Analyzing Risk and Disaster in Megaurban Systems - Experiences from Mumbai and Jakarta

PETERS, Gerrit\(^a\), BUTSCH, Carsten\(^b\), KRACHEN, Franziska\(^c\), KRAAS, Frauke\(^d\), SRIDHARAN, Namperumal\(^e\), and MARFAI, Muh Aris\(^f\)

\(^a\) Institute of Geography, University of Cologne, Cologne, Germany, e-mail: gerrit.peters@uni-koeln.de
\(^b\) Institute of Geography, University of Cologne, Cologne, Germany, e-mail: butschc@uni-koeln.de
\(^c\) Institute of Geography, University of Cologne, Cologne, Germany, e-mail: franziska.krachten@uni-koeln.de
\(^d\) Institute of Geography, University of Cologne, Cologne, Germany, e-mail: f.kraas@uni-koeln.de
\(^e\) School for Planning and Architecture, Vijayawada, India, e-mail: dr.nsridharan@gmail.com
\(^f\) Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia, e-mail: arismarfai@gadjahmada.edu

Abstract – The inherent qualities of megacities call for specific risk analysis and specific strategies and capabilities in megaurban disaster management. As megaurbanization proceeds at a hitherto unprecedented pace, the vulnerability of the world’s largest metropolises and the risk accumulated in them is gradually being understood. However, megaurban risk and disaster management are yet to be developed and established as full-fledged concepts. Thus far, empirically based knowledge and tools are scarce. The framework we introduce allows for an analytical approach to megaurban risk and disaster based on a systemic understanding of megacities as complex adaptive systems (CAS). Implications of our conceptualization are discussed using findings of empirical research on flooding in Mumbai/India and Jakarta/Indonesia. The application of the framework illustrates its potential for an improved understanding of root causes and effects of megaurban risk and disaster, amplifying factors that increase the impact of megaurban disasters and secondary risks that occur in the aftermaths of megaurban disasters. At the same time the CAS-framework allows for identifying options available for dealing with risk and disasters.

Keywords – Risk, disaster, megacities, system analysis, Mumbai, Jakarta

1. Introduction

This paper discusses the added value of a systemic perspective on megaurban risk and disaster. We argue that megacities are not only characterized through their population size and spatial extension but also through a hitherto unknown level of complexity, which urges us to change our perspective in the context of megaurban risk analyses and disaster management. The paper starts with a brief outlook on current urbanization processes, the development of megacities and how these processes affect India and Indonesia. Then, common concepts of risk and disaster are discussed against the background of megaurbanization, aiming at identifying the specifics of megaurban risk and disaster beyond those arising from being localized in a megacity. Subsequently, a systems theory perspective on megaurbanization and megaurban risk and disaster is unfolded, which is expedient in understanding their complex nature. Arguing that megacities can be adequately captured as complex adaptive systems (CAS), key concepts and terminology of systems theory are transferred to the disaster context. Findings of empirical research on floods in Mumbai and Jakarta are used to exemplify these conceptual assumptions and to translate the analytical framework into real risk and disaster scenarios. The paper concludes by examining the potentials of a systemic approach for understanding megaurban risk and disaster and illustrating the benefits of this perspective for developing strategies toward increasing megaurban resilience.

2. Megaurbanization and Risk

The scale and complexity of urbanization in the 21st century are unprecedented in human history. The world’s urban population is predicted to grow from 3.9 billion in 2014 to 6.3 billion by 2050 (UNDESA, 2014: 20). This growth will almost entirely take place in the countries of the Global South, where the majority of megacities are and will be located. Their number is projected to increase from
28 in 2014 to 41 in 2030. Furthermore, in 2014, megacities were home to 12% of the world’s urban population (Ibid.: 13). In Asia, there are currently 14 megaurban agglomerations and in addition to that eight cities are expected to cross the threshold of ten million inhabitants by 2030 (Ibid.: 26).

India’s urbanization rate in 2014 was only 32%; however, three of its cities classify as megacities (Delhi 24.9 million, Mumbai 20.7 million, Kolkata 14.7 million) (Ibid.: 22, 26). Indonesia, with 50.7% of its population living in cities, has only one megacity, the DKI Jakarta (Daerah Khusus Ibukota/Special Capital Region) with 10.19 million inhabitants (Ibid.: 22, 26). This city is the center of Southeast Asia’s most populated urban agglomeration often referred to as Jabodetabek or Jabodetabekjur (an acronym derived from the names of the cities Jakarta, Bogor, Depok, Tangerang, Bekasi and Cianjur that have grown together), which is home to more than 28 million people (Badan Pusat Statistik, 2013).

Parallel to the rapid global urbanization, in the last decades a significant increase in fatalities and economic losses due to natural and socio-natural hazards has been registered worldwide (Kraas 2003). The main reasons for this increase are the growing number and vigor of extreme weather events and current urbanization dynamics. These dynamics have arisen because cities, which are often situated in disaster prone areas, have accumulated an increasing amount of capital and goods, resulting in increased damage per event on average (Swiss Re, 2013).

