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Special Topic - 2011 Great East Japan Earthquake (Invited Paper)

RELATIONSHIP OF PEOPLE AND INFRASTRUCTURE DURING THE 3.11 EARTHQUAKE WITH INFORMATION TECHNOLOGY AS MEDIATING CHANNEL

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The Great East Japan Earthquake of March 11, 2011 resulted in not only 19,000 deaths and missing persons, mainly in the Tohoku Region, but also the evacuation of more than 400,000 people during the peak period. Although such disasters are very rare, creating robust civil engineering structures to prevent potential threats would be a difficult task.

On the other hand, even though information and communication technologies are just one of the means available, they have significant potential in terms of organically connecting support from people in a variety of capacities when an emergency arises. From this perspective, keywords such as "evacuation training," "group relocation," "real-time tsunami sensing," and "soft disaster preventions" emerged as a result of this earthquake.

I would like to describe how people utilize information and communication technologies as a mediating channel to secure their safety and security during earthquakes, whether autonomously or at other times through the protection provided by infrastructure facilities. In particular, the emergency mapping technology involving manual preparation as well as input from probe cars is introduced in Section 2 as a successful example of how information technology could serve as a mediating channel. Furthermore, in Section 3, I will describe the activities for the Open Government that did not necessarily function as a mediating channel but remain major issues for the future. In Section 4, the mobile phone technology is discussed in order to consider how mediating channels can be provided on a real-time basis, with consideration for the future.

Key Words : *Great East Japan Earthquake, information technology, emergency mapping, open government, people flow, mobile phone data*

1. BACKGROUND

The Great East Japan Earthquake on March 11, 2011 resulted in not only 19,000 deaths and missing persons, mainly in the Tohoku Region, but also the evacuation of more than 400,000 people during the peak period. In addition, people's daily lives were affected significantly by the enormity of the disaster, which had a complex nature and comprised earthquakes, tsunamis, and a nuclear power plant accident.

Furthermore, a variety of hazards for moving traffic occurred in the Tokyo metropolitan area on the day of the earthquake, resulting in commuters being forced to perform actions that differed drastically from their daily routine, due to, for instance, difficulties in returning to their homes. We could consider this a lesson on how the urban system of Tokyo, the largest metropolitan district in the world, should be structured in order to avoid major havoc when a large-scale disaster occurs.

Although such disasters are very rare, creating robust civil engineering structures to prevent potential threats would be a difficult task. From this perspective, keywords such as "evacuation training," "group relocation," "real-time tsunami sensing," and "soft disaster preventions" emerged as a result of this earthquake.

On the other hand, even though information and communication technologies are just one of the means available, they have significant potential in terms of organically connecting support from people in a variety of capacities when an emergency arises. The recovery support platform, based on volunteers, the website sinsai.info, and the Automobile

Traffic Performance Information Map produced by ITS Japan, which summarizes the probe car information provided by various automobile industries, is already known to many people as offering an overview of the overall trends and conveying daily changes in status.

Since the recovery status of the communication facilities and other conditions related to infrastructure during earthquakes are already described in the Special Issue of the Journal of Information Processing[1) and similar reports, in this paper I would like to describe how people utilize information and communication technologies as a mediating channel to secure their safety and security during earthquakes, sometimes autonomously and at other times through the protection provided by social infrastructure facilities. In particular, the emergency mapping technology involving manual preparation as well as input from probe cars is introduced in Section 2 as a successful example of how information technology could serve as a mediating channel. Furthermore, in Section 3, I will describe the activities for the Open Government that did not necessarily function as a mediating channel but remain major issues for the future. In Section 4, the mobile phone technology is discussed in order to consider how mediating channels can be provided on a real-time basis, with consideration for the future.

