

RECENT SEISMIC DISASTER REDUCTION EFFORTS IN JAPAN

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ABSTRACT

On this day, any single country cannot alone deal with vast problems caused by large natural disasters. Underneath this unprecedented internationalization of disaster problems is economic globalization that captures every country on earth. This capitalism at work, while intensifying and complicating disaster risk of nations, has produced at the same time mass quantities of potential resources for disaster reduction. This fundamental transition offers challenge as well as opportunity for disaster reduction efforts of nations. Our science and technology must accommodate this process through nimbly detecting emerging risks and resources and utilizing them wisely. For this purpose, some seemingly informative materials are reviewed below based on recent experiences in Japan.

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1. RECENT TREND OF NATURAL DISASTERS-WORLDWIDE PERSPECTIVE

Natural disasters never appreciate the existence of manmade borders, and once a large scale natural disaster occurs, its details promptly spread, more or less biased, around the globe; *i.e.*, large disasters are now far beyond a domestic affair. Even in a richest, democratized country, disasters may expose unspoken faults of unfair inequalities and discrimination underneath its society; neither governments nor leaders can be free from harshest critics from every corner of the earth.

Under this so-called globalization, nations are sifted and polarized economically; consequently, the persistent problem of human history, poverty, has increasingly emerged as a critical point. Many of low lying countries appear trapped economically in a downward spiral. In other words, sustainable growth, which is a basis of a nation's dignity, is a long way away from them, and this deepens the vulnerability of their people. Multi-faceted

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international assistance is therefore essential and, among others, disaster reduction collaboration is of utmost priority.

Very fortunately, a side effect of the globalization was a surge of economic growth prevailing in vast areas across Asia, implying that many Asian countries are getting capacity to ride out large scale disasters by themselves; *i.e.*, much less dependent on traditionally western-inspired, international donating practice. This is a big challenge to them, too, because they must now make up themselves all, from every political arrangement to preparation and mobilization of their own resources; they must build their own capacity on behalf of themselves.

But how? It is true that many Asian efforts toward elevated standards of lives of people have been raising questions about to which extent the Western paradigm, from worldview to occupational ethos, is universal or in which sense it can claim any exclusive superiority, but it is yet true that comprehensive and consistent alternatives to it are yet to be found outside the Western world. Above all, we are entering an age of looming crisis of fossil fuel, and three thirsty nuclear rivals, super-populated or super-armed, are going to confront a hard coordination, which is unlikely to be settled soon. But we can never overlook the fact that this apparently fragile and delicate situation is a rare chance for wide scale renovation of old norms on which things have been settled. A famous ancient Chinese military philosopher Sunzi said that we can always win if we know both ourselves and our enemy. In this age of looming uncertainty, therefore, we need to review both our weakness and strength. This is specifically significant in disaster realm.

A UN-led *World Conference on Disaster Reduction* was held in the city of Kobe in 2005. As the hosting nation, Japanese government promoted several international initiatives for its follow-up. (According to guidelines for application to governmental grants for the sake of research promotion issued by the Japanese government, its commitment toward Asia is increasingly clear and unmistakable.) Among these efforts, Japanese government funded a preparatory, one year research on exploration of the possibility of implementation-conscious study of existing disaster reduction technologies on an international, collaborative basis. This was completed this March [1].

In this project, we put together our recent experiences from across the world. Iranian researchers joined and made significant contribution. Japan team proposed a publicly Web-accessible database of worldwide good practices for disaster reduction, drafting a concept named *Disaster Reduction Hyperbase*. (Website will be open soon.)

Prior to this project, Japan group had achieved very big five year research project targeting disaster reduction of APEC economies [2]. This revealed that there were many hiding, untapped resources yet to be explored, specifically in Asian countries, notwithstanding their existing profound and pervasive vulnerability to natural disasters. There are even things that Western donors appear to have failed to appreciate so far despite their importance. For example, culture, religion or any other indigenous elements appeared to be a versatile well from which we can draw embryos of efficient and effective countermeasures, mostly too highly site-specific for outsiders to recognize. These elements also appeared to be capable of feeding motivation and concentration of people, which is most vital for disaster resiliency of the society. In fact, those who pursue their own interest, whether they be nations or humans, can best resist disasters. (Only proud nations can protect

themselves.) Nice thing about them is its endurance through the scrutiny of history, mostly longer than that of modern Western civilization.