Urban agglomerations face different types of hazards, which can be categorized by the nature of the trigger event: natural, socio-natural, or human-induced. With regard to natural hazards (e.g. volcanic eruptions, earthquakes, tsunamis), out of the 23 existing megacities in 2011, nine showed a high exposure to one natural hazard, seven were highly exposed to two natural hazards and one megacity (Manila) was counted in the 3+ category (UNDESA, 2012). A comparable assessment of megacities with regard to their exposure to human-induced hazards (e.g. environmental degradation, resource shortages, financial crises, technological failure, terrorism, ideological conflicts) poses a more difficult analytical approach and has, to our knowledge, not been undertaken (and of course, any analyses of human-induced hazards would be short-lived in comparison to those of natural hazards). Nevertheless, it can be assumed that high functionality, concentration, density, (global) interconnectedness and other scale factors characterizing megacities increase the probability of a disaster occurring. The term socio-natural hazard, which describes “the circumstances where human activity is increasing the occurrence of certain hazards beyond their natural probabilities” (UNISDR, 2009: 27), is particularly relevant in megaurban settings, where the natural environment is largely overlaid by a human-made landscape.

While distinguishing between different types of hazards on the basis of their origin proves reasonable, it hardly makes sense for disasters (Wischer, 2007; Felgentreff and Glade, 2008). Therefore, in this context, the term “natural disaster” is rejected (Felgentreff and Glade, 2008) and should be replaced by the term “Zivilisationsfolgekatastrophe” (civilization-induced disaster; Kraas, 2012: 58). The latter term catches the rationale that every disaster is the result of the societal embedding in which the hazard occurs. Besides, as cities are specific witnesses of the inherent characteristic of each culture and civilization, the term emphasizes the socio-cultural urban context’s importance.

Risk in megacities of the Global South is not only determined by the megacity’s location in space resulting in a specific exposure to hazards (e.g. due to the proximity to coastlines or tectonic fault lines, climate zones etc.), but also – and even more significantly – determined by diverse social, political, economic, ecological and cultural processes, which interfere and influence each other. The scale and dynamism of these processes create challenges that often remain unmet: e.g., the provision of basic amenities such as safe drinking water, enough (quantity and composition of) food, adequate shelter, sanitation, reliable access, access to health care and education, not to mention emergency capacities for increasing and denser populations. Vulnerability differs between megacities in relation to their ability to meet these development challenges. Within megaurban populations, the internal gradient of vulnerability is closely related to socioeconomic disparities, with the poor usually being most vulnerable.

Yet, megaurban complexity opens up opportunities for coping with risk. The embedding in global networks, the accumulation of financial and other resources, and the often dominant position (economically, politically and culturally) of a megacity in the national, regional and even global contexts results in a concentration of power (and political will), allowing for coping with disasters quickly, at least on the surface. In addition, the diversification, deconcentration and strong interconnectedness of services in megacities constitute an important resilience factor. In our two case studies, which will be discussed in detail in section 4, flood events resulted in a severe disruption of the traffic and supply systems and the economy. Although these functions were restored quickly and the formal systems recovered fast, a closer look on the sub-local scale reveals that especially the poor suffered from the economic losses long after the direct effects (infrastructural damages, supply shortages, ill-health, etc.) had been dealt with. While on a systemic level megacities recover fast, certain subgroups (subsystems) may need much more time to reach their status ex ante or never do so. The disruption of the development paths of poor communities (e.g. through the loss of livelihoods and assets, poverty is perpetuated and the communities’ baseline vulnerability increased) in a long-term perspective also weakens the city as a whole, due to the connections within the urban system. Furthermore, megaurban complexity and embeddedness across scales raise the potential of aftermaths on a regional, national and even inter-

---

1 The paper employs the ten million threshold used by the United Nations (UNDESA 2014) to define megacities quantitatively.
national scale. When the hubs of global urbanism are disrupted by a natural, socio-natural or human-induced hazards along with high number of victims, loss of livelihoods, resources and (critical) infrastructure, the functional primary of megacities bears the potential for far-reaching effect. Thus, in megacities – the ambivalent pinacles of urbanization – the occurrence of a hazard can set off disasters of exceptional magnitude and complexity.

3. A Systemic Framework for Megaurban Risk and Disaster

Disasters are rarely simple cause and effect events; their genesis is usually complex. It is argued here that the interactions between various factors that turn an event or hazard into a disaster can be understood better if a system perspective is applied – especially in settings characterized by a high level of complexity. Additionally, this perspective allows for following up on the multiple consequences and especially the long-term aftermaths scales triggered by one event across scales (from local to global). In this section, an approach toward framing megacities from a system perspective is outlined and possibilities for translating this understanding to the megaurban risk and disaster context discussed.

First, the understanding of megacities as systems has to be clarified. Attempts to establish a general system theory date back to the 1940s (Wirth, 1979; Seiffert, 2003; Ratter and Treiling, 2008). The vision of the pioneers of system theory – von Bertalanffy and Wiener – was to develop a meta-theory of sciences beyond the dichotomy of natural and social sciences (Egner et al., 2008). Their ideas were quickly adopted in the scientific community. Several strands of system theories developed, though system theory did not become a meta-theory of all sciences, as hoped for initially. The various strands of system theory that have been developed over the last 70 years can be broadly categorized in three main levels of systemic understanding (Simon, 2006):

First level systems consist of a defined number of inanimate elements and – following the rules of thermodynamics – strive to reach an equilibrium state. Earlier attempts in modeling urban systems and most urban metabolism (Wolman, 1965) approaches refer to such a rather cybernetic system conception. Although these systems have become established concepts for analyzing flows of matter and energy in cities, they seldom adequately address institutional frameworks, the social dimension and relevance of the resource flows or the highly dynamic and changing nature of urban systems (Bohle, 1994).

