THE GREAT EAST JAPAN EARTHQUAKE

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ABSTRACT

The frequency of natural disasters has increased sharply in the last 50 years and their impact - in terms of societies disrupted, the destruction of the productive capacity of land and waters and of public and private property, and beyond - grows faster with increasing densification and globalization of our societies. The Great East Japan Earthquake of March 11, 2011 exemplifies all of these problems. How do we put society back together after an event of this kind in the age of information and globalization? Japan's culture strongly emphasizes inclusiveness, debate, and consensus and today we see the nation moving onward from disaster response and restoration and toward the planning of the reconstruction.

This work is based on personal experience, beginning on March 11, 2011, of the opinions, challenges and approaches across Japanese society, which are compounded by a long period of economic stagnation. The paper will describe and illustrate the major impacts of the March 11th event and the methods employed during the response and restoration phases to secure the refugees and later to move them to more stable environments. Japan is now beginning a long and complex debate from the level of villages up to the central government about how to reconstruct the society and indeed what kind of society to reconstruct. Opinions vary from "re-build it as it was" to "a chance to re-invent Japan". Cities and citizens are beginning the deliberative dialogues and the complexity of the decision-making begins to appear.

The March 11th earthquake and tsunami heavily damaged a region that takes part in both global industrial and food supply chains and the event serves to underline the global inclusiveness that will be an increasing characteristic of major disasters. From radiation hazards, to food safety and GDP impacts, nations around the world feel that they are stakeholders in this event. We also see that information technologies can serve to increase the resilience of society but also introduce new risks. The notion of "Design for Resilience" emerges. Perhaps too we need some supra-national processes – akin to the roles played by the World Bank and the International Monetary Fund in stabilizing the global financial systems – to stabilize public safety, health, and industry.

Keywords: disaster, tsunami, resilience, reconstruction, global supply chain

INTRODUCTION

For reasons that are not well understood, the numbers of natural disasters, including earthquakes, have been increasing strongly since around 1950 [EMDAT, 2011] as shown in Figure 1. It is speculated that some of this rise is attributable to various consequences

of global warming, but this has not been clearly demonstrated and would still leave much to explain.

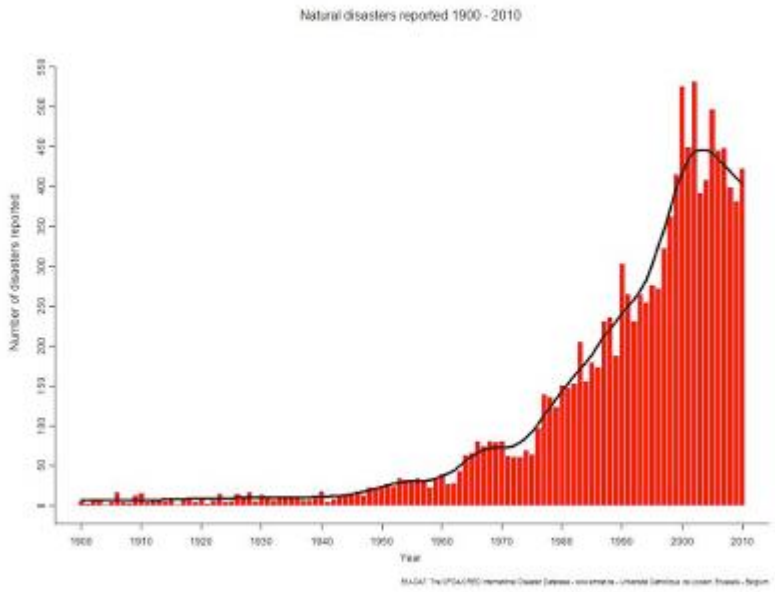

Figure 1: The frequency of natural disasters has been increasing rapidly in the last 50 years,

Although loss of life in disasters in developed economies has been decreasing, it is at record highs in under-developed countries. The direct costs of these natural disasters has risen even more rapidly, which may be attributable to the increased density of populations and their associated infrastructure as shown in Figure 2.