2. EMERGENCY MAPPING

(1) Life-support information

The first website to be cited as an example for emergency mapping is sinsai.info (`http://sinsai.info`). This site was launched three hours after the earthquake occurred, primarily by the Open Street Map Foundation, Japan, and others who support the Japanese branch of the volunteer-based map known as Open Street Map, which is created on a global scale (**Fig. 1**).[2) The experience of launching a site shortly after the earthquake in Haiti, just prior to this disaster, was considerably useful. The system uses a simple web GIS software that has an open source, known as the Ushahidi, to make it possible to post necessary information, such as the locations of lifelines and evacuation centers, as well as details on the safety and whereabouts of people in real time, immediately following the disaster and ahead of everybody else. The information is provided by a variety of people via Twitter, email, and forum entries on the website, as well as via other information websites. Furthermore, an attempt is being made to transmit information overseas, with proactive multi-language translation content. This groundbreaking case example indicated that cloud sourcing technology, which facilitates not only the contributions of information by some experts but also information brought in by ordinary people, functions appropriately even in the event of an emergency.

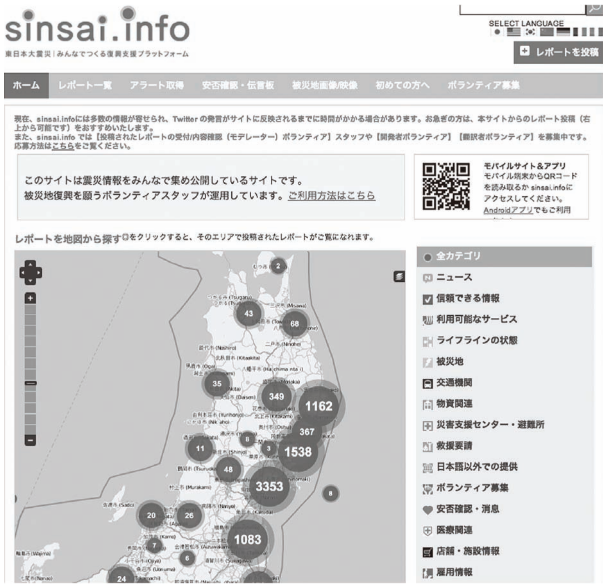

Fig.1 Sinsai.info (`http://sinsai.info`) for crisis mapping.

There are other websites that have been in operation since immediately after the disaster, such as the Great East Japan Earthquake Cooperation Information Platform[3) created by the National Research Institute for Earth Science and Disaster Prevention, and the Emergency Mapping Team (EMT) created by the Disaster Prevention Research Institute of Kyoto University.[4)

(2) Road recovery status obtained using probe car

Roads are networks. Fragmented witness information offers an insufficient amount of information, so understanding the status of roads is difficult. ITS Japan, a non-profit organization, therefore collected the positioning information of vehicles to determine whether traffic could pass on individual roads and provided such information, which was updated every day, as the Automobile Traffic Performance Information Map.[5) The innovative aspect of this is that such probe car information in the past was given by the individual users of car navigational systems, provided by each automobile manufacturer, so the information was obviously guarded by each company. Such information, however, was collected and consolidated into a single system, due to swift action taken by Honda, Toyota, Nissan, Panasonic, and ITS Japan. Taking into consideration the number of users with each company as well as the operating status of the cars after

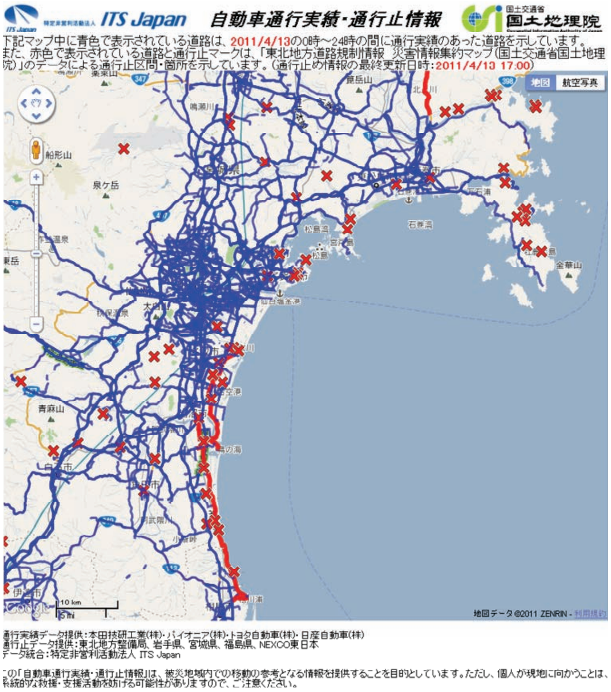

Fig.2 Automobile Traffic Performance Information Map provided by ITS Japan (`http://www.its-jp.org/saigai/`). Red "X" marks show road traffic points regulated by each local government. Blue lines illustrate roads where more than a vehicle had passed in one day, in this case, April 13, 2011, from probe vehicle information integrated with each commercial vehicle company.

