Lessons from East Japan Earthquake and Tsunami

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SUMMARY

The author tries to extract lessons from the stories of survivors who escaped from a narrow path from East Japan Earthquake and Tsunami occurred on 11th March 2011 in Japan. Many geo-spatial technologies such as high resolution satellite imagery, GPS wave height recorder, UAV (unmanned aerial vehicle), mobile mapping system (MMS), airborne laser scanners, GIS, digital camera/video etc. were used to investigate the damages and to promote recovery planning. Those damages were validated using satellite images and Tsunami maps as well as the site investigation.

The author also points out the role of surveying or geo-spatial technology for future city/urban planning of those towns and cities which were completely devastated by Tsunami.

Introduction

Japan is not yet managing the disaster but suffering from the associated hardships, particularly in tackling the stabilization of the Fukushima NPS. Even one year after the event, the consequent disaster, including the lack of cadaster surveying, reconstruction plan, railway transportation and so on are still ongoing. Though all Japanese people are in mourning over the horror of this event, I feel it is my duty as an old scholar to report to the rest of the world on the worst earthquake and Tsunami in living memory to hit Japan. I hope that my report will be useful to prevent the similar misery for others.

What happened and how much lost?

At 2:46pm on the 11th March 2011, the huge earthquake of M9.0 occurred offshore of Sanriku (north east of Japan) with its epicenter covering a region 500km long (north-south) and 200km wide (east-west) in the Pacific Ocean. Accordingly the damaged areas were also 500km long stretching from a part of Hokkaido (the north island of Japan) in the north to Tokyo in the south. We have had many big earthquakes in the past, for example Kobe Great Earthquake in 1995 with 6000 victims, but the damaged area from this earthquake was limited in several 10s of km. A sea bottom control point of the Japan Coast Guard located at the depth of 1700m near the epicenter proved to have moved 24m to the east and 5m vertically. The GPS station of Geospatial Information Authority (GSI) located at Ojika Peninsula showed a

5.3m movement to the east. This is the largest crustal movement ever recorded in Japan. More than 300 after-shocks have followed.

The damages as of the end of 2011 are as follows: 15,844 dead (so far confirmed); 3,452 missing (reported only); 334,786 evacuees. 219,555 houses were destroyed; 2,200 roads damaged; 56 bridges collapsed; 6 fuel power stations destroyed. Tohoku Shinkansen and Tohoku Highway were severely damaged. Tohoku Highway was repaired about two weeks afterwards while Tohoku Shinkansen recovered fully operational after 49 days. The main damage was caused by the Tsunami (92.5%) which swept away a huge number of people, cars, houses, fishing boats, ports and harbors.

The height of the Tsunami was measured as follows from the north (height at the coast/height as it travelled over land); Miyako (12.1m/37.8m), Kamaishi (9.3m/21.4m), Ofunado (11.8m/23.6m), Kesennuma (12.8m/19.6m), Minami Sanriku (15.8m/no data), Onagawa (18.3m/no data), Ishinomaki (10.3m/no data), Sendai (9.3m/no data), Natori (9.0m/no data), Fukushima NPS (15m/nodata) etc. The highest point of the Tsunami on land was 37.8 m above the sea level at Taro District, Miyako City, Miyagi Prefecture, according to the survey of University of Tokyo. The Tsunami hit small coastal towns 5km upstream along a river in the Sanriku Area, where the bay has a V shaped topography which exaggerates the height of Tsunami. Along the River Kitagami, the 5m Tsunami hit the mouth where it swept away all harbor facilities and boats, at the 4km point along the river a bridge collapsed, at the 6km mark riverside villages were flooded, at 14km along the river agriculture fields were inundated and at the 48 km mark the water level at the gauge station suddenly rose 10cm one hour after the earthquake. Even at Toda, 28km upstream on the River Arakawa, flowing into Tokyo Bay, the water level rose 1m 20cm after the earthquake. Such Tsunami propagation would normally be unexpected.

