Chapter 6
Natural Hazards Impacting on Future Cities

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Abstract Natural hazards will have a growing impact on future cities because the climate change dependent hazards will increase in intensity and because of the increasing vulnerability of cities. The global impact of each hazard in any city can be conveniently described through a probabilistic quantified approach to risk and a quantification of resilience. The supply chain must be included in the estimate. Real time methods of risk reduction must be implemented to manage emergencies in future city. It is essential the participation of citizens nudging them to proper behaviors and using also social networks and low cost networked sensors to get the needed information. Several advanced technological methods are available for effective real time risk mitigation as shown in Japan. The application in other countries is hindered by the lack of proper laws and people information programs.

Keywords Natural hazards · Future cities · Megacities · Black swans

6.1 The Urban Development Scenario

Since the first decade of the twenty-first Century most of the world population live in urban areas. The trend toward a growing urbanization accelerated a few decades ago. It is probably an irreversible process. According to the United Nations Population Division (UNPD) data, the urban population grew up from 600 million (30 % of the global population) in 1950 to 3.3 billions (51 % of the global

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population) at present time. The percentage of population living in urban areas is expected to grow to 60 % in 2030 (UNPD 2005).

A consequence of this process is the growth of mega-cities. This term indicates cities or large mega-urban regions encompassing several individual cities, such as the Ruhr area in Germany or the Randstad conurbation in the Netherlands (The Hague, Amsterdam, Utrecht and Rotterdam) with more than 10 millions inhabitants, high concentrations of values and infrastructures, high level of global interlinking, close interconnection among flows of goods, finance and information. At present days there are 50 mega-cities, most of them in developing countries. Some of the megacities in Asia, South America and Africa are rapidly becoming meta-cities (i.e. urban concentrations of more than 20 millions of inhabitants). Many of the megacities are located in areas with significant hydro-geologic, seismic, volcanic or meteorological hazard. All of them are threatened by some sort of natural hazard.

In industrialized countries also smaller cities are becoming “risk-attractors” because of the development of lifelines, inter-connected systems and highly vulnerable infrastructures. Cities amplify natural risk also for the increased probability of the cascade phenomena, i.e. a damaging primary event triggers a sequence of dangerous events originating in structures and systems created by man (such as failure of dams, urban floods due to extensive underground structures, industrial accidents, etc.). Typical examples in the last centuries have been the fire devastating San Francisco after the 1906 earthquake, the flood due to dams collapse after the Katrina Hurricane in the New Orleans neighborhood, the industrial accident due to the earthquake in Izmit, Turkey, in 1999 and Kobe, Japan, in 1995, until the more recent severe damage of the Fukuoka nuclear power plant, in Japan, after the M9 offshore earthquake and consequent tsunami in February 2011 (Wenzel et al. 2007; Trice 2006).

6.2 Natural Hazards Impacting on Future Cities

Natural hazards can be divided in two broad categories: geological and meteorological hazards. The main difference is that geological hazards can be assumed to not undergo inherent changes with time over periods of 10s or 100s of years, as long as human actions do not disturb the source system (as in the case of seismicity induced by massive fluid injections). Meteorological hazards may undergo significant changes, because of climate changes.

Figure 6.1 (based on data retrieved in Munich Re 2004) indicates that more than 50 % of the megacities are characterized by a high level of some natural hazard. Sixteen of them are threatened by more than one hazard source with high probability of occurrence. Further 21 are threatened by more than one hazard with medium to low probability. A high hazard level means that a catastrophic event can occur every few tens of years or so.