Fig.3 Railway recovery map as of Sep. 3, 2012 (`http://www.tetsudo.com/special/disaster2011/`). Blue lines show recovered sections and red means unrecovered.

a disaster, it would not have been possible for any one company to gain an overall status of the performance of automobile traffic. In such circumstances, such a decisive measure was extremely innovative. In fact, when the road network was fragmented following the earthquake disaster, the ability to obtain information that reveals at a glance where transportation is possible was significantly useful for logistics. This information was updated every day until April 28, 2011. Information was thereafter also provided continuously when Typhoon Talas struck in September of the same year; therefore, this trend of publicly disclosing data for public welfare when a disaster strikes is likely to continue.

(3) Railway recovery status

Finally, a railroad recovery map is being produced by Asahi Interactive, a private-sector organization. This system automatically detects and displays updates on pages that feature railway traffic information provided by the web pages of railway companies, because it seems easier to some extent to gain an understanding of the recovery of the railway if information is given on a daily basis.

3. OPEN GOVERNMENT FOR COLLABORATIVE WORKS

(1) Need for machine-readable data

The above descriptions were for a case that worked well with a system established by the private sector. Detailed information provided by the authorities, on the other hand, is the only reliable information during a state of confusion; yet such information is often produced in PDF and other such formats that are undeniably not very conducive for reuse. **Fig. 4** shows the posting status of traffic restrictions on the web, which was made available every day by the civil engineering departments of each disaster-stricken prefecture after the earthquake occurred. Display formats varied, with some using tables produced with html coding, while the others used speech balloons on maps to provide descriptions. Raw data were also not made available, which made it difficult for others to use the data. In the case of Miyagi Prefecture, non-profit organizations were reformatting information on maps acquired from Google Maps. Furthermore, the Geographical Survey Institute overlapped such traffic restriction information, issued by local governments as described above, on the Automobile Traffic Performance Information Map shown in **Fig. 2**, to make the automobile traffic performance information more effective. I have heard, however, that even in this instance the work by the Geographical Survey Institute

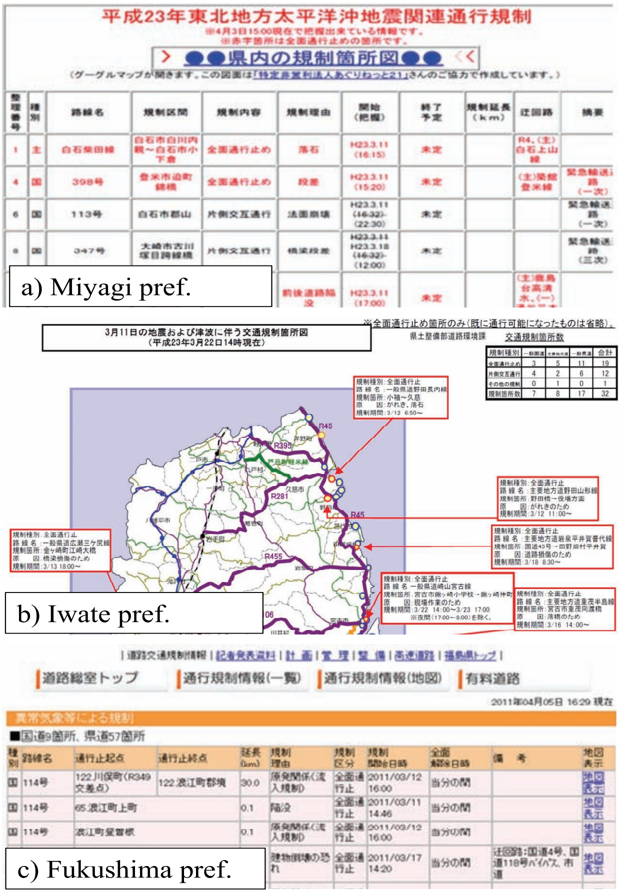

Fig.4 Road traffic regulation information from three prefectures.

