Paper: Dr16-4-11164; 2021/4/27

Interdisciplinary and Industry-Academia Collaboration Research for Enhancing Social Resilience to Natural Disasters in the Tokyo Metropolitan Area –DEKATSU Activity–

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[Received October 5, 2020; accepted November 4, 2020]

In 2007, we initiated a 5-year-research project named the "Tokyo Metropolitan Resilience Project." This project is intended to improve the resilience to natural disasters, particularly earthquakes, in the Tokyo metropolitan area. For this purpose, we have organized multi-disciplinary research including social sciences, natural sciences such as seismology, and civil engineering, with a focus on earthquake engineering. In addition, we facilitate mutual communication between industry and academia. We established the "Data Use and Application Council for Resilience" (Japanese abbreviation: DEKATSU) to organize private and public stakeholders. The DEKATSU council consists of four sectors: industry, government, NPO/NGOs, and academia. The policy promoted to the participating organizations is "When we make organizations resilient, the Tokyo metropolitan area also becomes resilient." To date, 67 organizational members and 13 personal members have joined, and the targeted idea is becoming accepted but not fully implemented in society.

Keywords: disaster resilience, integrated multi-disciplinary research, Data Use and Application Council for Resilience (DEKATSU), Industry-Government-Academia-Private Linkage, Tokyo Metropolitan area

1. Introduction

Japan is one of the most earthquake-prone countries in the world. Concentrating both urban functions and population, the Tokyo metropolitan area is the nerve center of Japan and the nucleus of its economic activities. In addition, the Tokyo metropolitan area, that is, Tokyo, Kanagawa, Chiba, and Saitama prefectures, will likely be hit by a major earthquake of magnitude (M) 7 or larger in the future [1].

Such an earthquake will likely generate a serious disaster due to the extraordinary exposure, that is, a population of more than 35 million. The Cabinet Office working group to study countermeasures for such an earthquake estimates that if an M7.3 earthquake hits, which is similar to those occurred in Kumamoto or Kobe, the areas experiencing seismic intensity of 6-lower[1] would cover up to 30% of the capital and three prefectures. If such an earthquake (referred to as the scenario Tokyo metropolitan earthquake) occurs, as many as 23,000 lives would be lost, and over 600,000 buildings would be completely destroyed or razed by fire. Extensive fires would break out over a wide area and burn for two days. More than half of businesses and households would experience power cuts, and major unease would continue for over a week. Transport would be paralyzed, as subways could potentially cease operation for a week and local lines even for a month [2].

Even if an M6 earthquake, much smaller than the scenario Tokyo metropolitan earthquake, occurs, Tokyo will suffer severe damage. An example is the event that hit northern Osaka-fu (Osaka Prefecture), one of the major cities in Japan [3]. The 2018 northern Osaka-fu earthquake stopped more than half of the approximately 120,000 elevators in the four prefectures of the Kinki region. It took four days until all of them were restored. This is also the case for the gigantic event that will likely occur in the Nankai trough. The source region is located as far as 400 km from the Tokyo metropolitan area, and ordinary seismic intensity may be 5+ or lower, but a large, long-period motion will hit high-rise buildings whose resonance period is exactly the same as the long-period earthquake generated motion. We can easily imagine that almost all elevators in the Tokyo area will be stopped for safety protection measures, not necessarily by damage. In light of the scenario earthquake, it is a pressing task to consider methods for keeping such damage to a minimum.

For reducing the impact of such an earthquake, it is vital to accurately evaluate disaster risks faced by the capital region, and to equip the Tokyo metropolitan area with comprehensive business continuity and response capabilities. In Europe, such an idea of integrating interdisci-

1. The Japanese Meteorological Agency (JMA) seismic intensity scale has 10 classes from to 7, where intensities 5 and 6 have two classes, that is, upper and lower. The JMA intensity of 6-lower is equivalent to a strong ground motion with which a low earthquake resistance wooden houses may lean or collapse.

plinary research has been also initiated by the Real-time earthquake rIsk reduction for a resilient Europe (RISE) project, which has been financed by the Horizon 2020 program of the European Commission since 2019 [4].

To this end, it is first of all important to make a more resilient capital region by pooling the resources of industry, government, academia, and private sectors.

