, the authors expand the possibilities for analysing how technologies are manufactured, remade, and subverted in the field. This transformation impacts not only the technologies themselves but has the potential to reshape the politics of recovery. This shows some of the risks involved in analysing the interactions between technology, citizens, disaster, and the state in local contexts.

If locality is fully taken into account, technology not only emerges as a politically embedded tool, but the politics of technology development, use and adaptation become more visible and clearer. In that sense, technology is more than a mediator or a predetermined tool. It can be both an object and a relation always in process and open to political contestation. Indeed, (techno)politics can and often is played out through technology (von Schnitzler 2016). In the case analysed by these authors, recuperative technologies are mostly analogue; it remains to be explored how these interactions operate in the case of smart and digital urban technologies.

2.2.6. Resilience and Technology

Resilience is a much-debated term in DRR and beyond. The richness of these conceptual debates is far beyond the scope of this review of the literature on DRR, emergency response, and digital technologies. However, some basic notions might be useful in navigating the particular relationship between resilience and technology. The Sendai Framework (2015) places great emphasis on the need to build resilience, particularly in communities that are vulnerable to disasters, but also in buildings and critical infrastructure. Resilience is presented as a way to enable communities to take disaster preparedness, prevention, response and recovery into their own hands. Numerous works exploring the science-technology-policy nexus, which have been mentioned extensively in this paper, often take resilience at face value. The notion of building the capacity of communities to respond to natural disasters and their aftermath is taken as a positive thing in itself, and thus the concept is often used without any meaningful conceptual discussion. In state approaches to DRR and technology, resilience often appears as a way of making communities responsible for their own safety and survival, without fully questioning the conditions under which resilience becomes a necessity.

Several authors have critiqued the concept of resilience, arguing that the contradictions and assumptions of resilience marginalise already vulnerable populations and encapsulate deep-seated inequalities. For example, Duffield (2016) has argued that many approaches to resilience celebrate a logic of bricolage and improvisation as empowering, failing to note that people in disaster-affected areas are unable to move beyond precarity. ‘Radical self-reliance’ is all that is left to disaster-affected people, particularly in humanitarian disaster zones, as experts rule from a distance because austerity, ground friction and strategic disengagement have eliminated their presence on the ground.

Resilience appears as a technologically enabled logic of remote governance that produces and reproduces inequalities associated with a neoliberal moment, in which the presence of the state, and even civil society, in disaster-affected areas recedes.

Other authors have argued that resilience is not enough, as the term may ‘fetishise the status quo’ (Derickson 2016). Often a conservative term, articulated by top-down logics and elite-driven discourses and policies, resilience can be understood as a demand placed on vulnerable communities to recover from repeated shocks arising from deep and multidimensional inequalities. Moreover, resilience often means maintaining a political, economic and environmental system that caused the problems that need to be addressed in the first place.

Davoudi (2018) argues that ‘resilience has been framed as persistence, adaptation and transformation. In the physical sciences and engineering, resilience is often used to denote stability and persistence. It is the ability to withstand external shocks and recover to the previous stable equilibrium, which is considered the state of ‘normalcy’. (p. 3) In contrast, ecological resilience thinks of resilience as a capacity to adapt and transform, breaking away from an ‘undesirable normality.’ This emphasis on change, Davoudi warns, is problematic when translated from the environmental to the social sciences.

By not fully accounting for human agency and power differences and inequalities, and by not questioning who resilience is for, from what and who decides, a simple translation could obscure how resilience operates. Self-reliance, for example, ‘is increasingly seen as a measure of the resilient self; an existential yardstick to which every citizen should aspire. Its promotion can be seen as an invocation of ‘social Darwinism’ and the survival of the fittest.’ (2018, 4) At the same time, by not questioning the unequal distribution of resilience, inequalities can be locked into an argument reminiscent of both Duffield and Derickson. For Davoudi, the numerous resistances to the supposedly neutral and technical use of the concept of resilience show how there is indeed a drive to politicise the concept, which emphasises the need for just resilience.

Following these critiques, Jon (2019) has explored the links between resilience and technicity in more detail. Echoing the arguments presented above, he acknowledges the critiques of notions of engineering and ecological resilience, and their role in reproducing inequalities in a neoliberal order. However, Jon aims to ‘enable other trajectories for embracing resilience theory in planning practice’ (2019, 12). To this end, he analyses the role of technology in disaster planning and resilience through the lens of digital geography (Ash, Kitchin and Leszczynski 2019) and its focus on knowledge production and its effects, based on the concept of technicity, which broadens the understanding of the relationship between humans and technology.

Technicity is defined as the capacity of technologies to ‘make things happen’ (Jon 2019, 113). At the same time, it draws attention to how technologies and humans ‘co-constitute each other in a continuous formulation of associative environments’ (Jon 2019, p. 113). By acknowledging this co-constitution, Jon argues, it is possible to understand how technologies are not objective or neutral and are instead entangled in relationships that may be subject to scrutiny in ethical and political terms.

Jon proposes linking technicality with disaster planning and resilience studies in two particular ways. The first has to do with the notion that resilience does not imply returning to an earlier moment of stability, but rather is intertwined in a process of change and adaptation. In that space, he suggests, paying attention to how alternative modes of knowledge are created can show the limits of technical knowledge in the engineering sense, *i.e.*, data, precision, objectivity, etc., and can show how local knowledge can be better targeted to respond to disasters and post-disaster situations. Resilience, therefore, 'need not only be referred to as a 'capacity' or 'characteristic' of individuals and communities but can also be useful as a particular type of practical knowledge that can be integrated into disaster planning in ways that are beneficial.' (2019, 120)

This second link between technicity and disaster is where digital technologies can be useful in abstracting and codifying these local forms of knowledge, enabling communities to better respond to disasters, and planning practitioners to approach the issue of disaster from a pluralistic point of view and way of doing. While the issue of digital technologies will be developed in the next section, it is important to consider how Jon describes technology as neither a neutral tool nor a device that simply reproduces inequalities. Instead, it is a politically and socially shaped material object and process that can be made differently by taking into account inequalities and unequal power relations and working with, through and against them.

3. Digital and smart urban technologies, disasters and emergencies

3.1. Introduction

As advanced in the previous section, technology plays an increasingly important role in DRR and emergency response imaginaries, policies and practices. This is particularly the case with digital and smart urban technologies. These hold the promise of more seamless communication, more accurate knowledge and more efficient action, whether as prevention, preparedness, response or post-disaster recovery. In this section we look at current proposals, applications and debates in this field. We begin by mapping the various types of smart and digital urban technologies that have been put forward as possible solutions to various problems in DRR and emergency response. This problem-solving approach is characteristic of many of the contributions we discuss here.

Derived primarily from engineering, computer science, and other related disciplines and fields, various digital and smart urban technologies are presented as technical solutions that often reduce disaster to a physical event (Alcántara-Ayala and Oliver-Smith 2019). This mobilises a hazard-centric approach to disasters, even if the promise is to know and track any event as it unfolds at different temporalities and scales. That is, even when considering disasters as multiple and complex events, the emphasis is on how to improve individual (and sometimes collective) responses in a moment of rupture, without taking into account previously existing spatial and social inequalities and relations, nor the protracted temporalities of emergency and disaster.

After mapping these technologies, we present the debates in which they participate. As already suggested, many of these technological proposals and applications are presented as arguments in themselves. Starting from a problem-solving approach, the technology doubles as a technical proposal and a practical solution that seeks to shape DRR and emergency response policy and practice. However, this is not the whole picture. Other contributions have critically questioned many of the promises and claims made through technology. They do so in a number of ways. Some are based on empirical analyses of how, for example, people use social media in disaster contexts, carefully analysing behaviours, patterns and possibilities. Others raise analytical and conceptual questions that interrogate the power relations involved in how various technologies, such as crisis mapping, are used in disasters and emergencies. Still others question the discourses, practices and processes that constitute the smart city and smart urbanism, particularly in relation to emergency and disaster. These critical positions are discussed last. An expanded summary of technologies and debates is presented in Table 2.

Technologies	Main uses	Debates	Specific topics
Social Media	*i.Supervision* *ii.Communication* *iii.Predictive models* *iv.Empirical analysis of disaster behaviour*	Improved information and communication flows	*Improved situational awareness*
Mapping and geospatial technologies	*i.Supervision* *ii.Predictive models* *iii.Reply* *iv.Recovery*	Exploring disaster-related cultures and behaviours	
Applications	*i.Communication* *ii.Supervision* *iii.Reply*	Collect, store, and use accurate data	*Developing appropriate technologies*
Drones and robots	*i.Supervision* *ii.Reply* *iii.Recovery*		*Enabling real-time monitoring and developing predictive models*
Games and visualization	*i.Communication* *ii.Disaster education*		*Promoting citizen perception*
Detection and IoT	*i.Supervision* *ii.Predictive models* *iii.Communication* *iv.Reply* *v.Recovery*		
Integrated platforms and AI	*i.Supervision* *ii.Predictive models* *iii.Communication* *iv.Reply* *v.Recovery*		

Table 2. Expanded summary of smart and digital urban debates and technologies in DRR and emergency response.