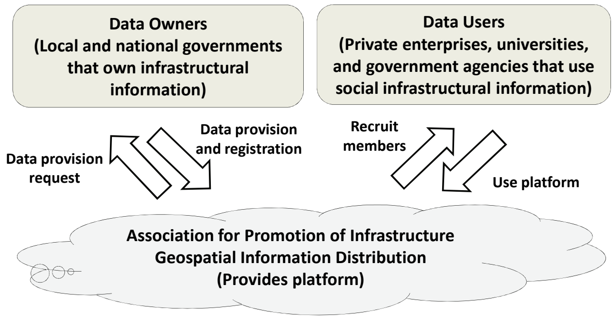

Fig.5 Data mobilization framework by AIGID.

involved manually consolidating the information obtained from local governments.

Various parties made suggestions regarding such problems immediately after the earthquake, stating that "raw data" and "machine-readable information" should be made available.[6)] However, these suggestions could not be implemented easily. This is associated with global trends of the past few years such as Open Data and Open Government, and is not limited to such occasions as when a disaster occurs. In order to make an application example that works fast, the information issued by the government would have to be proactively disclosed, except for personal information or information that is substantially concerned with national security, which is an issue for the future.

(2) Need for infrastructure data

However, currently not much data can be made publicly available by the government. Therefore, the Association for Promotion of Infrastructure Geospatial Information Distribution (AIGID) (`http://aigid.jp`), led by me, petitioned administrative governments, such as the national, prefectural, and municipal governments, to share data among the association's members on a daily basis. In order to realize this, an environment that facilitates the routine distribution of data has been made available with a framework and, as a rule, the association bears the costs related to the platform to achieve this, as well as the processing of the original data (**Fig. 5**). In fact, as of August 10, 2012, 84 member organizations have participated in this program, with approximately 40 data sets registered.

Furthermore, although this framework is intended to be shared among the members as a general rule, an inquiry as to whether it would be possible to disclose such data to external parties for a certain period of time during a major disaster (disclosure on the Internet) was made when the petition was made. A major disaster, say the earthquake described here, would be something at a magnitude of 6; in the case of rain, it would be an hourly total rainfall of 2,000 mm, and the disclosure period would be 1 month. This resulted in the acquisition of approval for providing data to external parties at the time of major disasters from a total of 95% of the organizations at a prefectural level that have agreed to share their data to start with, which excludes three organizations but includes a total of 55 organizations; 14 of these organizations provide uninteresting data, 11 organizations provide forestry data, and 30 organizations provide road construction drawings. Relying entirely on the government increases their burden, in consideration of the current situation where governments are required to cut back on their budgets and reduce personnel. The provision of such support by a new public sector would be highly desirable in order to make it possible for the administrative governments to concentrate on proactively creating forward-looking determinations and making decisions, which would be considerably closer to the work that they should be doing in the first place.

(3) Digital archiving for the next generation

After a considerable amount of time has passed following a disaster, the issue becomes, "How should the lessons learned be passed on to future generations?” A number of major archives, such as Michinoku-Shinrokuden[7] and the National Diet Library,[8] have been established for this reason. The Earthquake Disaster Recovery Investigation Support Archives (in which I participated as a member), established with the intention of including the promotion of an Open Government as described in the previous section, is introduced here.

The proposal “Hope Beyond the Disaster” of the Reconstruction Design Council, established by the government in response to the Great East Japan Earthquake, as well as a basic policy for the recovery of the government formulated in response to this proposal, stipulates the implementation of a detailed surveillance study to contribute towards future disaster prevention strategies. It seeks to maintain a framework for collecting, storing, and publicly disclosing records and the lessons learned from earthquake and tsunami disasters, as well as to build a framework for the unified storage and utility of such records in such a way that they are accessible to everyone, aside from being able to be transmitted. Based on such a policy, the City Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been conducting an exhaustive and systematic investigation into disaster-stricken local governments, entitled “Great East Japan Earthquake and Tsunami Disaster-Stricken City Area Recovery Support Survey” (hereinafter referred to as the “Recovery Support Survey”).

