Proceedings of the Tenth Pacific Conference on Earthquake Engineering
Building an Earthquake-Resilient Pacific
6-8 November 2015, Sydney, Australia

Lessons from Recent Earthquakes and New Initiatives toward More Resilient Society - A Japanese View

Masayoshi Nakashima

Disaster Prevention Research Institute, Kyoto University, Japan

Council for Science, Technology and Innovation (CSTI), SIP "Enhancement of societal resiliency against natural disasters", Japan

ABSTRACT: Recently, natural disasters including the March 11 Tohoku earthquake, super typhoons and sudden downpours, happen in Japan more frequently than ever. Scientists and citizens are afraid that a colossal earthquake induced by ruptures of the Nankai Trough will occur for some time in the mid-2000s. This earthquake will bring about devastating loss of property for most to even imagine. On the other hand, the reconstruction of social infrastructure is urgently essential against such large-scale natural disasters. Japan requires more resilient disaster prevention and mitigation systems. This paper discusses a recently-launched national project which complies with these serious societal needs. The program called "Enhancement of Societal Resiliency against Natural Disasters" aims at providing feasible disaster information in the real time to the society and its people.

1 BAKGROUND

Some regions of Japan are still physically and spiritually recovering from incredibly devastating impact of extremely large earthquakes and tsunami including the 1995 Kobe earthquake and the 2011 Tohoku earthquake (Nakashima et al. 2014a, b, Mori and Eisner 2013) reported the March 11 Tohoku earthquake in terms of the ground motion, tsunami, building damage, and post-event response. The earthquake struck the North-Eastern part of Japan. Damage became considerably critical due to the tsunami (Figure 1a), which implies a limitation of engineering and social organization. Although the preparation had been made against an earthquake, its magnitude was beyond their prediction. Liquefaction caused by the earthquake was observed in various locations, particularly in reclaimed lands in Tokyo and Chiba (Figure 1b). It has to be noted that these locations were far from the epicenter. In spite of relatively limited structural damage, considerable dysfunction of utilities occurred. For instance, in Tohoku region, more than 50 % of households (nearly equal to 4.5 million) were left without electricity. Even one month later, its recovery was not completed with around 150,000 households without electricity. In fact, similar loss of utilities occurred after the 1995 Kobe earthquake. These imply the vulnerability of utilities against natural disasters.

(a) (b)

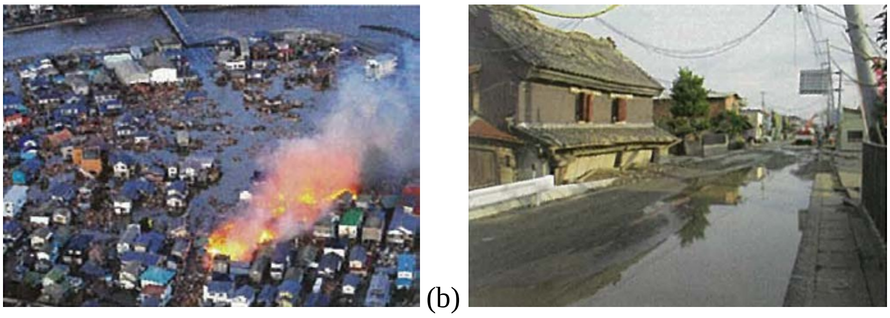


Figure 1- Observed damage after the 2011 Tohoku earthquake: (a) occurrence of fires in Tohoku after tsunami and (b) liquefaction in Tokyo.

Numerous scientists consent to the fact that another colossal earthquake will occur in the Nankai Trough or directly under Metropolitan Tokyo at some time during this century. The Nankai Trough runs through unignorably close to the mainland of Japan (Figure 2).

Figure 2- Nankai, Tonankai and Tokai Trough.

The Disaster Response Bureau of Cabinet Office of Japan make a estimate that an M9-class earthquake in this Trough would cause causalities of 323,000 people, loss of 2.4 million homes and economic damage running as much as 220 trillion yen (Cabinet Office of Japan). Extreme weather events including super typhoons and sudden downpours would result in serious damage derived from landslide. If the Tone River, one of the largest rivers in Japan and running the northern part of Metropolitan Tokyo, ever floods, the metropolis is estimated to suffer from more than 26,000 victims, with 2.3 million flooded out of their homes and more than 1.1 million people isolated in the aftermath (Cabinet Office of Japan). On the other hand, a rapid concentration of population is seen in Japanese large cities, notably Metropolitan Tokyo. Taking this into account, natural disasters may end in even more serious damage than before in those cities.