3.2. Mapping Technologies

3.2.1. Social media

Houston et al. (2015) have identified 15 different uses of social media in disasters and five different groups of users. The latter are: 1) individuals, 2) communities, 3) organisations, 4) governments and 5) media. With respect to the uses of social media, these include providing and receiving warnings, detecting disasters, sending and receiving requests for help, as well as discussing the implications of any particular disaster, and providing and receiving information about disaster response, recovery and recovery (see figure 2).

Social media is therefore useful throughout the disaster cycle and is seen as a key tool to enable those affected to participate more directly in DRR and emergency response. To a certain degree, social media also allows affected groups to express emotions, commemorate victims and thus discuss disasters beyond the moment of their occurrence (Houston et al. 2015, 14). It is important to note that social media can be used in different ways within the same disaster, both in terms of their purpose and their user groups.

Use of social media in disaster	Disaster Phase
Provide and receive disaster preparedness information	Pre-event
Provide and receive disaster alerts	Pre-event
Signalling and detecting disasters	Pre-event - Event
Send and receive requests for help or assistance	Event
Inform others about one's own condition and location, and learn about the condition, location, and condition of an individual affected by a disaster.	Event
Document and learn what is going on in the disaster	Event - post event
Delivers and consumes news coverage of the disaster	Event - post event
Provide and receive disaster response information, identify and list ways to assist in disaster response	Event - post event
Raising awareness and developing awareness of an event, donating and receiving donations, identifying or listing ways to help or volunteering	Event - post event
Providing and receiving mental/behavioural health support in disasters	Event - post event
Expressing emotions, concerns, good wishes, commemorating the victims	Event - post event
Providing and receiving information about (and discussing) disaster response, recovery, and reconstruction, telling and listening to disaster stories	Event - post event
Discuss socio-political and scientific causes and the implications and responsibility for events	Post event
(Re) connecting members of the community	
Implement traditional crisis communication activities	Pre and post event

Figure 2. Functions of disaster social media (Houston et al, 2015, 8).

Studies of the applications of social media for DRR and emergency response, therefore, range from descriptive analysis of the behaviours of the affected population in disaster situations, to arguments about its use to make communication more efficient between authorities and the public, as well as within organisations and first responders. For example, it has been argued that the use of social media in times of evacuation is increasing and is shaping the way people make decisions, as information from social media is seen as more reliable. This is the case with the behaviours of Hurricane Sandy evacuees in New York City (Ferris et al. 2016). It is relevant to keep in mind that, despite the increased use of social media, their weight and importance in decision-making depends on people's previous engagements with technology, which in turn are shaped by numerous socio-demographic elements, such as age, income or education. It has also been argued that commercial applications, such as Twitter, can be useful in improving the response of various groups, including government organisations, community groups, and disaster victims (Mills et al. 2009).

Others argue that these platforms can improve the interconnectedness between policymakers and public opinion (Vos and Sullivan 2014), although the amount of information shared by government officials and experts is taken by the public depending on its origin. Local government officials have been found to be more trusted than national government officials, and that trust is also higher among family members (Williams, Valero, and Kim 2018). Trust determines how information is perceived and used, which affects how decisions are made in disaster situations.

Finally, the use of social media among emergency response authorities can also be useful in identifying different institutional approaches to disaster management (Jungwon, Connolly Knox, and Kyujin 2018). It is important to note that most of these studies focus on how publicly available, usually commercial and for-profit, platforms are used. As we will discuss in the last section of this paper, this can have profound epistemic, ethical and ontological consequences, related to regimes and relationships of data ownership, use and representation (Roth and Luczak-Roesch 2018).

3.2.2. Mapping and geospatial technologies

The uses of geospatial technologies in disaster situations have been around for decades. Geographic Information Systems (GIS) have long been heralded as key tools to better understand disasters and enable more efficient DRR and emergency response (Cova 1999). More recently, a shift towards supposedly more dynamic, transparent and decentralised forms of mapping has been identified (Kawasaki, Berman and Guan 2013).

Three disasters have been identified as crucial to show the potential of collaborative mapping as a tool to better understand disasters and enable more efficient action, following the notion of a 'whole of society' approach, where much of the response task is assigned to communities and victims. These disasters are the 2008 Hurricane Katrina in New Orleans; the 2010 Haiti earthquake; and the 2011 earthquake and tsunami in Japan. Among these, the Haiti earthquake is the subject of much debate and analysis, as some claim that crowdsourcing allowed to overcome the barriers and gaps present on the ground by transferring the tasks of mapping and analysis to other locations, showing the potentialities of digital technology (Zook et al. 2010). Others have pointed out that this transfer is characterised by numerous power imbalances and has the potential to lock in inequalities as humanitarian and aid organisations withdraw from the field, placing an undue burden on affected populations (Duffield 2016, Read, Taithe and Mac Ginty 2016).

As we will discuss when addressing the question of digital humanitarianism, crowdsourcing and participatory mapping have been critically analysed, showing that these practices are fields where politics are at play (Petersen 2014, Brandusescu and Sieber 2018), intertwined with the inequalities that both precede, follow and are amplified by digital technologies (Givoni 2016, Gutierrez 2019, Sullivan-Wiley, Short Gianotti and Casellas Connors 2019). However, there is still a deep divide between these critical approaches and the problem-solving spirit that drives most contributions derived from engineering and computing disciplines and fields.

Recent reviews frame crowdsourcing, including mapping, as very promising tools for improving DRR and emergency response, enabling better knowledge and more efficient communication (Kankanamge et al. 2019). In that sense, crowdsourcing is an activity that should be encouraged through technological means, including the creation of ready-to-use platforms that allow citizens, volunteers and emergency services to interact and share information (Palen et al.2010, Ludwig et al.2017). While these applications will be discussed in more detail in the next subsection, it is important to note that they often follow a commercial purpose and, in that sense, appear to differ from others that emerged in emergency contexts as disasters unfolded: even if their uses have been transformed over time (Okolloh 2009).

3.2.3. Applications

A central concern among people developing technology for DRR and emergency response is how to enable information to reach people potentially affected by disasters more effectively. We have mentioned how existing social media platforms, such as Twitter or Facebook, are already being used by different groups in disaster situations, allowing communication to flow in multi-directional ways, potentially increasing its availability and impact. However, other proposals propose specific applications that seek to provide information on disasters as a service available to those who are part of these ad-hoc platforms. In that sense, Ludwig et al. (2017) have proposed the development of the 'City - Share' application, which would provide a communication infrastructure for citizens, volunteers and emergency services to manage disaster offers and demands and emergency response activities on the ground.

Other applications are not intended for public use but are designed to enable better communication between first responders and staff in command centres. This is the case with DistressNet, an ‘ad hoc wireless architecture’ that links sensors, people and databases and shares information through mobile messaging and handheld devices (George et al. 2010). Applications are also proposed as solutions for post-disaster environments, allowing for better integration of infrastructures and, at the same time, taking advantage of the opportunity that disaster represents for the reconstruction and transformation of urban spaces.

This is, for example, the case of L’Aquila, Italy, where an information sharing app is seen as a way to improve public transport after the earthquake that hit the city, impeding mobility and putting pressure on public services (Falco et al.2018). The notion that disaster is an opportunity to deploy different digital and smart urban technologies is present, either explicitly or implicitly, in other contributions (Marek, Campbell and Bui 2017), suggesting that disruption can be configured as a transformative moment and space, even if the consequences of such changes are not yet fully clear.

The applications promise a seamless integration of various digital technologies with the aim of providing DRR and emergency response information and tools as a service to end users. Those mentioned so far include remote sensing, citizen detection, the use of databases and the transmission of real-time information through mobile technologies. Essentially, these operate at different scales. For example, DistressNet is proposed as a transferable solution for response operations regardless of location and disaster specificity. Others, such as City-Share, are designed to be implemented at the urban scale, even if the particular characteristics of a given city are not fully taken into account.

The case of the L’Aquila ‘infostructure’ model is particular in that it starts from a specific context and seeks to solve a very particular problem in a particular urban region. Regardless of that, all these applications share common goals and views: providing faster and simpler information to end users; the notion that technology can be a simple tool to enable better action in the face of disasters and emergencies; and a vision of disaster that focuses more on the hazard than on previously existing and aggravated vulnerabilities.

There are other proposals that seek to operate on a global scale. Such is the case of the LastQuake platform and app (Bossu et al. 2018). Based on work conducted at the European Seismological Centre in the Mediterranean, LastQuake is a ‘multi-channel rapid information system’ that includes a smartphone app. The app is designed to provide information to users gathered both through seismic sensor networks and through data extracted from Twitter via a bot. This second data set, provided by eyewitnesses, reframed as real-time sensors, is considered more accurate and timelier than that collected by automated remote sensors, as has been argued in other studies (Earle, Bowden and Guy 2012).

Apps and other digital and smart urban technologies bring together both human and non-human data sources, combining them and sometimes confusing and obscuring how the processes of data acquisition, compilation, analysis and sharing take place, and what their consequences might be for different users. throughout the data cycle (Roth and Luczak-Roesch 2018). In any case, in looking at how these proposals are made and implemented, these are some critical considerations that may be worth bearing in mind.

3.2.4. Drones and Robots

Drones and robots are also widely used in DRR and emergency response. They have two main functions. The first is to enable remote command and control, particularly as the disaster unfolds. Both technologies allow responders to survey, search and rescue from afar, reducing the risk to which they might be exposed. The second function is to enable real-time detection and monitoring. This is particularly the case with drones, which offer the possibility of gathering information from a privileged aerial view.