Second level systems – complex systems – consist of inanimate and/or animate elements. They operate according to the three axioms of chaos-theory. 1) Their behavior is unforeseeable due to the high number of interlinkages and feedback-mechanisms. 2) As a result, minimal changes can trigger maximum changes. 3) These dynamic systems will produce patterns and organizational structures if the external influences (e.g. inflow of energy and matter) remain unchanged. Through self-organization, so-called dissipative systems can exist in a steady state far from thermodynamic equilibrium. This understanding of systems is, for example, the foundation of recent urban simulation models relying on methods such as cellular automata, agent-based models or network models (Batty, 2011; Portugali, 2011). Nevertheless, these models, trying to bring urban dynamics into simulations, miss the qualitative message of complexity theory for urban research. Implications of complexity for planning are ignored, and the role and the dynamics of civil society are not included in these types of models. By applying purely quantitative models, the explanatory potential of complexity theory for the organization of cities has been neglected; it has hardly been used to find qualitative approaches to understanding the urban (Portugali, 2011).

Third level systems produce the elements they consist of themselves (autopoiesis). These autopoietic systems, such as organisms, psychological systems or social systems, can consist of animate or inanimate elements. Parsons (1951) and Luhmann (1984) promoted this understanding of systems as entities demarcating boundaries towards their environment autonomously through self-reference and autopoiesis. Third level systems, hence, differ widely from level one and two systems as they are produced and reproduced only by their own elements. However, especially Luhmann’s system conception is rarely applied in urban analysis, as it focuses on social systems, making it difficult to incorporate non-social phenomena.

Researchers have applied system understandings of all three levels to analyze cities. From a disaster management perspective a second level understanding based on complexity theory seems to be best suited. As long as they are not reduced to quantitative models, conceiving megacities as complex adaptive systems (CAS), operating at the edge of chaos, offers a unique slant for understanding the megaurbanization-risk-disaster-nexus.

Kauffman (1990) points out that structures in CAS co-evolve. On the one hand, planners can guide this co-evolution, for example, by adapting to new technologies and new risks and reacting to changes in population size etc. However, on the other hand this co-evolution means that it is impossible to foresee all possible developments, as any element in the system can potentially – through different cascades – change the operating domain of the system as a whole. This panarchical perspective (panarchy being the antithesis to hierarchy) challenges for example top-down planning philosophies and directs our attention towards tipping points, path dependencies and the possibility of different potential temporary equilibrium states.

In the following section, the CAS understanding is transported to the disaster context. The widely acknowledged UNISDR (2009) definition of "disaster" then means the disruption of a temporary steady state of the CAS to an extent that makes external help necessary. Such a disruption can occur as a system disaster (disturbing the entire city, which to our knowledge so far never occurred in a megacity) or as a subsystem disaster (affecting either functional subsystems such as traffic, electricity grid etc. in the whole city or all functional subsystems in a spa-
Figure 1: Analytic framework for megaurban risk and disaster

Figure 1 visualizes our transfer of system thinking into the megaurban risk and disaster context. The upper part illustrates the configuration of megaurban risk, as related to risk governance. The disaster itself creates a new risk configuration, therefore, the lower part shows the potential aftermaths of a disaster, as a function of the effectiveness of disaster response.

The upper sphere in Figure 1 shows that megaurban risk, potentially resulting in a civilization-induced disaster, is constituted and augmented by complex-interwoven risk factors, either immediate or mediate (first-degree, second-degree, etc.). Immediate risk factors (IF) directly shape the conditions that turn a specific hazard into a disaster, e.g., a low capacity of storm water drains results in flooding during heavy rains. Mediate risk factors (MF) influence or constitute primary risk factors, e.g., pollution of storm water drains and their dilapidated state results in a reduction of their capacity. Sometimes these connections are more obvious, sometimes they are less obvious, and in many cases they take effect through a complex cascading path via different system elements. In this logic, shortcomings, such as of urban waste-management, can be seen as mediate risk factor for floods, as they may force communities or households to dispose of their waste in which ever way is feasible, for example, by dumping it in rivers, canals or drains. Thereby they unwillingly decrease the run-off capacity, thus elevating the risk of flooding. These configurations of different mediate risk factors and their interlinkages, constituting or adding to one immediate risk factor, are called here risk subcomplexes. The entirety of subcomplexes, immediate risk factors, amplifying factors and their configuration, determining one primary risk (PR) is called here risk complex.

Certainly one could deliberate extensively about the boundaries of these risk complexes in an open system.
Reality shows that causality of megaurban disasters can usually be traced back across multiple scales, pointing to meta-causes such as the north-south divide, distributional injustice, global environmental change etc. Nevertheless, to actually apply this concept on the ground, these meta-causes can only be regarded as external premises that cannot be influenced by local risk governance (at least not in the short run).

For effective risk governance, the analysis of risk complexes – instead of focusing exclusively on the immediate risk factors – is essential. Tracing these root causes not only requires a change in thinking but also the will (and the capacities) for substantial structural changes. In CAS, risks are often not constituted but amplified by unpredictable and unknown mediate risk factors or interlinkages. These unforeseeable factors are owed to the circumstance that in a complex system 1) one action can produce different results (behavioral complexity) and 2) the various consequences triggered through multiple connections by one action are hard to predict as not all connections are obvious and often they are indirect (‘butterfly effect’).