For details, refer to a paper by Sekimoto et al., (2012)[9] on how the “Recovery Support Survey Archive” (`http://fukkou.csis.u-tokyo.ac.jp`) was established to handle such data. The specific data items handled include the submergence status of a tsunami, disaster damage status of buildings, evacuation methods for individuals and business establishments, the status of disaster victims (dead and missing persons), the damage status of public facilities and lifelines, and the damage status of educational and cultural assets, in terms of the quantity of files. Furthermore, there are approximately 114,000 files of almost 90 types comprising more than 200 GB of data. In terms of page numbers, photographic images comprise the highest amount of data, but there are also many Shape files that offer GIS data and Excel files containing survey forms (it should be noted, however, that these figures may change in the future, as they represent the registration status, and there may be responsive action taken if defective data are identified).

The top diagram in **Fig. 6** shows the immersion range of a tsunami with Shape, whereas the bottom

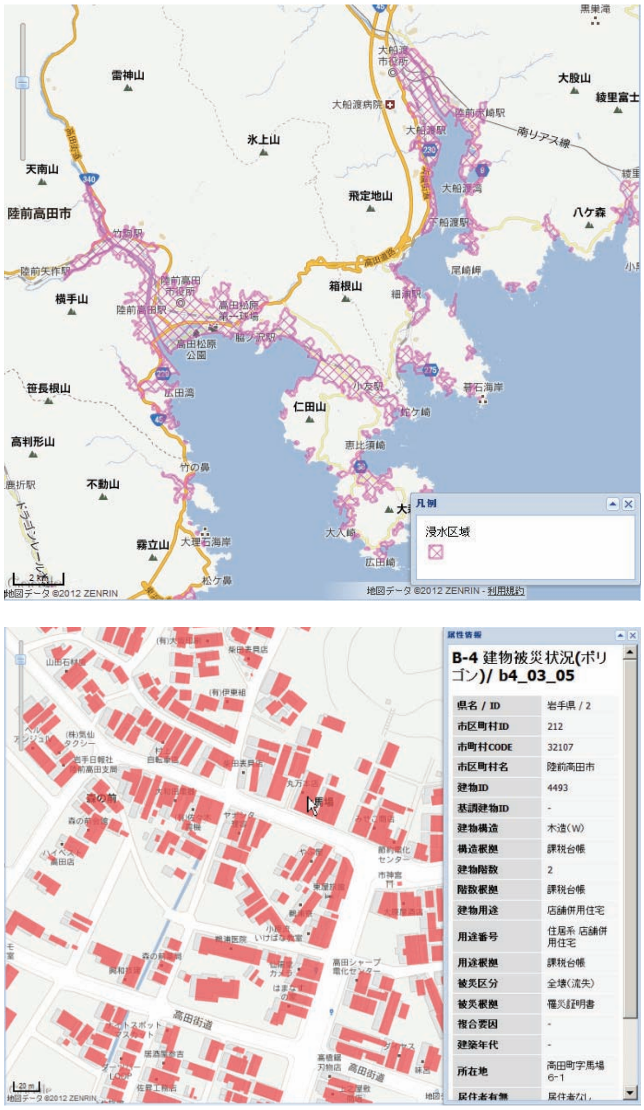

Fig.6 Screen of Recovery Support Survey Archive. Top: Immersion range of tsunami; Bottom: Extent of structural damage to individual buildings.

diagram represents the status of the structural damage to the individual buildings using house-shaped polygons to represent the shapes of the buildings, with the structure of the buildings, the intended uses, and disaster damage categories recorded as attributes. It is extremely significant that not only the detailed data obtained from the reports but also the GIS data of such recovery support surveys on disaster-stricken local governments, collected meticulously by the nation, are appropriately retained as records and made widely available.