Among these technologies, robots have a much longer history of use in disaster and emergency response. By the late 1990s, they were already being tested through events such as RoboCup, evaluating how they could be deployed in search and rescue operations, and developing standards for their design and construction (Kitano et al. 1999). Robots have also been used in real emergency situations. An example is the site of the collapse of the Twin Towers in New York City on September 11, 2001 (Davids 2002). The prevailing view is that technology could be a solution to tragedy and disaster by offering possibilities for better response.

Drones are a more recent development, but this does not mean that their uses have not been explored in the technical literature. Their use is typically included as part of wider networks of digital technologies, including sensors, wireless devices, and visualisation tools. Their particular use comes from the fact that they are highly mobile and provide a wide ‘eye from the sky’ view. Drones can be useful when conducting assessments, providing data to early warning systems, and providing evacuation support, among other functions (Erdelj et al. 2017).

If connected wirelessly, they can also enable more than observation and monitoring. They can be both a network of aerial sensors that provide real-time data to users accessing information through websites or apps (Quaritsch et al.2010), and they can also enable temporary mobile phone networks when these become operational (Hayajneh et al. 2016). Thus, drones promise more than just more efficient communication and more timely response. They are also described as tools that can make a system more resilient, understanding this concept from a technical point of view that does not necessarily imply regression to a previous order, but the ability to maintain flows and circulations in the face of unpredictable and sudden changes.

3.2.5. Games and visualization

Disaster-related games and visualizations are two technologies that seek to bring future possibilities into the present, thus allowing decision makers, planners, potential victims, and first responders to better react when disaster strikes. These tools have different characteristics, so the relationship they establish with these speculative temporalities is not the same. Contributions analysing the role of gaming highlight the potential it has to improve awareness among international organisations, governments and non-governmental organisations (Gampell and Gaillard 2016).

These applications often distinguish between common games and serious gaming platforms, which have been implemented in an effort to foster strategic foresight among key decision makers, such as the case of WeShareIt by Kenyan water experts and officials (Onencan et al. 2016). However, common games have also been analysed as they could be important tools for improving disaster education among users, which could generate greater awareness during disasters, although the link has not been explored in sufficient depth and detail (Gampell et al. 2017). Finally, it has been argued that games can be useful for introducing new conceptions of risk and hazard, particularly as the characteristics of disaster and disaster risk change due to environmental, demographic and urban transformations (Yamori 2007).

Visualization tools, on the other hand, are often part of broader technology interventions that seek to shape how DRR and emergency response are designed and carried out. For example, a survey of cloud-based technologies argues that visualization can be a critical tool for improving access to relevant information in disaster situations (Ujjwal et al. 2019). Urban planners can use visualization tools when designing and intervening in flood-prone cities by making the effects of potential disasters visible and tangible in spaces yet to be built. (Wang et al. 2019).

These ways of seeing can also be used when designing and predicting smaller scale responses. For example, Park et al. (2018) call for a fire management system that uses augmented reality as a way to make the occupants of a building ‘visible and understandable’. Here, the visualisation tool not only brings a future possibility into the present; it also engages in making a disaster, and those involved in it, more easily legible and therefore easier to act upon. This can be seen as a hazard-focused notion of disaster that displaces the issue of vulnerability by advocating increasingly refined and complex technological solutions that can be implemented anywhere, regardless of the contexts in which disasters may take place.

3.2.6. *Detection and IoT*

The proliferation of remote sensors, citizen sensing, and wirelessly connected objects and people has been taken up by many academics and practitioners working on the potential uses of these technologies from an engineering and computational standpoint. The applications for these devices and logics are manifold, and certainly include the issue of disaster and emergency. This is a rich field in which the technology offers the possibility to learn more about disasters by increasing the amount of data available, increasing the possibilities of automatically compiling and analysing it, and building networked architectures that are capable of containing the impacts of disasters and emergencies, regardless of their origin. Based on this supposedly accurate and real-time knowledge, there is a greater possibility of better reacting to a disaster as it unfolds. Here again we have a notion of disaster where problems related to efficiency, accuracy and speed of action can be solved through more technology, and where end users would respond in a predictable manner as a result of the availability of more information.

On the issue of detection, proposals and contributions can be divided into two broad categories. The first comprises the issue of remote sensing, usually automated and linked to non-human objects and flows, including natural ones. In this field, two main applications have been developed. The first is early warning systems (EWS). These are based on the idea that sensors, connected wirelessly, can enable various groups to better understand how and when disasters and emergencies may occur. These sensors would monitor, analyse, and share information about various disasters, leading to a decrease in loss and damage (Rahman et al. 2016).

The second application, closely related to the first in that it appears to provide a more accurate understanding of nature and natural processes, is that of monitoring and mapping. In this, sensors deployed both on the ground and on satellites are required, as the integration of data compiled on the ground and from above can result in more accurate data (Joyce et al. 2009, Kaku 2019).

Importantly, these sensors are offered as a cost-effective option that could enable countries, regional and local authorities, and other organisations to make wider use of these technologies. For example, Chen et al. (2013) propose a specific architecture that integrates wireless remote sensing equipment into monitoring centres (Figure 3), allowing authorities to make better decisions without incurring costs that may be out of reach in situations where budgets are limited.

This dual promise, that both losses and costs will be reduced, is an integral part of remote sensing proposals and architectures. These architectures, moreover, have a profound impact on how disasters and emergencies are imagined, as they frame them as something that can happen at any second, requiring constant monitoring. The boundaries between a normal and an emergency situation become blurred, and the ability to distinguish one from the other becomes a matter of greater scope and computational power: 'Disasters can be closely monitored by augmenting a variety of sensors, e.g., temperature, displacement, pressure, noise, and chemical concentration' (Chen et al. 2013, 651).

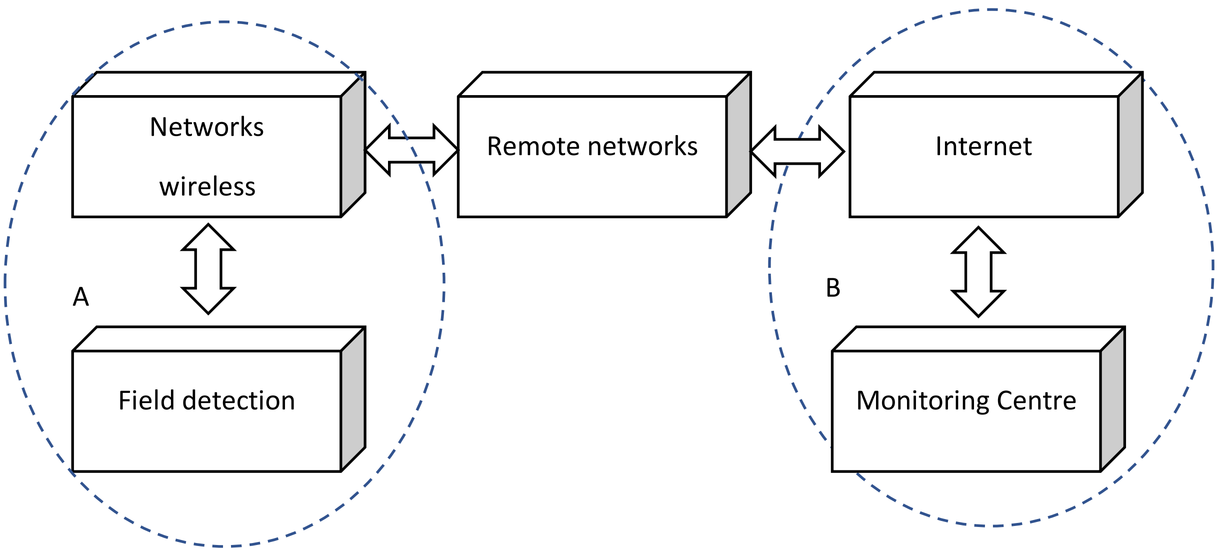

Figure 3. Conceptual view of a system architecture (in Chan et al. 2013).

The second broad category in relation to sensing is the notion of citizen sensing or 'people as sensors'. As mentioned, studies suggest that user-transmitted information can be more accurate, timelier, and more responsive than that gathered through object detection (Bossu et al. 2018). Closely related to the notion of crowdsourcing, the idea of people as sensors deepens the distributed and ubiquitous logic of computing, sensing, and data presentation on a planetary scale. As Kankanamge et al. (2019, 2) state, 'The spread of bidirectional Web 2.0 technologies creates an opportunity for the planet, with its seven billion inhabitants, to become a place with more than seven billion sensors in motion'.

How humans can become sensors is not limited to one possibility. Some proposals, such as the aforementioned DistressNet, imagine wearable-enhanced individuals and devices that constantly monitor their environment and transmit information to monitoring centres (George et al. 2010). Similarly, the notion of a human-centred, bottom-of-network (HWSN) wireless network also presupposes the use of certain wearable equipment by individuals, which monitors and transmits information. 'HWSN combines regular and human sensing devices that interact with each other to achieve a pre-specified common goal, *e.g.*, increasing the availability of information in a physical area.' (Ochoa and Santos 2015, 72)

Another form of citizen sensing involves voluntary information sharing through various applications, whether commercial (Twitter) or non-commercial (Ushahidi) (Okolloh 2009; Bossu et al 2018). These forms of sensing differ from the aforementioned in that they involve a certain degree of intentionality and are more open to expressing emotions, opinions and perceptions that exceed those that can be captured and transmitted through automated devices. They become part of sensing architectures and systems as dispersed information is compiled, analysed and reused according to different functions, whether they relate to mapping, warning, monitoring and other disaster and disaster risk related functions and activities. Despite this seemingly broader capacity for participation, it is important to note that while some forms of action are enabled, others may be excluded.

