The March 2011 Japan Earthquake

Analysis of Losses, Impacts, and Implications for the Understanding of Risks Posed by Extreme Events

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Socio-economic losses associated with the earthquake of magnitude 9 on March 11th, 2011 off the Tohoku coast of Japan are presented and discussed. These include presentation of building damage, casualty- and shelter needs disaggregated for the earthquake and tsunami, but also the implications of the loss of essential utilities in Honshu's production capacity, and consequences of the Fukushima 1 nuclear power plant accident. We trace the Tohoku catastrophe from the initial triggering earthquake through the cascading- and network phenomena of the Tohoku event, and discuss the concept of cascading phenomena triggered by natural hazards in society and the economy. Following the analysis of the Tohoku event, a summary of the key interactions of three different types of disasters which occurred in 2010 are presented in comparison.

1 Introduction

It is well accepted that catastrophes result from natural disasters only when the society affected, its infrastructure and institutions are too weak to cope with and absorb the adverse impacts of an event. Thus, we can talk about natural disasters, but not about natural catastrophes. This view is also reflected in risk assessment, where not only the physical elements of risk, but also the fragilities and capacities of people, processes, services, organizations, or systems affected must be analyzed. This applies not only for all types and scales of natural disasters, but also for risk as a dynamic interaction between natural phenomena, technological systems, and socio-economic aspects. These interactions become particularly obvious in the case of large-scale disasters, such as the Japan Tohoku event.

In this paper, we trace the path to catastrophes through the complex interactions between natural hazards, societal conditions, and the vulnerability of technical facilities on which the functionality of societies are based. The recent Tohoku earthquake of March 11th, 2011 and the tsunami it induced led to worldwide economic disorder and social consequences with political impacts. We take the Tohoku event as a case history for which we analyze the losses, but also show the complex network of interactions that were manifested in this event.

Even though historic tsunamis and earthquakes (e.g., 869 Sanriku, 1896 Meiji-Sanriku event) had in fact attained similar magnitudes and runup heights in the same areas that were affected by the Tohoku event (Hatori 1986), no widely-accepted existing scenarios or models had foreseen the occurrence of an event of Mw 9.0. If not a "Black-Swan" event (Taleb 2007), the multi-risk and disaster-chain phenomenon that was initiated in Japan on March 11th was an unprecedented large-scale catastrophe that at least could have been imagined. From the initial triggering earthquake through the cascading- and network phenomena of the Tohoku event, we show how several factors within the social, economic, technological, and environmental fabrics of Japanese society became highly relevant in exacerbating the impacts of this event. Following the analysis of the Tohoku event, a brief summary of the key interactions of three different types of disasters which occurred in 2010 (the Haiti earthquake, the Russian wildfires, and the Pakistan floods) are presented in comparison. Our aim is to show that the path to large-scale disasters should be sought and found within the key interactions between natural disaster, societal weakness, and the vulnerability of technical facilities. Finally, we draw conclusions from our observations and analysis with implications for addressing extreme events.

2 Characteristics of the Tohoku Earthquake

The Tohoku earthquake and the tsunami of March 11th, 2011 was typical for large-scale disasters with cascading expansion. Massive losses due to the March-11th earthquake occurred as the result of a chain of impact of three causes: the disastrous earthquake, the tsunami it induced, and the nuclear power plant incident. The magnitude (Mw 9.0) of the earthquake off the Tohoku coast of Japan initiated a tsunami with waves of up to 24 meters in height, which surged as much as 10 km inland, and devastated large parts of coastal Japan, particularly in the densely-populated coastal city of Shinomaki. In addition to the tsunami damage, the earthquake caused widespread building damage, the collapse of the Funjinuma irrigation dam in Sukagawa, widespread fires, and emergencies declared at the Fukushima-1 and -2 nuclear power plants.[1]

Building damage, human casualties, and economic losses are disaggregated for the earthquake, the tsunami, and the nuclear power plant. It should be noted that none of the results in disaggregating the impacts of the Tohoku events have been published elsewhere, and that the figures shown here are based on extensive investigation into the actual records and on statistical analysis. In presenting the losses from Tohoku, we also investigate a number of exacerbating factors and interactions which led to this event's total impact being much greater than the sum of its parts. We show that, while the losses from the Tohoku earthquake – an event of rare (low probability of occurrence) magnitude – are very severe, it was the simultaneous impacts of the earthquake, the tsunami, and the nuclear power plant crisis, as well as the complex interactions between several key characteristics of the society affected and of its infrastructure which led to unprecedented conditions that greatly impaired the capacity of Japanese society to respond. The following will review and summarize some of the main characteristics of this event and critical interactions between them.

2.1 Impact on Buildings

Over 1,000,000 buildings were damaged, destroyed, or abandoned as a result of these three combined disasters (see the additional figures in the online version of this issue). No data on the relative proportion of earthquake- and tsunami damage has as yet been given by government sources. Table 1 shows the distribution of damage for coastal and non-coastal municipalities. It should be noted that coastal municipalities are not narrow strips, but generally extend far inland. Thus, it can be assumed that the earthquake also contributed to a large extent to the damage in the coastal municipalities. To reconstruct the damage that would be expected in the coastal municipalities separate from that of the earthquake alone, intensity-damage relationships from the non-coastal municipalities were compared with those of coastal municipalities, as nearly all damage in inland municipalities must have been earthquake-related.