Although the disclosure attributes of such data would in the end depend on the intention of the source of the surveys (the MLIT), as well as the willingness of the local governments subject to the surveys, as a general rule it is considered to be for public disclosure and it has been decided that free use, including the commercial use of the disclosed data, would be permitted per the user agreement that stipulates “free use of data, including business use, which is permitted as long as such use is not for wrongful purposes or contrary to public order and customs or intended to infringe on the interests of third parties.”

On the other hand, since a certain level of understanding and traceability on the part of the user would be required for “those that have the possibility of including personal information” and “those that may not possibly be able to provide guarantees for a certain level of quality as the characteristics of the survey data vary among local governments,” it was decided that such data would be approved for government administrative purposes and research purposes, which require an application for “restricted accounts for administrative governments and research institutions.”

Other than these, data that the relevant parties did not approve for disclosure at the time of the survey, as well as those that are clearly personal information, would not be disclosed in the manner described above.

4. PEOPLE FLOW STATUS THROUGH MOBILE PHONES

Sections 2 and 3 have basically provided descriptions of the issues that arise a few days, weeks, or decades after an earthquake, but is there anything that can be done on a more real-time basis? Furthermore, potential disasters are not limited to earthquakes and tsunamis. Could there be any universal responsive strategies based on real-timeliness?

Mobile phones fulfilled a certain role by providing a means to verify the safety of people during the March 2011 earthquake; this may be the only available tool in the possession of a large number of people that can be used to transmit certain information and gain an understanding of the status of a large number of people in real-time.

(1) People movement on the day of disaster

Methods used for understanding the positional status of people using mobile phones can be largely categorized into those that use base station information and those that use GPS. Since the former provide positional information for nearby base stations, although positional accuracy is not too high, it is possible to gain an insight into the distribution status of all people who possess mobile phones subscribed to applicable communication service providers. NTT DoCoMo, for instance, actually disclosed the number of people, in terms of altitude, using mesh units as their statistical

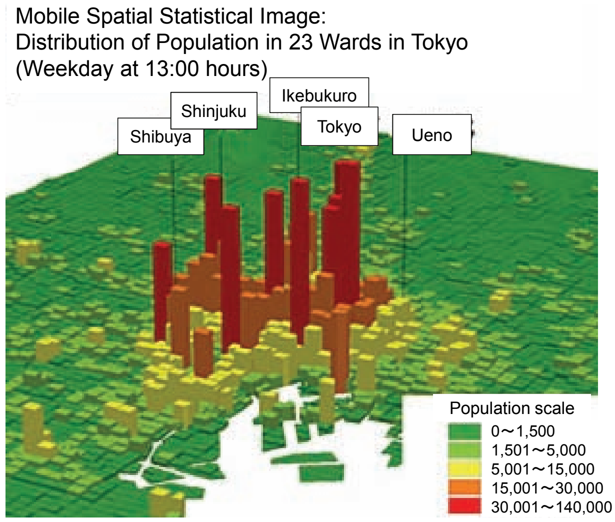

Fig.7 Mobile Spatial Statistics by NTT DoCoMo (http://www.nttdocomo.co.jp/corporate/disclosure/mobile_spatial_statistics/).

undertaking for mobile spatial statistics following the earthquake, although it is currently still in a tentative stage (**Fig. 7**).

The use of GPS data stored in mobile phones, on the other hand, requires the approval of individuals since it involves the Telecommunication Business Law. The Traffic Congestion Statistical Data® of ZENRIN DataCom are data based on the GPS data acquired from the Auto GPS function provided by NTT DoCoMo, which is processed to conceal the identity of individuals in order to ensure that they cannot be identified. The number of persons eligible is considered to be somewhere between 700,000 to 800,000, which is equivalent to more than 0.5% of the population, and the shortest data upload interval is once in five minutes. A number of results obtained from an analysis conducted by my associates and me, using disaggregated data obtained through a collaboration with ZENRIN DataCom, covers one year (centered around the day on which the earthquake disaster occurred) under the condition that individual persons should not be identified.

Fig. 8 represents the visualization of movement and compares the statuses before and after 1 446 hours, the time at which the earthquake occurred. Colors have been assigned for each direction in which GPS units were moving, revealing how people were actively moving in a variety of directions prior to the earthquake and how there was an abundant number of dots in large concentrations. Immediately following the earthquake, on the other hand, movements ceased to exist and hardly any colors were visible; the number of dots also decreased.