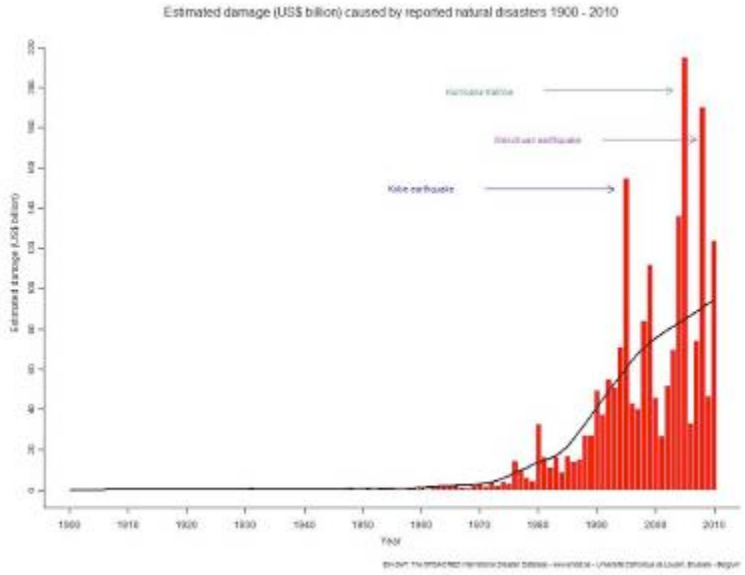

Figure 2: Estimated damages resulting directly from reported natural disasters, 1900-2010.

Technological disasters have also increased strongly during this period, although this is somewhat easier to explain in terms of increasing industrialization.

There may be role for Systems Science in understanding the origins of certain kinds of natural disasters, fluvial flooding, perhaps. But certainly a valuable area for investigation would be in the understanding of the collapse of social and urban systems as a result of a major disaster, whether natural or industrial, and what measures could be taken to mitigate these effects too. The technical literature of disaster places great emphasis on the mitigation of the physical effects of these events [Schwab, 2011] and on the reconstruction following such events [Olshansky, 2007], but there seems to be a dearth of research on how to apply Systems Science to the social and societal impacts.

It is not the purpose of this paper to develop such an investigation. Rather it is a journalistic review of the Great East Japan Earthquake of 2011, also known as the Tokohu Earthquake, and to highlight some of the issues that could be studied by the Systems Science community. It begins with a description of the immediate events and impacts of the earthquake and the related tsunami and then describes the situation about three weeks later, when the most urgent responses were beginning to wind down, and the depth of the social and societal impacts were becoming clear, but the recovery process had not yet begun. It describes the complex social engagement beginning over how to decide what to rebuild and where and concludes with two important lessons learned from this event that require the creation of a future, more resilient society.

THE GREAT EAST JAPAN EARTHQUAKE

On Friday, 11 March 2011 at 14:46 JST a 9.0 Magnitude [Tohoku, 2011] earthquake occurred at depth of 32 km approximately 70 km of the northeast coast of Honshu, the main island of Japan. Within seconds the Japan Meteorological Agency [JMA, 2011] monitoring system had determined that this earthquake was likely to cause severe seismic movements on land and issued an automatic signal to bring the Shinkansen high-speed trains safely to a halt. The monitoring system also determined that a large tsunami could be expected to arrive at the coast within 10-60 minutes and activated the tsunami alarm system along the coastal towns.

The earthquake turned out to cause relatively minor impacts in the built environment, rather more in the central mountains. However the tsunami caused an unimaginable toll in terms of people killed or missing and infrastructure and property damaged. In early April 2011, 12,600 deaths had been recorded across 48 communities along 400 km of the coast, and some 14,700 were reported missing. Major damage was reported to some 125,000 buildings with estimates of the cost to infrastructure and private property extending to over $200 bn. Figure 3 is a typical scene from the small fishing town of Minami-sanriku in Miyagi Prefecture.

Figure 3: The area of Minami-sanriku approximately 1 km inland from the fishing port on 3 April 2011.

Some 40% of the 28,000 km coastline of Japan is protected by massive concrete seawalls. These have been the subject of much contention as they block the view of the ocean for many people living on the coast and they are resisted by some environmentalists. The heights of the sea walls on the eastern coast of Honchu range from around 6 m to over 15 m. With few exceptions, in the area directly impacted by the tsunami the sea walls failed to protect the towns behind them. Figure 4 shows the extent of the destruction along the coast.