To solve the serious societal issue described above, a comprehensive research/development project was established as part of Cross-ministerial Strategic Innovation Promotion Program (dubbed SIP), tackles with these issues on natural disasters in Japan. The SIP is a Japanese project for science, technology and innovation, spearheaded by the Council for Science, Technology and Innovation (dubbed CSTI). The project was officially inaugurated in May 2014 and will continue till 2018. It has chosen ten programs that will address most important societal problems facing Japan, as well as contribute to the resurgence of the Japanese economy. Details are given in the next section (CSTI).

The concerned program discussed in this paper is one of the ten programs, called "*Enhancement of Societal Resiliency against Natural Disasters*". In order to realize better protection of society against natural disasters including extremely large earthquakes and tsunamis, heavy rain and tornadoes, a real-time disaster information sharing system will be invented. The system is named "Resilience Information Network". It will allow for sharing real-time disaster-related information between public and private sectors. In turn, it will consolidate capabilities to prevent the damage and enhance the post-disaster response. This system will contribute to more swift and efficient post-disaster rescues and responses such as evacuation, emergent repair, among others. For successful disaster prevention and mitigation, boundaries of a limited few fields of research have to be removed including basic sciences, engineering and possibly also social sciences. The program has formed a team of experts that gather from a variety of fields, and the writer of this article serves as the program director. The achievements of this cross-ministerial program shall also provide new business opportunities for Japanese industry as well as generate systems that integrate disaster prediction, prevention and response.

2 CROSS-MINISTERIAL R&D PROGRAM OF JAPANESE CABINET OFFICE

Science, technology, and innovation are critical components for Japan's economic regeneration and sustainable development. CSTI has made proposals on planning and coordination for comprehensive basic science, technology and innovation policies, taking into account the state of Japan's entire science and technology. Aiming for the consolidation of its own headquarters function, CSTI proposed three new policies: Strategic formulation of overall governmental science and technology budget, The Cross-ministerial Strategic Innovation Promotion Program (SIP) and (3) Impulsing Paradigm Change through Disruptive Technologies (ImPACT) (Director general for science, technology and innovation 2014). CSTI has selected these policies to respond critical social necessity and provide competitive advantage to Japanese industry and the economy. They are conducted on cross-ministerial initiatives, choosing a variety of subjects from basic research to practical application and commercialization. Achievements from these projects will be taken advantage of by different areas including regulations, systems, special wards and government procurement. They will also consider intellectual property management system for facilitation of strategic corporate use of the outcomes. CSTI appoints program directors (PDs) for each project and allocates budget (Figure 3).

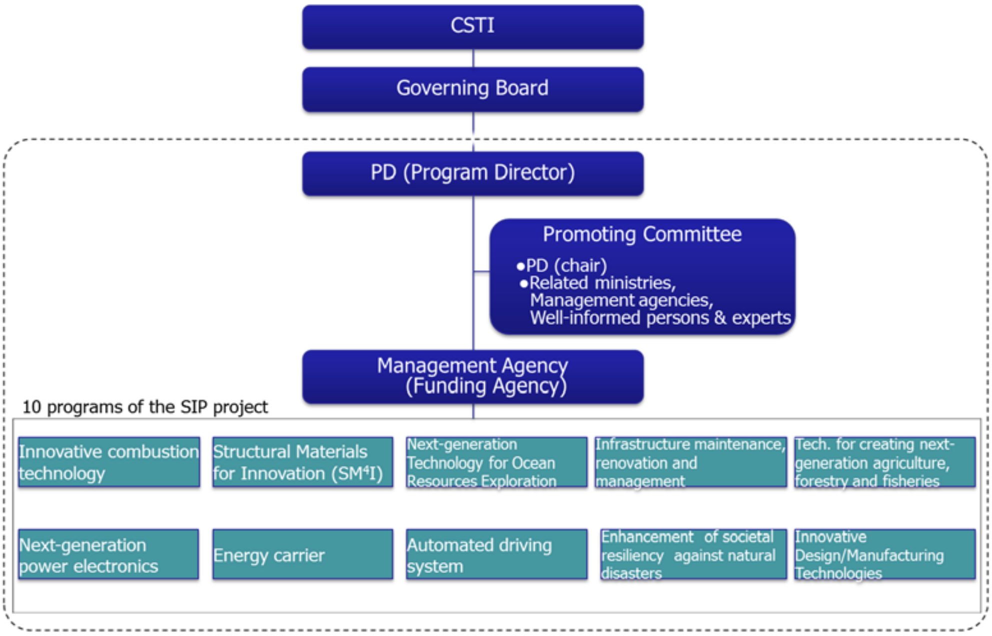


Figure 3- Governing structure of cross-ministerial R&D program.