The resolution of said *UN World Conference, the Hyogo Framework for Action* (Kobe is the capital of Hyogo prefecture), emphasized, among others, the urgency of sharing relevant knowledge among people, acknowledging a Sir Winston Churchill's saying: "If you have knowledge, let others light their candles with it."

2. RECENT JAPANESE EXPERIENCE OF SEISMIC DISASTERS

Japan has so far maintained efforts to reestablish its seismic resiliency since the 1995 Kobe earthquake. About ten years after Kobe, an earthquake occurred in Niigata prefecture in October 2004. Figure 1 shows tectonic setting around the Japan Arc: plate motions and the principal direction of the crustal stress. Characteristically severe circumstance in terms of seismicity is clearly seen.

The rectangle indicates the Kobe earthquake and the circle the Niigata one. The Niigata earthquake of magnitude 6.8 was significantly smaller than the Kobe one with 7.3. Although peak motions were nearly the same, hardest hit area was limited in the Niigata case, while the Kobe's strong motion had covered much wider area. But people saw here a good opportunity to review their decadal efforts since Kobe.

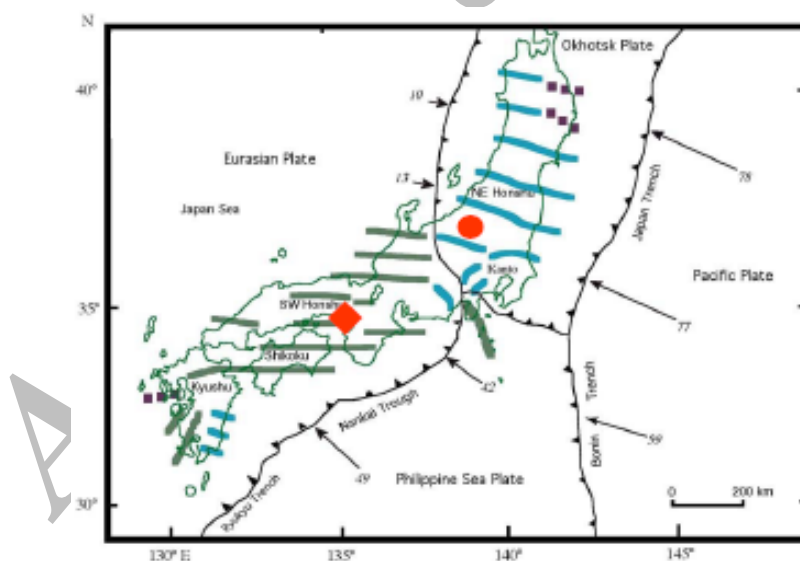


Figure 1. Tectonic setting of the Japan Arc

As Figure 1 shows, strong compression prevailed in east-west direction.

Seismological analyses revealed that many thrust faults developed underneath the area and formed a kind of three dimensional spider web. (Cf. Figure 2) This basic tectonics made the inland Niigata one of the nation's tectonically most active areas. The compression

generates extensive and rapid upheaval, which thrusts the slopes unstable.

As a result, this area has become well-known in Japan for its landslides. The earthquake triggered a great many slides together with failures of many soil structures like embankments. This is just the main feature of the swath of this earthquake; the damage tore transportation networks and isolated sparsely dispersed villages and inhabitants, leaving them hard to be reached by rescue operations. Although main highways were promptly repaired and the traffic was soon resumed, capillary roads were left untreated for a while.