At the center of Figure 1 is the civilization-induced disaster, which marks in a generalized temporal perspective the turning point between risk governance and disaster response and recovery. The civilization-induced disaster can trigger 1) direct and indirect effects, 2) risk chains and 3) risk cascades. The immediate consequences (primary effects, PE) are determined by the type of hazard that triggered the disaster. These immediate effects can be increased through internal or external amplifiers (amplifying factors, AF) and through negative feedbacks. One amplifier for the disaster impact would be shortcomings in disaster response capacities. This was explicitly addressed by consulted disaster management professionals in the context of the nexus between megaurbanization and low probability/high consequence events that might affect large population numbers. Additionally, primary effects can directly lead to further, secondary, effects. A risk chain occurs, when the effects of a disaster constitute new hazards, i.e. secondary risk factors, which might also trigger secondary effects (SE) through direct linear pathways. These could then of course trigger tertiary risk factors (TF), tertiary effects (TE) and so on. Secondary risk factors can either be a direct consequence of the disaster, resulting from the interaction of different consequences of a disaster or be the product of direct effect interacting with pre-existing features. To illustrate this idea: following the destruction of buildings by an earthquake (hazard/trigger), traffic might collapse (SE), as the debris blocks roads, resulting in problems for disaster response, provision of first aid, potable water, food, etc. (TE). Risk cascades are similarly triggered but unfold through multiple and complex pathways in a non-linear fashion. They pose an enormous challenge for disaster response as they potentially can lead to a systemic crisis or multiple disasters and are difficult to predict and prevent. An example for a risk cascade is the array of events unleashed by the 2011 Tōhoku earthquake that hit Japan, causing a tsunami (SF) which resulted among other adversities in the Fukushima meltdown (TF) – a multiple disaster.

A CAS perspective seems to offer added value, especially for predicting potential harm from risk chains and risk cascades. It emphasizes that not only the primary effects need to be well-known and taken into consideration but also the multiple possible ways in which primary effects of a disaster can add to other risks and trigger further disastrous events. This perspective compels disaster managers to think holistically in order to learn and adapt for preventing crises. In the next section, this framework is applied in the analysis of past flooding events in Jakarta and Mumbai.

4. The Case Studies - Jakarta and Mumbai Floods

The empirical research of the two case studies of this paper was conducted in 2010. It referred to major flooding events both cities had experienced (Mumbai 2005, Jakarta 2007). Three research sites in Jakarta (Kebon Baru, Glodok and Muara Angke) and another three in Mumbai (Shastri Nagar, Vashinaka, Vakola/Ashok Nagar) served as examples for a vast number of flood-affected areas in the cities. In both cases, the approach was centered on the assessment of factors that configure the local risk complex and the disasters’ multiple effects for the studied neighborhoods, the cities as a whole and the changes in risk perception, risk management and disaster management following these events. Expert and in-depth interviews, surveys and a set of participative methods were conducted in the neighborhoods. Findings generated with these methods were triangulated in the analysis.

The pre-existing risk constellations of the two case studies were analyzed and the primary, secondary and tertiary risk factors for the flood event identified. This categorization of factors naturally has to be case specific, since the same factor, which is a primary factor for flooding (e.g. the dimension of storm-water drains) becomes a secondary factor (or tertiary factor and so forth) if the focus of the analysis shifts and health problems are the concern (e.g. this might contribute to mosquito breeding). In addition, the events’ concrete effects were analyzed.

4.1. Jakarta Floods

The most visible and publicly perceived risk in Jakarta is flooding. In the past, severe flood events, such as the 2007 event that is described in detail, used to occur about every five years. They resulted in vast areas of the megacity being flooded for days, sometimes weeks, bringing public life to a near standstill. In 2013 and 2014, severe flooding occurred in two successive years. Additionally, minor floods occurred several times a year, affecting especially socioeconomically weak communities that had developed on flood prone riverbanks.

The 2007 flood, spanning over roughly three weeks from January 31 until February 22, was until this date the most severe flood event the city had ever experienced. About two thirds of the city was flooded with water levels in some areas of up to four meters. More than 50 people lost their lives (WHO, 2007). According to estimates, 420000 people (Ibid.) had to leave their homes.
and were evacuated to emergency shelters in mosques, schools and other public buildings – not counting those who found shelter in relatives’ homes. Economic damages added up to about $967 million (Dartmouth Flood Observatory, 2008). Disaster management decisions taken during the flood proved to be highly politicized, as flood gates were opened to protect the government quarter, causing massive flooding in neighboring areas inhabited largely by socioeconomically disadvantaged communities.

Inundation and flooding have been a concern since the city – then known as Batavia – was founded under Dutch colonial rule, as records reaching back to 1619 illustrate (Cybriwsky and Ford, 2001; Zaenuddin, 2013). However, annual floods experienced by Jakarta during monsoon season (October - May), predominantly in January and February, today show a much more complex causation than those documented in historical accounts. During recent major flood events, the configuration of the risk complex has been very similar and the mediate risk factors are well known to experts and affected population groups alike: heavy monsoonal downpours (trigger/hazard) hit the city during a tidal high (IF). As large parts of the city lie below sea level, outflow capacities are reduced, resulting in inundation. This regularly occurring hazard turned into a disaster through cumulative effects of other factors: The drainage system could not absorb the amount of water, due to its dimensions and condition (IF). Severe pollution, siltation, channeling and narrowing of rivers, canals and drains through human activities decrease the capacities of existing drainage facilities considerably (MF1), and a lack of willingness to take responsibility among local population and government (MF2) was identified as a strong catalyst for the drainage system’s deterioration. Due to the area’s topography (MF1), with the DKI Jakarta spreading over the lowest elevation zone within the Jakarta Basin, run-off from the catchment areas of Jakarta’s 13 rivers is directed towards the city. Additionally the total run-off and the run-off peaks have increased due to a reduction of infiltration capacity: Rambant urban sprawl led to deforestation in large areas of Jakarta’s hinterland, loss of flood plains along rivers and land sealing on the slopes of the Jakarta basin; erosion, also due to deforestation, is leading to silting up of existing waterways (MF2). The run off is slowed down once it reaches the city, thus furthering the accumulation of water (IF), due to land reclamation in previous centuries (MF2). The city’s coastline has constantly been moved northbound, prolonging the course of waterways before they discharge into Jakarta Bay (MF1). The waterways downhill gradient and run-off rate is thereby decreased. Especially in the reclamation areas, land subsidence is a serious concern, increasing the exposure to local flooding. Groundwater extraction for providing water to an increasing residential and commercial demand and compaction of the soft soils and medium stiff soils found in the Jakarta Basin (Irsyam et al., 2008) by the buildings’ surcharge add to rapidly progressing land subsidence (MF1). Locally, subsidence rates of up to 32 cm per year have been registered (Abidin et al., 2009). The expanse of low-lying highly flood-prone areas is therefore constantly growing (IF).