Participation through citizen sensing applications and architectures is not freely decided by the user/producer. Instead, the specific ways of presenting information, representing the environment, and generating a composite picture of a given situation, including disasters and emergencies, are often determined by systems and technologies. These logics, patterns, boundaries and flows shape not only how people participate, but also how disasters, spaces, emergencies and those potentially affected by them and their responses are governed (Gabrys 2016).

As can already be seen, these forms of detection require an increasing presence of Internet networks. Here, notions such as the Internet of Things (IoT), cloud computing and fog computing become relevant. These technologies are offered as solutions to computational capacity problems, whether they relate to data collection, compilation, analysis, storage and sharing. They often operate in tandem, although the fact that many practitioners and academics work closely with specific companies (such as Cisco, IBM or Oracle, among others) leads them to become competing options in a growing market for IoT devices for DRR and emergency response (see Ray, Mukherjee and Shu 2017 for a review featuring 'market-ready deployable products' for DRR and emergency response).

This market, encompassed under the more general term IoT for public safety, is expected to grow to over USD 2 billion by 2023-2025 (Grand View Research 2018, Markets and Markets 2019). Importantly, this market does not distinguish between natural disasters and other emergencies, including those with political origins and objectives. That is, earthquakes, hurricanes and protests all fall into the same category, as they are all configured as threats to the normal flow of people, information, capital, and resources.

In terms of its technical operation, IoT promises better monitoring of nature, people and their interactions through ubiquitous and distributed computing devices. These can be used to identify disasters as they unfold, enabling timely reaction by authorities and potentially affected people. Proposals envision a world full of connected objects, which are always surveying the environment (Yang, Yang and Plotnick 2013, Ray et al. 2017, Ujjwal et al. 2019). These networked objects can provide information during disasters, but also in a post-disaster management moment, as they could facilitate communication between victims, first responders and authorities (He, Zhang and Fang 2017, Kamruzzaman et al. 2017). IoT is therefore related to the goal of transforming people into sensors, which often includes this and extends that logic to a range of objects including household devices, industrial machinery, urban infrastructure and indeed any object that can potentially connect to a wireless network.

How these functions are enabled depends on a combination of hardware and software that includes the notions of cloud and fog computing. The former refers to the transfer of computational capacity from individual machines to centralised processing centres, which appear abstract (hence the cloud) to the end user, even if they are in fact geographically bounded and shaped by numerous power relationships (Amoore 2018). The cloud offers a greater ability to compile, analyse and store data insofar as it operates through the combined computing power of servers and machines located in various positions around the world (Ujjwal et al. 2019). In doing so, the possibilities of modelling (Dimakis, Filippoupolitis and Gelenbe 2010, Aqib et al.2018), monitoring (Suakanto et al.2012, Sakhardande, Hanagal and Kulkarni 2016) , communication (Catarci et al.2008) and further data usage emerge intensively in DRR and emergency response. The cloud, despite its increased computational power, is often framed as a potentially fragile technology, in that disasters can disrupt its normal operation due to power and wireless networks failing. This requires other solutions that can increase the resilience of a network.

The logic of distributed, pervasive or ubiquitous computing (a variety of terms used to conceptualise these technological trends and operations) is further extended with the introduction of Fog technologies (Bonomi et al.2012, Cisco 2015, Satyanarayanan 2017, Shi and Dustdar 2016). These transfer computational capacity to the networked objects themselves, which reduces the load weighing on the cloud and allows devices to continue to function even in disaster situations. Fog computing is presented as another tool to enable better knowledge and action in disasters and emergencies, as well as an instrument to promote resilience understood as a maintenance of the flows considered normal and necessary (Tang et al. 2015).

Fog technologies do not operate on their own and usually become part of integrated models that include cloud technologies, command centres, applications, and an increasing range of sensing devices that aim to make nature fully readable and, by constantly monitoring it, blur the differences between a time of emergency and a time of normalcy, without erasing them altogether. The fact that disaster remains a threat to the functioning of these technologies suggests that it is, in fact, a moment of potential rupture with sometimes unpredictable consequences.

3.2.7. Integrated platforms and artificial intelligence

Integrated platforms, such as control rooms and dashboards, are key to integrating and coordinating information flows and response modes enabled by smart urban and digital technologies (Kitchin, Lauriault, and McArdle 2015, Kitchin, Maalsen, and McArdle 2016, Luque-Ayala and Marvin 2016, Marvin and Luque-Ayala 2017). However, in the technical literature on the specific topic of DRR and emergency response, these sites are largely absent. When mentioned, they are generally defined as a setting populated by first responders and victims (Vos and Sullivan 2014, Catarci et al. 2008, George et al. 2010). The logics put forward by these technical proposals downplay the integrative role of platforms such as control rooms and dashboards. In some contributions, the aim is to do away with this instance of mediation and data consolidation, as it is assumed that it could hinder efficiency and slow down communication flows. The goal is to create device-to-device or person-to-person (often indistinguishable) forms of communication through the use of wireless networks and sensors (Ochoa and Santos 2015, Kamruzzaman et al. 2017).

These imaginaries suggest that the task of integration is moving from control rooms and dashboards to the automated technologies themselves. In this, Artificial Intelligence (AI) is crucial. Its utility underlies many of the propositions already discussed here. For example, applications that use Twitter data to monitor disasters (Bossu et al. 2018, Zuo et al. 2018) rely on AI capabilities to extract, organise, analyse, and compile information. Similarly, AI becomes a methodological tool when analysing how social media are used in disaster situations (Ferris et al. 2016).

As more and more DRR and emergency response activities and studies are digitally enabled and mediated, AI becomes a crucial tool for both practitioners and academics as a tool, object, and method (Leszczynski 2018). This is particularly visible in smart city imaginaries that are deeply shaped by the notion of technology as a solution to the potential and actual effects of disasters and emergencies. There, AI promises the integration of diverse data sources beyond human intervention, which is seen as a more efficient and accurate way to manage disasters.

The applications of AI in smart cities in relation to disasters are many. The following are only examples that illustrate this rich literature and are not an extensive review of a growing field. Some applications of AI are predicting, modelling, and managing transportation systems both during response (Alazawi et al. 2014, Aquib et al. 2018) and at post-disaster times (Falco et al. 2018). Others seek to model flood situations, often including visualization tools that planners and other officials can use (Schröter et al.2018, Wang et al.2019).

Stochastic models have been developed to capture the dynamics of disasters as they unfold. Ghosh and Gosavi (2017) propose using one of these models to quantify hazard rates, estimate restoration times, and determine which response centre is best placed to respond to an earthquake. They argue that smart cities are particularly fertile ground for these models, given the availability of data. This is often framed as a safety issue, where AI can help coordinate response, as cloud computing offers storage and computing capabilities in the face of any disaster or emergency, regardless of its specific characteristics (Palmieri et al. 2016).

It is in discussions about the role of AI in disasters, particularly in smart city environments, that the distinctions between natural disasters, political upheavals, and other types of emergencies become particularly blurred. For those designing technological interventions and solutions to the multiple disruptions posed by such events, their origin and characteristics are often irrelevant. Many of the papers reviewed here openly assert that these questions are not relevant, as their proposals aim to maintain and restore normal flows of people, objects, resources, and capital.

Problem-solving approaches rarely question the pre-existing vulnerabilities and unequal power relations that precede disasters and shape them as they unfold. They focus solely on the moment of rupture as a temporality to be minimised by deploying faster and more precise technologies. In doing so, the differences between humans and non-humans also blur, at least in terms of data acquisition. Both become potential sensors that can provide more accurate information about a disaster throughout its cycle. In addition, human responders can be enhanced through the use of different digital and smart urban technological devices, which would allow them to make better decisions, as it is in the availability of information that inefficiency lies. Before discussing critical approaches to these imaginaries and proposals, we summarise the different debates taking place across different smart urban and digital technologies for DRR and emergency response.

3.3. Discussions

As mentioned in the introduction to this section, smart and digital urban technologies are often arguments in themselves, particularly when implemented as products for a growing security-oriented market. However, there are other debates taking place in different fields and technology propositions. These suggest that there are shared concerns and assumptions for those working on digital and smart urban technologies from a problem-solving point of view. In what follows, we briefly discuss these issues, before moving on to consider critical viewpoints. We begin by exploring narratives around the need for improved information and communication as a solution to DRR and emergency response problems. We emphasise the issue of improving situational awareness, as this is one of the main concerns shared by the different approaches. We then move on briefly to discuss the question of how different disaster cultures are identified using digital data. This discussion shows how some of the approaches to digital in DRR and emergency response have considered differences that exist beyond technology, even if their contributions remain highly descriptive. Finally, we address the goal and concern of collecting, storing and using more accurate data. There, we discuss three particular issues: developing appropriate technologies for this purpose; building more accurate predictive models; and encouraging citizen detection.

