Crisis management as an evolutive and adaptable infrastructure

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Abstract

Crisis management is a field of research that transects several disciplines (sociology, organization studies and, notably, disaster studies). As such, reaching a general consensus regarding its definition is not an easy task. However, there is agreement as concerns its two principal dimensions: 1) technical tools and infrastructure coordination efforts during emergencies and out of the ordinary situations, without which coordination simply would not work; 2) crisis management activates a more or less extensive network of actors depending on the scope of the crisis. This allows for centralized coordination, which in turn implements a set of actions to undertake in order to contain the crisis.
However, the urban complexity that characterizes Parisian metropolitan area upsets this dominant concept of crisis management, since the interdependencies are numerous and dense. In other words, in a crisis situation, the urban environment is particularly vulnerable because it exacerbates the multiple interdependencies that constitute it. Their complexity is part of a nesting of spatial and temporal scales which oblige us not to restrict the study of crisis management according to the punctual and localized entry of the triggering event. This article proposes to consider crisis management no longer as a centralized coordination based on technical tools and/or infrastructures, but as an evolutive and adaptable, sociotechnical infrastructure. To do this we will mobilize three research areas: crisis management studies, urban studies and infrastructure studies. We will develop our argument by analyzing the articulation of these domains with each other in order to see to what extent crisis management, in this urban context, "acts as infrastructure."

Keywords

crisis management, socio-technical infrastructure, assemblage, coordination, urban complexity

1. Introduction

Crisis management is a field of research that transects several disciplines (sociology, organization studies and, notably, disaster studies). As such, reaching a general consensus regarding its definition is not an easy task. However, there is agreement as concerns its two principal dimensions: 1) technical tools and infrastructure coordination efforts during emergencies and out of the ordinary situations, without which coordination simply would not work; 2) crisis management activates a more or less extensive network of actors

depending on the scope of the crisis. This allows for centralized coordination, which in turn implements a set of actions to undertake in order to contain the crisis.
Crisis management mobilizes various crisis unit. In France, this organization tends to be highly territorialized and hierarchical such that each unit has its place in the chain of command based on its own territorial responsibilities. The scope of the crisis defines the involvement of all or part of the units in this chain of command. The chain begins at the municipal level, under the command of the mayor. If it surpasses the local level, the departmental level (headed by the departmental prefect) then takes over, followed by the zonal level and, finally, the national level if the consequences are widespread as such (see Figure 1 below). However, each unit is capable of managing both rapidly evolving (e.g. a terrorist attack) and slow-moving crises (e.g. major flooding of the Seine and its tributaries). Hence, it is the same actors who work within these crisis resolution units, regardless of the nature of the crisis. This organization, however – though typical of crisis coordination - is put to the test when implemented in an urban environment, whose complexity is specific. We retain the four dimensions of complexity directly related to the territory proposed by André Dauphiné, which are 1) the structure of the territory itself, 2) interlocking of spatio-temporal scales, 3) the different natures of different levels of organization and 4) nonlinear systems that create complexity through simple mechanisms whose evolution is complex (Dauphiné, 2001).

To these dimensions can be added the Parisian context. While the Ile-de-France region is home to all the national State institutions, it is an exception as the Paris Defense and Security Zone - whose territorial jurisdiction is based on that of the Île-de-France region - is under the jurisdiction of the police prefect, who is also the prefect of the *département* of Paris. Thus, Paris breaks the typically linear chain of command; it demonstrates the complex interweaving of legal and/or political technical elements and superimposes several territorial jurisdictions in a single geographical space.

The urban complexity that characterizes Paris challenges our classic understanding of crisis management, and thereby offers us the opportunity to rethink crisis management. In this paper, we propose considering the latter as an evolutive and modular sociotechnical infrastructure, and not merely as an interface or an overarching, coordinating body for different infrastructures. This allows us to fully understand crisis management's role in the urban context, and how the urban environment in turn requires that crisis management constantly reorganise, and thus "act" much like an infrastructure. It is for these reason that we propose considering crisis management as emblematic of the urban nexus, given that it brings together both human and non-human heterogeneous elements from the urban environment (e.g. water pipes, policemen, electricity, software, hospitals and so on).

To develop our argument, we considered three research areas: crisis management studies, urban studies and infrastructure studies. The first part of the article sets out in detail the

research strategy and methodology used. The second part considers the complex relationship between crisis management and the urban environment. The third section is a literature review that attempts to define the concept of infrastructure as developed in the field of the science and technology studies (STS). The fourth section elaborates upon our argument based on our observations and interviews, thus allowing us to understand crisis management as infrastructure. The last section provides a comprehensive descriptive model of crisis management understood as a modular, sociotechnical infrastructure, leading to a discussion of the relationship between this understanding of the crisis management and the urban nexus.

2. Research strategy

This paper is based on research begun in September 2015 as part of the EURIDICE[1] research program, conducted in collaboration with the Paris Police Prefecture. The research consisted of observing crisis units at the departmental, zonal and national levels during several major crisis events.
Generally speaking, our observations aimed to analyze how actors work, coordinate, make decisions and share information in crisis situations, and the technical tools used by crisis centers, notably Crisorsec. These *in situ* observations were supplemented by roughly 30 semi-directive interviews with crisis managers in 2015/2016, mainly responsible for zonal events, and were extended to the national level, and to private and public actors, i.e. police prefecture partners, when necessary.

We will develop three examples based on our research. The first is the rapid onset crisis that ensued following the November 2015 terrorist attack. The police prefecture's Zonal Crisis Center (CCZ) opened its doors at 7 a.m. November 14, 2015. The EURIDICE team observed the centre almost continuously until November 19th, when the CCZ closed its doors following intervention targeting the arrest of the terrorist group at the origin of the attacks. The research team was also allowed to attend the first round of feedback from the CCZ personnel.