Companies and organizations have developed systems for disaster resilience as a part of corporate social responsibility (CSR). CSR is a concept of a self-regulating business model that helps a company be socially accountable to itself, its stakeholders, and the public [5, 6]. Furthermore, a new idea of business management of creating shared value (CSV) is now available. Porter and Kramer [7] defined the concept of shared value as "policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates." Making a society resilient for natural disasters is definitely a new social value. A paradigm shift from CSR toward CSV is becoming realistic.

This research and developing project began in 2017, and ran the "Data Use and Application Council for Resilience." The Japanese translation of the name of council is "Data RiKatsu You Council," which we abbreviate DEKATSU. DEKATSU creates the opportunity for sharing the accumulated data the members have developed in daily business to create a new value.

2. Industry-Government-Academia-Private Linkage

The National Research Institution for Earth Science and Disaster Prevention (NIED) has initiated this 5-year research project, which is funded by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) since 2017. The project is committed to an all-Japan approach with researchers from companies, organizations, and universities who share the same goal. A wealth of data is used and applied in research and disaster response [8].

One of the remarkable characteristics of our project is integrating multi-disciplinary research with social stakeholders. Bridging social sciences, natural sciences, and engineering, this project aims for industry, academia, government, and private sectors to work in an integrated manner to enhance preventive, predictive, and response capabilities for disasters. To emphasize the linkage between industry and academia, we have a special organization for the current project as shown in **Fig. 1**. The basic academic research is conducted in three different disciplinary groups, hereafter, subprojects. Additionally, we organize the "Data Use and Application Council for Resilience," DEKASTU. To make our activities better known in industry and public community, we have carefully selected a good nickname for the council. We aim to gather, consolidate, and effectively use data for social resilience to natural disaster: that is, for industry, the overall business continuity and disaster response is necessary. Simultaneously, we carefully consider mutual communication among industry, government, academic sectors, and individuals.

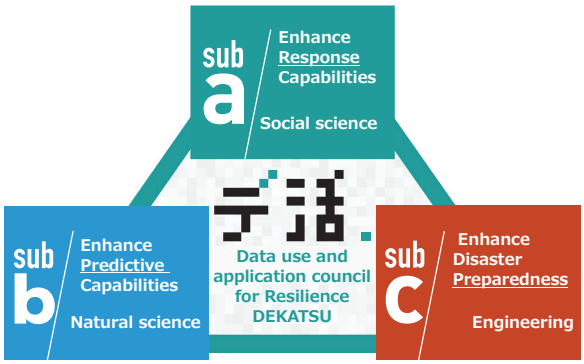

Fig. 1. Project structure: 3 inter-disciplinary research fields, and a data utilization council, DEKATSU.

To manage the project effectively, we have established a center for this particular project in NIED; the Research Center of Enhancing Metropolitan Resilience. Each subproject, that is, social science, earthquake science, and earthquake engineering, has two co-principal investigators, one from outside NIED through a joint appointment or a visiting researcher for nationwide collaboration among NIED and universities. Activities and results from each subprogram are presented in separate papers in the present special issue and we simply summarize an outline of the subprojects.

2.1. Social Science Group: Subproject *a*

Subproject *a* carries out "Establishment of industry-government-academia collaborative council to expedite data utilization conducive to mitigating damage" and "Extraction of technical issues for early recovery and reconstruction of urban functions using data" with the aim of improving "Damage mitigation capabilities/disaster response capabilities for urban disasters that cause significant damage" and "business-continuity capabilities for early recovery and reconstruction" [9–12].

Subproject *a* oversees the cooperative framework with a view to "Integration and utilization of collected, generated, and accumulated data and research results by Subprojects *b* and *c*."

2.2. Natural Science Group: Subproject *b*

For stably operating the Metropolitan Seismic Observation network (MeSO-net), Subproject *b* develops a multi-data integration system to integrate seismic data from NIED seismic networks, such as nationwide observation networks for earthquakes, tsunamis, and volcanoes over land and sea (MOWLAS) and MeSO-net, with a large amount of the shaking data held by private companies, and to make the data available as products. To collect dense observation data, techniques to observe shaking using smartphones and to transmit observed data from satellite devices to MeSO-net stations are developed. To eval-

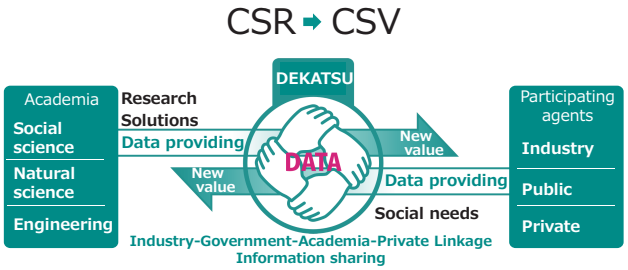

Fig. 2. From CSR: Corporate Social Responsibility, to CSV: Creating Shared Value.

uate seismic hazards in Tokyo metropolitan area, we investigate and analyze the seismic history of the Japanese islands and develop prediction methods for ground motions caused by large earthquakes in the future.