3.3.1. Improving information and communication flows

Technology-based approaches and interventions for DRR and emergency response often take the lack of accurate information and communication as a central problem to be solved. This lack may be due both to the lack of adequate channels, which need to be developed and enhanced, and to various breakdowns and inefficiencies in existing channels. Numerous technologies are used to do this, and these include drone-enabled mobile networks (Hayajneh et al.2016), social media, sensing devices, wireless networks, Internet of Things (IoT) and various computing architectures (Yang, Su and Chen, 2017). In the case of social media, the ways in which information and communication are potentially enhanced range from forming online communities to discuss the disaster and ongoing recovery (Kodrich and Laituri 2005), to fostering communication between volunteers, authorities and the public (Shankar 2008, Vos and Sullivan 2014, Park and Johnston 2017). Games are also seen as a potential tool for developing awareness (Gampell and Gaillard 2016) and developing better responses to future disasters by communicating changing conceptions of risk among the population (Yamori 2007).

Improved situational awareness

Numerous works identify a lack of situational awareness as a specific problem in disaster situations. This is particularly the case for first responders, who often intervene without having a full assessment of any particular disaster situation. Technological interventions, such as wireless sensor networks (George et al. 2010), peer-to-peer computer architectures (Catarci et al. 2008) and social network analysis (Mills et al. 2009), promise to reduce uncertainty and improvisation, increasing efficiency and leading to better disaster response outcomes (Ochoa and Santos 2015). Here the question of action is reduced to an outcome of technology, and the expansion of digital is promised as a way to improve it. When discussing the question of situational awareness, the types of disasters that are being mediated through technology and responded to by a variety of stakeholders are not distinguished between natural or ‘man-made’. Terrorist attacks, hurricanes, political unrest, and other situations are treated similarly, as temporary ruptures that are hastily resolved with better communication and information (Palmieri et al. 2016).

3.3.2. *Exploring Disaster Cultures and Behaviours*

More descriptive analyses of how digital technologies are being used by diverse groups involved in DRR and emergency response have mapped different disaster cultures and behaviours. Findings suggest that digital technologies, particularly social media, are embedded in wider social, spatial and political processes and, consequently, relate differently to stakeholders and disasters. It has been shown, for example, that people's engagement with technology varies according to particular variables, such as income, education and age (Ferris et al. 2016). More educated, younger, and wealthier people may use these media more effectively, or at least that was the case in relation to Hurricane Sandy.

Different emergency response institutions and networks have also been shown to have particular institutional cultures, leading to both differential relationships with the disaster and with affected communities (Jungwon et al. 2018). Social media can also be a way to track how affected populations enact everyday life disruptions and how coping mechanisms develop, among other behaviours (Murthy and Gross 2017). As mentioned above, these behaviours are shaped by trustworthiness and social relationships that exist beyond, but within, the digital (Williams et al. 2018). These works moderate claims made by more technosolutionist approaches by describing richly empirical contexts, even if the consequences of these problems are often not explored theoretically.

3.3.3. *Collect, store, and use accurate data*

One of the main concerns of digital and smart technology approaches to DRR and emergency response is the need to collect, store and use accurate data. This is certainly related to, but goes beyond, the goal of improving communications and information flows. Data collection involves more than just first responders, authorities, and citizen groups. Crucially, it includes the environment itself, measured and known through various technologies such as sensors, drones, or databases of past disasters.

Many discussions occurring in this area are primarily technocentric, focusing on which technology, understood as a mediating tool, can best fulfil a data collection and storage function, or best enable its proper use. Most assume an interaction of various technologies, constantly measuring and analysing information to manage the disaster as it unfolds. In this task, the technologies act primarily as sensing devices, and the focus of many discussions is to elucidate which works best, as mentioned above. Fundamentally, in these tasks, humans can become another technological tool, acting as sensors, not unlike the waves that precede, shape, and follow the onset of a disaster event (Goodchild 2007, Ludwig et al. 2017).

Combined with the collapse of divisions between emergency and normality, and human and natural disasters, technological debates about the role of DRR and emergency response are already operating in a space suitable for critical investigations that problematise what the collapse of these divisions means in terms of politics, governance, power relations, inequalities, and the production and reproduction of certain logics and patterns in urban space and beyond. Before turning to these critical analyses, we close this section by briefly looking at three particular debates held by proponents of various technical solutions to the question of obtaining better data to better understand disasters. These debates focus on 1) developing appropriate technologies, 2) enabling real-time monitoring and developing predictive models, and 3) encouraging citizens to facilitate the use of sensors (citizens sensing).

Developing appropriate technologies

As mentioned above, many of the discussions held in forums such as the Association for Computing Machinery (ACM), the Institute of Electrical and Electronics Engineers (IEEE), and various journals exploring human-computer relationships revolve around the question of which technologies are best suited to obtain accurate data and enable precise knowledge and rapid action. We mentioned how cloud and fog computing, and other IoT-based approaches, are often entangled with commercial enterprises and promises to develop infrastructure as a way to profit (Marek et al. 2017, Ray et al. 2017). However, this does not mean that these technologies do not have aspirations to produce data that is considered accurate and precise. Indeed, that is what they offer, as better information can lead not only to better decisions, but also to the prevention of both human and financial losses. The technical hurdles that need to be resolved include ensuring that technologies work even as a disaster unfolds, a technology-centric notion of resilience.

Enabling real-time monitoring and developing predictive models

These technological tools do more than offer the possibility of knowing better. They seek to reconfigure what knowledge is and how it is produced and transmitted. Two key concerns are to enable real-time monitoring, whether through sensor-driven early warning systems (Rahman et al. 2016, Ray et al. 2017), satellite-enabled detection (Joyce et al. 2009) and drone monitoring (Quaritsch et al.2010, Erdelj et al.2017). The advantages of each technological solution are often highlighted in these texts, but it is also clearly recognised that these technologies can act in tandem when implemented in real-life situations. The second concern is with developing more accurate predictive models and simulations. These are often highly technical discussions, where both hardware requirements and algorithmic computations are discussed and pitted against each other. Here, cloud and fog computing offer computational power, while advances in artificial intelligence point to a future where prediction would be fully automated and could be carried out in real time. As mentioned above, flooding, fire, evacuation and traffic are some of the flows and processes that have been modelled.

Promoting citizen perception

Finally, a key trend in the field is the encouragement and promotion of crowdsourcing solutions. Starting from a technosolutionist approach, these are not interrogated in relation to their political consequences and characteristics. Instead, the concerns are to enable people to become sensors, as they can be more efficient and timelier than other forms of sensing (Laituri and Kodrich 2008, Bossu et al. 2018). Seen as a positive trend, technological interventions that encourage and enable crowdsourcing and voluntary citizen sensing through mobile applications and computer architectures, also allowing supposedly more efficient interaction between different groups of people, including authorities, first responders and affected citizens (Liu 2014, Ludwig et al.2017).

This also leads to proposals to *empower* human stakeholders with various technological add-ons. In the case of DistressNet (George et al. 2010), 'first responders, support personnel, and C2 elements within a disaster area are equipped with BodyNets.' (131). BodyNet is a wireless body-worn sensor network designed to monitor the health and status of its host.' (130). This suggests a further breakdown of the divisions between humans and technology, a post-humanist stance that is already underway. Citizen sensing also allows those far from a disaster to act through digital technologies. Crisis mapping is a key example of this trend (Zook et al.2010, Kawasaki et al.2013), and is often described in a way that does not challenge the inequalities that might have led to this situation originally (Kankanamge et al.2019). We now turn to these critical positions as a conclusion to this literature review.

4. Critical Approaches to Smart and Digital Urban DRR and Emergency Response

Critical explorations of smart and digital urban technologies in relation to DRR and emergency response fall into three broad categories. The first we explore concerns the issue of smart cities and smart urbanism. While the literature on this topic is abundant, the specifics of disasters and emergencies are much less discussed. Here we draw on existing analyses of this topic (two exceptions are Luque-Ayala and Marvin 2016, Marek et al. 2017) and also broader literature to set a critical agenda for the future. We also draw on contributions that explore the spatial politics of disasters and inequalities, posing a critique of technosolutionism. Contributions range from analyses of how digital inequalities can exacerbate socio-economic ones (Madianou 2015) to those that discuss the politics of technology and technological objects themselves (Petersen 2014, Brandusescu and Sieber 2018). While some of these have already been introduced, here we explore in more depth what they might mean for a critical research agenda. Finally, we discuss some works that take a critical stance towards digital humanitarianism. These works question the political, economic and spatial inequalities that characterise new forms of humanitarian aid and action, shedding light on some of the consequences of deploying digital technologies for emergency response and DRR (Givoni 2016, Read et al.2016, Duffield 2016, 2019, among many others).

4.1. Smart cities and urban planning

Building on a technosolutionary approach to DRR and emergency response, smart cities appear as little more than an integration of various technologies flowing through increased computational power. This can be achieved through the deployment of smart infrastructures that enable distributed data acquisition, networked transmission and centralised analysis (Sakhardande et al. 2016); through the development of cloud and fog computing based simulations that should shape urban planning, governance and emergency response (Alazawi et al.2014, Ghosh and Gosavi 2017, Aqib et al.2018, Wang et al.2019), and making people, objects and flows fully readable and easy to understand through sensors, data mining and other digital technologies. (Yang et al.2017, Park et al.2018, Zuo et al.2018). This is a city where disasters and emergencies are threats to normal functioning that can be resolved through increasingly integrated and ubiquitous computing. Better response and planning are achieved by monitoring, mapping, and predicting behaviours and flows, human or non-human, in an effort to maintain a state of fragile normalcy that has the ongoing potential to become an emergency.