Tohoku, being the northern section of Honchu, has two distinct types of coastline. Starting roughly at Ishinomaki and going north is a "ria" coast. This coast is famous for its fishing and especially for its oysters. The coast is bordered by volcanic hills, some 50 m high, that are penetrated by small rivers draining the inland plateau. The many fishing ports in this area, such as Minami-sanriku, are or were constructed at the mouths of these rivers. In these river valleys the tsunami was funnelled by the converging valley walls and in extreme cases attained heights over 30 m. However it was strongly contained in the valley, leaving what one local official described to us on 3 April 2011 as a "0 and 100" world. Areas towards the coast were completely destroyed as seen in Figure 1, but there was abrupt transition further up the valley to areas that were completely undamaged. There was cultural knowledge from earlier major tsunamis, most recently in 1933, that the communities should not build in the lowlands of these valleys, but this knowledge seems to have been ignored in many cases. Figure 5 shows maps of Minami-sanriku (left) and the eastern part of the city Sendai (right) and indicates in pink the areas that were inundated by the tsunami.

Figure 4: Towns all along the eastern coast of Honchu were impacted.

In the southern portion of the coast, for example eastern Sendai, the land is flat to the coast line rising very gradually from sea-level and was predominantly used for rice paddies with generally sparse population. Here the tsunami, which was typically around 8 m high at the coast, was able to flow several kilometres inland. Near the coast line there was almost complete destruction as in Minami-sanriku, but after flowing inland for 3-4 kilometers, the tsunami had spent its force and fallen below 2 m height. Beyond this point, although it might still flood property and buildings, it caused little structural damage.

To the south a critical impact of the tsunami was on the back-up generators of the Tokyo Electric Power Company's (TEPCO) nuclear reactors in Fukushima Prefecture, some 200 km northeast of Tokyo. The automatic shutdown of the reactors was initiated correctly following the earthquake, resulting in the lost of power to auxiliary systems from the grid. The backup generators started correctly to maintain the circulation of cooling water in the reactor, but were destroyed an hour later when the 14 m high tsunami swept over the sea wall. Thus began a third disaster that will continue for many years.

This article will not consider further the reactor issues, other than note that as a result of the tsunami 590,000 had to leave their homes, of which 210,000 were evacuated because of radiation from the Fukushima no. 1 plant.

Still further south in Ibaraki and Chiba Prefectures, the earthquake caused structural damage and in particular disrupted the ultra-sensitive equipment of the large

semiconductor manufacturing industry. These operations were further impacted by rolling blackouts that were introduced by TEPCO to contain electricity demand within the reduced generating capacity. Although they were receiving some power every day, it is not possible to start up and shutdown such facilities on a daily basis and so they were effectively closed for several weeks.

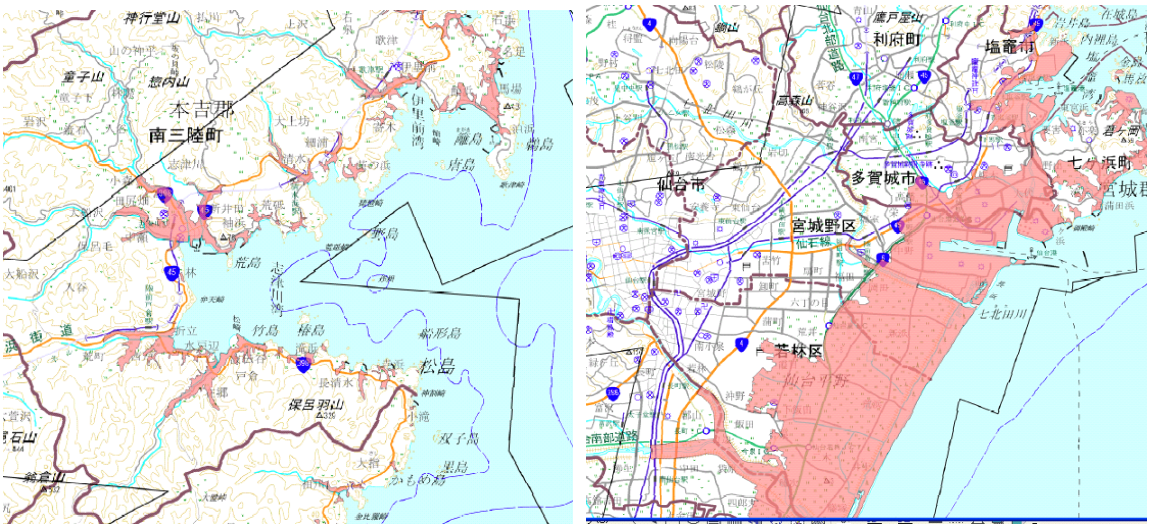

Figure 5: Maps of Minami-sanriku (left) and eastern Sendai (right) showing in pink the areas indundated by the tsunami. 1 km is about 5 mm.

