Behavioral Aspects of Urban Resilience

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Abstract: The current discussion on urban resilience is dominated by infrastructural and technological considerations. Although behavioral reactions to extreme events very well impact the overall resilience of urban systems, they are not very well considered. In order to close this gap, we review relevant insights on human decision making and collective dynamics, and propose a framework for studying behavioral aspects in the context of urban resilience. We find that human decision making is often based on simple ‘heuristics’. Especially in emergency situations, e.g. during or in the aftermath of extreme events, simple decision making rules replace careful and rational assessment of different choice alternatives. However, collective reactions to extreme events are note only dependent on individual decisions, but are shaped by complex interactions of various system elements, including the natural and manmade environment, people’s interactions with the environment, and people’s interactions with each other. For a proper anticipation of possible collective reactions and their impact on urban systems, we suggest agent-based simulations which utilize decision making insights and interaction data gathered in experiments and in the field.

Key Words: Extreme events, Heuristics, Collective Irrationality

1. Introduction

Due to recent disasters like the magnitude 9.0 earthquake in 2011, which evoked a huge tsunami and a nuclear disaster in Japan, considerable interest in potential unknown risks such as ‘X-events’ has emerged. X-events are events with low probability, but huge impact [1]. By their very nature, these events are difficult to anticipate, and hence usually hit the unprepared. Possible X-events which we need to pay more attention to include, but are not limited to: The collapse of the internet, global pandemics, natural disasters, large-scale electricity black-Outs, which could be caused by natural extreme events or also by an electromagnetic pulse, and other unknown risks. Such extreme events are difficult to foresee and usually impossible to prevent. Therefore, achieving ‘resilience’ against these unexpected, large-scale shocks seems to be an unrealistic hope. However, a certain degree of anticipation of such risks is conceivable. Consequently, human-made systems can be designed in a way so that they are capable to recover from shocks - they can be made ‘resilient’, at least to a certain degree.

Resilience is a growing topic in various fields, both in academia and in practice. While many practically relevant initiatives focus on building up resilience for cities, regions or even larger systems [2],[3], researchers discuss and further develop the theoretical concept of resilience. Rooting back to material science and physics, the concept of resilience is studied in a variety of disciplines. These discussions are definitely controversial and lead to different theoretical concepts on the one hand and to various applications and empirical case studies on the other hand.

While technological and operational aspects of resilience have been widely discussed [4], little is known about behavioral reactions to X-events. Although infrastructural and technological measures can help dealing with a variety of shocks, behavioral reactions are of critical relevance when it comes to overcoming the consequences of extreme events, too 1.

Therefore the aim of this conceptual paper is to develop a framework for including human factors into the study of resilient urban systems. In our research we consequently aim to address these gaps. We explore aspects of already existing resilience concepts that are useful for approaching urban resilience in face of X-events, and we identify findings on decision making which should be considered and integrated into the discussion. We also propose a possible framework for studying behavioral aspects of urban resilience. Studying those behavioral aspects means rather considering the short-term perspective of urban resilience than focusing on the long-term learning processes. This does not imply that we are not aware of the fact that the concept of urban resilience contains more than the short term capacity of maintaining functions and structures [4] in case of emergency. Nevertheless we see strong arguments to shed light on those (short term) human factors.

The remainder of the paper is structured as follows. In section 2, we discuss the concept of urban resilience. We will argue that human factors are underrepresented in the discussion of urban resilience and often left aside. In section 3 we therefore systematically review relevant insights on human decision mak-

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1 A Scopus search (July 26, 2013) returned 67 papers for ‘urban resilience’, and 58% of these were published since 2012. A closer look reveals that, almost exclusively, the focus of the contributions is on planning issues and risk management. The journal Cities (ISSN 0264-2751) addressed the topic in a special issue (Volume 35, December 2013).
ing under uncertainty as well as on decision making based on heuristics. In section 4, we address collective irrationality and the threat such irrationalities might pose on urban resilience. Finally, we suggest a framework for studying behavioral reactions to X-events in the context of urban resilience and come up with conclusions and limitations.

