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Resilience To Natural Hazards: How Useful Is This Concept?

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Abstract

Resilience is widely seen as a desirable system property in environmental management. This paper explores the concept of resilience to natural hazards, using weather-related hazards in coastal megacities as an example. The paper draws on the wide literature on megacities, coastal hazards and hazard risk reduction strategies and on resilience within environmental management. Some analysts define resilience as a system attribute, whilst others use it as an umbrella concept for a range of system attributes deemed desirable. These umbrella concepts have not been made operational to support planning or management. It is recommended that resilience only be used in a restricted sense to describe specific system attributes concerning (*i*) the amount of disturbance a system can absorb and still remain within the same state or domain of attraction and (*ii*) the degree to which the system is capable of self-organisation. The concept of adaptive capacity, which has emerged in the context of climate change, can then be adopted as the umbrella concept, where resilience will be one factor influencing adaptive capacity. This improvement to conceptual clarity would foster much-needed communication between the natural hazards and the climate change communities and, more importantly, offers greater potential in application, especially when attempting to move away from disaster recovery to hazard prediction, disaster prevention and preparedness.

1. Introduction

Some of the world's large cities have a long history of continuous occupancy and importance, although they have had to adjust continuously to changing circumstances. Cairo, Istanbul (Constantinople) and Baghdad began the second millennium as they ended it: amongst the world's largest cities. Other major cities in 1000 AD are now of relatively minor importance (*e.g.*, Kaifeng, China; Nishapur, Persia; Córdoba, Spain) or have even been abandoned (Angkor, Khmer Empire) (Harrison and Pearce, 2000). Without wishing to speculate about the causes of some cities' decline and other cities' continued importance, it is clear that some cities have been more able than others to cope with and recover from external shocks. Some analysts would term this ability "resilience".

The Oxford English Dictionary defines resilience as (*i*) the act of rebounding or springing back and (*ii*) elasticity. The origin of the word is in Latin, where resilio means to jump back. In a purely mechanical sense, the resilience of a material is the quality of being able to store strain energy and deflect elastically under a load without breaking or being deformed (Gordon, 1978). However, since the 1970s the concept has also been used in a more metaphorical sense to describe systems that undergo stress and have the ability to recover and return to their original state.

Resilience is seen as a desirable property of natural and human systems, including cities and coastal zones, in the face of a range of potential stresses, including weather-related hazards (UN/ISDR, 2002). According to Costanza *et al.* (1995), coastal ecosystems are highly resilient because of the diversity of their functions and the linkages between these functions. In the same manner, Adger (1997) argues that coastal economies are more diverse and have multiple niches, making them inherently more resilient than inland economies. Resilience is seen as contributing to sustainability and reducing vulnerability, although clear guidance as to how resilience can be promoted is lacking.

Using coastal megacities as a medium for analysis, this paper explores the concept of resilience, particularly its value and utility in the context of natural hazard risk reduction. First, a brief overview is given of coastal megacities and the weather-related hazards to which they are exposed. Section 3 then discusses strategies to reduce the risk of natural hazards and links them to approaches to proactive adaptation to climate change. Next, Section 4 reviews the academic debate over the last thirty years on the meaning of resilience in the context of natural resource management and hazard risk reduction. All this information is synthesised in Section 5 by addressing three questions:

- Is resilience a desirable attribute of megacities?
- Does enhanced resilience reduce the vulnerability of megacities to natural hazards?
- Is resilience a useful concept for hazard risk reduction in megacities?

Finally, Section 6 draws conclusions and proposes an alternative use of the concept of resilience, linked with the emerging concept of adaptive capacity.

2. Coastal Megacities and Weather-Related Hazards

The strong global urbanisation trend, combined with a general tendency for migration towards the coast, suggests that coastal urban centres will contain an increasingly large proportion of the world's human population (Small and Nicholls, 2003). The United Nations medium projection for population growth suggests that the world's population will reach 7.2 billion by the year 2015, 7.9 billion by 2025 and 9.3 billion by 2050 (2000: 6.1 billion; UNPD, 2001). Age structures in most developing countries are such that, during the coming decades, greater numbers of people will come into their prime reproductive years than in industrialised countries. Furthermore, fertility rates are generally higher in developing countries, albeit declining. As a result, all projected population growth until 2050 is expected to occur in the developing world (UNPD, 2001).