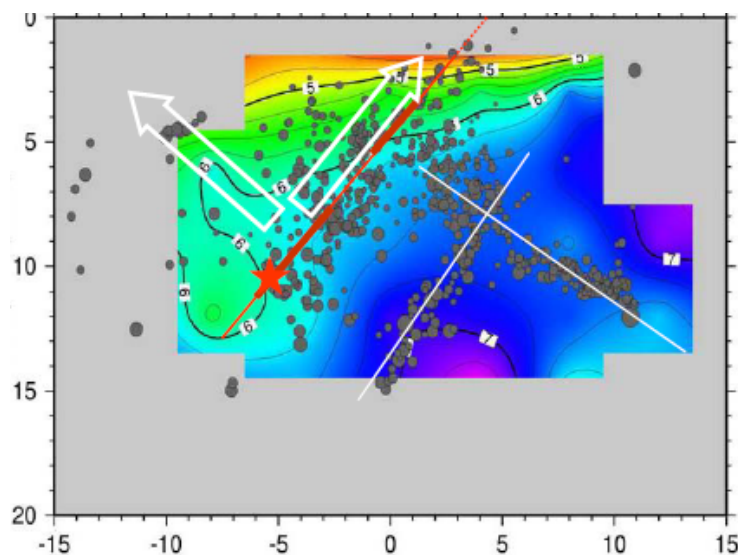


Figure 2. Seismogenic geometry

Figure 2 shows a vertical profile including the epicenter (designated with star) along a section perpendicular to the axis of compression. Plural seismogenic faults exist that are mutually conjugate, representing a common stress field. The main fault has two major asperities. Directions of principal radiation are shown.

Many aftershocks exceeding magnitude six repeated along different faults. This persistent succession of shakes largely prevented railways from early recovery, despite the company's traditional pride and adherence to prompt recovery. It also compelled stricken people to stay outside their home in freezing late autumn days. Thirty something aged people died during their evacuation. They had each anamnesis, which is a common feature of current Japanese countryside.

Through its modern history since the Meiji era, starting in 1867, Japan has developed and established a nation-led disaster response routine. This has resulted in high capability of carrying out rapid and extensive restoration of fundamental infrastructure to the status quo, letting Japanese being criticized to stick to the physical restoration too much. In fact, in the response to the Niigata earthquake, national activity maintained its legendary agility in terms of treatment of basic infrastructure.

Seismic resistance of civil engineering structures had been significantly enhanced. For

example, reinforced concrete piers of viaducts, highways or railways, had been the majority of the structural loss in the Kobe earthquake. Subsequent research was focused on their fracture modes, and new design codes were based on clear distinction between brittle or ductile fracture. Reinforcement was oriented toward enhancement of ductility.

Destiny of RC piers of stricken bridges was thus contrastive depending on whether or not they had been reinforced after Kobe. Figure 3 shows one of most severely damaged piers. This pier, of a railway bridge, was located in the direction of the strong wave radiation shown in Figure 2 and was damaged, suffering strongest seismic motion, more than 1 G and 1 m/sec, as large as Kobe's maximum records, but sustained repairable in harmony with the scenario drawn in the guideline created after the Kobe's experience, suggesting the specifications of the guideline was reasonably lean.



Figure 3. Severe but promptly repairable damage

Firm prioritization of skeleton infrastructures - rivers, roads and bridges - relative to buildings and life supporting facilities is a long-lived in depth philosophy of Japan, which was established in as early as the Meiji era. Aged timber houses collapsed and killed around twenty people, which occupied the majority of immediate human damage. Care of aged timber houses is practically most needed around the country. This is truly voluminous. Some devices, ductile metal joints of elements, to add the ductility are known effective, and the governments, national and local, have implemented an array of promoting subsidies, but there is still miserable lack of impetus. On the other hand, RC buildings sustained the earthquake with little damage, with few exceptions of shear fracture of RC columns of very old buildings. Buildings equipped with base isolator, all young, assumed no damage at all.

3. EARLY EARTHQUAKE WARNING SYSTEM

Since the Kobe disaster, Japan had established multiple dense networks of thousands of high performance seismometers, strong motion or high sensitivity, all over the country (Figure 4).

Based on these records, dynamic processes of moderate or larger earthquakes are widely analyzed and discussed openly. They are mostly Web-accessible worldwide.

A real time analysis system created by the *National Research Institute for Earth Science and Disaster Prevention (NIED)* enabled *Japan Meteorological Agency* to issue emergency warning several seconds prior to the arrival of main shaking [3]. In cases of remote, offshore earthquakes, it could earn anywhere from ten to twenty seconds. For example, in a magnitude 7.2 earthquake off Miyagi Prefecture of August 2005, as news media widely reported, the warning reached on to schools in the city of Sendai, the capital of Miyagi Prefecture, fourteen seconds before arrival of the main shock.