Smart cities are not always a real space, but an imagined one that is projected into the near future. The increased presence of sensors, the availability of abundant digital data and the computational capacity to analyse them are usually presented as a desired possibility for a time to come. The smart city is a blueprint for constantly monitoring urban space in an effort to increase security, regardless of its origin (Palmieri et al. 2016). Ideally, this should be included in urban planning from the start, thus creating cities that are not only smart but also resilient to various disasters.

Wang et.al. (2019) proposed the notion of a 'sponge city' to imagine what an urban space completely shaped by digital simulations and smart technologies would look like. Indeed, attempts to build smart cities from scratch, such as Masdar City (Cugurullo 2013) or Songdo, have been implemented, often through a marriage of corporate interests and technological imaginaries of a sleek future and continuous flow (Söderström, Paasche and Klauser 2014, Hollands 2015, Marvin et al.2016). That these smart cities have not worked as imagined has not stopped the proliferation of these proposals, projects and practices.

The post-disaster city presents an ideal opportunity to implement smart city approaches (Falco et al.2018). The post-disaster city becomes a space where smart technologies can be freely implemented. An emblematic case is Christchurch, New Zealand (Marek et al 2017.), where after the 2010 and 2011 earthquakes, a smart city initiative, called 'Sensing City ', was developed:

> 'Inspired by other "smart city" initiatives globally, Sensing City saw a unique opportunity, while a large proportion of the Central Business District (CBD) was (and still is) being redeveloped and rebuilt, to incorporate a range of environmental sensors into the city's infrastructure to engage in Big Data collection. The overall goal of Sensing City is to demonstrate the benefits that arise from using available sensor technology to collect environmental and health data to improve city management and raise awareness of public health issues and to make that data openly accessible to a multitude of stakeholders.' (45)

The earthquakes, as an example of disaster as a time and space of rupture, created a moment when the city became almost a 'blank slate' on which to develop and test smart city approaches. The authors document how this strategy was developed without taking into account the needs and desires of citizens. This led to a smart city approach that was not embraced by the population and represented corporate interests before the interests of Christchurchers. His call is for more participatory schemes for smart city and smart city technology development. However, this call must also be critically analysed, as the forms of participation enabled by smart and digital technologies can lead to degraded forms of citizenship that equate participation with data sharing, producing forms of governing space and populations through the digital (Gabrys 2016).

Luque-Ayala and Marvin's (2016) analysis of the Central Operations Room (COR) in Rio de Janeiro also provides a crucial intervention to understand the relationships between emergency, digital technologies and urban governance. The COR is an integrated platform that enables continuous monitoring and horizontal integration of services, with the idea of providing tools to respond effectively to both routine and extraordinary situations. It does this by integrating information from various interconnected technologies, such as sensors, cameras, and monitors, which are then visualised through maps in the control room itself. There, employees from various government agencies share and use this information.

In the face of visions of a fully integrated smart city managed through AI, the COR shows how material sites of integration, coordination and control remain crucial for urban governance. In the control room, infrastructures and their operations become transparent to city officials, but also to the general public, as the media constantly report on the status of different urban flows and possible disruptions in them.

This has profound implications for how the city is lived, imagined and governed. If in everyday life infrastructure is generally assumed to be solid and hidden from view, in the COR it 'always appears at a breaking point' (196). This imminent collapse, a state of emergency always lurking, is institutionalised as a permanent state. This involves the creation of risk maps, using predictive data to foresee the emergency and perform (both in execution and visualization) anticipation as a form of emergency governance. This emergency involves modelling and visualising a digital nature in specific ways.

For example, digital mapping techniques and three-dimensional representations are used to describe the city's weather patterns not only by COR experts, but also by the media present there. This operation turns nature into an object of detection and governance, and a potential threat that can be known and managed through accurate information. In this constant measuring and reporting, the sense of anticipation ceases to be extraordinary. 'Within COR, the everyday is seen in a state of permanent emergency; urgency is the paradigm that drives action. The focus is always the moment and the objective an immediate response' (Luque-Ayala and Marvin 2016, 202).

In this everydayness, nature and other objectified and unwanted disturbances become a similar threat to the maintenance of normal urban flow. 'Even when the disruption itself is political, as with the demonstrations against the World Cup, maintaining the flow as an operational requirement takes precedence over the very politics that are being manifested' (Luque-Ayala and Marvin 2016, 202). While this conflation of the political and the natural is also present in other descriptions of smart and digital urban technologies and disasters, this identification is rarely problematised and challenged.

Here, Luque-Ayala and Marvin highlight how the imperative beneath this imbroglio is the maintenance of urban flow in a permanent state of emergency. This opens up several areas of inquiry for future research exploring the relationships between disasters, emergencies and the logics of preparedness, prevention, response and recovery that characterise them in different geographies. These may include critical analyses of how emergency and the everyday are related, how political events and natural disasters are governed, what flows, logics or orders need to be maintained, how and by whom, and how digital technologies enable or disable particular forms of production and governance of nature and space in emergency situations.

4.2. Exploring ontologies, politics, and inequalities of disasters

In contrast to technosolutionist approaches to the issue of smart and digital urban technologies and their relationship to DRR and emergency response, many authors highlight the fact that this is an eminently political relationship. This is the case for critical analyses of citizen sensing, smart city control rooms and the development of smart city strategies in post-disaster situations, as discussed above. Explicitly politicising the issue of disasters, these approaches problematise the approaches found in simulation and modelling, communication and data acquisition, crowdsourcing, remote sensing, and other technological fixes and non-problematic solutions to vulnerability and risk.

The spatial politics of disasters operate differently at all scales. The case of recovery technologies in UK disaster response dynamics shows how these are constantly being negotiated by first responders, citizens and bureaucrats, even outside the digital (Easthope and Mort 2014). The introduction of digital and smart technologies does not make this politics disappear, even if they are often hidden in discourses that privilege the technical over the ongoing realms of disaster politics.

Even if disaster politics are common beyond the digital, those that emerge from digitally focused and digitally enabled tools have different interests. For example, Petersen (2014) has explored the material disaster politics of mapping practices in the context of the 2007 wildfires in Southern California. By analysing the official county map and a Google My Map created by local media and academic institutions, he argues that each produced different disaster spaces, which challenged priorities in disaster preparedness and response. Political tensions revolve around questions of temporality, boundaries, and responsibilities for disasters.

Crisis mapping is a practice also shaped by the politics of spatial knowledge. In developing maps through various applications, such as Ushahidi, there are technical challenges for various users, but also opportunities for local knowledge to be embedded in crisis mapping. These opportunities are characterised by tensions between witnessing an event versus the possibility of having political influence on responses to it (Brandusescu and Sieber 2018). Mapping practices are themselves fields shaped by diverse knowledge and power dynamics (Gutiérrez 2019), as well as differentiated experiences of vulnerability (Sullivan-Wiley et al. 2019).

These inequalities are also present, for example, in Social Media practices. Digital inequality can amplify already existing inequalities of class, gender and race, as some users are able to express and use digital tools more efficiently and effectively than others (Madianou 2015). The role of unequal exposure to risk and inherent inequality in vulnerability also informs other critiques of technosolutionism, at least in the case of early warning systems (Alcántara-Ayala and Oliver-Smith 2019). Taking into account pre-existing risk factors and spatial and social inequalities requires approaches that deviate from technology as a solution for all uses that can be implemented seamlessly in spaces that are profoundly unequal within themselves and different from each other.

Importantly, these inequalities are shaped and shaped by historical processes, logics and dynamics. These critical considerations show how already existing inequalities can be reproduced, extended, and maintained through the deployment of digital technologies. However, the widespread introduction of these might also introduce some ontological, epistemological, and ethical problems that are particular to the digital, even if they remain linked to other non-digital processes, practices and logics (Crawford and Finn 2015).

In relation to disaster ontologies, it is necessary to note that most technologies start from a definition of disaster that focuses squarely on the moment of rupture that it implies. Without denying that in fact a disaster or emergency rupture flows both spatially and temporally, the conditions in which these ruptures take place and are experienced backwards in time and are inscribed in the very fabric of space (Tierney 2007). This is not easily recognised and operationalised by digital technologies, which focus their strategies of data collection, analysis, and interpretation on the notion of rupture and its identification across different datasets.

A key example is Twitter, where the goal is to identify when people started talking about a disaster, either to identify its origin or to understand how different individuals and groups are behaving in relation to it. By focusing on markers of that moment, such as hashtags or trending topics, researchers may be inadvertently discarding valuable information that can transform how disaster is understood through digital and the responses that digital enables in disaster situations. This is compounded by unequal power relations in disaster situations, which over-represent certain voices, particularly on social media, while minimising and excluding others.

In relation to epistemological limitations, Crawford and Finn focus on how Twitter data is already biased in different ways. A key question for those researching the relationship between digital technologies and disasters is how to understand and explain these biases, which can be related to the class composition of participants; to the presence of bots and other automated accounts; to the cultural norms that shape Twitter use; and to the very form of the platform, which both enables and excludes certain forms of communication. Twitter is not a neutral representation of a communicative community but is embedded in broader processes and dynamics that transcend both disaster communication and the platform itself. Moreover, it is a performative space that privileges certain modes of participation and communication.