Table 1: The relative building damage in coastal municipalities vs. non-coastal municipalities (as of September 28th, 2011)

Buildings	*Destroyed*	*Partially Destroyed*	*Partially Damaged*
Coastal Municipalities	110,834	129,709	229,943
Non-Coastal Municipalities	6,946	48,530	382,537
Total	117,780	178,239	612,480

Source: CATDAT Situation Report 41 (FDMA, Prefectures, NPA etc.) (Daniell, Vervaeck 2011)

2.2 Impact on Key Infrastructure

Japan suffered serious disruptions to its essential utilities (water and energy) in the wake of the earthquake. At least 1.9 million households had no water supply, and the army had to be deployed to provide basic essentials, including bottled water, food, and blankets (Stedman 2011). The earthquake and the tsunami severely damaged power plants of the Tokyo Electric Power Company (TEPCO), including the Fukushima-I and -II nuclear facilities that serve metropolitan Tokyo and the neighbouring Greater Tokyo industrial area. About 40 percent of the electricity used in the Greater Tokyo area is supplied by nuclear power plants in the Niigata and Fukushima prefectures. After the quake, TEPCO announced a shortfall of 25 percent of the electricity it supplied, and installed a rolling blackout in Tokyo and vicinity. It is an aspect of the adaptive resilience of Japanese society for coping with such massive energy cuts by adopting measures such as reducing commuter-train services, dimming lighting in stores and public installations, and turning off some elevators and escalators. In most other developed-country settings, this would be regarded as an unacceptable failure to respond, and would have caused significant political damage to the governments responsible.

The earthquake-, tsunami-, and nuclear-plant problems also had devastating impacts on Japan's communications (cellular and landline) networks. Two-thirds of Japan's largest mobile provider's base stations in Northern Japan were dead, and it took months to repair them. Had it not been for Japan's resilient internet infrastructure, which not only sustained damage to undersea cables and overland infrastructure, but was able to cope with a 200 percent surge in traffic in the 24 hours following the disaster, the response would have been impeded even more seriously (Gold 2011).

Internet connectivity was a key asset in the wake of the earthquake, as the internet enabled effective communication and information exchange via services such as Skype, Facebook, Twitter and Mixi (the Japanese social media site) despite overloaded and disrupted phone networks. This allowed geographically-distant people to contribute their unique resources and collaborate with people unknown to them. In addition, crowdsourcing technologies such as Ushahidi were used to visualize the most severely-affected localities, which helped relief organizations coordinate and prioritize their response (Gao et al. 2011). The Japanese internet system responded very differently from that seen in the 2006 Taiwan earthquake, when several broken undersea cables left millions of users offline, in some cases for months.

Several characteristic geographic, demographic, and cultural factors in Japan significantly worsened the consequences from the loss of key infrastructure after the Tohoku earthquake. The aid and medical response in the aftermath of the earthquake was complicated by the sheer scale of devastation, widespread damage to supply routes, loss of power- and communications networks, and concerns about radiation leaks from the Fukushima 1 nuclear power plants. Even if the Sendai region, with a population density of 300 persons per square kilometer, would not be considered rural in most of the world, in Japan, such areas are considered to be predominantly rural, and their relative isolation made the transport of essential commodities (food, water, and fuel, etc), aid materials and rescue teams even more difficult. Even communities in the Fukushima Prefecture, which are more readily accessible than other prefectures because of their proximity to the Tokyo metropolitan region, radiation leaks prevented the transport of materials and human resources.

The existing shortage of healthcare resources in rural areas was also exacerbated by the destruction of hospitals, clinics, and nursing homes, and the loss of healthcare staff. In-patients in the damaged hospitals had to be transferred to other hospitals. In some cases, this was extremely difficult, as hospitals and nursing homes for the elderly were located in the suburbs of the city, or in small towns which were relatively isolated from public transportation. The isolation of the affected area led to slower recovery efforts when compared to events such as the Great Hanshin-Awaji earthquake of 1995, which occurred in one of Japan's largest cities. It should also be noted that, while the Tohoku earthquake affected the predominantly-rural Tohoku district, the loss of power had widespread technological and socio-economic ripple effects for urban communities in northeast Japan and globally.

A further impact as deleterious as the devastation of residential buildings and the long-term loss of key infrastructure (utilities, schools, hospitals) is population depletion due to migration to cities after disasters. Many of these people had been farmers and fishermen. Unlike urban residents, their lives are rooted in their land and communities, with houses and land inherited from their ancestors. The sudden loss of their jobs, land, homes, and families is catastrophic – socially, economically, and psychologically. Thus, a substantial proportion of survivors will leave the area and relocate, resulting in an even greater underpopulation of these rural areas. Japan's rural areas have been in decline for years, and many of the small coastal towns hit hardest by the tsunami had seen an exodus of young people moving to cities for work (Muramatsu, Akiyama 2011).

The disaster will leave long-term impacts on the agricultural economy and lifestyle of the region. An emerging issue in the recovery and reconstruction phase is the possible abandonment of village sites. The relocation efforts have so far been sensitive to preserving the social-support systems in earthquake-stricken communities, and local governments have relocated whole communities as intactly as possible (Muramatsu, Akiyama 2011). Nevertheless, rebuilding the completely-devastated waterfront communities in innovative plans that remain familiar, and can accommodate the largely elderly population remains challenging and controversial. The event also serves as a wake-up call to urban communities in Japan, especially in Tokyo, where traditional customs are waning, and the elderly may face greater challenges.