The second example is based on the EU Sequana European crisis management exercise, which took place from March 7-18, 2016. This exercise was exceptional in a number of respects from both a research and an operational standpoint: never before had such an exercise brought together so many actors and Paris police prefecture partners (approximately 150) for a major event, the flooding of the Seine. It was also the first time that the floodwater recession phase - versus merely the flooding phase - was simulated. The EURIDICE team

1 EURIDICE: Research team on risks, crisis management and tools for managing major crisis events, led by Valérie November.

attempted to maximize the opportunities offered by such an exercise by setting up multi-site observation, with 40 researchers across 30 crisis centres that agreed to open their doors to observers. The centres included those for the telephone operator Orange, Radio France, the Hauts-de-Seine prefecture, the Musée d'Orsay, EDF (electricity), GrDF (gas), Academie of Paris, France Télévisions, Axa France (insurance), SIAAP (sewage network) and the Gennevilliers city hall, to name a few. The EURIDICE team created a spreadsheet to collect the researchers' daily observations. The results (3000 entries) enabled it to simultaneously compare what happened where, how events played out, what questions were raised by crisis management professionals and what difficulties emerged in each crisis center at a time *t*. More specifically, particular attention was given to: 1) the technical tools used; 2) the networks concerned; 3) the flow of information (feedback, handling, response); 4) maps (how were they used? what information was mapped?); 5) internal/external communication between partners, and 6) the distribution of roles within crisis centers.

The third example is a slow onset crisis linked to the flooding of the Seine in June 2016. On this occasion, the Zonal Crisis Center was placed on active standby on 31 May at 11 a.m., reinforced on 3 June at 8 a.m., and closed on 10 June at 4pm. We monitored the site continuously from 31 May to 8 June 2016. For this period, the observation team alternated from 7 a.m. to 1 a.m., at which time the CCZ returned to standby mode for the night hours. The observation objectives were comparable to those for the EU Sequana exercise.

The table below describes the methodology used and observation conditions for the three examples.

Example observed	**Terrorist attacks**	**EU Sequana**	**Flooding of the Seine**
Type of event	Rapid onset emergencies	Crisis management exercise	Slow onset emergency
Places of observation	CCZ	Multi centres (30)	CCZ
Period of observation	From 14/11/2015 to 19/11/2015	From 07/03/2016 to 18/03/2016	From 31/05/2016 to 08/06/2016
Mode of observation	Ongoing/1 site	Ongoing/multi-site	Ongoing/1 site
Number of hours of observation	63	54	113
Number of additional interviews by the authors	14	5	11
Data collected	1 compilation report of all the observation notes	1 Excel table (3000 entries)	1 compilation report of all the observation notes

Table 1. Observations and interviews

Observation for these events required Confidential Defense clearances. The three examples chosen for this article respect the confidentiality requirements of the Paris Police Prefecture and other crisis management partners. Despite their seemingly narrow scope, we feel they

are emblematic of other crisis situations and/or follow-up actions the EURIDICE team observed (COP21, social uprisings of spring 2016, EURO2016) and are therefore generalizable.

3. Crisis management and urban context

Only recently importance has been given to crisis management in the urban environment. In our view, two factors fuel this relatively late connection: the first, the dominant angle by which crisis management is analyzed; the second, the complexity of the urban environment, which proves to be a key challenge in terms of management when one considers the classic definition of crisis management.

Analyzing crisis management by crisis: an approach that neglects crises as a process

Research tends to consider crisis management through the lens of the crisis itself, and thus by a description of accidents, disasters or catastrophes. In his literature review, Christophe Roux-Dufort points to this specific approach, which has dominated research on crises and isolated crisis management research from other related fields. "Seeing the crisis as an event has disadvantaged the discipline of crisis management because it leads to belief that the event prevails over everything else" (Roux-Dufort, 2007).

This approach has also led researchers to focus on exceptional crises, highlighting their unprecedented nature and dramatic consequences. Such a way of contemplating crises - which Roux-Dufort describes as "methodological monolithism" resulting from "sudden, unexpected, surprising and unpredictable" events - does not take into account their complex nature, given that "the exceptional nature of some crisis gives the impression of an abrupt shift from a normal situation to a crisis situation" (Roux-Dufort, 2007). However, a more thorough analysis would help us understand the escalation of crisis situations and, more importantly, identify their cause, which focusing on the suddenness of an event does not allow for. He considers that an "in-depth analysis of several organizational preconditions is necessary to better understand the reasons for and the processes of production of such a disaster," (Roux-Dufort, 2007). According to the author, it is only when we put the crisis in its temporal context, from its origin to its long-term impact, that we can understand its overall management. This finding is in line with the work of other researchers who recommend taking a broader view of crises in disaster studies and developing theoretical frameworks less focused on the crisis itself (see for example Pearson and Mitroff, 1993 or Sementelli, 2007).

Despite calls for a broader vision of crisis processes, it should be noted that several authors recommend clearly distinguishing between crisis and emergency situations. Ronald Perry and Michael Lindell suggest that emergencies can be considered as "unforeseen but predictable,

narrow-scope incidents that occur regularly," (Perry and Lindell, 2006). Arjen Boin and Allan McConnell add that "these events are delineated in time and space. As they are knowable and follow fairly predictable patterns, emergency services can train and prepare for these events" (Boin and McConnell, 2007). Roux-Dufort likewise insists on the fact that "in situations of urgency, the actors do not have much time to react but the solutions to the situation are known," whereas "in a situation of crisis, not only is time scarce but the solutions are still unknown," (Roux-Dufort, 2007).

These studies reveal that understanding the temporal dimension of crisis management seems easier than understanding its spatial dimension (and urban in particular).

Crisis management in the urban environment: interdependency, invisibility and complexity

Crisis management, which is seen as coordination supported by technical tools and a network of actors who respond to central coordination, is put to the test when considered within the context urban.

Will Medd and Simon Marvin already made this observation, noting that "in times of apparent stability, the intricate interdependencies between different socio, technical and natural worlds that enables urban metabolism remain largely hidden. However, the disruption, destabilisation and immobilisation caused by crises dynamics reveal the precarious interdependencies upon which times of perceived urban stability depend," (Medd and Marvin, 2005). In other words, the urban environment is particularly vulnerable as it exacerbates the many interdependencies that constitute it, what Jochen Monstadt calls "complex web of connectivities and new spatial interactivities," (Monstadt, forthcoming).

