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Perspective

Behind The Barriers: A Resilience Conceptual Model

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Abstract

Each natural event that affects urban regions reveals the limitations of present risk management strategies and shows the prevailing importance of technical systems before, during and after each crisis. The response of such systems to risk can be discussed in terms of resilience. Resilience is a concept that applies generally to systems, and concerns the capacity to absorb a disturbance and to return to a viable state. In the context of urban technical systems, one element of a resilience strategy is to analyse the technical constraints that apply to the design, management and adoption of technical systems. This paper presents the design of a conceptual model presenting the various possible resilience strategies applied to urban technical systems.

This conceptual resilience model for technical systems is based on the identification of four complementary types of resilience: i. cognitive resilience, linked to knowledge and culture; ii. functional resilience, representing the capacity of a technical system to protect itself from major damage while continuing to provide at least the services needed by critical infrastructure; functional resilience of technical services seeking intrinsically to increase their own resilience; iii. correlative resilience that characterises the relationship between service demand and the capacity of the technical system to respond. It is a matter of adapting demand to technical system capacity: decreasing demand enables a system to remain in operation and to recover more quickly. Internal system organisation as well as links between technical systems and other regions may also be a factor in the resilience of technical systems. iv. Organisational resilience expresses the capacity to mobilise an area much wider than the one affected.

KEY WORDS: Resilience, Conceptual model, Urban engineering, Networks, Floods, Urban, City, Technical systems

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1. INTRODUCTION

Since 2007, half the world population has lived in urban areas (UN-Habitat, 2007). The growth rate is equivalent to building a new city of one million inhabitants a week[1]. This means natural hazards cause major human and material damage to cities. The financial cost of damage is increasing rapidly and various insurance systems are changing in order to maintain their financial balance.

On a more local scale, experience shows that the success or failure of technical networks is of crucial importance in managing urban risks. Many urban malfunctions are linked to technical system malfunction and their criticality (Serre, 2011). In such a context, technical systems must be analysed with a two-pronged approach: not simply analysing the technical constraints involved in network design and management, but also analysing their physical, political and social context. Urban technical systems are "actors"2 within a region and play a major role in local risk management. In that sense, urban technical systems form a structured set of technical functions that supply a service in response to a need. They are made up of technical and organisational elements, as well as methods and agents, and are integrated in urban areas. At present, risk management in urban engineering has focussed on network reliability, leading to reliability-based methods concerned particularly with building strength, network meshing (Lhomme et al., 2013b), and network interdependency (Robert & Morabito, 2009). The cost of these methods, and their failure to prevent malfunctions in the event of natural disasters, are evidence of the limitations of a strategy that isolates networks and does not consider technical systems as a whole, and of the importance of technical systems in urban natural hazard management. New urban flood risk management strategies, for example, need to be contemplated (Zevenbergen et al., 2011).

We suggest that to improve on present methods and thus contribute to the renewal of urban engineering, there should be a focus on resilience, defined as the persistence of relationships within a system. There are numerous definitions and understandings of the term resilience (Aschan-Leygonie, 2000; Reghezza *et al.*, 2012). According to Holling (1973), measuring it means assessing the system's capacity to absorb and integrate changes in its components. He states that since systems evolve permanently, they are not characterised by a state of equilibrium but by a general stability, namely their continued operation. So, when a disturbance occurs, either the system can integrate it without its viability being jeopardised, or it cannot and sooner or later it will deteriorate because of the change in its structure (Sanders, 1992). Resilience implies the system is proactive regarding risk: the internal features of the urban system supply it with action-oriented risk analysis tools that enable it to respond appropriately to risk (Pelling, 2003). In addition to the objective of minimising the consequences of a disturbance, a number of authors consider system disturbance as an opportunity for urban planning (Pasche & Geisler, 2005). The capacity for response, but also for adaptation and absorption, then becomes central in describing a system as resilient and in approaching risk within dynamic systems (Serre, 2011).

To date, experiments with technical systems have led to some resilient approaches that challenge customary risk management strategies; however, these approaches remain specific and at present there is no common framework to analyse the proposed strategies. The aim of this article is to develop a conceptual resilience model in order to guide the implementation of resilience strategies and to build a reference framework for mediation, exchanges and description of the strategies. The main parameters are identified on the basis of experiments and methods in the field of flood risk management that are part of a resilience approach applied to urban technical systems.