2.3 Total Economic Impact

Reasonable estimates for direct economic losses from the earthquake and tsunami have ranged from 195 billion USD to 320 billion USD with a best estimate of around $270–280 billion USD accounting for completion and current prefectural estimates. According to the Miyagi prefecture, around 52 % of the direct loss was due to building loss. This does not include direct losses associated with the Fukushima incident (assumed to be around $58–71 billion USD from TEPCO estimates (Daniell et al. 2011a)). In terms of direct economic losses, the Japanese cabinet office estimated 28 % of direct losses in the four major affected prefectures (Miyagi, Iwate, Fukushima and Ibaraki), occurred inland. For the remaining direct economic losses in coastal areas, it is estimated that approximately between 58–75 % resulted from the tsunami observing work of Miyagi prefecture and other sources (Daniell et al. 2011a). Thus, the following estimates of tsunami, earthquake and powerplant losses results from the direct loss estimates of the Japanese Government and Prefectures as well as additional CATDAT information.

Table 2 shows that around 112–145 billion USD of damage was caused by the tsunami, while 48–81 billion USD can be attributed to the earthquake in coastal regions. This gives approximately equal components of earthquake (52 %) and tsunami loss (48 %) for the sum of both inland and coastal areas. About two-thirds of the total losses calculated by the cabinet office and prefectural reports are housing- or infrastructure-related. As yet, the monetary losses associated with the displacement of 70,000 residents within the evacuation zones, as well as the decommissioning of the Fukushima plant have not been calculated other than estimates via TEPCO and other sources.

Table 2: The estimated relative building damage caused by the tsunami vs. the earthquake

In Billion USD	*Earthquake*	*Tsunami*	*Powerplant*
Direct Loss Inland	77	0	58–71
Direct Loss Coastal	48–81	112–145	
Total Direct Loss	125–158 (42 %)	112–145 (39 %)	58–71 (19 %)
Indirect Loss	69–132	64–113	51–91
Total Economic Loss	194–290 (41 %)	176–258 (36 %)	109–162 (23 %)

Source: Daniell et al. 2011a

There will also be many indirect losses as a result of the Tohoku earthquake, as can already be seen on the example of the interruption of the automotive industry's production, and the power outages. The power shortage due to destruction of the electric-power stations and network was assumed at the time to contribute to ripple effects of up to 1 trillion JPY or about 12 billion USD. Kouno (2011) estimated direct losses from power failures at 166.3 billion JPY and all of the inter-industry indirect effects to add up to 1.5 trillion JPY.

The Tohoku region is the production center of Japanese semiconductors, auto parts, electronic devices, and other components. Many large-scale manufacturers of automobiles (e.g., Toyota, Nissan, and Honda), steel (e.g., Nippon Steel), and chemical facilities (e.g., Mitsubishi

Kagagu) went off production, causing a decline in global automobile production (Norio et al. 2011). The local industry supplies not only the domestic Japanese demand for industrial products, but also those involved around the world (e.g., 25 percent of the global supply of silicon wafers came from two semiconductor manufacturers which stopped working after the event) (Kusuda 2011). The interrupted parts- and materials-supply chain, together with the power outage, affected Japanese manufacturing severely, and rippled around the world. The car industry, which operates on the just-in-time principle with a minimum of inventory stock, suffered from the shortage of parts and components. Many key component manufacturers were based in the worst-hit region of Japan, which forced a slowdown of manufacturing in Japan itself, as well as overseas (Kusuda 2011).

2.4 Human Losses

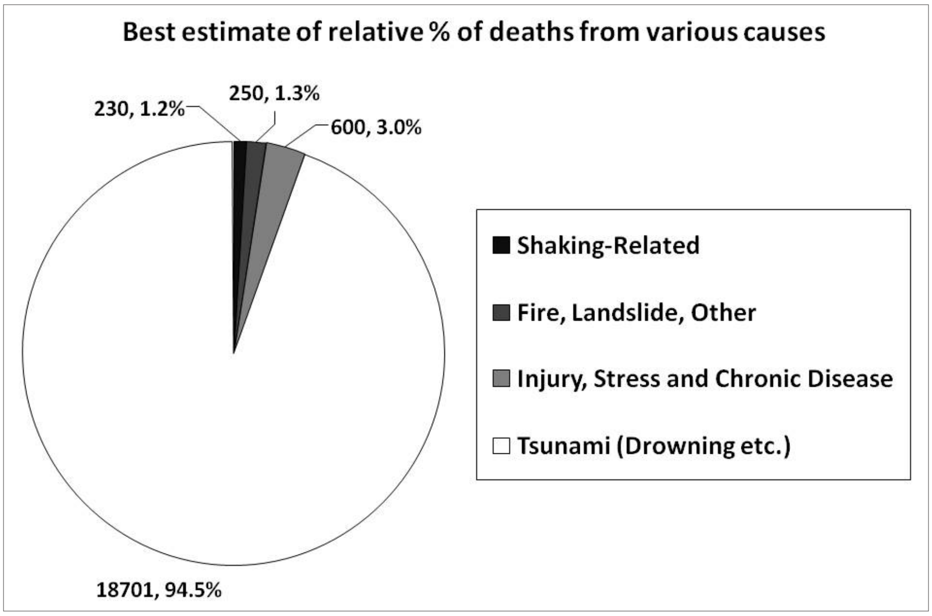
The human losses incurred by the Tohoku event were extremely severe. As of September 30th, 2011, 15,815 were counted dead and 3,966 missing (19,781 in total). It is unknown how many victims may have died directly due to the earthquake, not counting tsunami losses. However, autopsies from the first 13,135 killed indicate that the earthquake alone did not kill many people (NPA 2011).

Figure 1 shows the distribution of fatalities of the Tohoku event from different causes. The total quake-related death count estimated for Tohoku is currently as low as 230 (Daniell, Vervaeck 2011), but the actual number has uncertainties. This value corresponds quite well to the 133 non-tsunami-caused deaths that have been recorded in the non-coastal areas. In comparison, the 1923 Great Kanto earthquake resulted in 28,560 earthquake deaths, and the recent 1995 Kobe quake in 4,823 earthquake deaths.