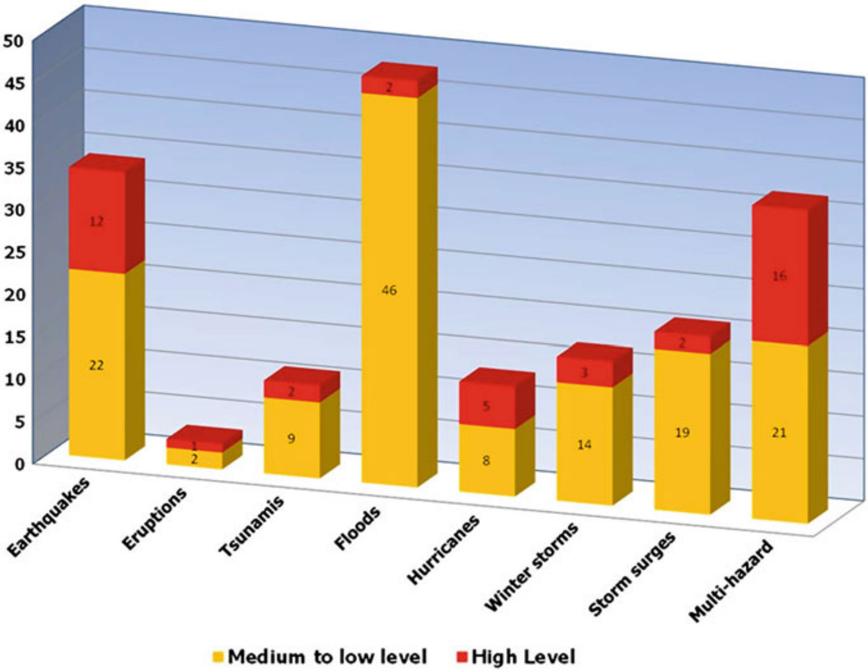

Fig. 6.1 Level of natural hazards impact on the 50 Megacities

Cities and megacities contribute to increase hazards as well, creating its own characteristic climate. Megacities are pronounced heat islands. The mean temperature in its interior can be several degrees Celsius (up to 10 °C) higher than in the surrounding countryside. In the warm season, the weather extremes are often significantly intensified: this causes heat waves, thunderstorms, hail. As urban areas are mostly paved with concrete and asphalt, a large proportion of rainwater runs away on the surface. The sewerage systems are often not designed for this, with the result that torrential rainfall in big cities regularly leads to local flash flooding (Munich Re 2004).

The percentage of the Earth surface covered by urban areas is 2.8 %. It almost doubled from 1992 to 2005. This increases the probability that a natural damaging event can occur within the limits of each city and not many km away. The important consequence of this is that a smaller magnitude event, having a high probability of occurrence, can have an impact comparable to that of a distant more rare larger magnitude event. This is particularly true for earthquakes, two recent examples being the April 6, 2009 M6.3 earthquake occurred about 10 km below the city of L'Aquila, Italy, and the February 22, 2011 event occurred just below the city of Christchurch in New Zealand.

6.3 A Better Way to Estimate Damages

The traditional way to estimate damages from a natural event is through the evaluation of Risk (R), defined as:

$$R = H * V * E$$

where H is the hazard, the probability that a certain adverse event generating a phenomenon of a given intensity will occur in a given area in a given time interval (1 y or 50 y or 1,000 y…), E is the total potential loss due to an adverse event in a given area, V is the Vulnerability, i.e. the fraction of E that could be lost after a specific adverse event (Marzocchi et al. 2012). Urban vulnerability usually includes structures, infrastructures, lifeline systems, transport networks, information and communication systems, financial and social assets. This approach is still used by insurance companies.

In recent years the consciousness that a complete estimate must also consider an additional quantifiable parameter, called *resilience*, has been reinforced.

Basically resilience was defined as the capability of a system to preserve or restore its state. It has been gradually broadened to the vision of a proactive resilience paradigm (cope with and adapt to change) where resilience is seen as the ability of a system to self-organise and build the capacity for learning and adaptation in addition to its capability to preserve or restore its functionality (Kleina et al. 2003). Robustness, adaptability and transformability as major elements of resilience provide a wider perspective for creating stakeholder interactions and go far beyond the traditional hazard and vulnerability reduction methodologies. The level of a society's resilience is influenced not only by its capacity of disaster management, but also by other social and administrative services, public infrastructure and a multitude of socio-economic and political linkages with the wider world.

Resilience can be measured as a function of the time needed to restore an assigned functionality to the system, which not necessarily coincide with the starting state (Cimellaro et al. 2010) (Fig. 6.2).