When the total number of GPS units were col-

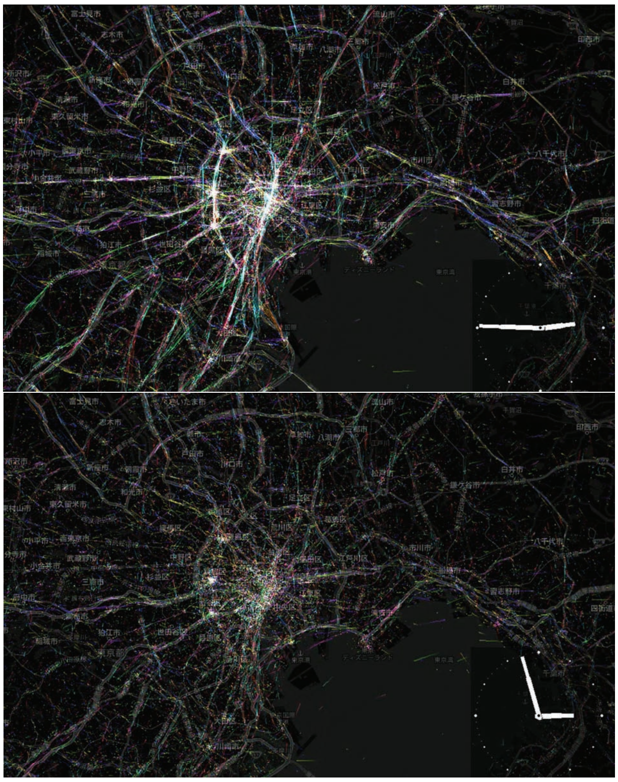

Fig.8 Comparison of flow status for people before and after earthquake (provided by Mr. Ueyama as project researcher, University of Tokyo). Top: Status immediately before earthquake, at 1 445 hours; Bottom: Status immediately after earthquake, at 1 457 hours; movements to various directions decreased and the number of dots, which indicate movements, also decreased.

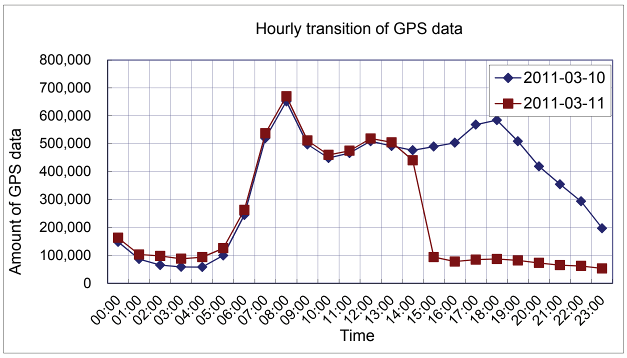

Fig.9 Mobile phone GPS status on disaster day.

lected and verified, it was shown that the number was about one-fifth of the number during normal times, as shown in **Fig. 9**.

Even though the amount of GPS data on the day on which the earthquake occurred was not very large, one could still see the movement of individual persons, at least in fragments. **Fig. 10** shows the plotting of two people selected from among those observed to have had a large amount of GPS data (people who had in excess of 20 points immediately after the earthquake occurred). Grids in which each of these people existed, with a high frequency during the night and day, were designated "Home" or "Office" on the basis of track records spanning more than a year. As a result, **Fig. 10** a) reveals that one of these persons left the Office (in the vicinity of Otemachi) in the evening and just kept on walking along National Route No. 6