The terrorist attacks of 2001 (the World Trade Center), 2004 (Madrid) and 2005 (London) helped not only to put the terrorist threat on the political agenda but also to make the interdependencies clear and concrete. They have changed the entire focus of Disaster Risk Management (DRM) activities and reshaped the Critical Infrastructures (CI) context by increasing awareness of the complexity and interrelatedness of infrastructure as socio-technical systems and the increasing likelihood of cascading effects (Bach et al., 2001, Rinaldi et al., 2001, Boin and Connell, 2007).

At the same time, given the vulnerability of the urban environment, reflection on urban resilience i.e. the urban environment's ability to adapt to new and unforeseen changes (see among others, Ahern, 2011) or recover from catastrophe (Vale et al., 2005) has developed. These works fall under an emerging interdisciplinary research field called sustainability science (Kates, 2001).

French organization, which is both highly territorialized and hierarchical, is also challenged by the urban environment, and by the Parisian metropolitan area even more so, which is complex in its own right. Beyond the multiple interactions, interdependencies and consequences in the form of chain and/or domino effects in crisis situations, metropolitan Parisian has the added effect of being a capital region. The Ile-de-France region brings together all the national State institutions, thus reinforcing management issues for the territory that go beyond its own perimeters of action. However, it is an exception since the Paris Defense and Security Zone, one of the national territory's seven defense and security zones, whose territorial jurisdiction is based on Ile-de-France, is under the authority of the Prefecture of Police of Paris. Consequently, in a crisis situation in the Île-de-France region, the district prefect, who elsewhere is the hierarchical superior of the departmental prefect, is obliged to report both at the national inter-ministerial level and at the level of the prefect, who is also prefect of the department of Paris. Thus, Paris breaks the linearity of the chain of command applicable elsewhere in France (see Figure 1). This highlights the complex overlapping of economic, technical, legal and political elements and superimposing of several territorial jurisdictions in a single territory.

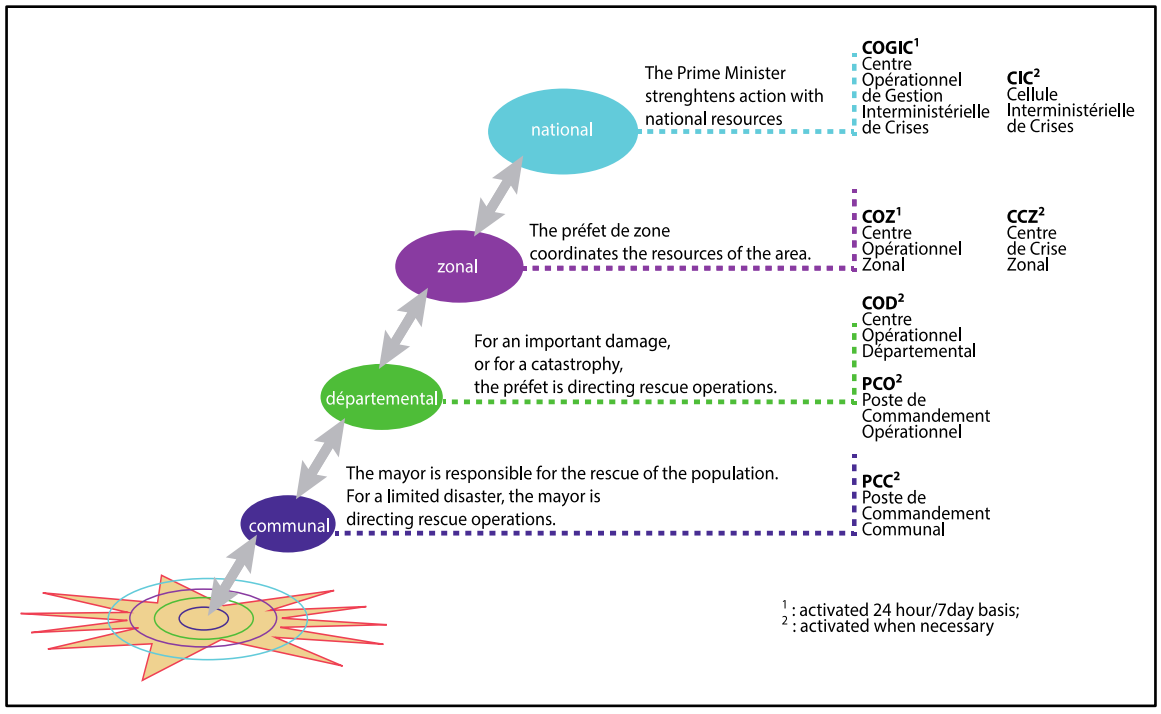

Figure 1. Organisation of crisis units within the chain of command. Source: www.mementodumaire.net (modified).

Thus, the complexity inherent to the urban environment and Parisian Metropolitan area, more generally, has led us to broaden the definition of crisis management that dissociates coordination from the technical networks on which it is based. In other words, our understanding of crisis management must be linked to an environment, a space and a time. Crises cannot be reduced to their visible part, which is characterized by the moment when the trigger element of the crisis occurs. We now must go further and discuss crisis management in the light of infrastructure studies.

4. Crisis management and infrastructure

Before addressing the relationship between crisis management and infrastructure, we must understand what the term commonly refers to. Here, too, we find not a single definition, as in the case of crisis management, but multiple definitions. Some reserve the concept of infrastructure to the technical networks that structure the urban territory and thus are referring to "networked infrastructures such as energy, water, wastewater, and transport systems," (Monstadt, 2009) (Graham and Marvin, 2001).

In the area of crisis management, most studies concern critical infrastructures, also known as "vital points" in France (Galland, 2010) and "essential infrastructure" in Canada (Therrien, 2010). The term critical infrastructure, which is defined by the European Union as "physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security" (Rostum et al., 2008), is used in several countries (Germany, the United Kingdom, Switzerland, The Netherlands, the U.S. and Norway) (Galland, 2010).