The Tsunami swept away 18,800 fishing boats and destroyed 326 fishing ports and inundated 23,600ha of agricultural fields with sea water. Many industries such as oil refineries and supply facilities, electric and electronic and car parts manufacturing plants, housing material plants, fish and other foods supply centers, transportation and so on were destroyed, which resulted in for example, halting the production of Toyota and Nissan cars not only in Japan but also in USA. The Tsunami severely damaged 43 railway lines of which 6,000 points were destroyed. A total of 22km of railways were washed away or inundated by the Tsunami. The state of the JR Joban line within 20km of Fukushima NPS has not yet been investigated because of atomic radiation risks.

A huge amount of debris and garbage including crashed cars were washed away by Tsunami, estimated to be about 25 million tones which will take three to five years to clear away.

Accident of Fukushima NPS

The most serious accident was the destruction of the Fukushima Nuclear Power Plants where the cooling system and electric and electronic facilities were severely damaged by the Tsunami, resulting in the extraordinary heating up of the nuclear reactors and protection vessels. Accordingly, a Hydrogen gas explosion occurred in No.1 Reactor at 15:36 on the 12th March and in Reactor No. 3 at 11:01 on the 14th March. In order to reduce the pressure of the Reactors, the valves were open at No.1 Reactor at 10:17 on the 12th March, at No.3 Reactor at 20:41 on the 12th March and at No. 2 Reactor at 11:00 on the 13th March. As the result, atomic radiation spilled out polluting the air, water and soil and as a result vegetables and milk. As polluted water was spilled out and also was discharged into the sea, fish caught in Ibaragi and Fukushima Prefecture were contaminated with atomic radiation and hence refused for sale at the market. This was a big shock for Japanese who are a fish-eating nation, and regularly consume Sashimi and Sushi.

68,000 people within 20km radius had to move out of their residences and 140,000 people within 20~30km had to stay inside their houses or evacuate. The total number of people evacuated was a maximum of 450,000 as result of not only the earthquake and Tsunami but also the nuclear power plant accident. The survivors and evacuees have had to stay in congested houses without lighting, heating, water, food, blankets etc. in spite of sub-zero temperatures, until supporting materials arrived. Those evacuees are gradually returning to their lands or locating in areas where supporters are kindly providing them with living facilities. The remaining evacuees who are located in the refugee camps are mainly aged persons over 60 years old. Two thirds of victims are in their 60's or older. One of the headaches is the damage to schools and the education scheme. One of the most serious problems is that all schools located near Fukushima NPSA were/are not usable due to high contamination of atomic radiation.

Electricity failures also commenced as the electric power stations stopped operations leading to shortages of electricity. Tokyo Electric and Power Supply Company (TEPCO) had the capacity of 52 million KW before the earthquake which was reduced to 31 million KW after the disaster, and which has recovered to 50 million KW a month after the earthquake. But this is not enough to support industrial and domestic demand which peaks at 60 million KW in the summer season. Fukushima NPS was providing about 9 million KW.

As of the end of January 2012, 50 reactors out of the total 54 reactors of nuclear power stations in Japan are being stopped for periodical security check. Even after the checking those reactors are not being operated because the governor of the area where the NPS is located is rejecting the reoperation due to strong doubt against the safeness. It would be strange that Japanese electricity can be managed without nuckear power stations. In the past

the Government has been always advertising that nuclear power stations should be necessary to support the electricity demand in Japan. But now people realized that Japan can manage the electiricty withput NPS if we save energy a little bit, say 10 to 15 %.