Delocalization of productive processes all over the world exacerbates the **supply chain risk**, above all in cases of **black swans**. Black swans are events occurring outside the real of regular expectations, because nothing in the past can convincingly point to its possibility. They have an extreme impact, producing a very large loss. They are characterized by the triplet: rarity, extreme events, retrospective (though not prospective) predictability (Taleb and Nassim Nicholas 2007).

Natural disasters effects can generate global consequences: a catastrophic event in China, for example, *would have far-reaching and long-lasting negative economic impact. It would slow down the global economy because China is not only a major exporter of goods, but also a major importer of goods* (Global 2011).

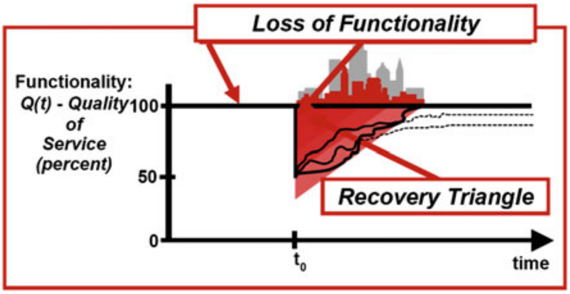

Fig. 6.2 Resilience can be quantified through the area of the *recovery triangle*. Different stages of functionality can be reached (Reinhorn and Cimellaro 2011)

On March 17, 2000 a fire in Albuquerque (New Mexico) destroyed thousands of cell phones in the Philips plant; Philips was the major supplier of semiconductors to Nokia and Ericsson.

Nokia found quick solutions to the emergency, minimizing the impact. Ericsson responded to the shock many weeks later, suffering a $2.34 billion loss in its mobile phone division and market share loss (Sheffi 2007).

In Thailand the share of parts and components in total exports of automotive products approximately doubled from 17 % in 1998 to almost 35 % in 2011 and the country became a significant part of the global supply chain of car production.

The flood hitting Thailand in July 2011 affected many industrial estates, causing a slump in the production with remarkable effects. The area is an important source of intermediate input supply through which some components are delivered just-in-time to final assembly plants. Therefore, the disruptions of components deliveries in this region inevitably compelled other stages of production in the non-flooded areas, in both Thailand and other countries, to cease their operations. For example, due to the shutdown of its plant in Ayutthaya, Honda experienced immediate shortages of auto parts which “forced Honda to cut production around the world, from the Philippines to Swindon in the United Kingdom” (Chongvilaivan 2012).

In December 2011 the Japanese Ministry of Economy, Trade and Industry (METI) conducted an emergency survey of 67 major Japanese industries to inquire on the effects of the Thai floods on their production. According to the survey, 81 % of the major Japanese companies production bases in Thailand are still producing less than they did before the heavy flooding broke out in July 2011 (Ministry of Economy 2011).

Moreover, Toyota stopped production in the Toyota Motor Thailand (TMT), causing Toyota in Japan to cut output by 6,000 units in 5 days (The Nation and Bangkok’s Independent Newspaper 2011a).

The effects on some factories are shown in the following table (Table 6.1).

These examples of global consequences from catastrophic events raise the issue of the need of risk mitigation strategies to be implemented by companies. Indeed, supply chain is an essential component of a disaster chain where resilient measures must be applied to reduce losses on a global scale.

Table 6.1 Effect of Thai floods on Japanese companies

	Status	*Effects*
Automobiles		
Honda	Factory submerged	No prospect of recovery
Toyota	Parts not supplied by flood-damaged manufacturer	Production suspended for several days. Considering air shipment of parts and other measures
Nissan	Parts not supplied by flood-damaged manufacturer	Production suspended for several days
Isuzu	Parts not supplied by flood-damaged manufacturer	Production suspended for several days
Electronics		
Nikon	Digital camera factory submerged	No prospect of recovery
Sony	Digital camera factory submerged	No prospect of recovery
Canon	Printer-related factory submerged	Considering production at a different factory in Thailand and other areas
Nidec	Two electronic parts factories submerged and employees at four factories evacuated	Considering production in China and other countries
TDK	Electronic parts factory submerged	Considering production at a different factory in Thailand
Food		
Ajinomotol Calpis	Jointly established beverage plant submerged	Considering production at a different factory in Thailand

Source The Nation, October 18, 2011—www.nationmultimedia.com (The Nation and Bangkok's Independent Newspaper 2011b)

Therefore, companies should be flexible enough to quickly switch their operation scenarios to adjust for disruptions. A scenario-based strategy will not only minimize damage but can be helpful to eventually overcome debilitated competitors.