However, definitions vary from country to country and may be broad. In the United States, for instance, critical infrastructure not only includes technical support but also services including emergency and rescue services (Boin and McConnell, 2007). Norway associates technical infrastructure with the concept of critical societal functions: "Critical infrastructure is those assets and systems which are essential to upholding the critical functions of the society." These critical societal functions include "banking, food, health and social security services, police, rescue and emergency services, **crisis management**, government, court of justice, defense, environmental monitoring and waste management," (Rostum et al., 2008). It would seem that considering crisis management as a critical function enabled by existing infrastructure is now generally accepted. Certain authors, like Rinaldi et al. 2001 for example, consider critical infrastructure as complex, adaptive systems.

However, the close relationship between crisis management and infrastructure remains unclear in these definitions.

To overcome this issue, it is interesting to consider the concept of the "second order large technical system" Erik van der Vleuten uses to analyze the social consequences of infrastructure development. He defines this "second order large technical system" as "a superstructure constructed on top of 'existing first order LTS…characterized by a rather 'heterogeneous' material network, as opposed to the 'homogeneous' networks of first order LTS," (Van der Vleuten, 2004). This approach, initially developed by German sociologist Ingo Braun, allowed him to examine the coordination of network overlap between first and second order systems in greater detail. He uses the example of organ transplantation (associated with second order) that is enabled by the existence of first order LTS, which consists of medical nodes like hospitals, communication networks and road/air traffic, from the local to the international scale.

One might think that crisis management faithfully follow this example. However, going back to the example of organ transplantation, the entire first order LTS on which it was built exists independently and functions independently of the latter. Hospitals, road and air networks and communication systems exist as such, as they were not specifically designed to contribute to the development of the organ transplantation field.

Organ transplantation's dependency on the networks on which it is based has been verified. However, the reverse is not developed in this understanding. The concept of second order LTS is therefore not entirely transposable to crisis management. Indeed, since the January 2, 2012 decree a new kind of professionalization of crisis management has spread through the creation and increasing number of crisis units. Such units can be found at the local, national and even European level among both public and private crisis actors. The former provide centralized coordination by mobilizing networks of actors and technical support. Their sole vocation, as is that of communication, transport and energy networks, is to facilitate crisis management.

If we look more specifically at the urban environment, the concept of urban infrastructure permits us to go further in linking infrastructure and crisis management, particularly in STS. Richard Little sees urban infrastructure as "vital networks, absolutely necessary for the functioning of the twenty-first century urban complex. Modern societies and their underlying economies rely on the ability to move goods, people, and information quickly, safely and reliably. Consequently, it is of the utmost importance to government, business, and the public at large to understand the nature of urban infrastructure and take the measures necessary to ensure that the flow of services provided by it continues unimpeded in the face of a range of natural and manmade hazards" (Little, 2010). Beyond this definition, STS on urban infrastructures have shown that cities produce, transform and reconfigure infrastructures that, in turn, reshape it (Hommels, 2005) (Coutard and Guy, 2007).

Finally, Susan Leigh Star, Geoffrey Bowker and Karen Ruhleder have helped us to consider more specifically the link between crisis management and infrastructure. In answering the question "when are we in the presence of infrastructure?", the authors identified eight dimensions necessary for its emergence (Star and Bowker, 2006) (Star and Ruhleder, 1996) (Star and Ruhleder, 2010):

> *1. Embeddedness: The infrastructure is contained, as though "poured" into other structures, social arrangements and technologies.*
>
> *2. Transparency: The infrastructure is transparent for users, i.e. there is no need to reinvent it for each event or assemble it for each task. Yet it remains an invisible support in these tasks.*
>
> *3. Reach or scope: This can be spatial or temporal. The infrastructure goes beyond an isolated event or single practice.*
>
> *4. Learned as part of membership: Accepting organizational arrangements and artefacts as a given is a prerequisite for being part of a community of practices (Lave and Wenger, 1991; Star, 1996). Foreigners and people from the outside see the infrastructure as an object they must learn to use.*
>
> *5. Links with the conventions of practices: Infrastructure both shapes and is shaped by the conventions of a set of practices.*
>
> *6. Embodiment of standards: Infrastructure, modified by scope and often contradictory conventions, becomes transparent by tapping into other infrastructures and tools in a standardized way.*
>
> *7. Built on existing foundations: Infrastructure does not come "from out of nowhere"; it fights against the inertia of the existing foundations and inherits its strengths and limitations.*
>
> *8. Becomes visible upon failure or breakdown: An infrastructure, though invisible when functioning correctly, becomes visible when it breaks down (e.g. a server crash, a bridge collapse or an electrical outage. Even where emergency mechanisms and procedures exist, this existence only serves to highlight the infrastructure that has become visible.*

They took the construction of a digital communication system for a community of geographically dispersed researchers as a case study to establish their criteria. The study was done in the early 1990s, during a radical transition phase in electronic information technology. The parallel with our topic of study - crisis management - is strong, as this area too has also undergone major changes since the January 2, 2012 decree on the creation of crisis units. Our aim in the following section is, firstly, to analyze whether or not they resonate with these dimensions of infrastructure based on our own observations of crisis

management situations and, secondly to provide a comprehensive descriptive model of crisis management understood as a modular sociotechnical infrastructure.

5. Discussion: Is this infrastructure?

Let us turn now to our case studies to determine whether or not our examples indicate the presence of infrastructure. In this section we will build on examples of dimensions that seem to be present in all our observations, which we will discuss in the light of those proposed by Star et al.

"Horizontal" spatiality, or the example of flow containment

Several structuring elements become visible when a crisis occurs. Though they existed prior to it, it is the emergence of the crisis makes them perceptible, highlighting an entire network of nodes, axes and zones.

In the event of a rapidly evolving crisis situation, such as one generated by a terrorist attack, nodes and/or gathering places initially take the form of localized points of impact in space and time. These are clearly identified locations where attacks were carried out at a time t. These points of impacts initially lead to the convergence of public security forces and civil security, who quickly organize the area surrounding the impact points into concentric zones. Three zones thus are formed: an exclusion zone (reserved for rescue, police and mine-clearing forces), a so-called controlled zone (reserved for the interveners in exclusion zone) and a support zone (for various mobile operation command posts, authorities, light casualties and the press).
Other crucial gathering points or nodes for welcoming victims then emerge and become key elements of crisis management infrastructure (e.g. hospitals or care centers). In order to link the initial points of impact with these victim support centers, several key routes (mainly roads) emerge.
The organization of traffic flows and reception points for the victims was nonetheless quickly overwhelmed the night of November 13-14, 2015. Unable to obtain information by telephone, certain victims' families went from hospital to hospital in search of loved ones, thus saturating the hospitals.