Lessons from the past Tsunamis in Japan

Japanese people are well educated on evacuation procedures in the case of earthquakes and Tsunami as so many terrible disasters have occurred in the past. In particular the area of Sanriku was heavily damaged by the Great Tsunami in 1896 which killed almost 22,000 people including my great grandfather. Following this terrible lesson, many coastal towns constructed breakwaters to protect them against future Tsunamis. For example, Kamaishi City, Iwate Prefecture constructed huge breakwaters 2km long, 20m thick, 8m above sea level and 65m deep, which have been registered as the deepest breakwaters in the Guinness World Records. Taro fishing village, Miyako District, Iwate Prefecture constructed 10m high breakwaters with the total length of 2.4 km against Tsunami, as the village was most seriously damaged by the 1896 Tsunami (with a height of 38.2m) and the 1933 Tsunami. But these breakwaters, called Taro Great Wall, were completely destroyed by the Tsunami this time, which was 14m high, much higher than authorities had prepared for. There was only one village, named Fudai Village, Iwate Prefecture, that successfully withstood the 12m Tsunami with a 15.5m high breakwater and water gate. The village head had constructed this high breakwater although many people criticized him for spending such a huge budget on the structure. The past village head had been informed by his ancestor that the 1896 Tsunami was 15m high and a lower breakwater could not work against future Tsunamis. None of the villagers died. Many people said that the Tsunami was higher than expected, but the Tsunami in 1896 was a maximum of 38m high! We should have learnt the lessons that ‘hardware’ including very high breakwaters, cannot guarantee saving people, but we need to use ‘software’ including procedures for providing early warning and evacuation systems.

There was a small village in Aneyoshi District, Miyako City, Iwate Prefecture which was thoroughly damaged by the 1896 and 1933 Tsunamis with only 2 and 4 survivors respectively. An ancestor built a memorial stone on which an important lesson was written, “Don’t build any house below this point!” The stone is located 60m above sea level. The villagers followed this lesson and built their houses in the upper area. When the Tsunami came all villagers ran 700m up the slope and escaped to their houses built on the hill. The Tsunami stopped in front of the hill and all villagers were saved.

In the case of the 1995 Kobe Earthquake, which killed more than 6,000 people the establishment of a GIS database was so important for recovery from the damage. Many local governments started a GIS database but everything including computers, databases, backups,

even city and town halls/offices were swept away. Most people lost ID cards and passports which made it difficult to identify them by documentary evidence. In several towns, the official registration data bases were also lost as well as town offices. It made it difficult to count the missing people. Such damages were not expected from experiences from the past disasters.

Lessons from the disaster; misjudges and mistakes

+Accident of Fukushima Nuclear Power Station

First of all, I have to say that there is nothing absolutely safe. Though many Japanese doubted the safety of nuclear power plant, the Japanese government and industry convinced people to support the construction of nuclear power plants as they believed them to be absolutely safe. In spite of their aversion to nuclear matters, as the Japanese have been the only nation to experience atomic bombs, the majority of local people accepted the construction of nuclear power plants through a referendum. Electric power companies and consultants always said that power would be cheapest if produced by nuclear power stations. But now we Japanese realize that the cost has been tremendously high and in addition the accident is robbing them of their life and their use of land more than 250km wide (Tokyo is 250km away from the Fukushima NPS and its drinking water is in danger of contamination from atomic radiation). We are learning how difficult, complicate and time consuming it is to control a nuclear plant after an accident.

There were several serious mistakes in the risk management of Tokyo Electric Power Company (TEPCO). I dare to list these misjudgments and mistakes. The fundamental misjudges were: 1) the estimated Tsunami height would be 5.7m high although the actual Tsunami was 13m high, and the external power generators for emergency were located underground, 2) an extra power supply for emergencies, as suggested by USA authority, was neglected, 3) TEPCO did not consider that Hydrogen gas explosion could occur and 4) the protection of the reactor pressure vessel by 16cm thick steel and the reactor containment by 3cm thick steel and 2m thick concrete was claimed to be able to withstand any force.

Mistakes and mismanagement were as follows. At first there was no leader who could make quick decisions and follow up with actions. In addition, communications were poorly established between the headquarters and the site of Fukushima NPS. In the beginning, TEPCO hesitated to cool the reactors using sea water as the NPS would become unusable in future. Secondly, the reduction of pressure in the vessels by opening valves was too slow as it was permitted by the Government only after the residents within a radius of at least 10km were evacuated due to the risk of atomic radiation. As a result a Hydrogen gas explosion occurred, which resulted in a tremendous spillage of atomic radiation into the atmosphere and

onto land. TEPCO continued to explain that the NPS should be safe as all risky radiation gas and water were enclosed in the vessels to prevent them from spreading outside, and there was no risk from the pressure vessels even after Hydrogen gas explosion the next day on March 12.