It is projected that, by 2015, there will be 33 cities with a population of more than eight million (UNPD, 2001). As shown by Klein *et al.* (2003), 21 of these 33 megacities are located in coastal zones and only six are not situated in developing countries (Tokyo, New York, Los Angeles, Osaka, Paris and Moscow). Of the 21 largest megacities in the list of 33, only four are not located on the coast (São Paolo, Mexico City, Delhi and Beijing). Continued growth of urban areas can be expected after 2015, especially in Africa and Asia (UNEP, 2002), resulting in the development of additional coastal megacities.[1]

The large populations in many coastal areas around the world are, to a greater or lesser extent, vulnerable to weather-related hazards. Some hazards can affect the entire terrestrial landscape, such as drought, river flooding and poor air quality enhanced by stagnant air masses and inversion. Other weather-related hazards are more specific to coastal locations. These hazards include:

- Erosion;
- Storm and wind damage;
- Sea flooding;
- Salinisation of surface waters.

Socio-economic sector	Erosion	Storm and wind damage	Sea flooding	Salinisation of surface waters
Water resources			✓	✓
Agriculture		✓	✓	✓
Human health		✓	✓	
Fisheries	✓	✓	✓	✓
Tourism	✓	✓	✓	
Human settlements	✓	✓	✓	

Table 1 — Qualitative overview of direct socio-economic risks from weather-related hazards and climate change to a number of sectors in coastal zones (adapted from Klein and Nicholls, 1999).

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[1] Some coastal agglomerations with populations exceeding 8 million do not appear in the dataset developed by UNPD (2001). These include Greater London in the United Kingdom and the Hong Kong-Shenzhen-Guangzhou conurbation in China (Nicholls, 1995). More dispersed agglomerations are not considered either, such as the Amsterdam-Brussels axis in The Netherlands and Belgium, the Osaka-Nagoya-Tokyo axis in Japan and 'Megalopolis' in the United States, which stretches over 600 km from Boston, MA to Washington, DC and has a collective population approaching 50 million. Such dispersed coastal agglomerations may also emerge in the developing world, such as from Accra, Ghana to Lagos, Nigeria, embracing parts of four countries.

Table 1 lists the most important socio-economic sectors in coastal zones and indicates from which of the aforementioned weather-related hazards they are at direct risk. Indirect risks, for example the risk to human health resulting from deteriorating water quality, are also likely to be important but these are not shown in Table 1.

Weather-related hazards are usually directly modified by the effects of other human activities in and around urban areas, including:

- Changing sediment supply due to changing land use, hydrological modification or coastal protection and the consequent influence on erosion and deposition (*e.g.*, rapid land loss in the Mississippi delta is increasing the flood risk in New Orleans; Boesch *et al.*, 1994);
- Land claim of intertidal areas and deepening of channels for navigation, which often increase extreme water levels and hence flood risk (*e.g.*, London; Kelly, 1991);
- Increased subsidence due to groundwater withdrawal, which has reduced land elevation in many large coastal cities, particularly those in deltaic settings in Asia (Nicholls, 1995).

In addition, human-induced climate change and sea-level rise are increasing the risk of weather-related hazards in coastal zones. Globally, the patterns and impacts of climate change are becoming increasingly clear, but it is still uncertain what the exact consequences of climate change will be on a local scale. This uncertainty makes planning and decision-making more difficult, especially when it concerns the building of infrastructure meant to last for several decades or more. Existing experience of weather-related hazards will cease to be a guide to future events, yet it is often unclear in which direction and by how much these hazards will change. Dealing with this uncertainty presents an additional challenge to hazard risk reduction.

3. Hazard Risk Reduction and Adaptation to Climate Change

As it is beginning to modify weather-related hazards, climate change is encouraging new thinking on hazard risk reduction (McCarthy *et al.*, 2001; UN/ISDR, 2002). Table 2 presents traditional strategies for reducing the risks of weather-related hazards. These strategies can be applied from the level of the individual up to the level of an entire city. *Choosing change* means accepting the hazard and changing land use, or even the relocation of exposed populations. *Reducing losses* includes trying to reduce the occurrence of the hazardous event or, more commonly, reducing the impacts of a hazardous event when it occurs. *Accepting losses* includes bearing the loss, possibly by exploiting reserves, or sharing the loss through mechanisms such as insurance. The strategies are not mutually exclusive: hazard risk reduction efforts within any coastal city might include elements of all three approaches. In addition, the implementation of any of these strategies may require social or institutional changes (not listed in Table 2).