2. URBAN DEVELOPMENT AND FLOOD RISKS

The economic cost of flood risks in cities is growing (Ashley *et al.*, 2007; EEA, 2008; EEA, 2012; European Commission, 2013), and understanding it requires integrating multiple aggravating factors such as urban development, climate change and all possible causes of flooding (Blanksby *et al.*, 2009). Urban growth usually affects the outskirts of existing cities and consequently goes hand in hand with urban spread. Cities therefore cover increasingly large areas that can be subjected to various other natural hazards (earthquakes, avalanches, *etc.*). At local level, this development brings added man-made (*e.g.* technological) hazards and magnifies natural hazards such as flooding. Indeed, soil sealing as a result of urbanisation increases runoff and restricts infiltration. Heavy rainfall results in storm water flooding locally, and generally an increase in downstream water flow that can induce further floods caused by rivers overflowing. The economic cost is already very high and will probably reach 100 billion euros a year globally by the

1 www.floodresiliencegroup.org
2 This concept of actor has been used in various sociological papers. It is used here to express the desire to include (human) actors and technical systems within the same analysis.

end of the century (EEA, 2008; EEA, 2012). It is estimated that almost 75% of damages occur in urban areas (Ashley *et al.*, 2007). Insurance systems are evolving so as to limit increases.

In view of these challenges, it appears that an approach of increasing urban density would help to generate greater energy efficiency, reduce mobility-related environmental costs, and preserve outlying agricultural land. While urban spread generates overall risks (significant CO_2 impact) and local ones (runoff), a move towards dense and compact cities will necessarily lead to an exploration of the building capcities of urban areas that are subjected to natural hazards, in particular flood-prone areas[3].

Urbanisation, like climate change, has generated uncertainties in risk assessment. At present, experts from the International Panel on Climate Change (IPCC, 2007) propose several scenarios for climate change, all of which predict an impact on the frequency and amount of rainfall. More severe droughts will alternate with heavier rainfall (Lamarre, 2008). These droughts could have a direct impact on floods by reducing soil infiltration. Heavier rainfall on less permeable soil diminishes the response time of watersheds, thus increasing the risk of flooding. Floods caused by higher sea levels are also to be feared. Climate change combined with the concentration of goods and people in urban areas foreshadows devastating events in the coming years. Yet the uncertainties linked to data reliability and availability are such that currently, the results generated by mathematical models cannot be considered reliable (Barroca, 2006). In such a context, how can risk be efficiently managed, flood forecast models be produced, and flood protection structures be sized?

The economic, urban and climate situation, as well as the increasingly fragile situation of society faced with natural hazards, highlight the need to develop new flood risk management strategies. The increasing number of disasters and victims reveals the failure of over five decades of disaster control (Gaillard *et al.*, 2010). New strategies will have to be developed to anticipate flood scenarios that probabilistic models deem at present to be extreme or rare (Zevenbergen *et al.*, 2011). This also implies setting those strategies in a long-term sustainable development context where societies will have to learn to live with natural disasters within their local area and above all learn to recover from them (Sanseverino-Godfrin, 2009 ; Lallau, 2011).

3. IMPORTANCE OF URBAN TECHNICAL SYSTEMS IN RISK MANAGEMENT

Although urban development must give preference to compactness, the growing dependency of cities on urban technical systems implies special forms of urbanisation that have given rise to the term "reticular" in the field of urban planning (Dupuy, 1991). Spatially, contemporary cities no longer have functional continuity. They depend heavily on urban technical systems, which create a spatial organisation within the region. Invisible links to urban systems guide urban development without fully constraining it. Technical systems can be defined on the basis of services rendered, organisation (functional aspects), and infrastructure (physical aspects, equipment, and whatever means are necessary to render services) (Blancher, 1998). Thus, public transport, supply systems for electricity, gas, telephone, fibre optics, district heating and waste management are technical systems. They are usually described as complex because of their interdependency (Toubin *et al.*, 2012b).