The dense railway network through northern Honchu was immediately shutdown and remained closed for some weeks while bridges and tunnels were inspected and rails re-aligned. All roads were also closed immediately, though most re-opened relatively quickly once they had been inspected.

A major highway runs north from Tokyo up the peninsular to the east of the central mountains. All along this highway are clusters of small manufacturing businesses that are parts suppliers to the automotive industry clustered around Tokyo. These facilities were not in most cases damaged by the earthquake, but the closing of the highway, the loss of electric power, and a shortage of petrol and Diesel fuel in the month following the event prevent them operating and delivering parts to their customers in the south.

The 11 March 2011 was also not the end of the seismic activity. In the following four weeks over 400 after-shocks exceeding 5 Magnitude [Japan Quake Map, 2011] were recorded, two greater than 7 Magnitude within an hour of 9.0 Magnitude earthquake.

WHEN THERE ARE NO SYSTEMS

My direct experience of the destruction in Tohoku began some three weeks after the event. However, it is difficult to convey the feeling of a world in which systems have simply ceased to exist. By that time some 150,000 people had been evacuated to shelters directly adjacent to the impacted areas. These were typically schools and sports facilities.

Food and drinking water were being distributed by the Japan Self Defense Forces (SDF), but water for bathing was still scarce. Japanese people are very fastidious and many people in the shelters went for three weeks wearing the same clothes and with no possibility of bathing.

Temperatures were in the low single digits Celsius and it was snowing gently. The buildings were unheated and frequent opening of the doors meant that indoor temperatures were also very low. There was no lighting so activity ceased after sunset. On the walls of these buildings were long lists of people still missing and unidentified bodies found. NTT, one of the national telephone companies, provided stations for re-charging mobile telephones, but there was little coverage.

Supplies were arriving in convoys of lorries and being offloaded into the gymnasiums of the shelters. Food, clothing, entertainment, batteries… Who knows what was in these storage areas, because they were simply being unloaded and stacked with no attempt to maintain an inventory.

The roads had been cleared of debris and traffic could move freely most places except where the road was damaged. Petrol and Diesel fuel were still hard to find. Water, electricity, and telecommunications services were out. But only a very few kilometers inland, life was relatively normal.

The fishing industry was totally destroyed: ports, processing facilities, fleets, equipment, and oyster beds all gone. In the agricultural areas the rice planting season was beginning, but the land was covered in debris, some of it toxic, and the soil soaked in sea water. Irrigation systems had been swept away. In the south the electronics industry was shutdown and inland the automotive parts manufacturers were unable to ship their production south.

The evacuees had been moved as quickly as possible to the nearest available shelters and so families and communities had been broken up. Volunteers were interviewing 150,000 people to work out who they were and where their families might be. The search and recovery teams were winding down, although isolated bodies continued to be found.

Beyond the losses of people and infrastructure, a majority of the information infrastructure was lost. Many town halls and some 20-40% of the municipal administrators had been killed or lost. Those that were still alive were working long hours to staff the emergency shelters. Many towns had lost all administrative records – residents, land ownership, vehicle ownership, even the employee payrolls. Some had kept backups of their data, but the backups had been lost as well. Doctors' offices and most hospitals along the coast were destroyed, taking with them the mainly paper medical records. The evacuees were being treated in the emergency shelters by rotations of volunteer doctors and nurses from other areas. No records of their conditions or treatments were being kept.

In a few weeks, new shelters or temporary homes had been prepared inland, where life was more or less normal. Yet many of the evacuees now refused to move. Their lives

were rooted in these smaller communities, villages, and they feared that if they once moved away they would become 'outsiders' and never be able to really return.