2. Urban Resilience

Since Holling [5] introduced the term ‘resilience’ into the ecological literature, multiple meanings of the concept have appeared [6], [7]. Many research disciplines study this concept, e.g. management [8], [9], computer science and ICT [10], corporate emergency management [11], and psychology [12], [13]; just to name a few. As a result resilience and its characteristics are being understood differently.

Holling [5] states that “resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist”. This definition means that ecological resilience can be seen as the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures. But according to Gunderson [7] there are also other authors and scholars which consider resilience as a return time to a stable state following a perturbation. Following the line of Holling [5], more recent publications see resilience as a capacity of a system to absorb disturbances and still retain essentially the same function, structure, identity and feedbacks [14], no matter if there are short-term disturbances, or long-term societal or environmental changes [15]. Walker et al. argue that four attributes of resilience are critical, namely latitude, resistance, precariousness, and panarchy [14]. Particularly interesting for behavioral aspects of urban resilience is panarchy. Panarchy describes how the states and dynamics of systems at scales above and below influence the states and dynamics of the scale of interest [14]. This means that separated adaptive cycles are connected with each other [16]. According to Chelleri [4] the concept of panarchy in an urban setting could reflect the complex cross-scale effects between neighborhoods, suburbs and the metropolitan regions. Even more, the connectedness of adaptive cycles is also relevant for modeling human behavior and short term reactions in cases of X-events: For example, disruptive micro-level behavior can cause the collapse of higher level systems (e.g. the political system).

Although definitions of resilience differ across fields, and even within the same fields, there is general consensus on two important points [17]: First, resilience is rather an ability or process than an outcome, and second, resilience implies adaptability rather than stability. Therefore, the definition of resilience we consider most useful for our purposes is as follows: Resilience is “a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance.” [17]

Aiming at discussing and clarifying the idea of behavioral aspects in the concept of urban resilience, the individuals within a system should be considered. This is one facet of resilience which, up until now, has not been discussed intensively. According to Obst [18] social resilience can be seen as a capacity of actors to access capitals to cope with and adjust to adverse conditions but also to search for and to create options in dealing with a threat. With the idea of social resilience being a capacity of actors and not only being a capacity of systems, we can state that urban resilience is a matter of processes and structures of the system itself, but also an ability which is handmade. This goes in line with the social science perspective on resilience, explaining how human capabilities return to normalcy after absorbing stresses or surviving negative changes [19]. We consider resilience of an urban system being the availability of a city and its inhabitants to take meaningful collective action to absorb the impact of an X-event, and to move on in the aftermath of an X-event - a definition which is similar to one given in Pfefferbaum’s paper [20]. In case of large shocks, redundancy, diversity and adaptability are characteristics which are crucial for urban resilience [21].

As for resilience in urban settings, the focus has up to the present been placed on economic and infrastructural aspects: Economic development planning can increase regional economic resilience, especially in times of de-industrialization and raising unemployment rates [22]. Available urban resources can as well contribute to resilience, but often lie idle. For example, some cities have the potential to cover up to 100% of electricity demand with mainly decentralized urban resources² for the most part photovoltaic and wind); utilizing these resources more efficiently would decrease cities’ dependency on centralized, and often external, energy provision, and therefore most likely increase resilience [23], [24]. According to Campanella [25] there are also other factors that affect a city’s resilience, whereby some of these factors cannot be changed easily, like political and economic realities or planning aspects in urban spaces. But nevertheless, factors like evacuation and emergency management plans can help a city or an urban system to minimize the loss of life during a crisis and therefore boost a city’s resilience [25]. Beside the already mentioned economic and infrastructural aspects in times of crises, other elements of urban resilience should be considered as well: a) redundancy, which provides back up if the main system collapses, b) flexibility to accommodate uncertainty and to learn from mistakes, c) capacity to reorganize, independently from political set-up and finally d) capacity to learn; this capacity to learn encompasses aspects of unlearning past practices which obviously did not work, learning from other cities and within the city, and learning from other successful interventions [19]. From the scientific perspective, the research topics in urban resilience research still need more attraction [4]. According to the Resilience Alliance led by CSIRO [26], the relevant topics in urban resilience research are: metabolic flows (production, supply and consumption chains), governance networks (institutional structures and organizations), social dynamics (demographics, human capital and inequity), and built environment (ecosystem services in urban landscapes).