The analysis of feedback from cities damaged by floods shows both the dependency of urban operation on technical systems and the dissemination of the effects of flooding through those same systems. A study of urban technical systems under constraint (natural and/or technological hazards) shows they are intrinsically vulnerable and that their malfunction increases the vulnerability of the region (Felts, 2005; Vigneron *et al.*, 2006).

The high dependence of a city on its technical systems means they have huge importance in risk dissemination. Technical systems have already been identified as key to improving city resilience (Lhomme *et al.*, 2010). They behave as propagators of malfunctions both because of their geographical extent and their interdependency (Lhomme *et al.*, 2013a) while at the same time they are essential for reconstruction (Felts, 2005). They are the city's "nervous system" in which the slightest breakdown can have knock-on effects for urban operation (Robert & Morabito, 2009).

The most indispensable services are described as essential or critical (Robert & Morabito, 2009; Barthélémy *et al.*, 2011). Analysis of such critical urban technical systems is based on two linked concepts:

- The concept of critical (essential, vital) infrastructure: an infrastructure can be defined as a set of facilities ensuring services necessary for a city to operate (ASCE, 2009). It is deemed critical if its failure threatens the safety, economy, lifestyle and public health of a city, a region, or even a state. These critical infrastructures are specific in that they go beyond geographical, political, cultural and organisational boundaries (Boin & McConnell, 2007).
- The concept of system interdependency: most critical infrastructures interact. Yet this interaction is often complex and poorly known understood because it goes beyond the boundaries of the system in question. Analysing interdependencies requires a change of scale in order to analyse first the components of a system (fine scale), then the links between systems (wider scale). Various studies on critical infrastructure vulnerability can be called upon (Petit, 2009). The most representative are certainly those of Benoit Robert (Robert & Morabito, 2009; Robert *et al.*, 2009). His work, based on actual cases in Montreal, shows the series of failures engendered by the temporary stoppage of part of a technical system (Robert & Hémond, 2012).

3 In France, in spite of stringent building regulations in flood-prone areas, land pressure has led to the erection of housing, and office and business premises. For instance, the Val-de-Marne Department in the outskirts of Paris has a high housing construction rate in flood-prone areas (over 8 000 housing units were built between 1999 and 2006).

4. COGNITIVE RESILIENCE, KNOWING RISK IN ALL ITS DIMENSIONS

In order to draw up regional strategies for resilience, it is necessary to characterise the needs of regions during or after crises on different spatial scales and on the basis of actual situations. In this approach, networks and flows need to be considered and analysed in assessment methodologies by drawing on local population knowledge and local actors' experiences. *Cognitive resilience* refers to all processes relating to knowledge, such as the memory and learning of risk. It also expresses the processes of identification, acquisition and processing of information, such as reasoning, memory, and decision-making, as well as more elementary processes such as the perception of risk, or the attention paid to it (Wisner *et al.*, 2004). Without being exhaustive, these processes facilitate organisational or operational flexibility, coordination, partnerships, identification of vital networks (water, electricity, communications and actors) in terms of operation and interdependency, as well as innovation, autonomy and anticipation capacities (adaptation and capacity to rebound).

This cognitive dimension goes beyond "human cognition" and refers to risk identification and evaluation of resilience factors, as well as the methods and tools that can be used to measure them. This defines the capacity of the service to know the needs of the urban system and the influence it will have on the technical systems during and after the crisis, and even the mutual influences and needs of the technical systems themselves. There are experimental attempts to establish a dialogue between the actors of the various technical systems in order to map their dependencies (Toubin *et al.*, 2012a).

If the services are identified as vital for society and therefore must operate reliably (which managers can usually do independently from each other), interdependencies between technical systems quickly appear as critical. This is because functional interdependencies (*e.g.* the transport network uses the telecommunication network to manage traffic which in turn uses the electricity network) does not necessarily mean there is cooperation between the many different managers involved (Toubin *et al.*, 2012b). Actors report inadequacies and discrepancies between, for example, model outcomes and actual situations, or between the scales of available data and tools they are supposed to provide.