2.3. Engineering Group: Subproject *c*

Effectively utilizing NIED's 3-D Full-Scale Earthquake Testing Facility (E-Defense) [13], Subproject *c* collects and consolidates data that would be significant for the judgment of seismic safety margins of buildings and structures with non-structural elements and components considered. This project aims at the establishment of an effective scheme for the following: 1) The automatic judgment of the safety of, in particular, those kinds of buildings that could be core hubs for enhancing disaster resilience, such as government buildings, hospitals, gymnasiums, stations supporting people having difficulty to get home, thus providing emergency evacuation places. 2) Maintaining the functionality or business continuity of the potential backbone buildings and facilitating their prompt recovery along with damage identification and recovery, and preventing dense residential wooden-house areas from disastrous damage. In this project, we plan to carry out four large-scale experiments in five years, and we have conducted two experiments so far.

In addition, using the data observed under the management of Subproject *b*, this subproject identifies the actual seismic effects on buildings considering the mutual interaction of building and soil-foundation.

3. Strategy for Collaboration

For collaboration of data use and application among industry, private, public, and academic sectors as shown in **Fig. 2**, we have developed a three-category system strategy: open, semi-closed, closed systems (**Fig. 3**). The open strategy consists of an open physical and/or online symposium. The semi-closed collaboration consists of a series of thematic panels. These panels openly call for participation in the panel discussion where a specific theme is prescribed. However, discussion is closed to public due to private nature of discussion among organizations who sometimes do not want to disclose their ideas and data. Only a summary of the discussion will be available for the DEKATSU members and finally to the public. The closed

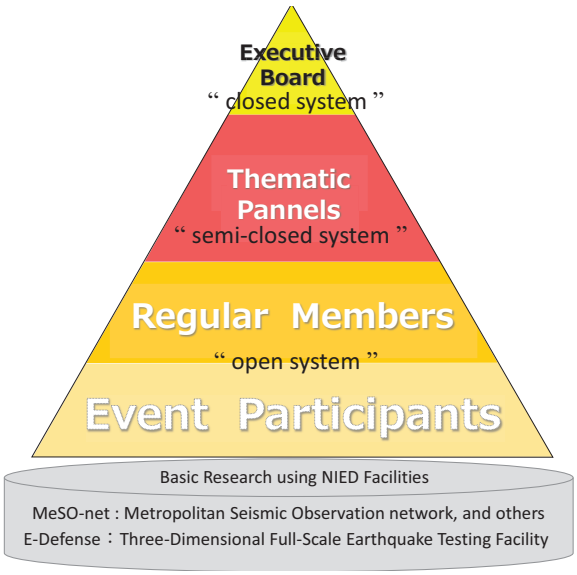

Fig. 3. Structure and the participant of DEKATSU.

collaboration comprises the data exchange between NIED and collaborators with an explicit contract such as non-disclosure agreements (**Table 1**).

3.1. Open Symposium

We have regular DEKATSU symposia three times a year and an annual meeting to report results; both are open to the public. The purpose of the symposia and meetings is to report our research progress and call for participation with the DEKATSU council. Our idea is to promote private and public organizations to create shared value for social resilience to natural disasters. We originally started from research of seismic disasters in urban areas, but later included meteorological disasters caused by severe typhoons.

We have a formal discussion as the annual general meeting of DEKATSU. DEKATSU is arranged as an organization with a formal rule of membership. DEKATSU has an executive board and a president that are selected by the DEKATSU members. The DEKATSU executive board decides on the basic direction of the activity and the board members include directors of several major corporations. The symposia are open and free to the public.

3.2. Semi-Closed Thematic Panel

We have organized several panels in which there is an in-depth discussion among stakeholders about data-holders and data-users. The idea of CSV is acceptable in general but it is sometimes difficult to implement in an actual situation. Therefore, we developed the panels for 1) sharing information among participating organizations, 2) developing a specific project with reporting on results, 3) sharing a technical issue, 4) management for development, and 5) dissemination of results. Some information is private and only available in closed meetings but inevitable for understanding specific aspects.