This observation confirms Susan Leigh Star, Geoffrey Bowker and Karen Ruhleder's finding most notably the 8th dimension of infrastructure which becomes visible upon failure or breakdown. In other words, if victims' families had been able to obtain information regarding their relatives by phone, they would not have gone from hospital to hospital trying to find

them. In our opinion, however, this interpretation is not entirely satisfactory, as it is essential to analyze the situation from within the crisis unit itself.

When a major event generates certain number of casualties, a hotline is automatically set up, a result of the type of forward thinking considered critical to any crisis management infrastructure. Depending on the situation, i.e. the severity or number of victims, this forward thinking involves finding the right design for the infrastructure. Given the exceptional nature of the events, the tool should have been adapted to callers' needs. A proposal was made to sort calls by running a banner under the hotline number, specifying that the latter was reserved for families and friends of victims. However, the proposal was not taken into account in a timely manner, i.e. from the night November 13 to November 14. Thus, this adjustment to the infrastructure's design remained invisible instead of becoming visible, as ultimately no additional banner was associated with the hotline number. This example shows the complexity of the coordination, linked to cognition (Comfort, 2007) and the delicate shift from routine operations to a crisis management mode involving the transfer of roles and responsibilities (Turoff et al., 2004).

This example also demonstrates that the infrastructure we are considering here is not only perceptible upon its failure. We must go beyond this transition from the invisible to the visible and also must take into account that which is *not* perceptible at the right time; it is likewise the non-materialization of this transition from the invisible to the visible that can be interpreted as a failure of infrastructure. Such infrastructure therefore reflects the gradual transition from invisible to visible throughout a crisis.

We must therefore not see crises as "sudden" events. As such, their management must be understood as a modular assemblage whose dimensioning is constantly evolving. This flexibility is all the more necessary in the urban environment, whose complex interdependency is sometimes revealed only in crisis situations, as Medd and Marvin (2005) have indicated.

"Vertical" spatiality, or the convergence of bottom up and top-down

The second, seemingly key dimension of this infrastructure is vertical – a cross between "bottom-up" and "top-down."

Arjen Boin and Fredrik Bynander show that, in crisis situations, two collaborative scenarios evolve simultaneously: "a top-down perspective in coordination" and "a bottom-up view of coordination," (Boin and Bynander, 2015). The top-down perspective is akin to formalized coordination processes. In France, this is based on the pyramidal organization of the chain of command and the executing of plans defined prior to the crisis in the preparation phase. However, during a crisis, this top-down perspective alone is seemingly incapable of providing

a comprehensive resolution. Ann Majchrzak, Sirkka Jarvenpaa and Andrea Hollingshead, for instance, describe it as "too slow, disconnected, and inadequate for the task" (Majchrzak *et al.*, 2007). It can likewise become counterproductive when it is restricted to the triggering of management plans based on fictitious scenarios that do not correspond to the crisis situation at hand (Clarke, 2006).
Crises naturally elicit complementary, bottom-up collaboration, which Boin and Bynander describe as the "collaboration [that] will simply emerge in times of crisis - but it is not clear why or under which circumstances this would happen" (Boin and Bynander, 2014).

The example of the #porteouverte hashtag created on social networks during the November 2015 attacks perfectly illustrates this type of emerging collaboration. Seeing tweets relaying requests for refuge by people present at the sites of the attacks and citizens' invitations to host them, a journalist decided to bring together the offers and requests via a hashtag. The initiative, however, which was quickly and widely adopted, was also perceived as a danger by the authorities; the hosts, who indicated their addresses, suddenly could present potential new targets for terrorists. In this example, citizens' apartments became part of the infrastructure and played an important complementary role in managing the crisis, above and beyond "official" crisis management plans.

The question then is how to integrate such emerging forms of collaboration into the crisis management process. Boin and Bynander propose combining the two perspectives under the name "collaborative crisis governance." They argue the need for a merging of top-down and bottom-up approaches based on the fact that "when a major event transcends geographical and sectoral boundaries, crossing public-private divides, coordination does not necessarily adhere to hierarchical lines and routine processes," (Boin and Bynander, 2014).

Thus, it is not so much a question of incorporating emerging forms of collaboration into the existing structure as of rethinking crisis management. We thus see another type of highly evolutive, constantly reconfiguring infrastructure emerging. In other words, this example shows that crisis management is, in fact, a blend, certain reconfigurations of which take the form of "collaboration crisis governance" and in which citizens spontaneously play a role.

Temporality, or the integration of far-reaching repercussions over time

Finally, the third dimension of this infrastructure is time, which allows us to develop a longitudinal vision of crisis management. Indeed, the various phases generally associated with crisis management (alert, emergency, overflow, crisis, post-crisis, etc.) may encounter factors that hinder or block coordination. Explanations for this disturbance must be sought out well before the triggering event (Roux-Dufort, 2007) or, conversely, after it. The following example illustrates this second scenario, wherein it is a question of legal liability and, more specifically, protocols for reopening public buildings that have been flooded.

In discussing the question of liability during interviews several weeks after the flooding of the Seine in June 2016, the response seemed unanimous and almost obvious: the decision to reoccupy a building after a flood is the responsibility of the person who made the initial decision to evacuate it, in order to maintain the continuity of the decision-making process. However, the observation of flood management from the *Centre de Crise Zonal* showed an entirely different situation.
Once the Ministerial service, Vigicrue, announced the time and level of flooding in Austerlitz (water height scale reference for Paris), the partners involved simultaneously redirected their actions in an attempt to restore order as quickly as possible. However, parallel to the switch to a "de-flooding" mode of management, efforts immediately shifted to the question of legal liability. More specifically, one of the partners contacted the defense zone for guidelines concerning the appropriate measures for reopening a building. In absolute terms, following a flood, the correct procedure is to pump out the water and clean the site before calling on a qualified building expert to verify the building's solidity, ensure that the different installations (electricity and water) are properly restored and finally reopen the building. Yet, in the midst of a stressful situation, legal liability is often a difficult topic among crisis management actors, who hesitate to assume responsibility. Consequently, several questions arise: who is legally liable? Which expert should intervene? Who should choose the expert? Faced with these questions and divided between its role as a support system for the various partners and its desire to protect itself legally, the Defense Zone limited its responsibility.