Strategy	Option
Choose change	Change location
	Change use
Reduce losses	Prevent effects
	Modify event
Accept losses	Share loss
	Bear loss

Table 2 — Generic strategies for hazard risk reduction (from Burton *et al.*, 1993).

Given the large populations and economic values in cities, there is usually a bias towards loss reduction: large coastal cities would not have evolved without the availability of warning systems, defence works and resistant infrastructure. Once a large city has developed and high levels of investment have been made, there is a large inertia against relocation. Hence, cities tend to develop increasing dependence on loss reduction strategies as they evolve and grow. Loss reduction strategies are most developed in coastal cities around the North Sea and in Japan, where flooding claimed many lives up to the middle of the twentieth century. However, the implementation of such strategies is often perceived as removing rather than reducing the risk, encouraging further development in what remain potentially hazardous areas (Parker, 2000). Relocation of particularly vulnerable parts of cities could be integrated in the planning of future development and the exploitation of redevelopment opportunities, possibly as part of disaster recovery (UN/HABITAT, 2001). Thus, disaster recovery and long-term disaster prevention and preparedness could be combined.

As stated before, climate change can increase the hazard potential for coastal megacities. The threat of climate change is extending the scope of strategies to reduce weather-related hazard risks, focusing attention over many decades into the future. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has highlighted the significance of adaptation (Smit *et al.*, 2001). Adaptation in the context of climate change refers to the process of adjustment that takes place in natural or human systems in response to actual or expected impacts of climate change, aimed at moderating harm or exploiting beneficial opportunities. This process is becoming increasingly important because impacts of climate change can no longer be avoided only by reducing greenhouse-gas emissions (Arnell *et al.*, 2002). There has been particular interest in adaptation in coastal zones because of the inevitability of global mean sea-level rise (Klein *et al.*, 2000; 2001; Tol *et al.*, 2004). Much analytical and policy attention is given to proactive or anticipatory adaptation: taking action aimed at reducing vulnerability to climate change before it results in undesirable impacts. Five generic approaches to anticipatory adaptation can be identified (Klein and Tol, 1997; Huq and Klein, 2003):

- Increasing the ability of physical infrastructure to withstand the impacts of climate change. One approach, for example, would be to extend the temperature or rainfall range that a system can withstand; another would be to modify a system's tolerance to loss or failure;
- Increasing the flexibility of potentially vulnerable systems that are managed by humans. This could include allowing for mid-term adjustments in management practices, including changes in use or location;
- Enhancing the adaptability of vulnerable natural systems. This could involve reducing stresses due to non-climatic effects, or removing barriers to the migration of plants or animals;
- Reversing trends that increase vulnerability. This could range from reducing human activity in vulnerable areas to preserving natural systems that protect against hazards;
- Improving public awareness and preparedness. This could include informing the public about the risks and possible consequences of climate change, as well as setting up early-warning systems for extreme weather events.

Each of these five approaches to proactive adaptation to climate change is also relevant for hazard risk reduction in coastal zones and megacities. There is no clear-cut boundary between preparing for climate change and reducing weather-related hazard risks (Füssel and Klein, 2002). Using the terminology of Table 2, the emphasis of these five approaches is on loss reduction by preventing the effects and on choosing change by changing the location or use of the exposed system. Whether a particular approach is appropriate for a given location depends not only on its (monetary and non-monetary) costs and benefits, but also on the level of uncertainty surrounding the hazard risk to be reduced. If uncertainty is high, an approach involving large investments or one that results in a situation that would be very costly to change as knowledge increases is unlikely to be optimal.

A key point about any of the aforementioned strategies is that they involve more than the implementation of a set of technical measures. Hazard risk reduction and adaptation to climate change are an ongoing and iterative process that includes information development, awareness raising, planning, design, implementation and monitoring (Klein *et al.*, 1999; 2000; 2001). Reducing vulnerability requires having mechanisms in place and technologies, expertise and other resources available to complete each part of this process. The mere existence of adaptation options does not mean that each vulnerable community, sector or country has access to these options or is in a position to implement them. The concept of adaptive capacity has been introduced to reflect this awareness.