Table 1. Provision of confidential data on NDA contract for our research.

Source	Data type	Amount	File size
Gas company	Three axis acceleration	7,058 waveforms at 10 earthquake events form 2009.8 till 2012.1	5.05 GB
Electric equipment maker	Three axis acceleration	Total of 233 observation points at 10 earthquake events form 2017.8 until 2018.9	13.6 MB
Construction consulting	Three axis acceleration	Total of 2,550 observation points at 142 earthquake events form 2015.3 until 2018.3	5.75 GB
Elevator maintenance Company	Earthquake sensor detection	Totally 8,912 observation points in 14 prefectures at 10 earthquake events form 2011.3 until 2018.7	16.3 MB

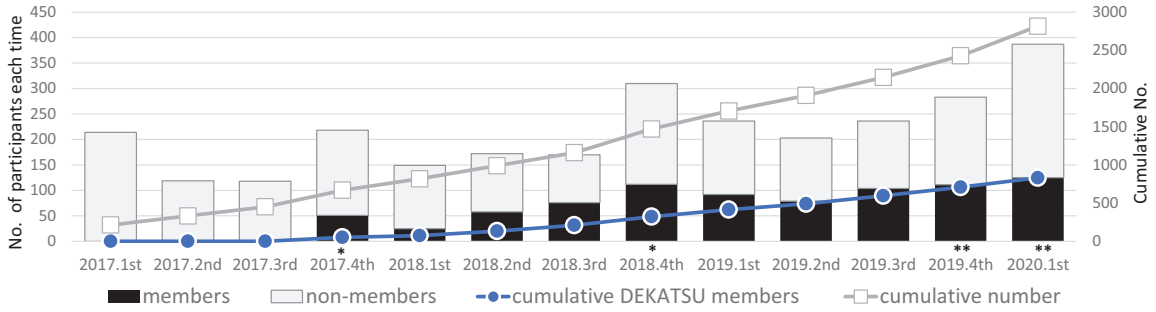

Fig. 4. Participants from members' organization. *A large venue was used for an annual result report meeting. **It was held by online without accepting the participant to a venue because of *COVID-19*.

3.3. Contract with Non-Disclosure Agreement

The final goal for CSV needs open collaboration on data. However, at the present stage, some companies agree to allow the use of their data only for a specific purpose. We want to use some data to demonstrate, if such data were available, how we could develop a useful system. Our original idea is to develop a system to combine a large amount of data collected by private companies with basic data from academic organizations such as NIED. This requires contracts with non-disclosure agreements (NDA).

4. Results

We have an increasing number of participants in the DEKATSU symposia and in the DEKATSU member organization and developed seven thematic panels. We have signed four contracts with private companies.

4.1. Increasing DEKATSU Members

General interest has significantly increased through the DEKATSU symposia. As shown in **Fig. 4**, the number of DEKATSU members in the symposium has also increased indicating that the open strategy has shown to be effective, particularly for the private sector. As of the end of August 2020, DEKATSU has members from 57 private companies, three municipalities, and nine NPO/NGOs. The cumulative number of participants in DEKATSU symposia is now more than 1,000, 65% of which belong to private companies that are assumed to be a main stakeholder in the Metropolitan project.

4.2. Thematic Panels

A thematic panel for discussing "a simple sensor-based building monitoring system" has been established since 2019 after a preparation phase over half a year. DEKATSU has had over 50 members and researched needs of member companies. There are currently seven thematic panels as follows:

(1) Simple Sensor-based Building Monitoring Systems Panel
(2) Resettlement Panel
(3) Quick-Damage Assessment Panel
(4) Local Government Disaster Management Panel
(5) Multiple-Dwelling Complex Panel
(6) Internet of Things in Chain Stores Panel
(7) Lifeline Utilities Panel

The panels consist of academic researchers, who belong to different subprojects for interdisciplinary approaches, and researchers or businesspersons from industry or public organizations. These usually hold either a chair or vice-chair position and thus decision-makers in their respective organization. Each panel opens on average once every few months. Discussions are basically closed to public; however, the chair can invite those experts who have excellent knowledge or interest in the theme with a non-disclosure agreement.