One year after of the accident, we now know that the myth of absolute safety of nuclear power has proved wrong and the majority of Japanese are shouting “no more nuclear power stations”. We have learnt that the halting operations and stabilizing the damaged NPS will take more than 30 years. This is a long way from the final goal. We also know that we will have no final goal as the problem of spent atomic fuel rods will remain since they have to be treated in France and not in Japan.

+Misjudgments and mistakes in the evacuation

Many local people made mistakes and misjudgments though they were given lessons by their ancestors on how to evacuate from a Tsunami. But some people did not know enough about the behavior of Tsunamis. For example, Asahi City, Chiba Prefecture located on the sea coast was hit by the first Tsunami at 3:45pm, one hour after the earthquake when local people had succeeded in evacuating to a hill. After the Tsunami withdrew, some people went down to their houses or the coast, and some people even tried to fill their cars with gasoline. But a second Tsunami came at 4:20pm, 35 minutes after the first Tsunami when these people were swept away and died. After the withdrawal of the second Tsunami, the survivors wanted to search for victims in the city area near the coast as they did not think that the Tsunami would return. Unfortunately a third Tsunami, an even bigger one, hit the coast at 5:26pm, an hour after the second Tsunami and killed the remaining people. One of the survivors said that there would be no more Tsunami after the second one.

The occurrence of Tsunamis and their recurrence were different from place to place. The earliest Tsunami occurred 15 minutes after the earthquake while most Tsunamis came 30 minutes after. But we Japanese knew that sometimes it takes a long time for Tsunamis to arrive. For example, the big 6m high Tsunami hit the Sanriku Area 22 hours after the Great Earthquake occurred in Chile in 1960, killing 142 people. This time a 2.5m high Tsunami hit Christ City, California State, USA, 6,000 km apart from Japan after 10 hours. NHK TV immediately announces whether we have to prepare for a Tsunami after every big earthquake. At this time many people evacuated to the second or third floors of concrete buildings. They should have been safe, but the Tsunami came up to the fifth floor of some buildings for which the roof was the only safe place.

In Japan, all local governments must produce hazard risk maps which show places of refuge or shelter and roads leading to them. Some villagers followed these guide maps and

successfully reached the refuge, but in other cases they were unsuccessful as the estimated height of the Tsunami was lower than the actual height. It should be said that we have made serious mistakes in producing such hazard risk maps. 123 out of 959 shelters authorized by 9 cities and towns were washed away even though many people evacuated according to the rehearsals. In particular in Minami Sanriku City, 31 out of 78 shelters were washed away! The disaster prevention center in Kamaishi City which was planned to rescue the refugees was washed away and 54 out of 200 evacuees died.

At Funakoshi Primary School located in Yamada Town, Iwate Prefecture, the school itself was designated as a place of shelter as it is located 13m above the sea level. 176 school children were first evacuated to this school but Mr. Shuzo Tashiro (55), a school helper judged the shelter was not high enough when he saw the Tsunami wave at the coast. He urged all children and teachers to escape up to a hill 40m higher. Then the Tsunami came and swallowed the school. If he had not guided them to the higher hill, all people would have died.

There was another successful story in the city of O-arai, Ibaraki Prefecture which was hit by a 5m Tsunami. A young 19 years old fire man continued to shout in front of the disaster wireless microphone which warned people through 45 speakers; “Escape to a higher hill immediately!” even though the Tsunami came to his legs, he continued to shout after the Tsunami receded “stay there and don’t move” for two and half hours. It resulted in all local people including an old lady aged 91 being perfectly safe. The lesson was obvious that ‘software’, particularly communication systems are more effective than hardware such as super high breakwaters. I can say that software is much more cost effective compared with the costly hardware.