However, in terms of tsunami deaths, the 2011 Tohoku event with 18,658 dead and missing is one of the most deadly events ever to hit Japan. Among the highest death counts from historic tsunamis are 31,000 in Tokaido 1498, anywhere from 5,000 to 32,000 in Hoei 1707, and 22,066 in Meiji-Sanriku 1896 (CATDAT 2011).

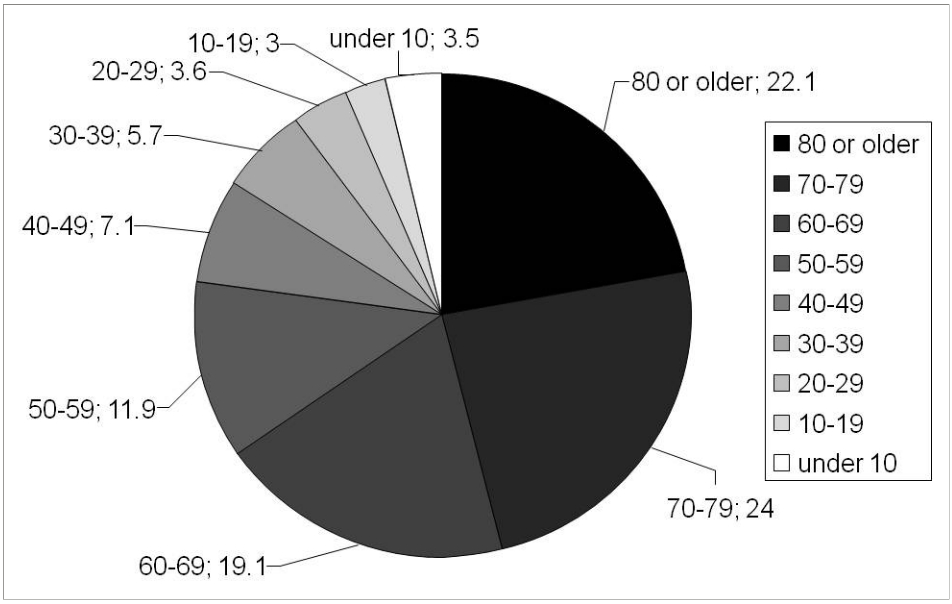
The maximum number of homeless and refugees in shelters is hard to calculate, due to incomplete data in the first few days. It was likely that a total of around 620,000–800,000 people were

Fig. 1: Proportion of fatalities from the Tohoku event from tsunami, earthquake, fire, landslide, and other causes



Source: Daniell, Vervaeck 2011

Fig. 2: Estimated fatalities by age for the dead and missing



Source: Estimation based on NPA results from April 21st, 2011 as a date of reference

living outside of their homes on March 12th, but data is lacking. With about 23 percent of Japan's 127 million people older than 65 (Tanaka et al. 2009), Japan has the world's highest proportion of elderly in the world. The March-11th disaster highlighted the current and emerging issues of a "super-aging" society, especially the need for community-based support systems. Age therefore played a major role in the survival chances of people escaping the tsunami; as people age, they generally become less mobile. 77 percent of all of the victims counted up to this point were older than 50, and 46 percent of the victims (nearly half) were over 70 years of age (Fig. 2).

The large elderly population presented a particular challenge for rescue teams and survival; older adults were particularly vulnerable to cold, influenza, relocation, and chronic mental and physical stress (Minami et al. 1997). Many suffered under lack of access to medication and treatment needed to control their chronic disorders. As of July 24th, 2011, 570 people were reported to have died due to stress and chronic disease as a result of the earthquake and the tsunami. In Japan, these are also included in the death toll. Stress and chronic disease contributed to over 90 % of the "earthquake-related deaths" in populations aged 65 and over (Muramatsu, Akiyama 2011). The inclement weather in northeast Japan further heightened the impact on shelter-seeking populations, especially on the elderly. Due to the lack of electricity and oil, evacuated residents spent nights freezing in unheated shelters. In addition to their injuries, many survivors had to deal with pre-existing chronic diseases under these adverse conditions.

2.5 Nuclear Power Plant Crisis

Fuel damage and substantial releases of radioactivity into the environment by the damaged Fukushima 1 nuclear power plants severely exacerbated the disaster. Radiation levels in Tokyo had reached 20 times the normal "background" levels by March 15th, 2011. As could be expected from a disaster of this magnitude, environmental health hazards and associated risks extend across a wide range of media, including contaminated air, water, soil, food, and waste. Japan banned the export of selected food products from the northeast of the country, and many countries placed restrictions on Japanese food imports, including normally large importers such as China and Korea. It is likely that soils exposed to high radiation will require reclamation, and long-term impacts of the disaster on plants, animals, fisheries, and forests will be assessed in the coming decade. Furthermore, the nuclear power plant emergency in Japan has resulted in a global reconsideration of the safety of nuclear power.

In Fukushima, the impact of the tsunami and of the earthquake was not as great as in other places, and the real impact of the nuclear disaster becomes apparent in the massive displacement of people in the Fukushima prefecture. The total impact of the radiation advisory in Fukushima was the following: once all of the people had been located, and those who had been evacuated were counted, the total of the population who fled to shelters and other prefectures was around 134,000 people, of which around 90,000–110,000 were evacuees of the Fukushima plant disaster, and between 24,000 and 44,000 were probably earthquake- and tsunami victims. Other influences causing displacement of the population affected may have included the gas-, water-, and power outages, landslides, and torrential rain. As of September 28th, 2011, around 56,000 people were living outside the prefecture of Fukushima, and around 50,000 internally (of which 42,000 are from the nuclear-affected towns).