4.3. Data-Offering/Receiving Contract

NIED has made data-receiving contracts with some private companies as shown in **Table 1**. To date, all contracts

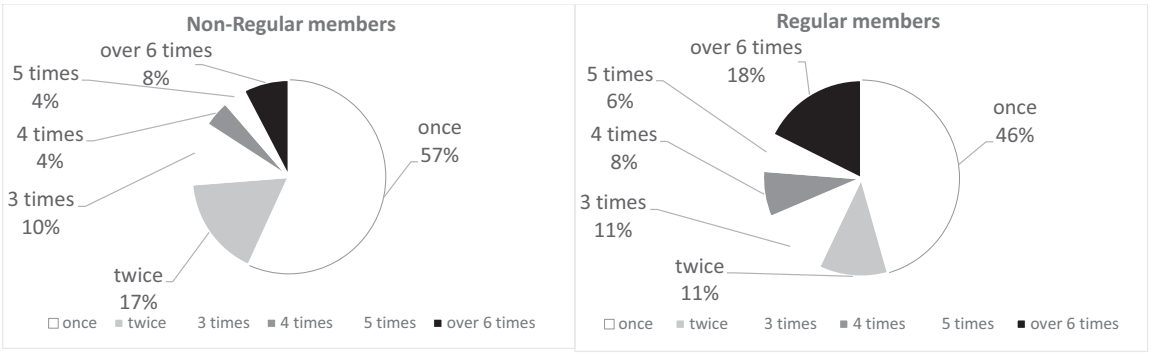

Fig. 5. Frequency analysis of participation in *DEKATSU* events.

are such that a company offers data to NIED for a specific research purpose, that is, for research within the scope of the Metropolitan Project. NIED can conduct research using these data but has further discussions with the respective company about how to release the results. The data will be used to demonstrate how the use such data will create excellent results of high interest. In this context, the data are not used in real-time. One example was conducted by subproject *b* and developed a multi-integration technology combining MeSO-net data, MOWLAS data, and data from a private gas company [14].

5. Discussion

5.1. Increase in Membership

As of August 2020, 12 open symposia have been held, including three annual meetings to report results. Until 2019, all symposia were held in a conference room with about 190 seats. The annual meetings were held in a larger room with 350 seats. More than 90% of seats were occupied by attendees, and three meetings had 100% occupation. Since the FY 2019 annual meeting held in February 2020, symposia have been held online due to counter measures to avoid the spread of COVID-19. The FY 2019 annual meeting is a combination of a physical and online meeting where presenters appeared in the meeting room and the audience joined online. The first DEKATSU symposium in 2020 was held completely online except for a master of ceremonies and the president of DEKATSU, who were in a studio with an audio-visual system.

As shown in **Fig. 4**, there has been a total of 2,800 attendees at meetings so far. The ratio between DEKATSU members and non-members is 1 : 2, which is a result of our open policy to the public. The idea is to call many attendees and promote interest in our research activities. The online symposium is also convenient for all participants from outside Tokyo and, due to the large capacity of the meeting room, we recorded an increased number of participants and also memberships. Originally, we were forced to hold the meeting online because of COVID-19 counter measures, but we are now increasingly encouraged to hold more online meetings to expand participation as compared to a physical gathering.

On the other hand, as shown in **Fig. 5**, many attendees only join once, which is equivalent to the fact that 50 to 150 new members attended every time. This has both good and bad aspects. An active circulation of the attendees expands horizons in potential participation. However, we should strive to make those attendees regular participants. One method to keep attendees from dropping out of the online meetings is to involve them in interactive communication. During the meetings, we asked the audience questions and received answers via the Internet. For example, a very simple but effective question is to ask attendees where they are currently located. Unfortunately, the area from where the attendees joined the 2020 February meeting was basically limited to the Kanto district, however, some were located outside greater Tokyo. We will encourage people from further afield to attend an online symposium. After COVID-19, we will aim to hold a hybrid symposium of both a physical and online gathering.

5.2. Result and Directionality of the Thematic Panels

During the first thematic panels, we aimed at addressing specific needs of individual member companies/organizations. One example is that the (3) *Quick-Damage Assessment Panel* was organized after the 2018 eastern Hokkaido Eastern Iburi earthquake occurred. An insurance company wanted to know the damage distribution for rapid payment of earthquake insurance indemnities. NIED provided the company with strong ground-motion intensity information to assess the damage distribution. The company then sent investigators to those areas reported to have experienced large seismic intensity with houses being likely severely damaged, resulting in faster indemnity payments.