Consider the example of flood-produced waste management. In addition to safety and public health issues, disposing of this waste is an issue for overall post-crisis management and a return to normal. It is in fact the very first stage of a return to normal so as to hand the region back to its occupants and its activities. It is essential for human safety, in particular by ensuring free movement first of rescue services and authorities, then of local people. Newly produced waste considerably increases urban system demand on waste management services. In such a case, downgraded or normal operation is impossible due to the huge quantities of waste[4] involved, and the fact that the waste can be wet, polluted and no longer adapted to treatment methods. In order to anticipate, organise and plan post-flood waste management, it would seem that estimating the quantity and nature of the waste produced is a prerequisite on several levels. This step is necessary to determine the material and human resources required, the partnerships to establish, and the spaces to make available so as to provide an adapted response that respects the environment and human health.

Estimating waste production helps to raise political awareness of the issue, which is all too often poorly known and therefore overlooked by the authorities. Without quantitative data, the problem can seem abstract and it is difficult to understand its importance. Making it clear that, on the one hand, a region may have to confront several years worth of waste (some of which may impact the environment and have short, medium, or long term effects on health and safety), and, on the other hand, that inadequate anticipation of how to manage such a quantity of waste could threaten the economic activity of a region for several years (as in New Orleans following the flood caused by Hurricane Katrina in 2005), can help to mobilise decision-makers about the issue (CEPRI, 2013).

Apart from the financial cost, representing a little over 25% of the total cost of regional recovery (FEMA, 2007), anticipating and planning post-flood waste management is a major aspect of resilience. Lack of knowledge, information and awareness of actors on this subject is at present the major hindrance to the setting up of resilience strategies (Beraud, 2013).

5. FUNCTIONAL RESILIENCE AS THE CAPACITY TO MAINTAIN CRITICAL INFRASTRUCTURE IN SERVICE.

There are different methods for assessing the reliability of a technical system and a critical infrastructure in order to manage urban risks. These methods focus on both the relationships between the infrastructures (which are strongly interdependent) and their relationships with the elements of their local environment. There are methods for analysing physical and statistical (mathematical) risks according to experts, and others arising from Operational Safety (UNIT, 2014). Just like physical approaches, Operational Safety is an internal method, in that it is based on a thorough knowledge of the system under study (Serre *et al.*, 2008). Physical modelling of the continuous or discrete system degradation processes is based on equations that govern internal phenomena. Operational Safety modelling is based on the principle of functional modelling, and consists in determining the interactions between the components of a system and its environment so as to formally establish the links between functional failures, their causes and effects (Gervais *et al.*, 2011).

4 In 2002, in Prague 270 000 tonnes of waste were produced, and their disposal took eleven months. In Dresden that same year, production was equivalent to three years of collection. Following the storm Xynthia in 2010, waste production was equivalent to twelve "normal years" for the towns of La Faute sur Mer and L'Aiguillon sur Mer.

Using these methods to analyse failure scenarios and model interdependency processes between complex systems yields relevant results. However, while these methods generally apply to complex systems, they do not necessarily apply to systems of complex systems, *i.e.* strongly interdependent systems. Using a combination of methods stemming from Operational Safety, it is possible to model failure scenarios for systems of complex systems by analysing each system more or less independently of the others (Lhomme *et al.*, 2011). First, the principle involves considering the various infrastructures as part of a single system, and carrying out a general external functional analysis. In a second stage, an internal functional analysis is carried out for each critical infrastructure and operational safety methods are used. Some promising recent studies (Serre, 2011) have made use of Failure Modes and Effects Analysis (FMEA), which is an inductive analysis method of potential system failures that considers each component of the system and analyses its failure modes. It is based on the systematic listing and assessment of potential error risks that may occur at all stages of system operation. Its output is a table which, for each component, establishes the causes and effects of the component's disruption. FMEA was adapted to various civil engineering fields in the late nineties (Serre *et al.*, 2007).

Functional Analysis and FMEA have been applied for all urban technical systems, and at this stage completing Functional Analysis and FMEA using a spatial approach seems relevant for applying the concept of resilience (Lhomme *et al.*, 2010). This application deals with the reliability of critical infrastructure on three levels: overall connectivity of the network, component resistance, and the capacity of the technical system to operate in downgraded modes that do not lead to total breakdown of the service it provides. Maintaining the functioning of the most important infrastructures is known as *functional resilience*. Functional resilience is implemented by working on reliability, increased redundancy and risk-related stock management. Making structures reliable implies overprotecting them compared to normal situations. Stock management generally involves creating temporary or permanent storage facilities as close as possible to the place of use. Finally, redundancy relates to surplus: in a network, it is measured by the capacity to find different pathways[5] or to use several action modes for the same service.