The SIP has identified ten themes which represent the most important social problems facing Japan. These projects will improve the situation and contribute to the regeneration of the Japanese economy (Table 1).

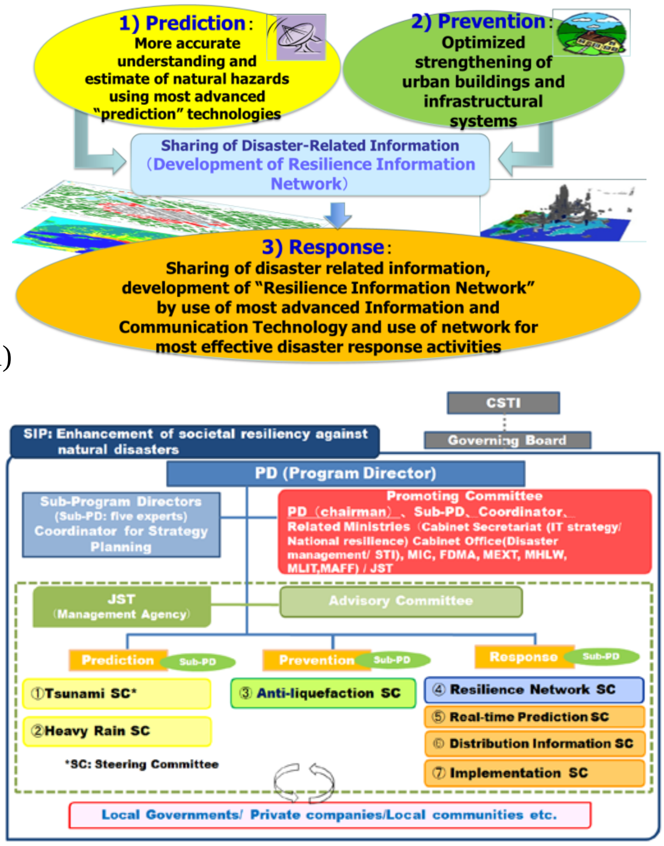
Table 1- Ten programs of the SIP project.

Program name	Program Director	Founding Agencies / Related Ministries	Annual Budget (yen)
Innovative Combustion Technology	Masanori Sugiyama	Japan Science and Technology Agency (JST)	¥2.00 billion
Next-Generation Power Electronics	Tatsuo Oomori	New Energy and Industrial Technology Development Organization (NEDO)	¥2.20 billion
Structural Materials for Innovation	Teruo Kishi	JST	¥3.61 billion
Energy Carriers	Shigeru Muraki	JST	¥3.31 billion
Next-Generation Technology for Ocean Resources Exploration	Tetsuro Urabe	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	¥6.16 billion
Automated Driving System	Hiroyuki Watanabe	Cabinet Office, National Police Agency, Ministry of Internal Affairs and Communications (MIC), Ministry of Economy, Trade and Industry (METI), Ministry of Land, Infrastructure, Transport and Tourism (MLIT)	¥2.54 billion
Infrastructure Maintenance, Renovation, and Management	Yozo Fujino	MLIT, JST, NEDO	¥3.60 billion
Enhancement of Societal Resiliency against Natural Disasters	Masayoshi Nakashima	JST	¥2.57 billion
Technologies for Creating Next-Generation Agriculture, Forestry and Fisheries	Takeshi Nishio	National Agriculture and Food Research Organization (NARO)	¥3.62 billion
Innovative Design/ Manufacturing Technologies	Naoya Sasaki	NEDO	¥2.55 billion

Each project is led by an experienced program director. These directors are responsible for research and development, facilitating coordination among government, industry, and academic organizations. They lead the project from basic research to practical application and commercialization, and ultimately to evident exit strategy. SIP project is different from numerous other government-sponsored research. The program intends to provide clear, quantitative outcomes and direct contributions to urgent societal needs with cross-ministerial cooperation and sharing information among ministries. Among the ten programs, eight are directly aimed at “innovation and new business opportunities” to promote the Japan’s competitiveness in international businesses. The remaining two, the concerned program of this paper and the other on infrastructure maintenance, has a taste of maintaining our infrastructure to better life and business.