Another example is the (7) *Lifeline Utilities Panel*, which is the newest panel founded for common interest and public welfare among many companies and public sectors for lifeline infrastructure; that is, electric, water supply, gas supply, traffic, and railway companies. This panel is of high importance because we discuss how to mutually use data on hazard, risk, and countermeasures as shown in **Table 2**. One important issue that we have to solve is how to use data from inside and outside of

Table 2. Progress of data collection between the space-time in the infrastructure subcommittee.

Category	Information type	Provider	Source/contents	Already open to the public	Delivered with map, or map service of each organization own	Source data is download -able	Embeddable in author's portal site, as is	Available in author's portal webGIS as layer service
Hazard	Water and Wind-related	Japan Meteorological Agency	High-resolution Precipitation Nowcasts	Yes	Yes	No	Yes	No
			Analysis & Forecasts of Precipitation	Yes	Yes	No	Yes	No
		Ministry of Land, Infrastructure, Transport, and Tourism	Slope failure Disaster Prone Areas	Yes	Yes	No	No	Yes
			Landsides Disaster Prone Areas	Yes	Yes	No	No	Yes
			Debris flow Disaster Prone Areas	Yes	Yes	No	No	Yes
			Flooding Disaster Prone Areas	Yes	Yes	No	No	Yes
		NIED: Storm, Flood, and Landslide Research Division	Precipitation intensity	Yes	Yes	No	Yes	*2
			1.5 hours working rainfall	Yes	Yes	No	Yes	
			72 hours working rainfall	Yes	Yes	No	Yes	
			24 hours working rainfall	Yes	Yes	No	Yes	
		NIED: Earthquake and Tsunami Research Division	Strong-motion Seismograph Networks: K-NET,KiK-net	Yes	Yes	Yes	Yes	*2
			High-Sensitivity Seismograph Network: Hi-net	Yes	Yes	Yes	Yes	
			Broadband Seismograph Network: F-net	Yes	Yes	Yes	No	
			Metropolitan Seismic Observation network: MeSO-net	Yes	Yes	Yes	Yes	
		NIED: Multi-hazard Risk Assessment Research Division	estimation of Seismic Intensity by Japan Seismic Hazard Information: J-SHIS	Yes	Yes	Yes	No	*3
	Snow-related	NIED: Storm, Flood, and Landslide Research Division	24 hours snow load by "Yukioro-signal" using numerical snowpack mode	Yes	Yes	No	Yes	*2
			30 days snow load by "Yukioro-signal" using numerical snowpack mode	Yes	Yes	No	Yes	
	Volcano-rerated	NIED: Volcano Disaster Resilience Research Division	Volcanic observation network: V-net	Yes	Yes	Yes	No	Unverified
		NIED: Volcano Disaster Resilience Research Division	Visualization system for Volcanic Activity: VIVA	Yes	Yes	Yes	No	Unverified
Risk	Water and Wind-related	NIED: Storm, Flood, and Landslide Research Division	Real-time flood/sediment disaster Risk Map	No	Yes	No	Yes	*2
		Japan Meteorological Agency	Real-time Landslide Risk Map	Yes	Yes	No	Yes	No
			Real-time Inundation Risk Map	Yes	Yes	No	Yes	No
			Real-time Flood Risk Map	Yes	Yes	No	Yes	No
Infra	Road Traffic	Expressway Company	Real-time traffic information service of the Metropolitan Expressway	Yes	Yes (schematic)	No	Yes	No
	Train Traffic	Railway Company	Train Status Information	Yes	Yes (schematic)	No	Yes	No
	Electric Supply	Electric Company	Electric Status Information	Yes	Yes	No	Yes, Partly	No
	Gas Supply	Gas Company	Emergency information service	Yes	No	-	Yes	No
			Gas Service Restoration Map	Yes	Yes	No	No	No
	Water Supply	Bureau of Waterworks	Water outage / Muddy water Information	Yes	Yes	No *1	Yes	No
		National Network for Emergency Mapping (N^2EM)	Water supply support information	Yes	Yes	No	Yes	Yes
	Telephone Service	Telephone company	Landline construction / failure information	Yes	No	No *1	No	No
	Cellphone Service	Cell phone carrier A	service area map	Yes	Yes	No	Yes	Yes
			4G service restoration area	Unverified	-	-	-	-
			3G service restoration area	Unverified	-	-	-	-
		Cell phone carrier B	service area map	Yes	Yes	No	No	No
			4G service restoration area	No	Yes	No	No	*2
			3G service restoration area	No	Yes	No	No	
		Cell phone carrier C	service area map	Yes	Yes	No	No	No
			4G service restoration area	No	Yes	No	No	Yes *4
			3G service restoration area	No	Yes	No	No	