This supports François Dedieu's observation of how different organizations involved in crisis management look to protect themselves legally. He uses *Météo France* to illustrate this point: "…due to its status as a public body, Météo France is formerly subject to an obligation of "means" and not "results." This statute, as part of *Météo France's* regulations, ensures that it will use "all the resources at its disposal" to produce the forecast" (Dedieu, 2013). In other words, when there is a doubt, public institutions will likely hide behind their obligation of means. This was the case with the Defense Zone, which acted as advisor in suggesting that the partner call on one of its service's architects to evaluate the possibility of reopening the building without directly giving its consent. According to Dedieu, such attitudes reflects organizations' fear of being found guilty of misconduct in the crisis after-math: "Following major disasters, we often see a critical trend of vulnerability whereby organizations are less apt to impartially reveal the limitations in a system's capacity to apprehend certain risks. Instead, their focus is on shortcomings, misconduct, or even guilty parties" (Dedieu, 2013). In the midst of flood management, i.e. before the situation was stabilized, the various parties' efforts focused on the common goal of controlling the flooding. However, the collective goal of restoring order tended to divide forces: the desire to protect oneself legally becomes a priority faced with the common goal of getting things back to normal as quickly as possible.

This example shows that certain factors, while theoretically indirect because they have far-reaching repercussions over time, e.g. fear of a possible legal repercussions following the

crisis, must be taken into account even in the midst of the crisis. In this sense, they are not anecdotal but rather infrastructural.

To summarize this discussion, the examples outlined above show that the different infrastructure dimensions highlighted by Star et al. are integral parts of crisis management. Crisis management is effectively "poured" into other institutions, social arrangements and technologies (electricity, hospitals, chains of command, number 117, etc.). It is also transparent for users because the rescue organization handles the situation to the best of its ability. The spatial and temporal scope of crisis management is directly linked to the situation (for instance, the extent of the resources mobilized varies throughout the duration of the crisis); it is neither a singular practice nor an isolated event. Managing a crisis requires knowledge of practice codes (e.g. chains of command and handling collaborative crisis management tools) and entails the development of a specific vocabulary (e.g. reporting updates). This last point also relates to the many practical conventions that exist in crisis management, which ultimately only becomes visible during failures or breakdowns.
Even dimension 7 exists in crisis management because infrastructure is not an isolated entity but rather is built on an established foundation, namely urban emergency organizations (fire-fighters, the police, security forces and public health workers). However, as Star et al. (1996) mention, infrastructures must constantly be reassessed to prevent inertia from setting in at the foundation level. Thus is the price of crisis coordination; it is often unsatisfactory and must constantly be improved upon. We can say then that the effort to maintain crisis management (and thus infrastructure) is indeed important. Regular exercises of varying scales (see the March 2016 Sequana European exercise) to simulate crisis situations in order to collaborate on the most appropriate resolutions are conducted by diverse groups of partners from a broad spectrum of regions.

These eight dimensions make it possible to at least partially understand crisis management as infrastructure. However, the characteristics of the urban environment, in particular its density and complexity, also add the dimensions of vertical and horizontal spatiality and temporality, whose importance we demonstrated in point 5. When it is not possible to scale infrastructure correctly ("horizontal" spatiality), or to integrate emerging forms of collaboration ("vertical" spatiality) or far-reaching repercussions over time (temporality), the metropolitan context exacerbates the complexity of managing crises due to density of population, activities and networks. This leads to cascading effects that follow a nonlinear system as A. Dauphiné explained (2001).

Likewise, factoring in the metropolitan context, infrastructure and crisis management as we have done in this paper has led us to further our understanding of crisis management as an evolving, modular infrastructure. We have intentionally moved away from the classic vision of crisis management based solely on events to focus instead on infrastructure practices while considering crisis management as an assemblage and nexusing in the urban environment.

This vision allows us to consider both small and large units, which are intrinsically linked during crisis situations ("vertical" and "horizontal" spatiality).

6. Crisis management as infrastructure: a modular, scalable assemblage

The three dimensions we have just discussed show the extent to which crisis management requires plasticity and modularity in order to be effective and become a sociotechnical infrastructure. In other words, it is a constantly reconfiguring assemblage, which is why we must consider the notion of assemblage. While considering infrastructure as assemblages is nothing new (Graham, 2010b, Graham, 2010a), assemblage thinking has real "generative potential" (McFarlane, 2011).

Leon Hempel highlights the existence of "infrastructural practices [that] require acting in a multi-dimensional landscape of technology, nature and the city, as well as tuning and adapting the respective temporalities of their heterogeneous elements, the resources and networks that become involved over time" (Hempel, forthcoming). Plasticity and modularity of heterogeneous elements in time are, moreover, two of the characteristics we found in the aforementioned examples.

Kathryn Furlong is likewise interested in the concept of assemblage which, according to her, lets us to look beyond infrastructure as a single unit that is static both as regards its physical state and in terms of its social/environmental effects. Rather, "[b]reaking infrastructure down into assemblages of small technologies that matter enables one to see the possibility of employ[ing] small change to mediate large problems" (Furlong, 2010). This definition is also in keeping with the characteristics of crisis management, which must manage a situation in constant evolution, and whose challenge is to both deal with a set of problems by coordinating a network of actors and various points that become more urgent than the others at a given moment during the situation. In this sense our thinking is in line with that of Louise Comfort's: "The relation between cognition and action transforms emergency management from a static, rule-bound set of procedures into a dynamic process". This author understands action as an assemblage of communication, coordination and control (Comfort, 2007, p. 189).