Concluding from the scientific discussions outlined in the previous paragraphs, we argue that, in addition to the already mentioned aspects, the following factors are vital for urban resilience in case of X-events: a) technology (e.g. available communication channels), b) preparedness and past experiences (e.g. collective experience with prior X-events), and c) human behavior and behavioral reactions to disturbances (influenced by e.g. learning effects and experience on individual level, or

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² These assessments were done for a Dutch case
cultural aspects). While the potential impact of external shocks on infrastructure [27] is well considered and attempts are being made to build in resilience into infrastructure systems [28], little is known about (short-term) behavioral reactions to extreme events, and collective behaviors in such emergency situations. While long-term aspects like reorganization, learning on a system level, and feedbacks are integrated, decisions of uncertainty and high complexity are not considered that much. Therefore, behavioral reactions in the context of urban resilience receive attention in this article.

3. The human ‘system component’

After all, behavior of people is crucial for the functioning of any human-operated system. Whether and to which degree an urban system is resilient in face of large-scale shocks ultimately depends on the behavioral reaction to this shock. Human behavior is always embedded in a specific environment; it is not rational, but habitual - and not always predictable. It usually is based on heuristics and simple rule of thumbs, and these decision making heuristics are well adapted to the environment - as long as this environment is stable and not subject to radical changes.

3.1 Decision making under uncertainty

The long-prevailing model of rational human decision making has been heavily challenged by studies in psychology, behavioral economics and neuroscience. Cognitive limitations simply do not allow for rational utility maximization, as the human brain has to economize on its scarce resources [29]. It operates in a highly energy efficient manner by neglecting substantial parts of available information. Choices involve, or are even dominated by an initial emotional evaluation [30]. Furthermore, the common sense of more information leading to better decisions is inaccurate. The processing capacity of the prefrontal cortex, the center of rational and deliberate thinking, is limited. It experiences not only a diminishing, but above all a negative feedback from an increase in available information [29].

Consequently, many human decisions are based on unconscious or automatic mechanisms, or on heuristics. “A heuristic is a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and or accurately than more complex methods” [31]. Heuristics might both be applied consciously or relied on unconsciously. Surprisingly, heuristics are very useful in many environments characterized by uncertainty, or information overload [32]. Gigerenzer et al.[33] introduced the notion of ‘ecological rationality’, referring to heuristics which are well adapted to the structure of the environment. ‘Homo heuristics’ [34] thus is able to explain human behavior much better than ‘homo economicus’ (the ideal model of rational, ego-centric and utility-maximizing man applied in neo-classical economics). Especially in emergency situations during or in the aftermath of an extreme event, heuristic decision making is of increased relevance, since time might be too scarce for a careful and rational assessment of different choice alternatives.

A number of useful and frequently applied heuristics have been explored in recent years; and based on the results human decision making eventually does not look as complicated as one might think. Very often human decision making is based on rather simple rule of thumbs, and not on Bayesian models or carefully undertaken cost-benefit calculations. Interestingly, simple decision making rules often yield better results than ‘sophisticated’ decision making processes [31]. Several simple decision making rules also apply to behavioral reactions to X-events in cities. For example, one good reason is often sufficient for making a particular decision (‘one-reason decision making’). Many people would already be willing to evacuate from home if there are rumors on a nuclear accident nearby. Others would only evacuate, if there is an official report plus instigation for evacuation. In both cases, one single factor determines the decision. Another example for heuristic decision making is recognition-based decisions. Humans usually prefer a choice they are already familiar with. When fleeing a fire in an unknown building, most people would try to retrace their steps to the entry they used to get into the building, instead of looking for the nearest emergency exit. Apart from that, trade-off heuristics are a popular strategy, i.e. spending equally much effort for each in a set of tasks, or allocating equally many resources for a set of operations. Most policy makers, as well as other decision makers, apply this strategy at one time or another.