3 THREE KEY PILLARS OF THE PROGRAM: PREDICTION, PREVENTION, AND RESPONSE

This program has been tasked to make significant contributions in three main themes related to disasters: (1) develop forecasting and early-warning technologies that indicate nature and scope of disasters (*prediction*), (2) strengthen cities and infrastructure with enhanced capacity that can prevent disasters (*prevention*), and (3) advance disaster response functions that minimize damage during and in the aftermath of damage events (*response*) (Figure 4a). The overall scheme of the program is outlined in Figure 4b, including the committees to oversight the program and individual projects.



(a)

(b)

Figure 4- Program "*Enhancement of Societal Resiliency against Natural Disasters*": (a) interaction of "*prediction*", "*prevention*" and "*response*" and (b) governing structure.

3.1 Prediction

The first task of this program (*prediction*) focuses on developing new technologies to predict tsunamis, torrential downpours, and cyclones. This task will provide technologies which, in the wake of a natural disaster, permit more accurate understanding of its nature and influences. Data collected using the technologies will be shared between public-private sectors. The system will result in achieving greater precision in disaster response, observation, and forecasting efforts. Two technologies will be developed as shown below.

First, the development of tsunami prevention technology is ongoing (Figure 5). For this purpose, the focus is made on fundamental research to reduce the tsunami damage. Reduction of the damage will be realized by suggesting evacuation on the basis of tsunami prediction with high precision. In other words, it will develop techniques which permit estimation of tsunami arrival within a few minutes after the tsunami detection. High-definition tsunami run-up simulator can take into account the collapse of protective facilities. An observation system of seafloor crustal activity predicts aftershocks and subsequent earthquakes by taking advantage of observed data obtained from the Japan Trench undersea earthquake tsunami observation network (S-net). The systems discussed will generate tsunami estimation of inundation in three minutes.

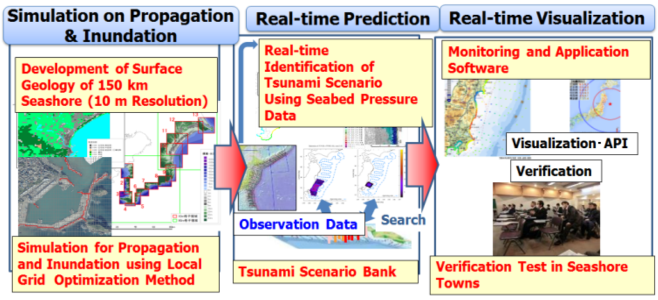


Figure 5 – Development of tsunami prevention technology.

Second, downpour, cyclone prevention technology is under development. Focus is given on the sophistication and utilisation of prevention information against heavy rain, tornado prediction information through the development and utilization of multi-parameter array radar (Figure 6). It is difficult to estimate local weather disasters induced by cumulonimbus clouds, such as guerrilla heavy rain and tornadoes, with existing observation technologies. In this research, challenge is oriented to the development of the world's first multi-parameter phased array radar (MP-PAR). It will enable high-precision, high-speed, three-dimensional observation of clouds. The system will attempt to predict flood with one-hour prior estimation.

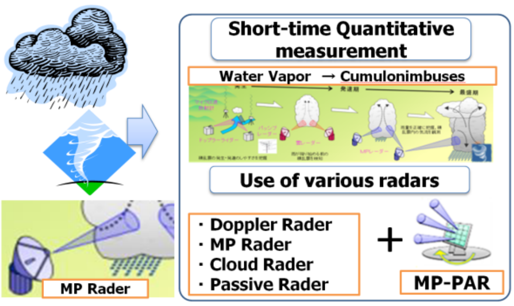


Figure 6 – Prediction of heavy rain using MP-PAR.