Adaptive capacity is defined as the ability to plan, prepare for, facilitate and implement adaptation options. Factors that determine a country's or community's adaptive capacity to climate change include its economic wealth, its technology and infrastructure, the information, knowledge and skills that it possesses, the nature of its institutions, its commitment to equity and its social capital (Smit *et al.*, 2001). It is therefore not surprising that most industrialised countries have higher adaptive capacities than developing countries. For example, Bangladesh and The Netherlands share a similar physical susceptibility to sea-level rise, but Bangladesh lacks the economic resources, technology and infrastructure that The Netherlands can call on to respond to the potential impacts. On the other hand, having adaptive capacity is no guarantee that it is used successfully. In this respect, the development and use of new and existing information are especially important. For example, significant coastal development and urbanisation occurred on the east coast of the United States from 1966 to 1989, increasing exposure during a period when hurricane activity was well below average. New inhabitants were often ignorant of the hurricane risk, which became manifest with the more frequent and stronger hurricanes that began with Hurricane Hugo in 1989 (Pielke and Landsea, 1998).

In view of the purpose of this paper, the question now arises as to how this discussion on natural hazards and adaptive capacity relates to resilience; in particular, whether resilience is a helpful concept when developing strategies to reduce the vulnerability of megacities to natural hazards. The next sections explore this question.

4. Resilience Conceptualised

It is widely assumed that more resilient megacities (as well as other human and natural systems) are less vulnerable to weather-related and other hazards (UN/ISDR, 2002). However, for this assumption to be valid and useful one needs to have an understanding and clear definition of resilience, including by which factors it is determined, how it can be measured and, most importantly, how it can be maintained and enhanced. Resilience has been analysed for a range of natural and social systems and this literature is reviewed here. The authors are not aware of any literature that deals specifically with the concept of resilience in the context of megacities and weather-related hazards, although Burton *et al.* (1993), Mitchell (1993, 1999), Godschalk *et al.* (1999) and Pelling (2003) do raise relevant issues. In addition, recent work has focused on the resilience of cities to terrorism (*e.g.*, Harrigan and Martin, 2002). Next, Section 5 discusses the usefulness of resilience in the context of megacities and weather-related hazards.

Holling (1973) coins the term resilience for ecosystems as a measure of the ability of these systems to absorb changes and still persist. As such, it determines the persistence of relationships within an ecosystem. This is contrasted with stability, which Holling (1973) defines as the ability of a system to return to a state of equilibrium after a temporary disturbance. Thus, a very stable system would not fluctuate greatly but return to normal quickly, whilst a highly resilient system may be quite unstable, in that it may undergo significant fluctuation (Handmer and Dovers, 1996).

Since the seminal work by Holling (1973, 1986), resilience has become an issue of intense conceptual debate amongst ecologists. The literature provides many perspectives and interpretations of ecological resilience and, in spite of thirty years of debate, there appears to be no consensus on how this concept can be made operational or even how it should be defined. Alternative definitions have been provided, focusing on different system properties. For example, Pimm (1984) defines resilience as the speed with which a system returns to its original state following a perturbation. Irrespective of its definition, many ecologists argue that resilience is the key to sustainable ecosystem management and that diversity enhances resilience, stability and ecosystem functioning (*e.g.*, Schulze and Mooney, 1993; Peterson *et al.*, 1998; Chapin *et al.*, 2000).

Other ecologists question the core assumption that underpins the concept of resilience, namely that ecosystems exist in an equilibrium state to which they can return after experiencing a given level of disturbance. They argue that ecosystems are dynamic and evolve continuously in response to external influences taking place on a range of different time scales. Attempts by ecosystem managers at maintaining some equilibrium state will therefore be bound to fail.

In spite of the relative lack of specificity with which resilience has been defined in ecology (or perhaps as a result of it), the concept has also gained ground in social science, where it is applied to describe the behavioural response of communities, institutions and economies. Extending the line of thought of ecologists who argue that resilience promotes sustainable ecosystem management, some ecological economists argue that resilience is the key to sustainability in the wider sense (*e.g.*, Common, 1995). Timmerman (1981) was one of the first to discuss the resilience of society to climate change. In so doing, he links resilience to vulnerability. He defines resilience as the measure of a system's or part of a system's capacity to absorb and recover from the occurrence of a hazardous event.