Informal and non-registered settlements located on riverbanks – accounting for about 20% of Jakarta’s settled area at the time of the 2007 flood (Ooi, 2008) – add to the narrowing of waterways. However, not only the settlement activities of marginalized groups increase the risk of flooding (IF). It has been observed that the construction of prestigious upper and upper-middle class real estate on the coastline, for which the ground has been artificially raised as a mitigation measure, increased flooding in adjacent areas (IF).

Flood disasters such as the 2007 event happen in Jakarta when a combination of factors coincides and intensifies when amplifying factors unfold their impact. Once a certain threshold of flooding is crossed, the city’s narrow street pattern serves as such an amplifying factor: When flooded, the narrow alleys create dangerous whirlpools and undertows, frequently responsible for drowning, thus directly increasing the severity of direct effects. Additionally, this street pattern poses a challenge for effective risk governance since heavy search and rescue equipment or aid resources cannot reach the affected areas. Commonly only accessed by alleys of about 1-2 meter in width, much of the inner-city neighbourhoods (kampungs) stay inaccessible and thus isolated for days after flooding sets in. As the head of a red cross organization in Jakarta stated: "The emergency response system is in a wretched state. Probably the only way to do it, if it is even wanted here in Jakarta, would be by helicopter." Insufficient local disaster response capacities do not allow for preventing primary effects, risk cascades and risk chains.

While there are a large number of state-run and civil society organizations involved in disaster response in Jakarta, their coordination is often not sufficient and commonly not all flooded areas benefit from their efforts, as interviews with affected communities showed. Moreover, there is a discrepancy in many cases between the technical resources available and qualified personnel for their operation, which is often the limiting factor here.

Another aspect related to disaster management is the lack of confidence of the population in disaster management authorities: False tsunami warnings, raised by criminals in several riparian and coastal communities with the intent to rob abandoned homes, have created mistrust and reluctance to evacuate. This reluctance has been increased by experiences with looting (SE) during past flood events. Therefore male family members often stay behind to guard their homes, exposing themselves to considerable dangers. As a resident stated: "They evacuate children and women and the men guard their belongings by staying on the rooftops to keep burglars away".

Effects of the 2007 flood were manifold: The primary causes of death were drowning and – with even more incidents – electrocution (SE). Electrocutation during flooding occurs mostly as a result of illegal, makeshift tapping of power supply lines and due to delayed cutting of power supply lines by network operators. In this case, the direct effect (water logging) interacts with a pre-existing condition of the risk complex (deficits of the power supply infrastructure). Following the 2007 event, the number of infectious diseases (SE) rose, which was observed to happen
wherever floods last longer than two days (WHO, 2007). Due to the collapse of the water supply and sanitation (PE), the population suffered from water-borne diseases such as cholera, typhoid, dysentery, hepatitis and diarrhea (SE). Additionally, stagnant water served as a breeding ground for mosquitoes (SF). The population was therefore exposed to vector-borne diseases such as dengue hemorrhagic fever. Acute gastro-enteritis and dengue hemorrhagic fever were the two major causes of death. In addition, dermatitis and eye infections regularly occurred (SE).

Another secondary effect was the temporary loss of shelter for a large number of people. Temporary loss of livelihoods together with the costs of recovery put a substantial financial burden on affected families. Furthermore, prices for potable water and food prices increased steeply as vendors saw supply and demand shifting in their favor. In this situation, the affected families did not only lose their regular sources of supply but also had to indebted themselves to buy food basics. The closure of education and child care facilities required parents to look after their children themselves. This restricted at least one parent from going to work while children missed days or even weeks of curricula. With the vast majority of families in the selected study areas having no insurances at all, floods bring long-term economic impairment and perpetuating poverty (TE). Psychological effects as tertiary effects of flood disasters, especially on children, are often overlooked in assessments and are not properly addressed in response and recovery but were emphasized by almost all parents participating in the study. Emotional trauma and fear among children that the mass of water could return at any given time are hardly ever attended to in the wake of a flood (own interviews with experts and lay persons).