2.6 Causal Interactions

Natural and technical systems are involved in complex social systems of highly developed societies. The Tohoku earthquake was typical of disasters with cascading expansion, and dynamic risk-assessment procedures should follow from recent disaster experience that incorporates dynamic interactions between natural hazards, socio-economic factors, and technological vulnerabilities. In the case of Japan, the effects of the cascading phenomena in the long-term loss of electric power in large parts of Honshu, with all of its consequences for the economy, and the reverberations of the nuclear accident at Fukushima 1 have critical impacts on the assessment of direct and indirect risks from the event.

Causality mapping (also known by several other names, such as Fault Tree Analysis, Event Tree Analysis, and Failure Mode and Effects Analysis), is an essential tool for dynamic risk assessment (Hodgkinson, Clarkson 2005), as it can be used to provide advice for anticipating potential failures, their potential causes, and their consequences. These methods are beneficial for improving understanding of the system, and for providing guidance for locating critical points for risk mitigation.

In accounting for all of the factors relevant during the Tohoku disaster, the main initial earthquake and both the tsunami and the nuclear power plant incidents are depicted in Figure 3. The direct and indirect interactions between the various triggering events and their causes found in the literature are shown. This method follows the tradition of System Dynamics. The map also depicts the concept of cascading phenomena and exacerbating factors in society and the economy triggered by the earthquake. Table 3 summarizes the main direct and indirect impacts resulting from the earthquake, the tsunami and the nuclear power plant incident, as well as a set of factors that intensified these impacts.

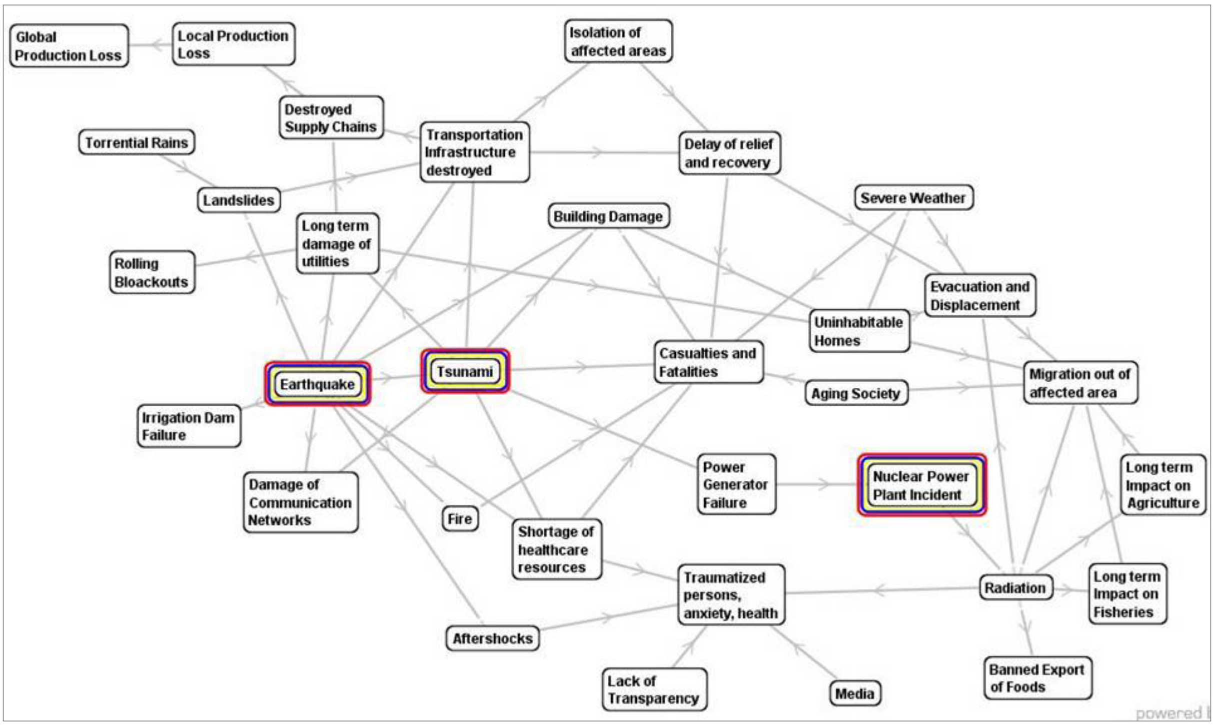
It should be noted that, while the earthquake was the initial trigger, many of the direct and indirect impacts are themselves causes. For example, damage to the transportation infrastructure, worsened by the conditions in remote areas, led

Table 3: List of causes, direct and indirect impacts, and exacerbating factors in the Tohoku event

Causes	*Direct Impacts*	*Indirect Impacts*	*Exacerbating Factors*
Earthquake; Tsunami; Nuclear power-plant incident	Casualties and Fatalities; Building damage; Long-term damage to utilities; Damage to transportation infrastructure; Evacuation and Displacement; Radiation; Landslides	Uninhabitable Homes; Supply chains destroyed; Local and global production loss; Migration out of the area affected, Banned food exports; Long-term impact on agriculture and fisheries; Delay of relief and recovery; Traumatized persons, anxiety and health concern	Aging Society; Isolation of affected areas; Shortage of health resources; Lack of political transparency; Severe weather; Different power circuit topology; Lack of preparedness for nuclear emergency

Source: Own compilation

Fig. 3: Causal Map and direct/indirect impact chains of the Tohoku earthquake



Source: Own compilation

to hampered relief and recovery efforts. Long-term indirect impacts on agriculture and fisheries, exacerbated by a lack of support for an aging society, may lead to migration out of the affected areas and population depletion. For a more complete representation of the direct and causal interactions, the map in Figure 3 depicts the disasters and their impacts as nodes and arcs representing the "causal concept" and "causal connections" through the chain of different impact events.