Dovers and Handmer (1992) distinguish between the reactive and proactive resilience of society. A society relying on reactive resilience approaches the future by strengthening the status quo and making the present system resistant to change, whereas one that develops proactive resilience accepts the inevitability of change and tries to create a system that is capable of adapting to new conditions and imperatives. This is an important broadening of the traditional interpretation of resilience, based on the premise of resilience being tested by an initial perturbation. The distinction made by Dovers and Handmer (1992) is based on the major difference between ecosystems and societies: the human capacity for anticipation and learning. Thus, proactive resilience as defined by Dovers and Handmer (1992) contains very similar ideas to those underpinning the concept of adaptive capacity (see Section 3).

Dovers and Handmer (1992) thus link resilience to planning for and adapting to hazards. In a later paper, they develop a typology of institutional resilience, which provides a framework for considering the rigidity and inadequacy of present institutional responses to global environmental change (Handmer and Dovers, 1996). They argue that current institutions and policy processes appear to be "locked" in a type of resilience that is characterised by change at the margins. Responses to environmental change are shaped by what is perceived to be politically and economically palatable in the near term rather than by the nature and scale of the threat itself. This type of resilience, as well as a type that is characterised by resistance to change, provides some level of stability in society, although there is a potentially large risk that this apparent stability is not sustainable and could lead to collapse if society cannot make the social, economic and political changes necessary for survival.

The third type of resilience described by Handmer and Dovers (1996), one that is characterised by openness and adaptation, is more likely to deal directly with the underlying causes of environmental problems and reduces vulnerability by providing a high degree of flexibility. Its key feature is a readiness to adopt new basic operating assumptions and institutional structures. However, there is also a potentially large risk involved in moving towards this type of resilience. Change deemed as necessary could turn out to be maladaptive, rendering a large cost to society. Moreover, uncertainty surrounding the impacts of climate change will make planning particularly difficult.

Adger (1997, 2000) investigates the links between social resilience and ecological resilience. He follows Timmerman (1981) in his definition of social resilience: the ability of human communities to withstand external shocks or perturbations to their infrastructure, such as environmental variability or social, economic or political upheaval, and to recover from such perturbations. Social resilience is measured through proxies of institutional change and economic structure, property rights, access to resources and demographic change. Adger (2000) observes that whilst resilience is certainly related to stability, it is not clear whether this characteristic is always desirable (*cf.* Handmer and Dovers, 1996).

Focusing on human (individual) vulnerability, Pelling (2003) breaks down vulnerability to natural hazards into three components: exposure, resistance and resilience. Following Blaikie *et al.* (1994), he describes resilience to natural hazards as the ability of an actor to cope with or adapt to hazard stress. It is a product of the degree of planned preparation undertaken in the light of potential hazard, including relief and rescue. Pelling (2003) mentions formal and informal insurance mechanisms as the most important policy options available to enhance resilience.

In a conceptual study of the resilience of the Dutch coast, Klein *et al.* (1998) focus on the combined functioning of morphological, ecological and socio-economic processes in determining coastal resilience. These processes produce a coastal system that is continuously changing, so no original or equilibrium state can be identified. Moreover, perturbations are not isolated events from which a coastal system may or may not recover but are ever-present and occur at different temporal and spatial scales. Klein et al. (1998) define coastal resilience as the self-organising capacity of the coast to preserve actual and potential functions under changing hydraulic and morphological conditions. This capacity derives from the (potential) dynamics of morphological, ecological and socio-economic processes and is constrained by the functions that are to be preserved. In this analysis, the relationship between the different processes contributing to coastal resilience remains to be resolved, especially with regard to whether and how these processes can substitute one another.

This overview of the conceptual development of resilience shows that what was once a straightforward concept used only in mechanics is now a complex multi-interpretable concept with contested definitions and relevance. Nonetheless, the concept of resilience is now used in a great variety of interdisciplinary work concerned with the interactions between people and nature, including vulnerability and disaster reduction (*e.g.*, UN/ISDR, 2002; IHDP, 2003). The most important development over the past thirty years is the increasing recognition across the disciplines that human and ecological systems are interlinked and that their resilience relates to the functioning and interaction of the systems rather than to the stability of their components or the ability to maintain or return to some equilibrium state.