All these heuristics mentioned can also be fed with social-information to a certain degree; e.g. the common emergency strategy ‘only flee, when others flee’ can be considered as a socially fed one-reason heuristic. Additionally, there are ‘social heuristics’, also referred to as ‘social intelligence’, since they often, but not always, yield preferable outcomes [35]. One example for that is imitation. People tend to imitate behavior of others, either successful behavior of single persons, or behavior of the majority. Social heuristics are of particular importance in urban emergency situations, for example when telecommunication means are out of order and people use other people as primary source of information. In such a context, social circle heuristics become important as well. The search for social information is primed by the social distance to other people, i.e. people who are closer in one’s social network are considered to be more reliable information sources[35].

3.2 Human cooperation strategies

Apart from that, cooperation is of particular interest in the context of urban resilience. Evidently, cooperation among people is absolutely necessary for overcoming the consequences of extreme events. Cooperation might even be crucial for survival in such situations. But under which circumstances do people cooperate with each other, and under which circumstances is cooperation lacking? Individualistic societies, where cooperation levels are low and people place much more weight on their own benefits than on the benefits of the group, consequently might face difficult challenges under extreme circumstances. In a variety of disciplines, the matter of human cooperation has been studied extensively and in a very systematic way. Especially experimental research yielded important insights which are of interest for behavioral reactions to X-events.

One main outcome is the observation that most humans have strong aspirations for reciprocity [36],[37], i.e. they apply ‘Tit
for Tat’, which can be considered as another social, and usually very efficient heuristic. Humans will behave cooperatively, if their counterparts do so, and will obey to social norms, if a majority of others does so. Consequently, people are more likely to help injured people, if already one other person is helping. Reciprocal cooperation also entails that a minority of non-compliers might induce wide-spread defection from prevailing norms [38].

Reciprocity has been playing a huge role throughout human evolution, since individual cooperativeness has been rewarded through mutual cooperation, and individual defection has been punished by mutual defection. Building up on extensive research, Nowak summarized five main mechanisms for the evolution of cooperation [39]. His systematization of cooperation strategies is very helpful when human behavior has to be abstracted and mapped to models. The discovered mechanisms mainly involve two characteristics - reciprocity and selection:

- Direct reciprocity: Repeated encounters increase probability for cooperation.
- Indirect reciprocity: A cooperative individual is more likely to receive help; cooperativeness is here based on reputation.
- Network reciprocity: Clusters of cooperators will out-compete clusters of defectors.
  - Item Kin selection: Genetic relatedness increases probability for cooperation.
- Group selection: Competition happens not only between individuals, but also between groups.

It has to be noted that globalization might shape societal perceptions [40], and that cultural differences in human cooperation have been studied as well [41],[42]. While some societies have strong social norms of cooperation (e.g. Northern European countries), cooperation levels are rather low in others (e.g. Southern Europe, Arabs). Notable differences regarding cooperation levels have also been detected in small scale societies around the globe [42]. Differences with regards to age (i.e. generation gap) and living environment (e.g. rural versus urban population) have to be considered as well. Last but not least, the ‘stakes of the game’ do matter [43]. Sometimes, the question whether to cooperate or not just determines the size of a monetary gain or loss. Sometimes, stakes are as high as loosing or saving one’s life.