6. CORRELATIVE RESILIENCE AS A TENDENCY TO ADAPT NEEDS TO SERVICE CAPACITY.

Because crises are rare and difficult to predict, it can be difficult to raise the funds required for technical system adaptation. This generally leads to under-adaptation, and increased costs when crises do occur. Yet other approaches that do not derive from Operational Safety have appeared and throw new light on how to plan risk management for technical systems. These approaches are based on identifying and analyzing climate change adaptation strategies. Various methods are being introduced in practice to support resilience-oriented implementation. The most interesting one, because it goes beyond mere observation and provides operational guidance, is called Adaptation Tipping Points (ATP) (Kwadijk *et al.*, 2010). This method was applied to the case study of an existing technical system (rainwater disposal) in Wielwijk on the outskirts of Dordrecht (Netherlands) (Gersonius, 2012). First, the method assesses planned risk management strategies to find out whether they will still be efficient in future, more demanding, conditions. The ATP method helps to determine both the time point at which the extent of climate change is such that strategies will become inoperative, and the role and functions of the system under consideration as well as the acceptable degradation level. The ATPs are identified at the end of this stage. If technical system performance becomes unacceptable, it is necessary to change strategies and take adaptation measures. At that stage, various structural and non-structural options must be proposed and assessed.

It is then necessary to engage with all the stakeholders in order to select a realistic and acceptable adaptation strategy. The implementation of the strategy must change the nature and timetable of the critical ATPs. If efficient strategies are too costly or unacceptable for society and/or the environment, the acceptable level of risk must be reworked and changed.

The iterative part required to implement realistic and shared solutions reflects a reversal of the conventional approach to risk management, since the most innovative side of the ATP method lies not so much in establishing a link between the boundary conditions of the technical system – changes in the hazard and use dependency of the technical system – as in changes in the level of acceptability. ATPs express the search for a link between the risk of technical system service reduction or stoppage and acceptability of the reduction. There is recognition that service and use form a single set whose parts are in mutual correspondence. None of the parts can change without the others also changing: technical system resilience is possible when correlation between service and use remains acceptable throughout the risk period.

7. ORGANISATIONAL RESILIENCE AS A MEASURE TO ADAPT TO A CRISIS, AND PROMOTE ABSORPTION AND POST-CRISIS RECOVERY

Apart from adapting infrastructures and buildings (functional resilience) and adapting needs to service capacity (*correlative resilience*), each disturbance also reveals the capacity of the regional organisation to cope with them. Even when organisation is taken into account, for instance in service continuity plans, it generally remains internal to the service or the company. To our knowledge, there is no method providing flexible response capacities to express the resilience of a technical system as regards its regional organisation. A study of the bibliography specific to risk geography has not uncovered a theoretical framework that defines precisely this form of re-

5 There can be various redundancy indicators, some developed to assess the vulnerability of technical systems to flood risks (Lhomme *et al.*, 2011).

silience. However, most studies discuss resilience in relation to the concepts of absorption or recovery[6] (Campanella, 2006; Hernandez, 2009). This capacity of regional organisations to promote post-damage recovery also applies to technical systems. Various cases could be presented, but the experience of Storm Xynthia that hit France on 27th February 2010 is a good example.

Xynthia was caused by a low pressure system with severe winds blowing at about 160km/h that hit Europe between 26th February and 1st March 2010. This coincided with a tidal coefficient[7] of 102, and flooding ensued, particularly in various French coastal areas in the Charente Maritime, Vendée and Côtes d'Armor. Human casualties were high, with 65 people dying in Europe, including 53 in France. French coasts were severely damaged, at an estimated cost of €457m in public expenses and of €690m for insurance companies (Migaud & Bertrand, 2012).