Additionally, the presence and absence of certain groups further skews the data, raising important questions for those using this data for research. ‘In short, the Twitter platform is inhabited by a mix of humans, institutions, and bots, all attractive for a wide variety of reasons. The challenge for researchers is how to account for what is in the data (including bots and biases) and what is not (such as the most vulnerable and least connected populations) while helping to make sense of a crisis’ (497). When analysing other platforms, whether commercial or not, it is relevant to keep in mind these questions about the accuracy, representativeness, and overall composition of the data, understanding technology not as a neutral tool but as a relational process and a field shaped by various power relations.

Finally, the production, storage, analysis, use and transmission of digital data in disaster contexts raises some relevant ethical issues. A crucial one is that of privacy. The assumption that individuals will be able to self-manage their privacy settings across different social media, particularly given the increasingly complex arrangements put forward by technology companies, does not seem a realistic proposition (Crawford and Finn, 2015). This is particularly the case in crisis situations, when individuals may be inclined to share particularly sensitive data that they would not otherwise disclose. Information about location, identity and other personal characteristics may be shared voluntarily, albeit under duress, only to be collected and integrated in ways that may infringe on people’s privacy. This calls for greater legal protection for this type of data (499), as well as particular ethical considerations. This is relevant not only for practitioners who engage with digital data in disaster contexts, but also for researchers who are working on this topic. Finally, it is important to note that ethical considerations in relation to this issue go beyond the issue of privacy and are intertwined with other unequal relationships that shape the field of disaster management and emergency response.

4.3. Digital Humanitarianism

An alternative entry point for analysing the relationships and interactions between digital technologies, disasters and emergencies is the critique of digital humanitarianism. This term refers to the growing practice of managing and governing disasters remotely using different digital technologies. It is widely acknowledged that a turning point in this field was the 2010 Haiti earthquake (Kawasaki et al. 2013, Read et al. 2016). As the country lacked sufficient infrastructure to monitor, map and coordinate disaster response, various tools were deployed to enable people far from the ground to fulfil these roles using collective collaborative mapping, mobile messaging, and other digital technologies. This meant that there were no longer authorities and agencies on the ground carrying out these analysis, coordination and management processes and practices. Instead, ‘digital humanitarians’, often located far from the disaster site (Roth and Luczak-Roesch 2018), became central stakeholders in carrying out these tasks. On the ground, victims and others at risk were reporting to different platforms using mobile phones and relaying information to teams present in Haiti. This shift, which transfers responsibility for information gathering and disaster response to affected populations, while allowing aid organisations to command, control, and coordinate remotely, has been both celebrated (Zook et al. 2010, Liu 2014) and widely criticised.

A major criticism is that these ways of governing disasters embody inequalities and unequal power relations in affected areas. By promoting a notion of resilience that offers only resistance as a way to survive, rather than as a potential way out of the vulnerabilities that led to disasters having profound impacts on victims’ livelihoods, digital humanitarianism appears as a neoliberal technology for governing at a distance (Duffield 2016, Duffield 2019). Digital technologies allow aid organisations to withdraw from the field while retaining an edge in how disasters are managed. At the same time, they enable and deepen ‘bunker mentalities’ characterised by a commodification of aid and humanitarianism.

The logics of remote command and control produced through digital technologies in the humanitarian sector follow imaginaries of threat and risk that characterise not only war and security but also the broader logics of contemporary capitalism. By mobilising resilience as ‘remote smart messaging aimed at optimising the behaviour of hard-to-reach populations’ (Duffield 2016, 148), which ‘helps to operationalise systems of experimental welfare abandonment under conditions of pervasive security surveillance’ (148), new ways of governing precarity and marginalised populations in an increasingly pervasive state of emergency are put into practice.

Critiques of digital humanitarianism have also analysed the issue of data in depth. Big Data, as an essential component of AI, is taken as a necessary and desired input in many technosolutionary approaches to digital technologies and disasters and emergencies. However, it has been argued that the way in which Big Data is used constitutes a form of data colonialism (Thatcher, O’sullivan and Mahmoudi 2016). Digital technologies allow personal information shared and mined across different platforms to be appropriated and reused as a commodity, dispossessing those who generated it in the first instance.

This argument highlights the existing power imbalances in the production, analysis, transmission, and use of data, and serves as a critical counterpoint to push for Big Data analytics. Furthermore, by making explicit the links between Big Data and accumulation, the authors show how claims of greater efficiency, accuracy, and better knowledge are always intertwined with the pursuit of profit through data applications. ‘Linked together, billions of data points promise an increasingly smooth and predictable surface of capitalist consumption. As such, Big Data serves as a 'solution' to capitalism's inherent tendencies toward overaccumulation, not through an outward spatial expansion, but by smoothing the rough surfaces of individuals' lives as they become cognizable as commodified representations of the self' (Thatcher, O'Sullivan, and Mahmoudi 2016, 998).

Other studies have focused on the question of whether digital humanitarian technology has been able to deliver on its promises. Namely, these promises are to provide greater accuracy, faster data flows and to promote equality (2016). In relation to accuracy, the promise is that EWS, drones, robots and other technologies can fill information gaps, providing 'actionable information'. In relation to speed, the argument is that digital technologies can provide real-time information even when other forms of technology fail, thereby improving the timeliness of humanitarian response.

Finally, the egalitarian claim promises a shift in the balance of power between donors and recipients, changing top-down approaches 'in favour of 'lighter' and more 'horizontal' networks: 'systems built to move information up and down hierarchies face a new reality where information can be generated by anyone, shared with anyone, and acted upon by anyone'' (Read et al.2016, 1321). As discussed throughout this paper, these promises are not only present in the digital humanitarian domain, but also in other proposals that posit technology as a solution for disaster management and emergency response in urban spaces, in national sales, and as a global strategy.

However, a closer inspection of how digital humanitarian technologies are used in the field seriously questions the foundations on which these promises can be kept. Read et al. (2016) focus on crowdsourcing and crisis mapping, on the one hand, and Big Data, on the other, to critically question this issue. Regarding the former, they argue that these promises should be considered in relation to the unequal relations present in disaster-affected areas. They highlight the issue of low and unequal levels of Internet and mobile phone access, which remain so even if the use of both has increased in particularly vulnerable regions. To counter this inequality, some platforms have relied on local informants entering data into digital technologies that are provided by different aid organisations.

This, while it may increase the accuracy of information, transfers risk to already vulnerable local informants (as argued by Duffield 2016). These processes challenge both the accuracy of data and claims of empowerment. Moreover, rapid data dissemination can lead to the spread of misinformation, leaving humanitarian organisations unable to respond to security incidents (Read et al. 2016, 1322). Furthermore, private ownership of data and mapping tools raises ethical and political questions regarding the ownership, control, and use of humanitarian information (Roth and Luczak-Roesch 2018).

In relation to Big Data, Read et al. (2016) argue that, for humanitarian practice, this represents not so much an increase in the volumes of information available, but a shift in the way data is analysed and interpreted. Because Big Data analysis requires specific knowledge and expertise, the possibilities for meaningful interpretations remain an uneven field. Many organisations are unable to perform these tasks, resulting in high concentrations of power for reasons of both expertise and infrastructure availability. Therefore, Big Data seems to lead to less transparent forms of data production, analysis and interpretation that promise more accuracy without the possibility of questioning the validity of this claim. Furthermore, the current unequal distribution of infrastructural capacities and expertise does not lead to greater equality in relation to humanitarian data, but to greater differences within the aid field. Therefore,

> '[The] most significant empowerment that data technology risks bringing is that of those who believe in the technology's potential. The promise of greater accuracy and speed in information gathering, coupled with the novelty aspect that technology can bring, can constitute material power and a reallocation of resources and demand within organisations and international NGOs. Although wrapped in the language of empowerment, data technology can be based on a proxy participatory logic in which local communities feed data into the machine (either through crowdsourcing or by being enumerators or subjects in most traditional surveys) but have little influence over the design or deployment of the technology. It begs the question: where does the power lie in the deployment of humanitarian information systems?' (Read et al.2016, 1324-25)

5. Conclusions

The objective we set for this paper was to map current debates and proposals that elaborate and discuss the role of digital and smart urban technologies in disaster risk reduction (DRR) and emergency response as a starting point for establishing a research agenda that can advance current knowledge about this emerging field from a critical perspective.

In the first instance we note that the dominant views of technology in disaster and emergency situations see it as an unqualified good that promises improved decision making and reduced economic loss and damage to human life, property, and infrastructure. In relation to the conceptualisation of disasters and emergencies and their relationship to technologies, we posit that there has been a significant shift from a risk paradigm that focuses on the event as rupture and individual behaviour, to a vulnerability paradigm that highlights how pre-existing social and spatial inequalities shape how disasters unfold and are experienced. This shift that was favoured by the adoption of the Sendai Framework and lays the groundwork for technological developments focused on prevention and preparedness rather than response, we stress is a discursive shift that is not necessarily reflected in practice.