There are several large-scale infrastructure and policy measures that are being discussed (e.g. renaturation of the Ciliwung; construction of further flood canals; a proposed ban on plastic bags that strongly contribute to the clogging of the drainage system etc.), about to be initiated (e.g. the Jakarta Sea Wall Project, a large dam in the Jakarta Bay for lowering the sea level on the city’s coastline) or ongoing (e.g. early-warning systems monitoring water levels; planes equipped for weather modification, resettlement of riparian communities; dredging of waterways). The probability of flood disasters in Jakarta will increase until these measures unfold a positive impact. Until then, a substantial part of disaster preparedness, response and recovery will have to be borne by the affected population itself, as other past events have shown that governmental disaster response does not reach all areas in a timely and adequate manner, if at all. The informal institution of "gotong royong", a help system among neighbors that is rooted in Indonesia’s culture, is among the major assets of the megaurban CAS, since this form of self-organization adds to the city’s resilience. However, this traditional social capital is steadily being eroded in Jakarta, as the city’s society is growing more pluralistic and individualistic. A decrease in social cohesion, dividing society along ethnic, confessional and socio-economic lines, has been observed, adding to Jakarta’s overall risk: "Social sensitivity is actually a big value. So if you cannot have this self-help and co-helping with others it is going to be a major problem. Because a city can actually be resilient if it also depends on self-help of the population. It Jakarta is a melting pot. And it is really dynamic. It is very in-homogeneous. And there is a really wide gap between the haves and the have-nots. It’s gonna be a big problem", as a senior researcher of a national research institute explained.

Given the current rates of land subsidence, sea-level rise and annual flooding and the limited impact of measures taken after the 2007 flood, as reflected in the re-occurring of severe flooding in 2013 and 2014, numerous scholars have a bleak outlook: “In thirty years Jakarta will have become sea” a senior scientist at a national research agency stated.

4.2. Mumbai floods

Just like Jakarta, Mumbai is prone to annual flood events with some of the causes being similar to the situation in Jakarta. The monsoon climate brings cloudbursts during the rainy season (June to September), large areas of the city are land reclamation areas, with a low elevation above sea level and the city’s drainage system is insufficient. These factors result in annual flood events during which affected areas are flooded with depths between 0.5m and 1.5m (Gupta, 2009: 241). Primary effects are loss of property and among the secondary effects are health problems for a large proportion of the population. Malaria occurs because stagnant water provides ideal breeding ground for malaria-transmitting mosquitoes and diarrheal diseases arise due to contamination of fresh water by sewage entering the water supply through leakages (De Sherbinin et al., 2007). As in Jakarta, these small flood events pose severe challenges for the affected populations, but do not disturb the megaurban system as a whole, as it remains on a subsystem level. In July 2005, however, large parts of Mumbai were heavily struck for several days by a civilization-induced disaster. The trigger for the large-scale inundation was unusually heavy precipitation. A localized area of rainfall generated extreme rainfall values of 944 mm within 24 hours (Gupta, 2009: 240) which resulted in areal inundation of Mumbai (based on diverse sources between 20% (Government of Maharashtra, 2006a: 15) and 60% (Gupta, 2009: 243) were affected) with water levels up to three meters for more than 24 hours (Government of Maharashtra, 2006a; Gupta, 2009).

This hazard turned into a disaster due to the pre-existing risk complex which was constituted by following factors: Mumbai’s is on average located slightly above sea level, with substantial areas of the city also being located below sea-level (IF); the drainage during high flooding is insufficient (IF). Mediate factors are the high degree of sealed surfaces resulting in decreased infiltration capacity (MFI) and deforestation of mangrove forest (MFI), which served as natural flood-protection (Vijay et al., 2005). These factors are related to tertiary factors such as the steep population increase from migration during the last decades, which, because of lack of financial subsidiarity, resulted in lack of investment in a new and depilation
of the existing infrastructure (Gupta, 2009). The sewage network of the city for example dates back to colonial times and was designed for a much smaller population. Therefore the existing drainage system is forced to transport an ever-increasing amount of wastewater, eventually resulting in the loss of functionality (MF). In addition, in 2005, the canals were blocked by random waste disposal, which prohibited the water flow. The population increase has also led to permanent settlement in low-lying flood prone areas (IF) due to the scarce availability of land on the peninsula.

In the beginning of the 2005 civilization-induced disaster, a high tide acted as an amplifying factor because it reduced the already insufficient drainage capacity. An initial 4.48 m tidal wave washed additional seawater into the city’s canals. A second tidal wave aggravated the situation and the flooding increased, covering large areas (Government of Maharashtra, 2006a). Another amplifying factor was the lack of information about the situation. Weather forecasts predicted approximately 125 mm precipitation in the 24 hours prior to the event; the actual amount of precipitation exceeded the original forecast by 819 mm (Ibid.: 16). Since only two rainfall stations were available, this fact became apparent quite late (Gupta, 2009). Due to the areal flooding, the city’s functions collapsed almost completely. More than 200 road-kilometers were impassable for up to ten days (PE), which also greatly hindered first response- and later clean-up measures (SE) (Government of Maharashtra 2006a). The railroad network collapsed too (PE), resulting in 150000 people being unable to evacuate South-Mumbai (SE). This led to severe supply shortages on the peninsula, which was cut off from the mainland (SE) (Ibid.). The airport had to be shut down completely for two days because, in addition to the main terminal, the runways were flooded by the Mithi River (PE) (Ibid.). Disaster response was hindered (SE) by the collapse of the communication network (PE). Consequently, the military was involved in the evacuation (Ibid.).