3 Recent Major Catastrophes

In the following, we review very briefly some of the critical interactions which led to major catastrophes in 2010: the Haiti earthquake, the Russian wildfires, and the Pakistan floods. The aim is to reconstruct a pattern that has been analyzed in-depth for the Tohoku earthquake, but which is believed to be typical for extreme events of many types: the complex interaction of natural factors with societal structures and technical facilities. Some of the main loss parameters for these events are shown in Table 4.

3.1 Russian Fires

The very dry summer 2010, with record temperatures in Western Russia, led to widespread wildfires. The ensuing heat wave and smog caused, even without fires, major crop failures and significant burdens on the health system, as people suffered from heat and smog. The most frightening aspect of the fires, however, consisted in the potential nuclear threat when fires raged near Sarov, the site of nuclear research- and weapon-production facilities which had been heavily polluted during the Chernobyl nuclear accident in 1986. Fortunately, these fears did not materialize, and no major increase in radiation levels has been reported. Nevertheless, this example again shows the adverse interactions of natural disasters (drought, fire) with insufficient capacities to respond (fire prevention, fire fighting) and to reduce their adverse effects, with technological facilities and circumstances (nuclear installations and contamination from a previous accident). Even if one assumes that climate change is responsible for the most intensive heat wave

Table 4: The main loss parameters in each of the four catastrophes analyzed

	Tohoku 2011	*Haiti 2010*	*Russia 2010*	*Pakistan 2010*
Main Disaster Types	Earthquake, Tsunami, Nuclear Accident	Earthquake, Disease	Heatwave, Bushfires	Flood, Food Shortage
Main Dates	11.03.2011–	12.01.2010–	15.06.–17.08.2010	21.07–08.10.2010
Deaths	< 19,781 (15,815 dead, 3,966 missing)	136,933 (46,190-316,000)	15,000–55,760	1,781–1,985
Injuries	>6,000	310,928	n/a	3,000
Homeless	400,000–700,000	866,142–1,500,000	7,000	6,000,000
People Affected	40,000,000	2,500,000	45,000,000	20,000,000
Buildings Destroyed/ Uninhabitable	118,000	78,000	2,900	1,890,000
Buildings Damaged	890,000	100,000	n/a	unknown
Direct Economic Losses	USD270-351bn	USD8bn	USD16.08bn	USD9.7-30bn

Source: CATDAT 2011

Russia ever experienced, the threats it actually posed to society resulted from its interaction with societal shortcomings and dangerous technologies. The fires near nuclear installations had the potential to spread a regional disaster to a large area, including neighbouring states, via radioactive contamination.

3.2 The Haiti Earthquake

The Haiti earthquake of magnitude 7.0 on January 12th, 2010 was a shallow earthquake which struck a very poor country, where 80 percent of the people were living below the poverty line of one USD per day. The immediate consequence of the earthquake was a widespread collapse of residential buildings, schools, hospitals, a breakdown of infrastructure (harbors, airports, communication, fresh- and waste water, power, radio), but most important, many government buildings collapsed. This almost complete loss of institutional capacity led to significant delays in restoring functions and services, in forwarding international help, and in distributing it quickly. The lack of governance due to unstable political conditions greatly hampered reconstruction. Even after one year, many people lived in poor shelters, without adequate sanitary conditions. Consequently, a cholera epidemic spread ten months after the earthquake, with a total of 6,000 deaths of nearly half a million people affected, among which the elderly and the children were the most vulnerable groups. This example shows that even a moderate earthquake can cause an extreme catastrophe if it affects an area with a poverty-stricken population living in highly vulnerable locations and buildings, with poor governance structures, and lacking in response capacities. These circumstances bring about new risks – in this case, an epidemic, which again affected the most vulnerable persons most severely.

3.3 The Pakistan Floods

The heavy monsoon rains in Northern Pakistan beginning in late July 2010 caused enormous floods in the Indus River basin, the worst in the past 80 years. As a result, one-fifth of Pakistan's total land area was submerged, affecting 20 million people, mostly by destruction of property, of key infrastructure (power, transportation, and schools), and loss of livelihood. Floods submerged vast areas of Pakistan's most fertile cropland in the Punjab, killed livestock, and washed away massive amounts of grain, resulting in a food crisis. This disaster hit Pakistan in a situation of poor governance and declining political stability, due to ineffective leadership and corruption. Civil war led to unstable conditions in the Northwest Frontier Province, and Taliban insurgents tried to take advantage of the disaster wherever government representatives were absent, or corruption compromised trust in institutions. This example shows the interaction of a natural disaster (heavy precipitation and subsequent floods) with weak governance and a society stricken by civil war. It caused immense losses for the economy and future growth, growing distrust in government institutions, and increased societal instability, which can have a serious impact on global politics, given the fact that Pakistan is a nuclear power.

4 Conclusions

By evaluating the examples of the catastrophes discussed here, we can learn that two effects characterize large-scale disasters. First, they emerge as complex interaction patterns between the natural hazard, societal conditions, and the vulnerability of infrastructure and institutions on which the functionality of societies is based. These interactions can give rise to new risks, such as epidemics or nuclear radiation, and can have long-term consequences for the economy. Haiti was struck by a cholera epidemic long after the earthquake, the Russian wildfires had significant potential to cause health risks due to exposure to nuclear radiation, the floods in Pakistan led to food shortages and to further erosion of political stability in a region of high geopolitical importance, and the full consequences of Fukushima 1 in Japan are yet to be seen. While foreign aid has brought vast quantities of food and aid to Haiti, without rebuilding and reform of its institutions and infrastructure devastated by the earthquake, Haiti is a victim-of-poverty trap that condemns its people to live unprotected in urban slums. In affluent countries such as Japan, the economic loss remains limited to a small percentage of the GDP, but as the earthquake has struck it in a debt crisis of the public financial system, a downgrading by ranking agencies causes long-term losses and an increased debt-load for the state and its citizens.