3.2 Prevention

The second task (*prevention*) concentrates on the development of technologies to deal particularly with large-scale liquefaction. A wide variety of tests and analyses is ongoing for verification of retrofit methods that are to be developed in the program. The information on the seismic performance gained through these tests will be incorporated into practical guidelines that present diagnosis against liquefaction and effective countermeasures. Research and development primarily concern liquefaction-countermeasure techniques. In other words, contribution is made for the development of technologies related to liquefaction countermeasure, liquefaction diagnosis and ground survey. These developments will be adopted in coastal industrial complex areas, aiming for seismic consolidation. Another attempt is made to establish and disseminate a system that strengthens bridge foundation which can be the risk of road network disruptions. For the development of these technologies, large-scale experiments, disaster analyses and numerical analyses are being carried out.

3.3 **Response**

The third task (*response*) attempts to create a resilience information network that assists the recovery from large-scale disasters and to bring life back to normal as quickly as possible. This task aims to develop technologies relevant to real-time sharing of damage estimates and on-the-ground damage information. It will strengthen resilience in the face of natural disasters on both the individual and societal levels. Four different assignments are underway for this task.

First, information-sharing system utilizing Information and communication technology (ICT) is being researched and developed for disaster response agencies. In order to perform accurate disaster response across the country including government ministries, relevant agencies and local governments, an integrated disaster-related information system will be established. Second, disaster-information-collection system and real-time damage-estimation system will be researched and developed. Contribution is made to the establishment of disaster response system against earthquakes, tsunamis and heavy rains in the real time. The system will enable to estimate the damage state and grasp in the street unit with high precision by taking advantage of various kinds of information analysis such as satellite data and social media. As real-time disaster and damage prediction and confirmation at the event of an earthquake, location and severity of affected regions will be estimated within 30 seconds and with precision of a mesh of 250 meters. Third, technology for disaster-information distribution is being developed. The technology will secure communication between residents and disaster measurement organizations even during a most severe disaster. Specifically, focus is made on three topics: "disaster information delivery by means of a variety of information media group of communications and broadcasting", “automatic generation of disaster information” and "securing communication between disaster response headquarters and disaster-stricken area”. The achievements shall be distributed in Japan and other countries through verification tests. Last, applications for disaster response are under development. Through this task, different applications will be developed including tools relevant to disaster-response support and tsunami evacuation. For the former, an application will be developed to provide support against a complex disaster in large cities and large-scale area around a terminal station. The application to be developed will make it possible to take appropriate response actions. It aims to help respond to damage caused by the earthquake in large cities and secondary disasters such as fire spread and hordes collection of panic and to further complex disasters such as simultaneous occurrence of floods. For the latter, tsunami evacuation drill and support tool will be developed. Focus is made on the invention of effective tsunami mitigation and evacuation measures. A drill package will be developed for residents so as to carry out evacuation training under appropriate related information and realistic situation settings. Specifically application techniques have been developed as to "individual training time trial". Such applications will be used not only for a drill but for evacuation support as well.

4 **INSTALLATION OF PROGRAM TO SOCIETY AND CONTINUING EFFORTS**

As discussed in Section 4.3, achievements of the program will be taken advantage of for better protection against natural disasters including tsunami and heavy rain. The program considers continuation by installing the achievements to the society, as is another advantage of the program. The implemented system will secure communication among disaster response institutions, local governments and residents. A few examples are as follows.

4.1 **Prediction of Inundation after tsunami**

As for tsunami technology, with the current status, prediction can be made on tsunami height at seashore within 3 minutes. As an achievement of this project, inundation will be visualized and warning will be provided within few minutes by the aid of seabed observation networks, which has been established separately under a national project after 2011 Tohoku earthquake. Propagation and inundation will be simulated with development of surface geology of 150 km seashore with 10 m resolution. This can be achieved by using local grid optimization method. Real-time prediction will be established with identification of tsunami scenarios using seabed pressure data named "tsunami scenario bank". Practical real-time visualization will be invented by a series of verification tests in seashore towns.

4.2 Prediction of Heavy Rain using MP-PAR

Today, capturing of rainfall spatial distribution is qualitative every 30 seconds and qualitative every five minutes. In three years (after the program), spatial distribution of rainfall distribution capturing system will be invented. With this newly developed system, prediction of heavy rain will be accomplished quantitatively every 30 seconds. For realization of this short-time quantitative measurement, various radars will be used including doppler radars, MP radars, cloud radars and passive radars. This prediction will result in better disaster responses such as flood control, railway management, data sharing, and local government response.