Prediction of earthquakes

No one has succeeded so far to predict earthquakes. It is one of the world’s most difficult sciences and technologies. Japanese seismic scientists and engineers have not yet succeeded either. I tried to make a prediction using GPS fixed stations located all over Japan, which are constructed by Geo-spatial Information Authority (GSI). Dr. Harumi and I have developed a method for prediction by checking whether the changes in dimensions of triangles between GPS Stations exceed a threshold. I have already submitted a paper on “Prediction of Earthquakes with GPS Data” to GIM, Coordinates and Journal of Digital Earth. Unfortunately Dr. Araki and I are retired persons who have no assistants or research funds. We could confirm that all earthquakes in the past showed early signals before they occurred, but we could not predict exactly on which day the earthquake would occur. The longest period between detected changes and the occurrence of the earthquake was two months and shortest

case was only one day. Sadly not many people showed interest in our research and the method has been neglected even though we succeeded to register the method as a Japanese patent in 2006.

Dr. Araki and I are not interested in business but contributions to help people. I hope someone can follow our prediction method in future.

Role of geo-spatial technologies for the disaster management

RS and GIS are useful for damage assessment to compare between situations before and after the earthquake and Tsunami. There are two remarkable issues on this occasion. One was that high resolution satellite images clearly showed the damage and accidents at the Fukushima NPS. Air survey was not available because of the high level of atomic radiation in the air, as well as the destruction of local airports. Satellite images showed the damage to the power station buildings caused by the hydrogen gas explosion, which was useful for recovery planning. Another issue was damage assessment by comparing images before and after the Earthquake and Tsunami. As the damaged area was so huge, helicopters were inadequate. High resolution satellite images and also SAR were very useful to realize the scale of the damage. Aerial photography and airborne laser scanning were executed all over the damaged areas except the dangerous zones of Fukushima NSP. Those data were sued for mapping the inundated area of Tsunami.

A GPS wave height recorder located 20km offshore of Kamaishi City showed a 6.6m high wave (the first Tsunami) which would usually be doubled depending on the sea depth and topographic conditions on land. The recorder showed there were 7 Tsunami waves in about 6 hours. A GPS recorder cannot be an early warning system as the speed of Tsunami is 800km per hour in deep sea areas and reduces to 50~100km per hour on the coast and land. This means that cities 10km across will be inundated by the Tsunami waves in only 10 minutes. UAVs were very useful to photograph Fukushima NPS for analyzing the damage in detail and planning the next action, as ordinary aerial surveys are impossible due to the high risk of atomic radiation, while high resolution satellite images were also useful in the early stages.

Reconstruction planning

Those local governments including cities, town and villages start to propose reconstruction plan with agreement with local people. In order to avoid the similar damages and mistakes, several options have been proposed. Those options include 1) all cities located in low land which will be devastated by Tsunami in future should be moved to high land, 2) only city areas which were devastated by Tsunami should be moved to high land, 3) higher breakwater should be constructed with elevated roads with filled soil to protect existing cities and 4)

reconstruction should be made with better evacuation system.

The introduction of the concept of “smart city” would be a good idea to reconstruction planning. A few cities try to provide self-support electricity with solar power generation. One of the serious problems to make a new city planning is lack of professional city planner as many staff of local government became victim of Tsunami.

Concluding remarks

Although my family and my house in Tokyo are safe without any damage, I could not stand to watch the TV scenes as the real situation was too miserable. I sympathized with the affected people and those who lost their lives but as an old man living in Tokyo I cannot directly help those people except by donations. What I can do is to inform my friends and colleagues around the world about the real situation and stories. It could be somehow useful for our society to assist in saving human lives.

In conclusion, Japan committed a big mistake in listing nuclear power plants as a sustainable development which has proved to be not sustainable. I would say that natural and man-made disasters can be much bigger than we can imagine. The so-called safety myth cannot be relied upon. An event with a probability of one in a thousand years may occur tomorrow anywhere and at any time.

Finally I extend my condolences to those victims and their family who were lost as a result of the East Japan Great Earthquake 311.

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