To sum up, people often rely on simple rule of thumbs when making decisions - consciously or unconsciously. They usually will cooperate with cooperators, and they will flee, when others flee. They will stick to well-tested choices and they will help a relative before helping somebody else. And as a final point, people find themselves in an unfamiliar situation, they increasingly lose orientation to facts, and opinions replace to others replaces orientation to facts, and opinions replace knowledge [53]. Both factors - emotional arousal plus uncertainty - are fairly prominent in the aftermath of X-events.

Under two prerequisites, other-directedness becomes especially strong. The first factor is emotional arousal, which makes people more susceptible to psychological suggestion [52]. The second factor is uncertainty. If experience is lacking, and people find themselves in an unfamiliar situation, they increasingly use other people as the primary source of information. Orientation to others replaces orientation to facts, and opinions replace knowledge [53]. Both factors - emotional arousal plus uncertainty - are fairly prominent in the aftermath of X-events.

Furthermore, synchronization of thoughts and alignment of behavior [53],[54] are very common for mass behavior, resulting in a very particular ‘mass sentiment’, or a collective social mood, as for example Casti puts it [55]. Strong emotions, e.g. euphoria or fear, usually accompany this process, sometimes escalating towards irrational exuberance and disruptive mass behavior. Nonetheless it has to be noted that not every emergency situation is dominated by mass psychology and irrationality. Rational and cooperative behavior might occur as well, as also has been seen after the 2011 earthquake/tsunami in Japan. Table 2 summarizes mechanisms that are frequently observed in mass phenomena.

Moreover, in extreme cases collective irrationality is often reinforced by feedback loops, as shown in the Causal Loop Diagram depicted in Figure 1. Depending on their scale, unknown situations generate uncertainty and frequently, in further conse-
In extreme situations, many human attitudes are becoming irrelevant, and in general a decrease in heterogeneity of agents can be observed due to large-scale synchronization of thoughts and behaviors, as discussed in the previous section. Imitation of majority behavior, or of successful behavior, usually replaces independent thinking.

However, certain heterogeneity features will largely remain even in these cases, such as ethnicity (and xenophobia), self-control or leadership skills. A few character traits like social-mindedness are as well central in such situations; it for example matters whether somebody is ego-centric, social-minded or reciprocal; and how easily somebody is influenced by others. The 1923 earthquake in Kanto can also provide examples in this respect, as in some police stations chased migrants were protected against the mob, and in one case a high-ranked police officer publicly drank water from an allegedly poisoned well in order to calm down the heated atmosphere [56].

5. Towards a framework for studying behavioral aspects of urban resilience

Based on the discussion so far, we identify three interlinked elements that are crucial for studying behavioral aspects of urban resilience, namely environment, behavior of people, and interactions.

The first element is the natural and manmade environment, including a city’s infrastructure, available technology, geography, climatic conditions, etc., as well as possible vulnerabilities, plus the current situation. Usually, a lot is known about this element, and it is well considered in the overall discussion.

Eventually, most districts of New Orleans recovered from the X-event ‘Katrina’ despite manifold problems [25].
Considering publications on urban resilience, one could argue that there is a bias on this element. Urban resilience concepts focus on infrastructure, risk management and environment, and usually take a meta-level, i.e. system level, perspective.

The second element is decision making, respectively behavior of people. After decades of extensive research, quite a lot is known about human behavior. However, behavioral aspects are often not considered appropriately in discussions and analyses, as the review in section 2 indicated.

The third element is interactions, involving interactions between people and human-environment interactions. Behavior and environment are no static elements - they change over time and are shaped by interactions, and they themselves shape interactions. Interactions of people are heavily studied the growing field of in social network sciences. Network sciences made remarkable progress in recent years. Especially mobile phone and GPS data provide a huge database for the analysis of human interactions. Data on interactions can be also gathered via field experiments. Nonetheless, it should be considered that these interaction patterns might change in the immediate aftermath of extreme events, for example if the communication infrastructure is badly damaged.