Second, within the interaction pattern, one or a few circumstances become highly relevant, and can worsen the disaster significantly. Striking examples are the nuclear consequences of the Japanese earthquake and (potentially) of the Russian wildfires. The collapse of the organization of the UN peace-keeping force in Haiti prevented deploying 6,500 soldiers familiar with the country, who could have played a major role in immediate response, have restored the functionality of airports and of major roads, and have assured the safe distribution of international help. There is a growing debate on understanding risks as dynamic processes, because risks change with time, and because hazards and/or exposure and vulnerability are functions of time. This view results in striving for risk monitoring rather than static risk assessment. Here, we add another aspect to the understanding of the dynamic dimension that – in our view – characterizes several recent catastrophes – the cascading processes among the three key parameters of catastrophes: natural phenomena, technological systems, socio-economic and political functions.

Some of the implications for risk assessment as a prerequisite for the mitigation of extreme events are:

1. Risk analysis must consider the full complexity of the interacting and cascading effects we face when they emerge. This analysis cannot be done exclusively with quantitative and probabilistic methods, as some of the interactions are difficult to model, and uncertainties are not only high, but unknown.
2. The residual risks – what happens beyond the regulatory safety measures – are not well understood, neither component-wise (for instance the residual risk to residential buildings and life safety) nor for systems (lifelines), or the entire complexity of potential interactions and cascades.
3. Scenario methodologies and stress-testing for extreme events may be a tool for exploring the key cascades, interactions, and factors of influence that create losses and surprises. In recent months, the method of stress tests became popular for financial institutions, insurance companies, nuclear power plants, etc. It may become an adequate disaster-management approach for extreme events, but it has no scientific basis.

Note

1) Both power plants consist of several reactors and are situated at a distance of 12 kilometers.

References

Daniell, J.E., 2010a: The CATDAT Damaging Earthquakes Database. Paper No. 6, AEES 2010 Conference, Perth, Australia

Daniell, J.E., 2010b: EQLIPSE Individual Country Building Inventory. Digital Database and Report, Karlsruhe

Daniell, J.E., 2011: The Development of Socio-economic Fragility Functions for use in Worldwide Rapid Earthquake Loss Estimation Procedures. PhD Thesis (unpublished), KIT, Karlsruhe

Daniell, J.E.; Vervaeck, A., 2011: The 2011 Tohoku Earthquake – CATDAT Situation Reports 1–41, Earthquake-Report.com

Daniell, J.E.; Vervaeck, A.; Wenzel, F., 2011a: A Timeline of the Socio-economic Effects of the 2011 Tohoku Earthquake with Emphasis on the Development of a New Worldwide Rapid Earthquake Loss Estimation Procedure. Australian Earthquake Engineering Society 2011 Conference, Nov 18–20, Barossa Valley, South Australia

Daniell, J.E.; Wenzel, F.; Vervaeck, A., 2011b: The Socio-economic Effects of the 2011 Tohoku earthquake. In: Geophysical Research Abstracts 13, EGU2011-14270

Daniell, J.E.; Khazai, B.; Wenzel, F. et al., 2011c: The CATDAT Damaging Earthquakes Database. In: Natural Hazards and Earth System Sciences 11 (2011), pp. 2235–2251, doi:10.5194/nhess-11-2235-2011

Daniell, J.E., 2003–2011: The CATDAT Damaging Earthquakes Database. Digital Database, updates v0.0 to latest update v5.024

FDMA – Fire and Disaster Management Agency, 2011: Situation Reports 1-139. FDMA Reports from 11/03/2011 to 28/09/2011; http://www.fdma.go.jp (download 17.11.11)

Fukushima Prefecture, 2011: Damage, Casualty and Shelter Reports 1-376. Reports from 11/03/2011 to 28/09/2011; http://www.pref.fukushima.jp (download 17.11.11)

Gao, H.; Barbier, G.; Goolsby, R., 2011: Hanressing the Crowdsourcing Power of Social Media for Disaster Relief. In: IEEE Intelligent Systems 11 (2011), pp. 1541–1672

Gold, S., 2011: The Gain and the Pain: Japan Cybercrime Floods Vulnerable Networks. In: Engineering and Technology 6/4 (2011), pp. 50–51

Green, C.; van der Veen, A., 2007: Indirect Economic Damage: Concepts and Guidelines. In: Evaluating Flood Damages: Guidance and Recommendations on Principles and Methods, FLOODsite, Report, T09-06-01

Hatori, T., 1986: Classification of Tsunami Magnitude Scale. In: Bull. Earthq. Res. Inst. 61 (1986), pp. 503–515

Hodgkinson, G.P.; Clarkson, G.P., 2005: What Have we Learned from Almost Thirty Years of Research on Causal Mapping? Methodological Lessons and Choices for the Information Systems and Information Technology Communities. In: Narayanan, V.K.; Armstrong, D.J. (eds.): Causal Mapping for Information Systems and Technology Research: Approaches, Advances and Illustrations. Hershey, PA, pp. 46–79

Iwate Prefecture, 2011: Damage, Casualty and Shelter Reports. Reports from 12/03/2011 to 28/09/2011 (over 200 reports); http://www.pref.iwate.jp (download 17.11.11)