The floods claimed 454 victims directly (Mumbai and Mumbai Railway; Government of Maharashtra, 2006b: 5) and – through the disastrous hygiene conditions (SE) – another 216 indirectly. The hygiene conditions were responsible for numerous illnesses resulting from contaminated water, water-borne pathogens and vectors (Government of Maharashtra, 2006a; Gupta, 2009). The extensive, long-term power-cuts disabled fresh water supply because they rendered the water pumps inoperable. Due to decreasing water pressure, wastewater contaminated the freshwater. This lack of fresh water also became apparent in the household surveys conducted in three affected areas: An average of 15.3% of the surveyed people stated that they did not have drinking water for more than one day, and 19% stated that they did not have electricity for more than one day.

Despite areal spraying of insecticides, a significant rise in malaria cases was reported as secondary effect. Due to the destruction of pharmaceutical storage facilities, the immediate distribution of medication to the population was insufficient. Long-term health-damages due to the release of cyanide, lead and zinc from illegal industrial companies are to be expected as well (TE) (Ellenrieder, 2006). Economic losses occurred due to the stock-market closure, the loss of earnings in the secondary and tertiary sector. Furthermore, damages to production facilities (TE) were extensive and not only limited to the city itself because of Mumbai’s high degree of functional and economic primacy: “If suppose Mumbai stands still for a day, ok. But catastrophic impact, you know, it creates a tremendous problem for the national GDP. And therefore, you know, any hazard or any disaster in the city is not affordable for the national GDP” (own expert interview).

However, the shortfalls of the municipal authorities’ disaster management were to some extent compensated by civil involvement in a remarkable manner (self-organization within the CAS). Experts and affected communities alike reported positively on neighborly aid during the flooding events: “So most people […] just walked home and then saw what all was in their house. You know you had one gunny-bag of rice. They just cooked the whole thing. As long as the gas lasted there. If they had two liters of milk they made tea, if they had dhal they just cooked it, if they had vegetables they cooked the whole thing. That within one hour, and then they just brought out what they had and then everyone on the roads, stuck, just ate from it. Protected each others properties” (own expert interview). Many interviewees believed that this “spirit of the Mumbaikars” significantly contributed to keeping negative consequences to a minimum and restoring essential functions quickly and efficiently. Real disaster relief took a long time, for example, it took four weeks to fully restore railroad traffic, the main artery of Mumbai.

Following the 2005 flood, several of the public authorities’ measures to prevent future flooding resulted in an alteration of the risk complex. In 2006, an automated early warning system with 30 rainfall-radar-stations, which, if necessary, can send automated messages to the responsible authorities, was set up (influencing the amplifying factor “lack of knowledge”). In an effort to prevent blockage of the waste water system, an extensive cleaning campaign is now conducted annually prior to the monsoon season (affecting the primary cause “insufficient drainage”). However, due to insufficient capacity of landfills, only 70% of the canals could be cleaned prior to the 2010 summer monsoon season (Hindustan Times, 22.05.2010). The decision-making competencies were reformed with the newly developed disaster management plan (DMP) in an effort to minimize response time in case of disaster. However, the lack of definition of competencies and the strong focus of the DMP on flooding still poses weaknesses in Mumbai’s disaster management capacities. Numerous technical measures were implemented (e.g. building flood protection walls and elevating roads), mobile pump stations were installed and emergency shelters established. The population also demonstrates increased awareness in handling risk situations, also because of training courses offered by the urban administration. In an effort to lower vulnerability to flooding, many citizens have implemented technical measures themselves in and around their houses (e.g. erect-
ing small dams and walls in front of the entrances to their houses, moving electrical lines and water lines to higher elevations or the roof).

Due to climate change, the monsoon precipitation is expected to increase and the sea level to rise by 32 – 63 cm (mean 47 cm) by the end of the century (IPCC AR 5 medium-high scenario RCP6 2007 – median scenario) (Revi, 2008; IPCC, 2013: 23). Especially the combination of heavy precipitation, tidal waves and consecutive storms constitutes an increased hazard for Mumbai. Whether the city is able to face this risk and the endangerment resulting from other hazards is largely dependent on the success of its resilience building.

5. Discussion

The application of the CAS concept for the analysis of the flood events in Mumbai and Jakarta illustrates the framework’s applicability and analytical value. It permits findings to be structured and underlying causes and not directly visible consequences to be identified. Flood events in both cities can be explained by the cumulative causation of various factors: monsoonal rains, their coastal location, densely populated low-lying areas, proneness to land subsidence and an overall highly artificial, human-made environment etc. However, these are not only found in megacities. Ethnic diversity, the mélange of actors and jurisdictions or socio-economic disparities can be found in smaller scale cities. However, all the aforementioned factors cannot only be considered to be more distinct in megacities but the multiplicity and simultaneousness of processes and feedback mechanisms in the wake of ramified actor constellations result in a hitherto unprecedented level of complexity. The case studies further show that during large-scale events the primacy of megacities bears another risk – the spatial concentration of resources. Response capacities and other resources (institutions, assets, experts; e.g., trauma surgeons, heavy machinery operators etc.) are typically stationed in or close to megacities, thus they might become affected or even rendered non-operational by the same disaster they are supposed to respond to.

Both case studies attest that megaurban populations in the wake of civilization-induced disaster face notable intra-urban disparities in risk exposure and vulnerability between communities. Disparities in coping capacities were also observed. Although capacities and resources for disaster prevention, mitigation and recovery are available, they are insufficient to cover all affected areas. During the floods in Mumbai and Jakarta, capacities were proven to be insufficient for blanket coverage. Thus, their allocation was a politicized decision, and the most vulnerable communities profited least or not at all. The vulnerability of these communities was thus perpetuated in the long run.