This recognition has led to the establishment of the Resilience Alliance, a network of scientists with roots mainly in ecology and ecological economics, which aims to stimulate academic research on resilience and inform the global policy process on sustainable development. The Resilience Alliance consistently refers to social-ecological systems and defines their resilience by considering three distinct dimensions (Carpenter *et al.*, 2001):

- The amount of disturbance a system can absorb and still remain within the same state or domain of attraction;
- The degree to which the system is capable of self-organisation;
- The degree to which the system can build and increase the capacity for learning and adaptation.

This comprehensive interpretation of resilience became the basis of a scientific background paper for the World Summit on Sustainable Development (Johannesburg, South Africa, August/September 2002), produced by the Resilience Alliance on behalf of the Environmental Advisory Council to the Swedish Government (Folke *et al.*, 2002). This background paper refers to resilience as the “flip side” of vulnerability (p. 13) but also lists resilience as one of the three elements or determinants of vulnerability, along with exposure and sensitivity (p. 13). Conceptually, the former interpretation (resilience as the flip side of vulnerability) does not add any new substance to the debate but rather appears to be motivated by a desire to emphasise the positive side of things (enhancing resilience as opposed to reducing vulnerability). The danger of this interpretation is that it lends itself to circular reasoning: a system is vulnerable because it is not resilient; it is not resilient because it is vulnerable.

The latter interpretation (resilience as a determinant of vulnerability) is analogous with recent work by Pelling (2003, p. 47; see also above) and very similar to the IPCC’s interpretation of adaptive capacity as one determinant of vulnerability, along with exposure and sensitivity (McCarthy *et al.*, 2001; see also Section 3). Perhaps aware of this similarity, Folke *et al.* (2002) gave their background paper the title “Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations”. However, throughout the document it remains unclear exactly how they relate adaptive capacity to resilience. Folke *et al.* (2002) appear to equate adaptive capacity with the third of the aforementioned three dimensions of resilience: the degree to which the system can build and increase the capacity for learning and adaptation. This would suggest that, according to the Resilience Alliance, adaptive capacity is one of the three determinants of resilience, which, in turn, is one of the three determinants of vulnerability (or its flip side). If this is indeed the case, it is not clear why Folke *et al.* (2002) emphasise adaptive capacity and how they would propose going about building the other two dimensions of resilience in a world of transformations.

The UN International Strategy for Disaster Reduction (UN/ISDR) has also adopted the term resilience. With particular reference to natural hazards, it defines the term resilience as follows (UN/ISDR, 2002, p. 24):

> The capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level in functioning and structure. This is determined by the degree to which the social system is capable of organising itself and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster.

In addition, it states that "the motivation to invest in disaster risk reduction is first and foremost a human, people centred concern. It is about improving standards of safety and living conditions with an eye on protection from hazards to increase resilience of communities" (UN/ISDR. 2002. p. 27). It argues that adapted, sustainable and integrated management of natural resources, including reforestation schemes, proper land use and judicious settlements, should increase the resilience of communities to disasters by reversing current trends of environmental degradation and dealing with hazard management.

Both the approach promoted by the Resilience Alliance and the one put forward by the UN/ISDR are amalgamations of interpretations of ecological, social and institutional resilience discussed above. However, resilience remains at the conceptual level and approaches to making the concept operational are not provided. Both in the academic realm of the Resilience Alliance and in the practical realm of the UN/ISDR, the same problems as with previous definitions persist: there is limited scope for measurement, testing and formalisation. Yet, there is an unrelenting devotion to using the concept and an unquestioning, almost naïve acceptance that resilience is good and must be promoted, irrespective of the potential risks to society (*cf.* Handmer and Dovers, 1996; Adger, 2000). The challenge remains to transform the concept into an operational tool for policy and management purposes: a challenge that thirty years of academic debate does not seem to have resolved.

5. Discussion

The vulnerability of megacities to hazards and disasters has been the subject of increasing academic interest, with recent special issues of GeoJournal (Parker and Mitchell, 1995), Applied Geography (Mitchell, 1998) and Ocean & Coastal Management (Barbière and Li, 2001), as well as influential publications by Timmerman and White (1997), Rakodi and Treloar (1997), Mitchell (1999) and Cross (2001). This academic interest has complemented the increasing policy interest, as reflected by initiatives of the International Decade for Natural Disaster Reduction (and now the UN/ISDR) and the Disaster Management Facility of the World Bank.