Japanese Cabinet Office, 2011: Japan Estimates Quake Damage at 16.9 trln yen. Reuters http://www.reuters.com/article/2011/06/24/japan-economy-estimate-idUSL3E7HN3CM20110624 (download 29.11.11)

Japanese Government, 2011: Japan Sees Quake Damage Bill of Up to $309 Billion, Almost Four Katrinas. Bloomberg, Keiko Ujikane, accessed March 23, 2011

Kleindorfer, P.R.; Saad, H.G., 2005: Managing Disruption Risks in Supply Chains. In: Production and Operations Management 14/1 (2005), pp. 53–68

Kouno, 2011: The Effects of Power Shortages on Japan's Economy. The Lessons of the Great Tohoku Earthquake and Its Effects on Japan's Economy (Part 4); http://jp.fujitsu.com/group/fri/en/column/message/2011/2011-04-14.html (download 29.11.11)

Kusuda, Y., 2011: Japan Quake and its Impact on Japanese Robotic Industry. In: Industrial Robot: An International Journal 38/5 (2011)

Li, F.; Bi, J.; Huang, L. et al., 2010: Mapping Human Vulnerability to Chemical Accidents in the Vicinity of Chemical Industry Parks. In: Journal of Hazardous Materials 179/1–3 (2010), pp. 500–506

Messner, F.; Green, C., 2007: Fundamental Issues in the Economic Evaluation of Flood Damage. In: Evaluating Flood Damages: Guidance and Recommendations on Principles and Methods, FLOODsite, Report, T09-06-01, pp. 95–105

Minami, J.; Kawano, Y.; Ishimitsu, T. et al., 1997: Effect of the Hanshin-Awaji Earthquake on Home Blood Pressure in Patients with Essential Hypertension. In: American Journal of Hypertension 10 (1997), pp. 222–225

Miyagi Prefecture, 2011: Damage, Casualty and Shelter Reports. Reports from 12/03/2011 to 28/09/2011 (over 300 reports), http://www.pref.miyagi.jp (download 17.11.11)

Morita, K.; Nagai, Y., 2011: Japan Economic Focus, Economic Implications of Earthquake. In: Barclays Capital, Japan Economic Research, March 15, 2011

Muramatsu, N.; Akiyama, H., 2011: Japan: Super-Aging Society Preparing for the Future. In: The Gerontologist 51/4 (2011), pp. 425–432

Okada, S.; Takai, N., 2004: Damage Index Function of Wooden Buildings for Seismic Risk Management. In: Journal of Structural Engineering 582 (2004), pp. 31–38

Porto, M.F.; de Freitas, C.M., 2003: Vulnerability and Industrial Hazards in Industrializing Countries: An Integrative Approach. In: Futures 35/7 (2003), pp. 717–736

Porto, M.F.; Fernandes, L., 2006: Understanding Risks in Socially Vulnerable Contexts: The Case of Waste Burning in Cement Kilns in Brazil. In: Safety Science 44/3 (2006), pp. 241–257

Stedman, L., 2011: Japan: Country Suffers Water Shortages Following Earthquake and Tsunami. In: Water21 – Magazine of the International Water Association (IWA); http://iwapublishing.com/template.cfm?name=news679 (download 15.3.11)

Taleb, N.N., 2007: The Black Swan: The Impact of the Highly Improbable. London

Tanaka. T.; Kazui, H.; Sadik, G. et al., 2009: Prevention of Psychiatric Illness in the Elderly. In: Psychogeriatrics 9 (2009), pp. 111–115

Tokyo Metropolitan Government, 1985: Report on Earthquake Damage Estimation in the Ward Districts of Tokyo. Disaster Prevention Council Report. Tokyo

Vervaeck, A.; Daniell, J.E., 2011: Tohoku Earthquake Articles on earthquake-report.com. Many updates from 11/03/2011 to 28/09/2011

Zsidisin, G.A.; Ragatz, G.L.; Melnyk, S.A., 2005: The Dark Side of Supply Chain Management. In: Supply Chain Management Review 16 (2005), pp. 46–52

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Systemic Risk in Global Finance

by Helmut Willke, Zeppelin University

The paper addresses the emergence of systemic risk as a property of global finance. Part 1 describes two factors of the post-Bretton-Woods global financial system which John Eatwell has singled out as pushing the propensity for systemic risk: the focus on single firms, and a misguided focus on homogeneity. Part 2 of the paper then broadens the perspective in order to expose some aspects of a political economy of systemic risk in global finance. Now, after the fact of a global crisis, the major controversy is about the nature of systemic risk: is it mainly an economic problem, or is it a political issue, that is, must it be understood in terms of political accountability and the limits of political regulation? Part 3 discusses some consequences for regulation and supervision within the context of irreducible conflicts between national egoism and global collective goods.

1 Introduction

The veil of ignorance covering the operational modes and the consequences of arcane financial models and instruments becomes a public concern as soon as the failure (bankruptcy) of financial institutions (banks, investment firms, insurance companies, private equity funds, semi-official mortgage agencies like Fannie Mae or Freddie Mac) threaten to engender system-wide consequences. The question is: what are system-wide consequences?

Systemic repercussions of the (possible) failure of financial corporations are closely related to the notion of "systemic risk". In general, systemic risks emanate from an intransparent interplay of layered and leveraged components of a concatenated compound. The case of the global financial system is an exemplary one, since the focus of all governance and regulatory action has been on single components, i.e., issuers, Chief Financial Officers, individual firms and corporations etc., whereas the interplay of these components has remained intransparent: "A lack of focus on the changing *system* characteristics of the interna-