Three key elements were identified to analyse how technology is implemented and imagined in the Sendai Framework: (a) technology seen as a fundamental tool to strengthen DRR measures with a whole-of-society approach, in which social organisations, potentially affected people and communities, academics, scientists, private sector as well as governments are part of the development and use of technological tools; b) technology is useful in various phases related to disasters (preparedness, response, recovery or mitigation) and is understood as a set of flexible tools that can be used by as many users as possible in various spaces and periods in a disaster environment; and c) there is a concern to level the technological development worldwide through cooperation, due to the prevailing inequality in the subject.

Proposals on science-technology-policy linkages were reviewed on the basis of six debates:

1. On the link between knowledge and action, in which a close relationship between science and technology is assumed, where the former often follows the correct application of the latter, and in which the question of how policies and technological developments consider local knowledge and action is relevant. With hazard-centred approaches dominating, proposals such as those of Gaillard and Mercer (2013), who investigate the roles of the full range

of existing stakeholders, reconciling them between different forms of knowledge and action, and who argue that the development and use of monitoring and early warning systems may work best if they are based on community-based, locally developed technologies and responses, are gaining importance.

2. Capacity building and promotion of DRR networks; relating to contributions that understand technology to be inextricably linked to science and adopt a concept of technology that does not question its politics in depth, and that analyses the great inequalities in terms of access to technology at international and national levels. We find that there has not been a full analysis of how these science and technology networks operate and the role they might play.

3. Developing and improving access to reliable data is an underlying concern, whether in the belief that data, whether real-time or not, can lead to better DRR policies, strategies and technologies, or in the quest for greater availability and reliability. Added to this are proposals around data reliability, such as the development of standards, so that data generated in different contexts can be compared and used in the development of rigorous approaches to DRR (Aitsi-Selmi et al. 2016b).

4. Prevention and preparedness technologies as key stages with profound implications for DRR and emergency response, as anticipation and planning are prioritised over disaster response. The approach impacts on the type of technologies that are imagined to be relevant to DRR policy, such as the need to develop early warning systems for hazards; the use of remote sensing technologies; data repositories of past disasters; and information technologies that help those potentially affected by a disaster to take timely action.

5. Technologies of recovery, in which analyses focus on understanding how these technologies (sets of documents, practices and socio-material relations that seek to govern life in post-disaster contexts) are implemented and transformed, we highlight how these technologies often fail to acknowledge the variability, unpredictability and mutability of local emergency contexts.

6. Resilience and technology; standing out as a conservative term, articulated by top-down logics and elite-driven discourses and policies, where resilience can be understood as a demand made on vulnerable communities to recover from repeated shocks arising from deep and multidimensional pre-disaster inequalities.

In a third moment of the work, digital and smart urban technologies were mapped as possible solutions to various problems in DRR and emergency response, considering that this technosolutionist approach (technology as technical proposal and practical solution) is characteristic of many contributions, which emphasise how to improve individual (and sometimes collective) responses in a moment of rupture, without taking into account the previously existing spatial and social inequalities and relations, nor the prolonged temporalities of emergency and disaster.

The mapping included various technologies, their uses, and the debates that they enable. Starting with the case of social media, it is highlighted that they are useful throughout the disaster cycle and are considered a fundamental tool to allow those affected to participate more directly in DRR and emergency response and even allow affected groups to express emotions, commemorate victims, and discuss disasters beyond the moment of their occurrence (Houston et al., 2015, 14).

On the other hand, in mapping and geospatial technologies, a shift was identified towards supposedly more dynamic, transparent, and decentralised forms of mapping in which crowdsourcing and participatory mapping emerge as very promising tools by enabling better knowledge and more efficient communication, improving DRR and emergency response.

While the apps (remote sensing, citizen sensing, use of databases and the transmission of real-time information through mobile technologies) promise a seamless integration of various digital technologies with the aim of providing DRR and emergency response information and tools as a service to end users, they share common aspects such as, providing faster and simpler information to end users; the notion that technology can be a simple tool for better disaster action; and a view of disaster more focused on hazard than on pre-existing and compounded vulnerabilities. It is highlighted that apps and other digital and smart urban technologies bring together data sources (human or non-human), confusing and obscuring how the processes of data acquisition, compilation, analysis and sharing take place, and what their consequences might be for users throughout the data cycle (Roth and Luczak-Roesch 2018).

About drones and robots, two functions were identified, enabling remote command and control, particularly as the disaster unfolds and enabling real-time detection and monitoring (drones). The predominant view of them is that technology could be a solution to tragedy and disaster by offering possibilities for better response, while drones promise more efficient communication and more timely response.

Regarding Games and visualization, the contributions highlight the potential of gaming to improve awareness among international organisations, governments, and non-governmental organisations (Gampell and Gaillard 2016) and to improve disaster education among users. It also highlights the use of visualization tools by urban planners to design and intervene in cities by making the effects of potential disasters visible and tangible. A hazard-focused notion of disaster prevails here, displacing the issue of vulnerability by advocating for refined and complex technological solutions that can be implemented anywhere.

Detection and IoT, is a rich field (of remote sensing, citizen sensing, and wirelessly connected objects and people), where technology offers the possibility to better understand disasters by increasing the amount of data available, the possibilities to automatically compile and analyse it, and build networked architectures capable of better containing and reacting to the impacts of disasters and emergencies. A notion of disaster prevails where issues of efficiency, accuracy and speed of action can be solved through more technology, and where end users would respond in a predictable manner as a result of the availability of more information. In terms of sensing, two categories were identified, remote sensing (usually automated and linked to non-human objects and flows) and the notion of citizen sensing or 'people as sensors', where it is suggested that user-transmitted information can be more accurate, timely and responsive. For its part, the IoT promises better monitoring of nature, people, and their interactions through ubiquitous and distributed computing devices.

In terms of integrated platforms and AI, we find imaginaries suggesting that the task of integration is moving from control rooms and dashboards to automated technologies themselves, where Artificial Intelligence (AI) is crucial for both practitioners and academics as a tool, object, and method (Leszczynski 2018). Particularly in smart city imaginaries AI promises the integration of diverse data sources beyond human intervention and is seen as a more efficient and accurate way to manage disasters. As problem-solving approaches, they focus on the moment of disruption as a temporality to be minimised by deploying faster and more accurate technologies.

Regarding the concerns and assumptions of those working on digital and smart urban technologies from a problem-solving point of view, three narratives were addressed: (i) those that address the need for improved information and communication as a solution to DRR and emergency response problems, which highlight the issue of improving situational awareness through technological interventions, such as wireless sensor networks, peer-to-peer computing architectures, and social network analysis, to reduce uncertainty and improvisation, increasing efficiency and leading to better disaster response outcomes (Ochoa and Santos 2015); ii) those focused on how different disaster cultures are identified using digital data, suggesting that digital technologies, in particular social media, are embedded in broader social, spatial and political processes and, consequently, relate differently to stakeholders and disasters; iii) the goal and concern of collecting, storing and using more accurate data, where we found many technocentric discussions, focusing on which technology, understood as a mediating tool, can better fulfil a data collection and storage function, or better enable its correct use. Three particular topics were discussed: the development of appropriate technologies; the construction of more accurate predictive models; and the promotion of citizen sensing as a positive trend that encourages crowdsourcing.

Finally, critical explorations of smart and digital urban technologies in relation to DRR and emergency response fell into three broad categories:

a) The issue of smart cities and smart urbanism, seen from a technosolutionary approach where cities appear as an integration of various technologies flowing through increased computational power and where disasters and emergencies are threats to normal functioning that can be solved by increasingly integrated and ubiquitous computing.

   This involves better response and planning through monitoring, mapping and predicting behaviours and flows, in an effort to maintain a state of fragile normality that has the ongoing potential to become an emergency. They have also been seen as imagined space projected into the near future, in which a greater presence of sensors, the availability of more digital data and the computational capacity to analyse it are presented as a desired possibility.

b) The spatial politics of disasters and inequalities was approached from a critique of the technosolutionism of smart and digital urban technologies and their relationship to DRR and emergency response. It highlights approaches that explicitly politicise the issue of disasters, underlining that the introduction of smart and digital technologies does not make politics, negotiations and interests disappear, even if they are hidden in discourses that privilege the technical.

   Another critique highlights pre-existing spatial and social inequalities, calling for approaches that deviate from technology as an all-purpose solution that can be seamlessly implemented in spaces that are profoundly unequal. These critical considerations show how already existing inequalities can be reproduced, extended and maintained through the deployment of digital technologies.

   In relation to disaster ontologies, we note that most technologies start from a definition of disaster that focuses on the moment of rupture, discarding valuable information that can transform the way in which the disaster is understood through the digital and the responses that the digital allows in disaster situations, which is aggravated by unequal power relations in disaster situations. In relation to the production, storage, analysis, use and transmission of digital data in disaster contexts, we identify relevant ethical issues such as privacy.

c) Works that take a critical stance towards digital humanitarianism, referring to the growing practice of managing and governing disasters remotely using different digital technologies. One critique points out that they enclose inequalities and unequal power relations in affected areas, by promoting a notion of resilience as resistance (a way to survive) and not as a potential way out of the vulnerabilities that derive in deep impacts of disasters, so digital humanitarianism appears as a neoliberal technology to govern at a distance (Duffield 2016, Duffield 2019).

   Other critiques revolve around how Big Data is used, and how it constitutes a form of data colonialism (Thatcher, O'sullivan and Mahmoudi 2016), because digital technologies allow personal information shared and mined across different platforms to be appropriated and reused as a commodity.

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