In spite of the high hazard potential of megacities in general and coastal megacities in particular, there is no compelling evidence that megacities are more vulnerable to hazards than smaller cities and towns. Handmer (1995) argues that major cities have inherent features that enable them to deal with hazards more effectively than smaller settlements. The immense power and resources of large cities confer considerable capacity to respond (*i.e.*, resilience). Most major cities are able to harness massive financial resources and expertise from within the city, the country and the rest of the world to combat disaster and to aid recovery. Parker (1995) supports this view and argues that the inbuilt complexities and redundancies characteristic of very large urban systems and the modern global electronic trading systems of which they are part may also enhance resilience.

Cross (2001) also emphasises the greater resilience of megacities compared to small towns. He argues that the different response capacities of smaller communities profoundly influence the long-term consequences of a disastrous event on the individual victims and whether they receive timely or adequate emergency assistance. Individuals in both small communities and megacities are vulnerable to hazard losses but losses for residents of large cities are more easily reduced by the warning and protection systems that the cities' concentrated wealth can justify.

On the other hand, urbanisation in the developing world is also concentrating poor populations in potentially hazardous areas. It thus raises the vulnerability of these groups and hence the city as a whole to hazardous events and disasters. This increase and concentration of vulnerability attracts considerable attention in the literature (UN/HABITAT, 2001). Whilst coastal megacities in the developed world might be seen as more resilient than smaller settlements or rural areas, in the developing world there are competing processes influencing resilience and vulnerability, which are dynamic and not fully understood.

Resilience is seen as an important characteristic of megacities that helps to reduce the vulnerability of its citizens to weather-related hazards. However, as shown in Section 4, resilience is a relatively poorly defined concept not yet operational for policy and management. Following Timmerman (1981), there seems to be a consensus that a resilient city is less vulnerable to hazards, but no systematic and reproducible analysis exists to date as to what makes cities resilient and how resilience can be enhanced.

In this section, the authors query this consensus view by asking the following questions:

- Is resilience a desirable attribute of megacities?
- Does enhanced resilience reduce the vulnerability of megacities to natural hazards?

- Is resilience a useful concept for hazard risk reduction in megacities?

5.1. Is resilience a desirable attribute of megacities?

Whether or not resilience is a desirable attribute of megacities depends on the definition of the concept. Even though some may consider the traditional definitions that assume some equilibrium state to be outdated, they still tend to capture the imagination of many when resilience is mentioned. It is clear that megacities are in a continuous state of flux and that “bouncing back” to the original state after a disaster is impossible. More importantly, if a megacity is struck by a disaster it follows that the original state was one in which it was vulnerable to the disaster in the first place. Going back to this original state is undesirable, as it would leave the city just as vulnerable to the next disaster.

Later definitions of resilience focus on the functioning of systems, including their self-organising capacity. Resilience interpreted in this manner is desirable in megacities: once a disaster happens it facilitates and contributes to the process of recovery. A resilient megacity thus would be less likely to experience a severe lasting impact from a disaster. However, this type of resilience does not help to prevent disasters or reduce their immediate impacts.

Recently resilience has also been interpreted as including the degree to which a system can build and increase the capacity for learning and adaptation (Carpenter *et al.*, 2001; *cf.* proactive resilience as defined by Dovers and Handmer, 1992). The capacity for learning and adaptation is clearly a desirable attribute, although few would intuitively associate the ability to increase this capacity with resilience. This interpretation of resilience relates to adaptive management and adaptive capacity: two concepts with their own literature and interpretations but perhaps more appropriate for policy and management.

5.2. Does enhanced resilience reduce the vulnerability of megacities to natural hazards?

As for the previous question, this is also a matter of definition. The early interpretations of resilience would not reduce vulnerability, later ones would. However, it is also important to consider who or what would be vulnerable and how this vulnerability would manifest itself. A megacity typically covers a large and often physiographically heterogeneous area, with different exposure and susceptibility to hazards. In addition, the population will be diverse, as will be the conditions under which the people live. As a result, whilst a megacity has a particular vulnerability to hazards, some population groups within the city may be particularly vulnerable due to their high exposure and unfavourable socio-economic situation.