In contrast to these aspects, which point to the negative effects of megaurban size and complexity, the CAS-perspective also directs attention toward positive aspects. Self-organization processes such as social networks, informal solutions and private action add to megacity resilience. In both case studies, ad hoc self-organization for response measures by affected communities was a decisive momentum during past floods when formal structures failed. Another feature of CAS is the system’s capacity to learn from past events and adapt to or even anticipate changes. In both cities a number of measures were adopted after the events, increasing the cities’ overall resilience, even if not all measures adopted have the same impact. Learning is a central feature of CAS and because 1) megacities are a relatively young phenomenon, 2) the constellations between megacities differ significantly in some respects, and 3) experiences with large-scale megaurban disasters are fortunately still few learning and adaptation will remain a challenge.

When discussing increasing megaurban resilience, it becomes clear, that factors configuring the risk complex differ in their persistence and how easily they can be altered. While the narrow street pattern of Jakarta’s kampungs and Mumbai’s slum colonies or the dimensioning of the drainage systems can only be reconfigured with substantial investments, behavioral factors might prove to be more feasible starting points for resilience building. Reasoning and learning of the system can be achieved through knowledge dissemination and capacity building among the population. Additionally, the experiential knowledge of the population usually remains largely under-utilized as it cannot easily be connected to the scientific-technical knowledge on which disaster response managers usually rely. Therefore, community-activating and -involving actions are highly valuable tools in the risk governance and disaster management kit. Also small legislative actions based on learning, such as banning plastic bags, as in Dhaka/Bangladesh (Ahmed, 2005), to improve the run-off capacity of the drainage system, can have an important impact.

Planning process that ignore risks and are short-sited investments – for example in prestigious waterfront development in flood-prone areas – decrease resilience. Often these shortcomings are the result of path-dependencies, economic logics of profit maximization or a consequence of corruption, nepotism and kleptocratism. These underlying causes only have a mediate influence on civilization-induced disasters, but without them hazards could not unfold such a high potential as in the two case studies. Disaster management strategies, but also development strategies in general, therefore have to be reconsidered, accepting these realities and developing new approaches toward dealing with informality. Including these important social realities in megacities of low and middle income countries is a hitherto under-utilized resource for increasing the cities’ resilience.

Furthermore disaster management strategies have to acknowledge that complexity is a distinct feature of megaurban systems. Acknowledging this fact has two implications: 1) Risk assessment must not only be limited to the analysis of hazards but has to take secondary and tertiary factors into consideration, and disaster management has to develop an understanding of amplifying factors and consider potential secondary and tertiary effects. In doing this, negative cascading chains and cascades could be cut off at an early stage. 2) Risk minimization and disaster
management have to become a cross-cutting issue when planning of cities. This cross-sectional thinking is also important for the development of scenarios. These scenarios are needed both for risk chains and risk cascades prediction and for developing disaster response structures. Authorities are eager to be prepared for worst-case scenarios and to anticipate hazards and their effects, but events like Hurricane Katrina in 2005 or the 2011 Tōhoku earthquake revealed the limitations of imagination in worst-case scenario development. What was thought to be the worst-case was dwarfed by the devastation caused when multi-hazard risks culminated into multi-hazard disasters and the effects started cascading. Such “black swan” events (Taleb, 2007) are not only subjects of blockbuster movies but can easily become real life events. Therefore disaster managers have to imagine the unexpected in order to be able to create resilient response structures.

6. Outlook

Many studies on megacities have been undertaken without explicitly referring to their specific nature or aiming at understanding specific features of the megaurban. Yet, a coherent theoretical understanding of megacities has not been developed so far. The CAS perspective applied here might therefore be considered for further application in the future. The background provided by this specific branch of system theory could well strengthen the analytic depth of megacity research. Although megacities are considered to be global risk areas, so far no megacity has been affected by an utterly devastating disaster. However, extreme events occur unexpectedly and can unfold a high potential damage in megacities. As a result, resilience has officially become a guiding principle for the development of a number of megacities around the globe (e.g. Resilience Cities, Hyogo Framework etc.). Taking this rhetoric seriously would mean going beyond business as usual. Applying a CAS-perspective can potentially become a guideline for developing tailored resilience building measures:

- As a basis, up-to-date knowledge on the factors involved in risk complexes of local hazards is needed.
- Resilience building must not be limited to primary factors and effects of potential disasters but has to consider baseline vulnerabilities of the population at risk (accessibility of safe water, shelter, livelihoods, health status etc.).
- Building resilient megacities requires new approaches for combining experiential knowledge of the population with scientific-technical knowledge of planners and administrators.
- This knowledge then has to be translated into cross-sectoral tools and applied down to the household level.
- Consequently the development of participative planning methods, based on a redefined attitude towards informality, are required.
- International cooperation, especially city-to-city exchange can help to open up fresh perspectives and result in joint development of good practice.

Analyzing risk and disaster in megacities with complexity theory and a CAS-perspective might at first glance be daunting. Underlying causes of risk and disaster are deeply rooted and are beyond the control of urban managers, especially in the congested and underfinanced metropolises of the Global South. However, only ruthless analysis allows for identifying the options available for dealing with risk and disaster under the given circumstances. Strategies based on these findings then have to address the main problems with adequate time horizons. Finally, this perspective illustrates not only city governments’ limited room for maneuver but also the large and often under-utilized potential of the population at risk.

References


Swiss Re (2013): Mind the Risk – a global ranking of cities under threat from natural disasters, Zürich: Swiss Re.


Citation