The mitigation efforts can be classified into three phases:

- proactive, building a resilient supply chain, investing in early warning systems;
- reactive, working for an expedite recovery (Agility);
- post-recovery, reporting, revaluating the supply chain, and recovering losses through insurance claims.

To demonstrate that risk awareness can lower failures, Plenert and coauthors (Plenert et al. 2012) analyzed the case of two companies undertaking different approaches in facing global effects from a catastrophic event: company A does not undertake risk mitigation measures, whereas company B implements a Business Continuity Plan. Once the adverse event occurs at time T, company B is able to discover more quickly (at point B1) than company A the disruptive effect of the event on the Supply Chain, recovering more rapidly and so minimizing the impact. Company A detects the disruption only at point A1 and takes a longer time for recovery, facing a stronger disruption impact (Fig. 6.3).

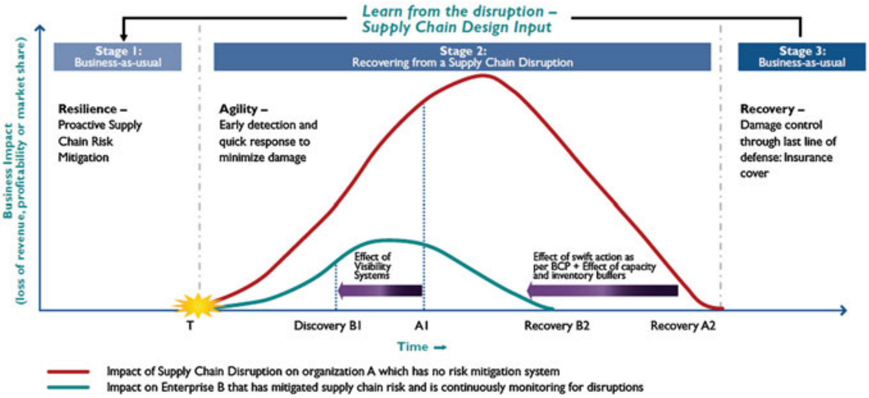

Fig. 6.3 Supply chain risk mitigation effects (Plenert et al. 2012)

6.4 How to Manage Urban Catastrophic Events

Megacities are Natural Risk attractors: how can we prevent them to become Risk Traps?

Sustainable Risk Mitigation actions must approach the complexity of city systems and include:

- A systemic and global approach (multi-risk) to risk evaluation aimed at actions planning based on a rank of possible risks;
- Mitigation action to be selected on the basis of consequence analysis, including evaluation of the effects on the supply chain;
- Definition of the acceptable level of risk;
- Urban planning conscious of natural risks;
- Adoption of real time risk reduction methods, such as early warning.

Early warning and methods of real time risk mitigation are becoming crucial for managing disasters in urban areas. In these methods the role of citizens is essential. Several EU projects are investigating these issues. Two of them, both dealing with earthquake risk, are the FP6 SAFER (Seismic Early Warning for Europe) Project and the FP7 REAKT (Strategies and tools for Real Time EArthquake RisK ReducTion) Project.

As most operational earthquake forecasts are associated with a significant degree of uncertainty, it will be desirable for the public response to be self-organized to such a degree. There are many safety decisions which an individual risk-informed citizen might make, affecting all aspects of daily life, from work to travel and recreational activities. Each individual should be ‘nudged’ to doing what is in his or her best safety interest, being given an informative hazard advisory by civil protection officials (Woo 2011).