Resilience interpreted as facilitating and contributing to the process of recovery after a disaster is irrelevant to those who lose their lives during a disaster. Those losing their marginal livelihoods in shantytowns may not benefit as much from being able to display resilience as those who could afford insurance to cover any damage to their property. This shows that overall (socio-) economic standing is an important factor determining whether resilience reduces the vulnerability of megacities to weather-related hazards.

5.3. Is resilience a useful concept for hazard risk reduction in megacities?

The fact that, amongst others, the UN/ISDR (2002) has adopted the term resilience would suggest that it is a useful concept for hazard risk reduction. However, the problem with resilience is the multitude of different definitions and turning any of them into operational tools. The answers to the previous two questions depended on the assumed definitions of resilience, none of which are operational. After thirty years of academic analysis and debate the definition of resilience has become so broad as to render it almost meaningless. The aforementioned definition by Carpenter *et al.* (2001) includes many issues currently en vogue in discussions of sustainable development and hazard risk reduction. Rather than the definition providing an explanation of an observable, measurable system attribute, resilience has become an umbrella concept for a range of system attributes that are deemed desirable. This leads to considerable confusion. Without an explicit operational definition, resilience has only the broadest meaning and remains a vague concept rather than a practical policy or management tool.

6. Conclusions

Whilst resilience is widely seen as a desirable property of natural and social systems, including coastal megacities, the term has been used in a number of different ways. Based on the present knowledge, we conclude that the definition of resilience is best used to define specific system attributes, namely:

- The amount of disturbance a system can absorb and still remain within the same state or domain of attraction;
- The degree to which the system is capable of self-organisation.

These specific attributes refer to what Dovers and Handmer (1996) call reactive resilience, which enables what is known in the natural hazards literature as coping (*e.g.*, Corbett, 1988) and what the climate change community labels autonomous adaptation (*e.g.*, Carter *et al.*, 1994). Both these attributes are to a greater or lesser degree amenable to measurement and monitoring, although questions about the relationship between natural system and social system resilience remain to be fully explored.

We propose the use of adaptive capacity as the umbrella concept that includes the ability to prepare and plan for hazards, as well as to implement technical measures before, during and after a hazard event. We then propose that resilience be regarded as one property that influences adaptive capacity, representing the two system attributes listed above. In this way, umbrella concept and system attributes are kept distinct in a conceptual hierarchy.

Since the publication of the IPCC Third Assessment Report, adaptive capacity has been the subject of a worldwide interdisciplinary research effort aimed at making it operational for the international climate policy process, as well as for national planning agencies (Smith *et al.*, 2003). This concept has gained recognition in climate policy and science and has been used outside the climate community as well (*e.g.*, Turton, 1999). Climate variability is increasingly considered along with climate change and uncertainty when planning for adaptation, as it is recognised that in many areas the most direct and immediate impacts of climate change will occur through changes in the frequency and intensity of weather-related hazards.

The framework for adaptive capacity and resilience proposed here differs from the approach followed by the Resilience Alliance and the UN/ISDR. It links the analysis of present and future hazardous conditions (focusing on climate variability and climate change) with the evaluation of specific strategies for enhancing the capacity for disaster prevention and preparedness. This approach should encourage much-needed communication between the natural hazards community and the climate change community. More importantly, it would provide hazard managers with a tool that is similar to resilience in its relationship to vulnerability but offers greater potential in application, especially when attempting to move away from disaster recovery to disaster prevention and preparedness.

In the case of megacities, maintaining and enhancing both resilience and adaptive capacity for weather-related hazards would be desirable policy and management goals, although based on the conceptual hierarchy defined here, maintaining and enhancing adaptive capacity is the overall goal. This is consistent with the challenges for the future identified by the UN/ISDR (2002).

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- What will be the combined effects of global change on terrestrial and coastal ecosystems and the functions and services they provide to society?
- How will these changes affect social and economic processes and how will they interact with other ongoing developments in society?
- What capacity do ecosystems and society have to adapt to global change and which are the opportunities and constraints on increasing this capacity?

These research questions have formed the basis of seven externally funded projects: ATEAM, DINAS-COAST, Security Diagrams, cCASHh, SEVERE, AVEC and WAKE.

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