However, even if these three elements are well-studied, the picture is incomplete. Urban systems are always complex systems with complex interconnections. As already Aristotle recognized, “the sum is more than the sum of its parts”\(^5\). In order to adequately integrate behavioral aspects into the study of urban resilience, a multi-level, holistic approach is required, which incorporates complex interconnections between single elements.

For this purpose, the utilization of agent-based modeling (ABM) appears promising. ABM is a simulation technique and a suitable method for closing the gap between micro-level data and interaction, and macro-level outcomes [58]. Simulation techniques are increasingly gaining relevance across social sciences [59], and ABM is a particularly useful technique, since it follows a bottom-up approach [60]. Behavior of individuals - so called ‘agents’ - is described on the micro-level, as well as the interactions of these agents with each other, and interactions of agents with the environment. Both, interactions and behaviors are dynamic elements which might change over time as a result of previous interactions or external influence. The effects which micro level interactions and behaviors possibly have on the macro level are explored via simulations. The available systematization of heuristics and cooperation strategies (see section 3) facilitates a realistic description of agent behavior, as for example in Schwenk et al.[61], and respective collective outcomes can be tested\(^5\).

Though, one word of caution has to be added. ABM is in general not very well-suited to provide concrete and accurate predictions. But it enhances the understanding for complex interconnections between micro and macro level [59], and aids analysis of collective behavioral dynamics. Thereby ABM is supposed to represent a useful tool for enriching scenario development, e.g. in order to show how different individual behavior traits generate different collective reactions to external shocks like X-events. Nevertheless, no definite statement can be made about the predictive power of single (agent-based) modeling scenarios. In our view, the main purpose of ABM is to point out possible collective reactions to large-scale disturbances.

Figure 2 illustrates this approach. Various data sources contribute to agent-based simulations, which aim at anticipating certain collective behavior patterns and behavioral reactions to X-events. The insights gained in this way are supposed to enrich the urban resilience discussion and consequently aid to mitigate the effect of disruptive mass behavior.

6. Concluding Remarks

Resilience in general involves the ability for adaptation after a disturbance, i.e. the ability to recover, the ability to return to a positive trajectory. However, this ability also depends on the scale of the disturbance, and there might be disturbances where recovery simply is not possible. Though, the concept of urban resilience

\(^5\) Although many decision making heuristics have been explored, it is not entirely clear, which heuristics humans are actually applying in which situations, and under which circumstances. Research attempts are addressing this challenge [63].
resilience helps to deal with possible consequences of X-events. Properties such as redundancy and adaptability cover various conceivable disturbances, but fail to address the human dimension. As we pointed out, the discussion of behavioral aspects so far is underrepresented despite undeniable relevance. We tried to address this gap and proposed a possible study framework.

The focus in this paper was placed on rather short term reactions which may have implications on long-term developments. The relevance of short-term behavioral reactions is directly grounded in one of the main resilience attributes, namely panarchy [16]. Panarchy describes how one level of a system is influenced by the states and dynamics of the system at the levels above and below. For the urban context the implication is as follows: If a system like a city is under pressure, e.g. by the impact of an X-event, its eventual collapse might be caused by a lower level of the system, e.g. the collective behavioral reaction of inhabitants. Therefore, we need to pay attention to this aspect. However, a longer term perspective on human aspects is necessary as well, involving, e.g. processes of learning and unlearning and adaptation. Moreover, we have to be aware that the two perspectives should be interconnected. The long-term perspective is depending on short-term individual behavior and short-term behavior to a certain degree depends on long-term learning processes and experience. Aspects such as technology, infrastructure, preparedness and past experiences affect both perspectives.

Without doubt, the complexity of the issue comes along with methodological challenges, which still need to be solved. ABM promises to be a useful tool, but its applicability to questions of urban resilience has still to be proved. Data on interaction patterns and behavior is available or can be collected, but mapping it to models is everything but trivial. Deriving practical lessons from the results and communicating them to decision makers is yet another story. The debate is just beginning.

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