*1 Just copiable as text in incident occurred.
*2 Requires development for dynamic connection to database.
*3 Required manual operation.
*4 Will be activated during system failure.

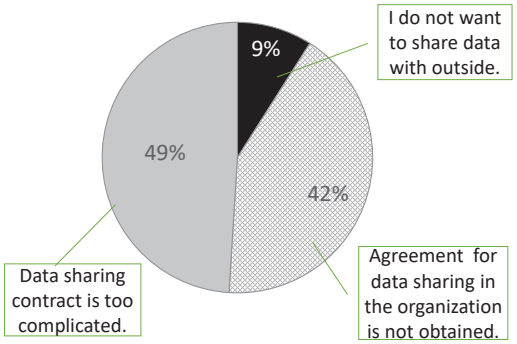

Fig. 6. Participant's opinion from online voting.

one's own organization. There are several difficulties in information security, legal issues, and policies related to management strategy. We have partly identified problems to be solved for data exchange in the panel.

Some common topics among the panels are discussed in joint panel sessions. Currently, four such sessions have been initiated. The activities have just started and will be reported elsewhere.

5.3. Further Improvement

According to the results of a questionnaire during the online symposium, as shown in **Fig. 6**, there are several reasons participants hesitate to collaborate on data exchange. However, only less than 10% of those that participate in the symposium "do not want to share data with others." One half of the participants think that the data sharing contract is too complicated. Finally, agreements for data sharing in organizations are rather difficult to obtain. We need more work to identify the real difficulty in data exchange in our society. More concrete opinions are listed as follows:

- It takes time to adjust contracts among organizations.
- It is necessary to make data understandable for those who have not obtained them.
- It is time consuming to clarify why and how data exchange benefits the own organization.
- There is a need for more knowledge regarding using data correctly in the public domain.
- When a company's data are opened, a competitor can take advantage of it.

6. Conclusions

We have initiated an interdisciplinary and industry–academia collaboration research project for enhancing social resilience to natural disasters in the Tokyo metropolitan area. We have three academic subprojects: a social science project (*subproject a*), an earthquake science project (*subproject b*), and an earthquake engineering project (*subproject c*). In addition, to enhance collaboration between industry and academia, we have organized the *Data Use and Application Council for Resilience*, that is, *DEKASTU*.

We have 70 *DEKATSU* member organizations including private companies, public, and private corporations. We emphasize participation of private companies because we hypothesize that increasing the resilience of such companies will increase the resilience of the Tokyo metropolitan area. We have organized seven thematic panels to discuss specific problems in-depth by organizing closed meetings of the *DEKATSU* member companies and academic researchers.

However, very important data is not necessarily collected from such corporations. For example, although we have collected a very dense seismic data from a private gas company, the data consist not of real-time data, but previous large earthquakes seismograms. These data are important for developing a new system to demonstrate the effectiveness of dense seismic data for estimation of spatially high-resolution hazard and damages in the Tokyo metropolitan area. However, the data are not useful in a real disaster to recognize the damages and make a decision for countermeasures. That is, real-time data sharing, including sharing of personal information associated with clients and corporate strategy, is still "middle-of-the-road." Future challenges for contribution to ongoing business continuity management is still under development.

Particularly, data including customer information and data related to corporate strategies are still very difficult to use in public. We need a long-term collaboration system for creating shared values in society for social resilience to disasters.

Acknowledgements

The present work is partially supported by Tokyo Metropolitan Resilience Project of National Research Institute for Earth Science and Disaster Resilience (NIED). The authors are indebted to Professor Keiko Tamura and Dr. Isao Kamiishi, who provided them with great cooperation regarding the unification administration of this project. The authors express appreciation for everyone concerned. In addition, this work was partially supported by JST Belmont Forum Grant Number JPMJ BF 2006, Japan. We thank Dr. Danijel Schorlemmer for improving the English of the present manuscript.

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