RECOVERY

Nothing has made the reality of systems of systems more convincing than their total absence. Infrastructure and houses can, in principle, be re-built. But how we can reconstruct the systems that turn them into a living community?

Some records can be re-constructed. Japan had a national census in 2010, which should provide much information on who was living at addresses in the impacted areas. Satellite and aerial photographs can show where buildings and the lines of fields were located. Some aspects of medical records may be recovered from pharmacy transactions, although this requires cooperation from insurers, who have plenty of other problems on their hands.

Remaining municipal administrators may be able to reconstruct their main business processes and it may be possible, one day, to re-implement these from remote, Cloud-based applications. However, first it will be necessary to restore telecommunications between Cloud data centres, well inland, and the devastated areas near the coast. Overhead cables were ripped down, buried cables were shredded, mobile telephone base stations were swept away as were local telephone switching stations.

Yet there are many pressing municipal tasks: families who have lost parents and property need to file claims for compensation, some 230,000 vehicles that were destroyed or lost needed to be de-registered and refunds paid out, lost passports need to be re-issued, new-born babies need birth certificates. Even a disaster does not remove the bureaucratic requirements by various levels of government and insurance companies for proof of….all kinds of things that no longer exist. Kafka was here.

Beyond these reconstructions of facts, lie relationships, social networks. Families have been reunited, or at least reconnected, although in the immediate aftermath of the event, many younger people simply moved away to other parts of Japan where they can find work. So this region, which has been slowly declining economically, has seen a sudden shift in demographics.

Too late we realized that it should have been possible, while the evacuees where in the primary emergency shelters, to document their social networks – their families, friends, schools, places of work, favourite shops and restaurants. All their points of connection into the communities that no longer exist.

It is likely that many of those homes and businesses that were closest to the coastline will not be re-built. Such land may be re-zoned by the Prefectures to prohibit residential use and even housing further inland may have to meet new construction requirements. For example, as was adopted in some parts of New Orleans, houses may be raised several meters on an open frame that may serve as a car port. New defences against future tsunamis will be constructed, changing the topology of a district. So it may not be

possible to reconstruct the world as it was and hence to reconstruct social networks and systems as they were.

City officials are developing initial plans for reconstruction, trying to balance the desires of many to rebuild their community as it was against the evident need for greater protection – but how much exactly – and the limited funds that are available for purchasing land, paying for major civil engineering works, and redeveloping enough residential space for those who still want to live there. They will then have to conduct a debate with their citizens on which set of options they want to pick. Japan is a country well-known for proceeding by consensus. Meetings are not places for decision-making, but rather ceremonies in which the several parties can express their points of view and desires. Decisions are reached separately.

Then the preferred plan has to be approved by the Prefecture and aligned with the plans of the neighbouring communities. Finally several central government agencies have to agree to fund it. Systemic deliberation seems like a great theory to apply here, but already people are frustrated with the slowness of the government in planning for the recovery. Even when the plans are agreed and funded it will be five to ten years before the reconstruction is complete. During much of that time, the coast will be highly exposed to yet another major tsunami.

In the weeks immediately following the event, some leaders expressed the view that this disaster was an opportunity to re-invent Japan and to re-energise its sluggish economy. Now, some three months later, with little progress shown so far, this thought seems to have been lost and there is a desire just to get the reconstruction going at all.

The event will leave scars for one or two generations. Yet urbanists have observed that it is very hard to kill a community. Even cities that have been bombed flat will recover their former character, given time. Somewhere the spirit of those systems haunts the destruction.

RESILIENT SOCIETIES

Clearly despite its amazing real-time earthquake warning system and its thousands of kilometres of seawall, Japan was not prepared for this event. It had in fact prepared for a different event, an overdue earthquake associated with a fault off the southern part of Honchu island that was expected to be around 8.4 Magnitude. The 9.0 Magnitude earthquake was the fifth strongest ever recorded. The record is the 9.5 Magnitude Valdivia earthquake experienced in 1960 in Chile.

So how should a rich society like Japan's develop its plans for a more resilient future? How closely can people hope to live to the coast? How much land can be sacrificed or left fallow? How much should be invested in ever bigger seawalls and other defences? Would that money be better spent on improving the safety of roads?