Jane Bennett also uses the concept of assemblage to analyze the North American blackout of 2003. She notes that "an assemblage is not governed by a central power: no one member has sufficient competence to fully determine the consequences of the activities of the assemblage." (Bennett, 2005; Bennett, 2009). We also verified this with regard to the problem of toll-free number set up at the time of the terrorist attacks.

Thus the concept of assemblage truly seems useful for describing crisis management infrastructure by explaining practices that do not fall under classic categories. As Janet Vertesi suggested, we must "develop a vocabulary for studying environments in which many layers of infrastructure are co-present". This vocabulary must "accommodate heterogeneity, not only because of combination of multiple users, actors, and system constraints but also because of the unique combinations of overlapping yet different categorical distinctions," (Vertesi, 2014).

To clarify the idea of crisis management infrastructure as we envisage it, we propose the following model based on our observations from our case studies of the November 2015 attacks, the EU Sequana exercise and June 2016 flooding of the Seine. 14 indicators were chosen to construct this model and, consequently, shed light on the modularity and adaptability of crisis management infrastructure. These indicators include *actions* (e.g. activation of emergency services or communication), missions (*legal liability*), identified political and economic *issues*, needs (crisis management exercise), tools (united under the indicator *coordination between actors* precisely because they support this coordination) and even networks' technical infrastructure (*network maintenance*). In this respect, the 14 indicators incorporate the three dimensions of "horizontal" spatiality, "vertical" spatiality and temporality described above.

The importance given to a particular indicator varies from 0 to 4 depending on the crisis/event in question and a time *t*, reflecting qualitative values designed to give an order of magnitude to the indicator observed[2]. We synthesized our observations results based on these indicators, assigning them a value on this scale and considering three times: routine phases (prior to the onset of the crisis or in preparation of the exercise), the peak of the crisis or exercise, and the post-crisis or -exercise phase (integration of new knowledge after the event). Level 0 corresponds to the absence of indicators; level 0.5 to a standby state; level 1 to an issue raised individually; level 2 to an issue raised collectively but not specifically addressed; level 3 to a key issue collectively recognized as having to be dealt with; and level 4 to a major concern shared collectively and that evolves relative to the indicator (planning changes, action, etc.).

[2] For example, 4 is greater than 2 but is not considered the double of 2.

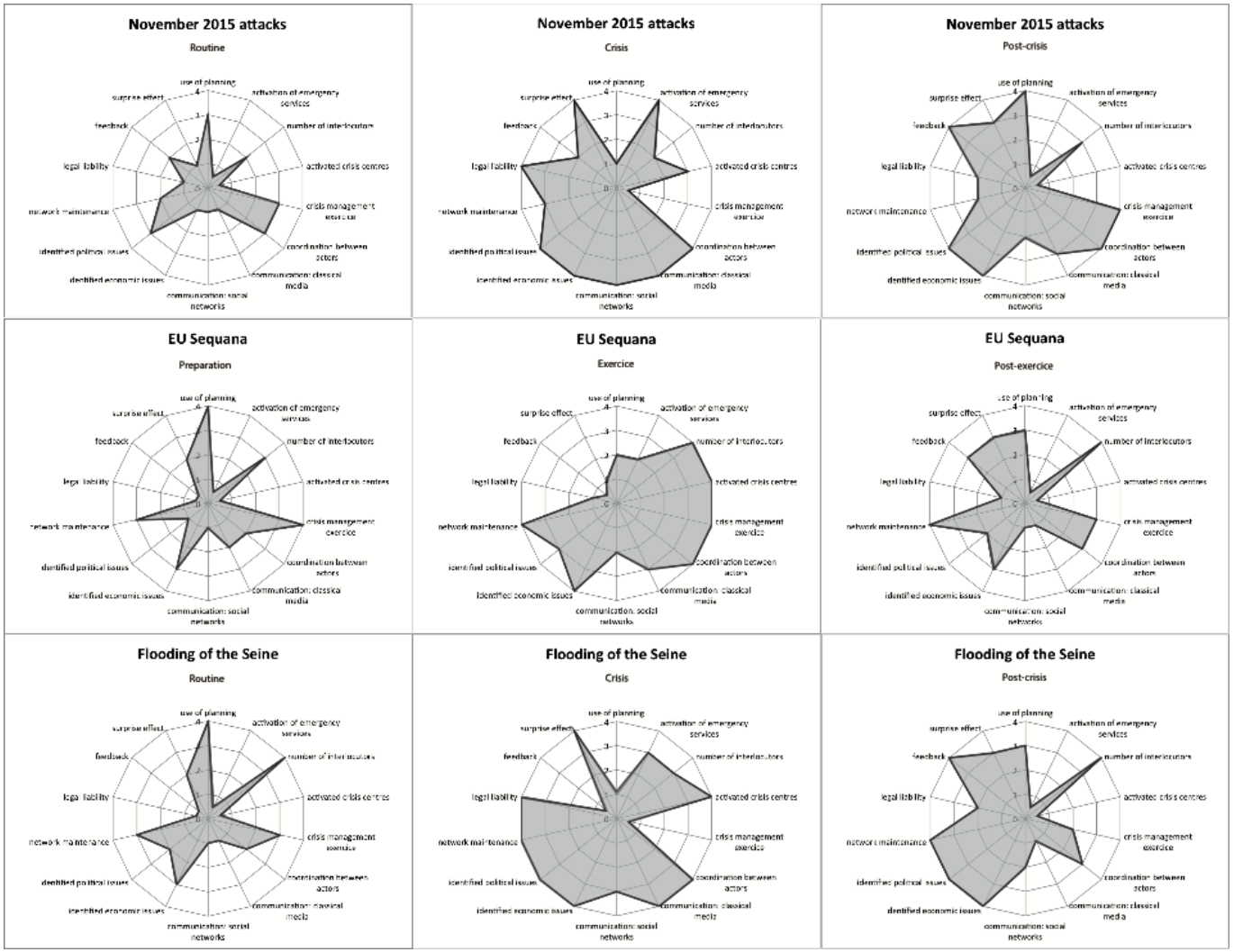
November 2015 attacks
Routine
November 2015 attacks
Crisis
November 2015 attacks
Post-crisis
EU Sequana
Preparation
EU Sequana
Exercice
EU Sequana
Post-exercice
Flooding of the Seine
Routine
Flooding of the Seine
Crisis
Flooding of the Seine
Post-crisis
use of planning
activation of emergency services
number of interlocutors
activated crisis centres
crisis management exercice
coordination between actors
communication: classical media
communication: social networks
identified economic issues
identified political issues
network maintenance
legal liability
feedback
surprise effect