During the storm, the equivalent of twelve years of waste production[8] was generated overnight in the towns of La Faute-sur-Mer and L'Aiguillon-sur-Mer. The municipalities responsible for household waste collection and the waste treatment syndicate (Trivalis) had to deal with this new and exceptionally large production while attempting to continue treating "normal" waste. Measures adapted to the situation were put in place. This capacity to respond can be explained by a combination of several factors, basically linked to waste management, regional organisation and the capacity to call on support from outside the sector. On the one hand, the area covered by the Trivalis waste treatment syndicate includes the Vendée Department. On the other hand, only the towns of La Faute-sur-Mer and L'Aiguillon-sur-Mer were severely hit by the storm (Beraud *et al.*, 2013).

This meant the significant resources Trivalis could call on at Departmental level considerably boosted waste management and limited its impact on the towns. The availability of Trivalis staff and equipment also meant the region benefited from guidance that enhanced solidarity between local actors (businesses, farmers, *etc.*) and neighbouring towns. Finally, it should be noted that few management infrastructures (particularly for treatment) were affected.

However, although the waste management system was capable of recovering rapidly from the Xynthia-induced flooding, there is no certainty that it would be the same if flooding affected a larger area[9]. If the number of stricken towns had been greater, resources would have been more scattered and certainly less efficient. Managing the event was facilitated by the fact that the disruption only affected a fairly limited area within the region covered by the household waste treatment syndicate. Its capacity to respond and adapt was therefore all the easier. It was the strong capacity of all the stakeholders to mobilise and coordinate on a larger regional level that generated the *organisational resilience* of the waste management system for the towns involved.

Organisational resilience expresses the capacity for local conditions or local regions to mobilise general conditions or larger regions. This solidarity between levels is also a major factor of resilience that is generally reflected in the absorption and recovery dimensions of resilience.

8. DEVELOPING A CONCEPTUAL RESILIENCE MODEL: "BEHIND THE BARRIERS CONCEPTUAL MODEL".

Resilience, a concept borrowed from other disciplines (Lhomme *et al.*, 2010), places risk management within a dynamic approach focused on adaptation. This represents a shift in the way risk management has been approached within urban engineering. Present management is based essentially on a static view relying generally on Operational Safety, whereas what is now needed is a move towards integrating information about the whole risk timeline in terms of prevention, crisis, and post-crisis. Regional organisation and integrating malfunctions are also major elements of organisational resilience. The research we carried out, primarily on the subject of urban resilience to flood risks, shows that the concept of resilience combines four complementary criteria: cognitive resilience, functional resilience, correlative resilience, and organisational resilience. This view, stemming from an analysis of various methods and experiments, can be represented in the form of a schematic model (Figure 1).

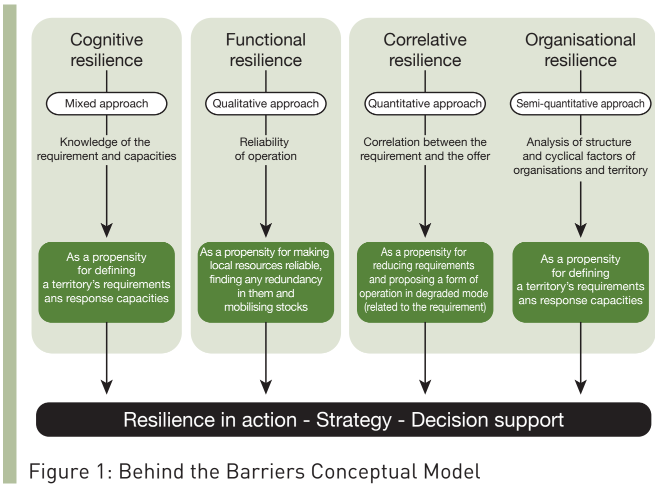

Figure 1: Behind the Barriers Conceptual Model

A model is an abstraction that simplifies the actual system under study (Coquillard & Hill, 1997). The conceptual model represents a generalised view of urban resilience. It incorporates information from numerous sources, often linked to the specific risk of flooding in urban areas.

The conceptual model proposed here includes the technical

6 This can be difficult to understand when applied to urban areas (see: Campanella, 2006) where recovery must be distinguished from rebuilding.

7 The tidal coefficient is the difference in height between consecutive high and low tides; excluding meteorological effects, the highest possible tidal coefficient is 118.

8 *i.e.* about 7 000 tonnes of waste in the two towns (Robin des Bois, 2010).