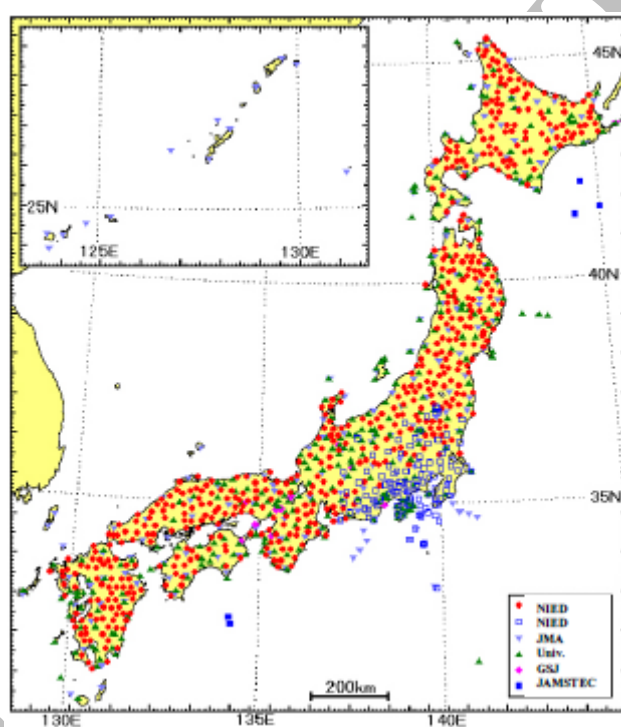


Figure 4. Integrated network of seismographs

In the Niigata earthquake, its JR (Japan National Railway Company) version worked; all of six neighboring Shinkansen trains caught the warning signal and could immediately start decelerating and stopped safely. One exceptional derailing occurred; a train was running with 200 km/h speed unfortunately just in the very vicinity of the epicenter when it met the main shock immediately after having received the signal. All the worse, seismic wave was geographically being amplified at the point of encounter. There was no overturn nor human damage. Some structural detail of the train is believed to have happened to prevent the cars from excessive lateral displacement, which no one ever had dreamed.

Another category of the lessons from the Kobe was emergency response. Since Kobe, the nation developed and implemented a variety of emergency response schemes. As a result, an extensive array of prepared emergency response operations was carried out. Among others,

the Self Defense Forces-Ground, Maritime and Air jointly-, emergency response teams from the Fire Department and its police version joined successfully for the first time.

Local governments in the focal area lost immediately and completely their function, but mutual assistance conventions among local governments that had been institutionalized after Kobe functioned as was expected; many staff teams were soon sent in from outside the area and covered virtually abandoned basic public needs. Similar agreements had been installed among medical institutions; e.g., many *Emergency Assistance Teams* of the *Japan Red Cross*, national *Disaster Medical Assistance Teams* and similar private voluntary teams were organized and submitted.

Non governmental activity showed progression, too. Private facilities serving electricity, gas, water and sewage had established nationwide mutual assistance network and common manuals. Transportation industry and retail commerce lived up to their assignments enlisted in the guidelines created after the Kobe disaster. Many other big commercial companies contributed greatly, suggesting the concept of corporate social responsibility has well rooted in the society. Progress in organized behavior was observed among volunteers gathered from across the country.

4. NEW CHALLENGES FOR SEISMIC SAFETY OF JAPAN

On the other hand, the Niigata earthquake illuminated problems that are all too common in recent Japanese countryside, which had hidden from disaster researchers' attention so far, overshadowed by the memory of Kobe. Until very recently in its more than hundred years of modern history, major workforce in Japan has been fed in the countryside and then installed into cities. They are those who shouldered Japan's miraculous economic growth from the war-torn, resourceless nation to an economic power. But on this day, as an inevitable conclusion of the process, the countryside is deeply suffering from depopulation and aging. Restoring a right balance between cities and the countryside in terms of the liveliness, or the quality of life, is an after care of Japan's rare rapid postwar reconstruction and economic growth. This is duty of young generations that were fed with the wealth those generations earned and created.