Figure 2. Drawings of the evolutive and adaptable infrastructure.
What first emerges from the graphs is the models' modularity and how they change depending on the time frame observed. The graphs show more extensive infrastructure (i.e. involving larger surfaces) during the crisis peak or exercise than during the routine or exercise preparation phase of the EU Sequana exercise. Effectively, crisis management infrastructure exists independent of the event itself but emerges, becomes visible and takes on its full meaning during the event. Moreover, none of the axes, even in the routine or preparation phase of the EU Sequana exercise, was assigned a value of 0. Our observations and interviews help demonstrate that crisis management infrastructure exists permanently, not merely relative to a particular event. We have given this indicator a value of 0.5, which corresponds to a standby state.

To facilitate and explain the reading of these graphs, we have selected certain indicators that we will detail below.
Concerning the graphs associated with the November 2015 attacks, we assigned level 3 to the *use of planning* indicator for the routine period. The November attacks were preceded by those of Charlie Hebdo in January 2015, which effectively led to a planning overhaul. We therefore assigned this indicator a value of 1: while present in the minds of crisis managers, it was not yet shared or operational. Following the crisis, the issue of planning became a major concern and top priority. This indicator was given a value of 4.

The indicator for *surprise effect* is, in our opinion, a level 1 indicator prior to the November attacks: crisis managers had been expecting a potential incident since the Charlie Hebdo attacks and thus were on active standby. However, the November 2015 attacks surprised crisis managers and emergency services due to the fact that they were multi-locational. We therefore considered it a level 4. Following the crisis, we reduced it to a 3 because crisis managers were aware of the fact that they would have to take such surprise effects into account in the future. Since this time, they have been aware of this type of surprise element, whereas prior to this they did not collectively imagine the unforeseen nature of an attack having such important repercussions as to lead to serious disorganization of coordination and emergency services.

Communication via classical media (television, newspapers and radio) has been distinguished from that via *social networks*. Before the November attacks, the police prefecture used social networks to disseminate certain information and recommendations to citizens based on a top-down logic. During the attacks, social networks were used horizontally, between citizens, via #porteouverte. We therefore increased the level of this indicator to 4. After the emergency, the indicator was reduced to a level 2 and thus higher than before the crisis: however, during the crisis, social networks revealed a dimension the public authorities are

now trying to take into account in crisis management. Similarly, TV channels' desire to keep citizens informed of what is happening on the ground in almost real time has greatly disturbed crisis managers and, the work of the RAID[3] in particular. We thus raised this parameter to a level 3 post-crisis, meaning that the issue of information dissemination by television channels has become central to managers for future crises.

For the EU Sequana exercise, we gave the *number of interlocutors* indicator a value of 3 during the preparation phase. 87 police prefecture partners officially participated in the preparation phase. During the exercise, about 150 partners participated. We considered this a level 4 indicator that revealed the partners' intense concern for a possible 100-year flooding of the Seine. At the end of the exercise, the partners' interest persisted; several truly became cognizant of the issues, notably economic, linked to the crisis and joined the list. Thus, when the Seine actually flooded in June 2016, the actors' alert level was high. However, we lowered this indicator to a 3 because the level of the Seine ultimately did not reach a level of centennial flood and all of the actors did not have to be mobilized.

However, the surprise effect was maximal in June 2016. All of the crisis managers admitted that the probability of a century-scale flood occurring was greatest in late winter, and not June. Similarly, the Sequana exercise scenario did not provide for the extreme sharp rise of the Yonne and the Loing, two Seine tributaries. As such, the action plans devised before the flood could not be implemented as initially envisaged. We therefore gave the *surprise effect* indicator a 2 prior to the flood, a 4 during the flood and a 3 following the flood. Crisis managers now know that major Seine flooding can occur any time of year and take different forms.

Finally, the change in the *legal liability* indicator is also interesting to consider. This issue was raised neither during the exercise preparation phase, nor during the actual exercise. This aspect of crisis management was not mentioned in the feedback. As such, we assigned this indicator only a 0.5 during these three phases and prior to the flood in June. However, it was logical to assign it a value of 4 during the June flooding in light of the example described above, in connection with the protocol for reopening flooded public buildings. While the lack of response to this question during the flood management phase somewhat blocked action, it was not handled clearly by the crisis managers. For this reason we lowered this indicator to a 2 during the post-flood phase, corresponding to an issue raised collectively but with no specific official follow up.

3 French police intervention forces

7. Conclusion

We have presented our argument so as to show the link between crisis management and adaptive sociotechnical infrastructure based on three research fields: crisis management studies, urban studies and infrastructure studies. This literature review has allowed us to highlight the fact that crisis management infrastructure should be considered neither as a juxtapositioning of several technical infrastructures allowing for coordinated action, nor as a body overarching a network of critical infrastructure that all the while uses it.

Naturally, crisis management infrastructure depends on other existing infrastructure. However, what specifically characterizes it is both the assemblage of elements and parameters described and its specific link with the urban nexus. The urban/metropolitan nature of crisis management infrastructure is linked to high density which automatically involves complexity. It is therefore not only the number of interrelations between the many actors involved - regardless of the type of crisis in Ile-de-France and, consequently, the number of activities and networks to maintain - but also its high population density, which adds to the complexity and feeds the urban nexus. In other words, the different indicators of the model presented, their importance and their modularity depending on the time period in question helps reveal the urban nexus through crisis management infrastructure. More specifically in our opinion, the urban nexus is inherent to crisis management infrastructure as we have described it.

Further research is now needed to enhance the link we have made between crisis management and infrastructure. For instance, it is important to look at how crisis management is implemented in other cities. A comparison with other, less dense cities with less complexity would also be useful for verifying whether or not the model is generalizable and is made of the urban nexus, as we believe it is, in light of our observations.

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