9 Note that in the exceptional situation of the flooding caused by Katrina in 2005 in New Orleans, post-disaster waste was still partly visible in 2012 in the form of heaps.

system under study, urban dependence on the system, participants' knowledge, and regional organisation. It provides information on the methods or principles helping to achieve a result and therefore supplies a conceptual framework to implement a resilience strategy. It does not define the technology or actions required to implement the established strategy, since they depend on context and therefore tend to change, but it does represent the global structure of urban resilience.

Such a model has several aims:

- conveying a common conceptualisation, providing references for mediation, exchanges, and description;
- helping to develop a framework for analysis of the relevance of existing rules;
- helping guide resilience strategies.

Even though the terms cognitive resilience, functional resilience and organisational resilience may appear in other fields, using this conceptual model outside the field of urban areas and technical systems cannot be done without specific studies to determine its validity and relevance. Its scope, however, extends beyond the specific risk of flooding. The development of the conceptual model and the analysis of technical system resilience in this article are not based on the specific flood degradation mode. The elements remain valid for any risk affecting large areas that entails an attack on large parts of a network, such as earthquakes, storms, landslides, avalanches, technological hazards, *etc*.. The model will have to be tested for other risks, such as prolonged droughts, forest fires, terrorism, insect infestation, transport of hazardous materials, epidemics, *etc*..

9. CONCLUSION

Two major advances should be recalled when asserting that resilience is a key component of risk mitigation objectives. One is conceptual: over the last two decades natural hazard analysis, traditionally focused on uncertainty and vulnerability, has extended to the concept of resilience, marking a major epistemological change. The second one, consequently, is methodological: moving from a restrictive quantitative techno-centered view of vulnerability to one that includes systemic aspects, integrating technical system approaches that are qualitative, "socio-centered" and semi-quantitative.

It is difficult today, however, to apply the concept of resilience to urban planning, since it is essentially concerned with the design of so-called resilient buildings. When a so-called "resilient" approach is applied to technical systems, it is usually highly restrictive and strives to achieve reliability by adopting service continuity objectives. One of the reasons for this restrictive view of resilience in the context of technical systems is certainly linked to governance that separates the development and management of each technical system. Considering the links between technical systems, urban morphology, and participants is certainly an avenue to explore. Resilience then takes on a new dimension, and simultaneously becomes synonymous with:

- knowledge of risk, culture of risk;
- reliability of critical infrastructures, generally opposed to the concept of vulnerability;
- integrated management of resources and adaptation capacities deployable during the crisis in order to compensate for dysfunctions of usual services;
- the capacity to adapt service needs to the ability of technical services to meet them;
- post-event recovery and rebound.

To fulfill these objectives, resilience must work through measures applied at different spatial and temporal scales (Serre *et al.*, 2013). The challenge is to prepare the existing city for risks and to design new districts and new forms of urban planning with a view to future risk adaptation.

Preparing for risk and seeking resilience without the help of a conceptual model is possible: the numerous participants in the field of risk management are proof of it daily. However, preparing for risk doesn't only mean implementing prevention measures; what is required is an analysis of the most appropriate actions and knowing what attitudes to adopt in crisis and post-crisis contexts. Conceptual models help to structure participants' thinking and target or guide priority actions. They do not determine standard solutions. The diverse criteria listed in the model, and the multiplicity of possible answers, match the given objective of respecting the technical, urban, and regional context. The conceptual model is integrated in the shift in risk management paradigm that advocates to not simply combat the hazard, but rather to live with it by minimizing negative impacts (Pasche & Geisler, 2005). It describes a vision of resilience, particularly for urban technical systems, and can thus contribute to modernising urban engineering practices.

Some of the resilience strategies can be implemented in parallel with technical system maintenance cycles, as well as with urban changes and renewal (Zevenbergen, 2007; Veerbeek *et al.*, 2010). Resilience does however entail a cost if adaptation is included in urban dynamics; some studies show that this cost appears to be very low in the medium term (Van de Ven *et al.*, 2011).

Current experiments with the "Behind The Barriers Conceptual Model" in various studies and the debate within groups of young researchers are the first tests to validate the model and develop the formalism that facilitates its application. Approaching the concept of resilience through its "action" dimension is a must for numerous regions, but attention should be taken that the issue of strategy evaluation and sustainability is not forgotten (Lallau, 2011).

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