Yet the big city problems are persisting. Now that Japan is seen to start escaping from a prolonged duration of its economical depression, proactive policies must be laid out for public investment for societal infrastructure. It has been years since people became aware of the urgency of resolving the big city problem. Above all, there is wide consensus on the priority of reconstructing the attractiveness of Tokyo in view of a global or regional competition. Augmentation of the seismic durability is critical here.

A serious hole in the Japanese quality assurance system of housing was dramatically publicized when possibly criminal misconduct of architects and developers, conceived violation of the building-codes for residential structures, was revealed. The society is struggling for a renewed, more tightened control, while people are questioning about possible harm done by excessive privatization in the realm of public safety.

5. COORDINATION PROBLEMS OF SEISMIC RESPONSE

As mentioned above, in today's modern society, a lot of resource organizations for disaster response exist and can contribute post-disaster activity. In this situation, coordination among them is of utmost importance. In the Niigata case, *e.g.*, while individual participants moved actively, coordination among them was lacking or at best poor. One crucial lesson of Kobe is thus yet to be digested.

One vital new face on this emergent theater was the military. Currently in Japan, introduction of the military into civil affairs is steadily growing. Japan has long been so "obedient" to its war-renouncing Constitution as to hesitate even its peaceful use. This may be a kind of Japanese version of restraint, but it is nothing other than isolation of the military from the civil society. It is not only inefficient but also a possible reproduction of another Japanese prewar military that lost touch with the civil society and eventually perished involving the whole nation.

A healthy way of controlling the military could be to keep intense contact and interchange between it and the civil society. Establishment of schemes that allow consistent coexistence of a well-disciplined, highly autonomous system and an extremely diverse, open system of Japanese society, in case of emergent civil disruptions, is thus urgent. This is no easy. While current Japanese military is highly modernized and rationalized, gaining a sort of American-born universality and sophistication, the diverse society of ours is full of specificity of historical, sociological or cultural background. This is casting a big challenge to Japanese disaster response.

Coordination is not confined to the military; the Fire Department and the police have their own stripes in terms of organizational rules and practice. Even the language is not common, although this is all too common in every country. In Japan, local governments in hit areas have to take charge of coordination; they must solve the problem of assigning power and responsibility or logistics. As a matter of fact, Japan's legal system is assigning many competences to the elected top of basic local governments. Capacity building of local governments is under way. For example, *NIED* has developed a GIS engine suitable for disaster management of local governments.

Coordination is a most crucial core of any management issue. Management capability is one of the areas in which many of us are feared inferior to Westerners. As a matter of fact, while Japan has long suffered from long stagnation of its economy, questions were actively raised about apparent lack or collapse of governance. Management issues could be shared among Asian countries. This was exposed in the 1997 Asian economic crisis, in which we had to tolerate Western chorus attacking lack of rigidity of the marketplace or poor governance of private firms of Asia as responsible for the crisis although some of them have been rejected later by researchers.

6. THEORETICAL FRAMEWORK TOWARD DISASTER RESPONSE STUDY

In disasters, or in any management problems, quite a lot of factors and elements join the

process, arising highly complicated interaction; *i.e.*, every element of disaster process has context dependency. Management requires multi-faceted approach. In order to solve this kind of problems, simultaneous consideration of all aspects is necessary, and a sense of balance is needed. In the aftermath of Hurricane Katrina, the US government's *Homeland Security Department* was intensely criticized by news media about its failing in striking a right balance in their efforts between counterterrorism and preparation for natural disasters. But simply mentioning the context dependency itself offers no hint for approach to the problem. Important thing is how we can treat the context, and we need a methodology that can guide us through a jungle of joining factors.

While it is obvious that study of management requires very wide knowledge, management itself is no more than a human behavior and is expected to allow some theoretical approach. Once a mathematical modeling is made, the thinking goes, it can provide us with some insight and suggestions. Disaster response is a series of choice of human actions, in which people seek to optimize their efforts. Post-disaster responding, from search and rescue to recover and restore, proceeds with time. This is a kind of control process, and we should seek to treat human behavior of responding to disasters by means of the theory of control. This aspect affords us some clue to model building. This model would assume the following cycle:

sensing \rightarrow decision \rightarrow action \rightarrow sensing \rightarrow ...