4.3 Ensuring communication in disastrous situations

The current communication service allows for communication after one hour in very vicinity of ICT unit. In three years, an improved communication service will permit communication after 10 minutes in 5 km area (Figure 7). Modulation of ICT unit will be optimized. Mobility will be enhanced by downsizing and lightening, and network establishment will be automized. Versatile modification can be made according to the location and type of users. International standardization will be sought for. Verification is planned to implement in Philippines.

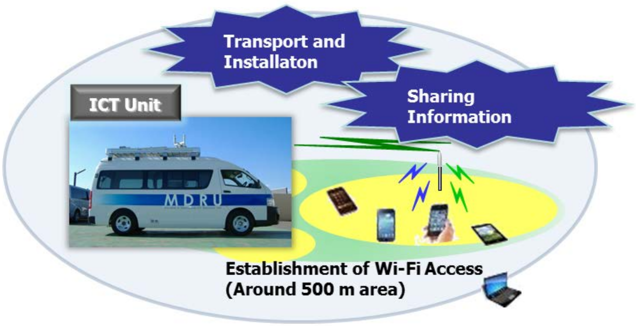


Figure 7- Diagram of securing communication using ICT unit.

5 CONCLUSION

The writer, as the program director of the concerned program, has discussed the overview and challenges of the program named "*Enhancement of Societal Resiliency against Natural Disasters*". The outcomes of this program provide new business opportunities for Japanese industry and generate systems that integrate disaster prediction, prevention and response. In the program, a variety of contributions to the society's welfare are sought via the enhancement of resilient society against natural disasters. Notable contributions expected from the outcome of this program are as follows.

Contribute to disaster prevention measures: The program will provide technologies for seamless communications of disaster information collected through public and private sources; this disaster prevention system will allow for officials determining disaster responses to have access to useful information.

Provide continuity: The program will create a system of consistent disaster prevention training and education to train citizens in immediate safety responses during disasters and share useful disaster information throughout rural communities. The program will foster and utilize regional disaster research centers throughout Japan to ensure continued improvement of disaster responses at the local level.

Ensure Japanese industrial competitiveness: The program will provide a system for real-time information sharing using the latest scientific technologies to facilitate industrial and community continuity in the aftermath of large-scale natural disasters.

Create industries based on disaster prevention/mitigation: The program will transfer technologies related to real-time disaster information and immediate disaster response to the private sector (businesses) and local governments, and nurture new businesses that can be expanded to overseas countries.

The past natural disasters including the 2011 Tohoku earthquake pointed out the necessity to improve prediction measures of earthquake and tsunami, tsunami warning systems, landslide and liquefaction mitigation, emergency planning and response. "Resiliency" is lately a frequently-used term to describe earthquake engineering although what the term means is not clarified. "Resiliency" signifies the capability to recover to usual conditions as soon as possible. Resiliency can be realised in a true sense when full cooperation and exchange between all disciplines are achieved. The collection and spread of knowledge derived from past disasters should be shared not just locally but globally. Many countries can learn from Japanese experience and have paid serious attention to the Japanese response. From this viewpoint, this program has to be promoted internationally.

REFERENCES:

Cabinet Office of Japan. http://www.cao.go.jp/fusuigai/index.html Last access 1st September 2015 (in Japanese).

Council for Science, Technology and Innovation (CSTI). http://www8.cao.go.jp/cstp/gaiyo/sip/ Last access 1st September 2015 (in Japanese).

Director General for Science, Technology and Innovation (CSTI) 2014. SIP "Pioneering the Future: Japanese Science, Technology and Innovation". Cabinet Office of Japan

Mori J. Eisner R. 2013. 2011 Tohoku-Oki Earthquake and Tsunamis. *Earthquake Spectra, Special issue*. 29(S1), vii-S499.

Nakashima M. Becker T.C. Matsumiya T. Nagae T. 2014a. A Lesson from the 2011 Tohoku Earthquake–The necessity for collaboration and dialog among natural scientists. *Performance-Based Seismic Engineering: Vision for an Earthquake Resilient Society*. 101-116.

Nakashima M. Lavan O. Kurata M. Luo Y. 2014b. Earthquake engineering research needs in light of lessons learned from the 2011 Tohoku earthquake. *Earthquake Engineering and Engineering Vibration*. 13(1), 141-149.