It is customary for hazard advisories to be given to the public, which suggest changes in public behaviour, but do not force the public to take any specific course of action. For example, people are advised to wash their hands more frequently during a pandemic crisis, but they are not coerced to improve their personal hygiene. Similarly, travellers might be advised of a higher terrorist threat in some countries, without being forbidden to visit them.

Citizens can be also involved giving them the possibility to get or access information directly. For example, SAFER proposes a completely new generation of early warning systems, based on low-cost sensors (taken from the air-bag system of the car industry) that are connected and wireless communicating with each other in a decentralized people-centred and self-organizing observation- and warning network. "Decentralized" means that the total information available in the network will not only be transmitted to a warning centre but will also be available at every node of the network. "People centred" means that people can afford to buy their own sensor and by installing it in their home may not only gain from, but also contribute to the warning network. This would ensure the dense coverage of an urban area with early warning sensors, not tens or hundreds, but thousands or ten thousands, which is necessary to gather accurate warning information. The system has to be "self-organizing" in order to automatically adapt to changes in the network configuration if, for instance, the number of users will increase, or some of the network sensors will fail as a consequence of a strong earthquake.

The prototype of such a low-cost and self-organizing system has been successfully tested in the city of Istanbul. It has also been applied to monitoring the health state of critical infrastructures such as the Fatih Sultan Mehmet Suspension bridge across the Bospouros or certain buildings in L'Aquila (Italy) after the strong earthquake of April 6th, 2009. Although the number of nodes for which the network has been configured at present is still conventional, SOSEWIN (Self-Organizing Seismic Early Warning Information Network) as the system is called, has opened a novel avenue for seismic early warning that is extremely promising. The REAKT project aims at establishing the best practice on how to use jointly all the information coming from earthquake forecast, early warning and real time vulnerability assessment. All this information needs to be combined in a fully probabilistic framework, including realistic uncertainties estimations, to be used for decision making in real time.

REAKT will follow also an innovative strategy considering each citizen as an individual decision maker. A way to set up citizen operated networks is given by the existence of accelerometric sensor on some laptops. They can provide numerous additional ground motion measurements especially in large urban areas where the density of such laptops is high. The development of such networks goes in line with a presence on social networks. This is a way to engage with citizens as well as with the online communities which rapidly emerge after damaging earthquakes. We propose a feasibility study and network/system design for citizen-operated networks of embedded laptop motion sensors, which can contribute to the damage estimation with additional local measurements of ground motions in populated areas, as well as providing means to engage the community for feedback, eyewitness reports, and educational purposes. The activity will be mainly focussed on the city of Istanbul.

These considerations apply also to EEW. With online news and social networking, and communication systems (like reverse 911 in the USA) which automatically send emergency messages to cell phones, the informed and risk-aware individual is in a position to react much more swiftly and sensibly to an event than if he or she relied on any central directive. In the application of early warning methods to infrastructure such as transportation and critical industrial installations, civil protection organizations have a joint role with the infrastructure managers in deciding on an appropriate real-time algorithm for system closure and shut-down. REAKT will develop such an algorithm balancing the benefits of reducing casualties in the event of a major earthquake with the economic cost, aggravation and disruption of false alarms.

6.5 The Future

Natural hazards will have a growing impact on future cities both because the climate change dependent hazards will increase in intensity and because of increasing vulnerability of cities. The global impact of each hazard in each city can be conveniently described through a probabilistic quantified approach to risk and a quantification of resilience. All the supply chain must be included in the estimate. To manage emergencies in city real time reduction methods must be implemented. For its implementation it is essential the participation of citizens nudging them to probable behaviors and using also social networks and low cost networked sensors for them to get the needed information. Several advanced technological methods are available for effective real time risk mitigation as shown in Japan. The application in other countries is hindered by the lack of proper laws and people information programs.

The crucial technical issues to be pursued are:

- Protection of strategic structures and infrastructures in European high risk areas
- Specialized decision support modules
- Low cost very dense sensor nets in urban environment
- Citizen’s involvement in the protection actions
- Co-existence of centralized and de-centralized decision making.

They require the implementation of social and legal issues, such as:

- Education and training
- End-to-end diffusion of information
- Solution of legal problems.

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