Two, closely related 21st century lessons emerge from this event. The first is the dependence that we have built in the last 10-15 years on Information and Communications Technology (ICT) for the operations of society, of our systems of

systems. Today no urban administrative process, whether public sector or private sector, can operate in the absence of ICT. Yet computers and networks are easily destroyed. Large commercial organizations recognized this dependency over ten years ago and introduced resilience mechanisms that would allow them to restore operation in a matter of hours or a few days, provided enough of the staff survived. It was the backup processing centers in New Jersey that allowed lower Manhattan to recover after 9/11. Business statistics have shown that a business that is put out of operation for more than two weeks has a high probability of failing. Local governments have yet to learn this lesson.

Cloud computing no doubt has a role to play here in increasing the resilience of local government ICT, but it too assumes network connectivity between the data centre and the terminals in the government offices. In an earthquake prone country, nothing prevents the data centre itself being destroyed by an earthquake. Some more generally distributed approach seems desirable, but this increases dependence on the network infrastructure.

Japan's Internet backbone and external connectivity survived well, despite at least one undersea cable near the epicentre being destroyed. But there was a clear lack of adequate redundancy in the last few miles of the network, so that failures of individual mobile telephone towers and fixed network cables could knock out service that will take many months to restore. There was also a lack of mobile satellite systems and on Cells on Wheels, mobile base stations on lorries. Satellite links, especially to geo-stationary satellites, are less than idea for computer networks, but would be better than nothing.

In some countries one could imagine that ad hoc wireless networks – using the extended range of Pringles antennas [Pringles, 2011] – would have sprung up. The impacted area is relatively narrow, as shown in Figure 5, and it should be possible to beam in from edge where the telecommunications infrastructure was not damaged. However the Japanese are perhaps far too law-abiding to attempt such outlaw network services.

The second lesson is closely dependent on the first. Japan is major manufacturer of automobiles and other types of vehicles as well as a parts supplier to such industries through the world and a manufacturer of advanced semiconductor devices and other electronic components. The Internet has allowed the supply chains for these and other industries to connect these manufacturing centres to assemblers and distributors throughout the world with an implicit assumption of high resilience.

When these supply chain links were disrupted either directly or indirectly by the earthquake, companies all over the world suddenly learned that they have a critical dependence on Japan. In some cases manufacturing of vehicles had to shut down for lack of parts. In other cases the parts buyers looked for alternative sources in other, less earthquake-prone countries. Even Japanese companies themselves moved manufacturing out of the impacted regions into existing plants in other parts of the country.

Will that business ever come back? Certainly Japan's reputation as a highly reliable source of very high quality products has suffered. Beyond the industrial sector, the export of agricultural products possibly contaminated with radioactivity has been a problem. What are the economic impacts of this disaster beyond the loss of life and

destruction of infrastructure? Japan's growth has been sluggish for several years, achieving 2.9% in 2010 and had projections of some 2.7% in 1Q11 [OECD, 2010]. It seems likely that actual growth will be close to zero or even negative [Koydo, 2011].

Beyond Japan, what is the impact on the global society? The debate that arose soon after the earthquake and the reactor problems showed that nuclear accidents are no longer only national problems. Through the atmosphere and more importantly through the food supply chain such events have global implications. Likewise the disruption of the industrial supply chains could, in other circumstances, be a matter for global economic stability. What does Systems Science have to say about these problems?

CONCLUSIONS

The 21st century trend to greater integration of societies at the local and global level has many positive aspects [Harrison, 2011], but these should not blind us to the risks associated with creating new dependencies on both technology and on distant supply chains. The Great East Japan Earthquake of 2011 dramatically illustrates these as well as the challenges that even rich, highly-developed societies face in correctly judging risks and allocating resources to their mitigation. The trends to greater frequency and greater impact of both natural and industrial disasters argues for both national and global debate on this.

Agencies such as the United Nations, the World Bank, and the International Monetary Fund were created out of the recognition of the global systems that bind nations together and such agencies serve to ensure stability in many domains. The advent of the Internet and global supply chains introduces new global systems and that may easily be disrupted by the collapse of local systems. Perhaps some new supra-national organization are required to assure stability in these processes.

There are new roles here for Systems Science both in the challenges of restoring local systems that have been destroyed through disaster as well as in understanding the new global systems that we appear to have created.

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