This scheme is universal; it will drive the Shuhab missile, too. Sensing and action are transformation from the physical world into mathematical one and vice versa. Sensors and actuators will carry out this switching. The logic for decision will assume an optimization scheme. The process is represented in terms of state variables and control variables and formulated as a minimization problem; minimize $C[\mathbf{x}(t), \mathbf{u}(t); \boldsymbol{\lambda}]$ in which C is the objective function; $\mathbf{x}(t)$ is the state variable and $\mathbf{u}(t)$ the control variable. The both are ordinarily vector-valued. They are subject to constraints and governed by the equation of motion: $d\mathbf{x}/dt = F[\mathbf{x}(t), \mathbf{u}(t); \boldsymbol{\mu}]$ in which $\{\boldsymbol{\lambda}\}$ and $\{\boldsymbol{\mu}\}$ are parameters representing needs, resources or infrastructures in an appropriate manner. Constraints and the objective function are given in advance.

If we want, for example, to analyze the emergency management of medical sources, personnel or medicine or ambulance etc., these variables are to be control variables. Situation of patients, supplies, traffic or any other relating factors will be state variables. One must then determine the control variables in a manner to satisfy the constraints and optimality conditions. This is the optimization of operations of post-disaster response, in which infrastructures remain invariable.

Preparation prior to potential hazards is reflected as an enhancement of infrastructures. Infrastructures here should be understood most extensively; *e.g.*, it includes regulations or codes. Social norms or customs based on religions or tradition can be vital parameters. Capacity building of the society and people is also important. The capacity and quality of the infrastructure is also reflected by the constraints and the equation of motion. Our optimization scheme can, therefore, evaluate the effect of the capacity enforcement of infrastructure through sensitivity analyses.

In the real world situation, a great many players participate in the disaster process. Each player, while pursuing its own optimality, interacts with one another. This problem is

logically equivalent to a simultaneous treatment of quite a many, mutually interacting optimal control problems and in general highly complicated. This is the multi-agent model. Latest computers are becoming able to handle it if one can appropriately model the problem.

7. OTHER TECHNICALLY VITAL TOPICS

Research of disasters must eventually reach on to forecasting or prediction of hazards. In Japan, above mentioned early earthquake warning is going to spread across the society. Japan's efforts for earthquake prediction is being huge, too, including highly expensive deep underwater exploration around seismogenic zones skirting the Pacific Ocean, although no space is available here for detailed description.

For the foreseeable future, energy and environment will be global keywords. Specifically in Japan, residential housing is evolving, keeping up with the known progress of the auto industry, toward low energy consumption and low environmental load. New materials and IT technologies are actively being attempted. Earthquake resistant design must support and encourage this innovation, too.



Figure 5. Nuclear Power Sites in Japan

Drastic and worldwide surge of energy prices is forcing many nations to redefine their reluctance to the nuclear power. As Japanese reactor technology is approaching to its maturity, people's concern has increasingly focused on the seismic safety of nuclear power

plants and many disputes persist. Figure 5 shows the location of Japanese nuclear power plants, each one is commercial, of course. Very recently, a district court upheld a claim of criticizing current seismic design-code, ordering to restrain a running power reactor that is encircled in Figure 5. Nuclear Safety Commission of the Japanese government has conducted a review of its seismic design criteria needed for licensing construction of power plants, and is due to finalize its new version soon. While the court judges are seen to have confirmed carefully that its influence to the society was tolerable, it is still unknown whether they are satisfied with the new codes or what was inadequate in the current codes.

8. CONCLUSIONS

In this age of fast-moving and wide-spreading events, it is desirable to learn from others' experiences. The world surrounding us is changing rapidly, so we must capture new, unprecedented problems for us to deal with. One of the world's deadliest seismic environments of Japan has so far stimulated people's efforts together with unavoidable loss. Issues appearing useful for other countries were summarized and discussed.

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