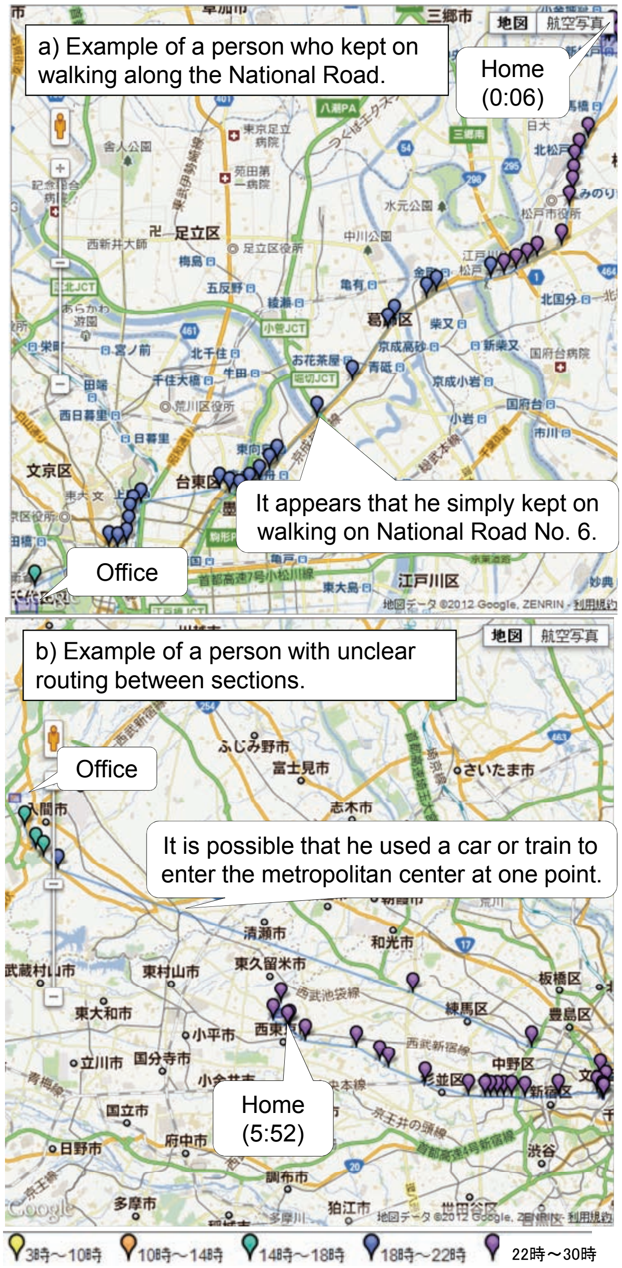

Fig.10 Examples of people returning home from work on the day the earthquake disaster occurred, based on GPS data. (Home and office locations were extracted from data spanning a one-year period in advance, followed by a selection of people who had at least 20 points of GPS data immediately after the earthquake, until the following morning): a) Person believed to have walked home by walking along the main road. b) Person whose movements between sections are unclear.

until he reached Home (in the vicinity of Matsudo) at approximately 0000 hours. **Fig. 10** b) shows that the other person left the Office in the vicinity of Iruma, intentionally going via the central metropolitan area to arrive home at about 0600 hours in the suburb of Tokyo (Nishi-Tokyo). However, the details of the paths taken by the second person are unclear (refer to Sekimoto et al. (2012)[10] for details).

(2) Daily evacuation activity in Fukushima

The evacuation activity on the day of the disaster can be understood by using the same GPS data. **Fig. 11** illustrates the activity at night (0–6 am) of people who live in the cities in the evacuation-prepared area. It clearly identifies the evacuation processes of this particular zone. **Fig. 11** a) describes the normal situation before the nuclear accident occurred on March 11; **Fig. 11** b) shows the sudden decrease in activity in the area the day after the disaster. **Fig. 11** c) explains the situation on March 14 after the explosion of the first and third nuclear reactors.

This analysis can also be a valuable tool for decision-makers to have a better idea of the quantitative estimates of evacuation behavior and patterns.

(3) Recovery of visitors in Tohoku district

Almost a year after the earthquake, many people are now visiting Tohoku district. The Tourism Bureau of the MLIT has a policy of creating 28 tourism zones, activating connections between each area.

The same GPS data can be applied to this kind of long-term tourism analysis as well as to people movement (1) and evacuation activities (2). **Fig. 12** shows a comparison of trips in Golden Week (GW) in 2010, 2011 and 2012. The number of trips is worst in GW of 2011, that is, just after the earthquake. The number of trips in GW of 2012, after the earthquake, is greater than in 2010, before the earthquake. Actually, in 2012, many areas were crowded with visitors. We would like to introduce the details of these analyses at another time.

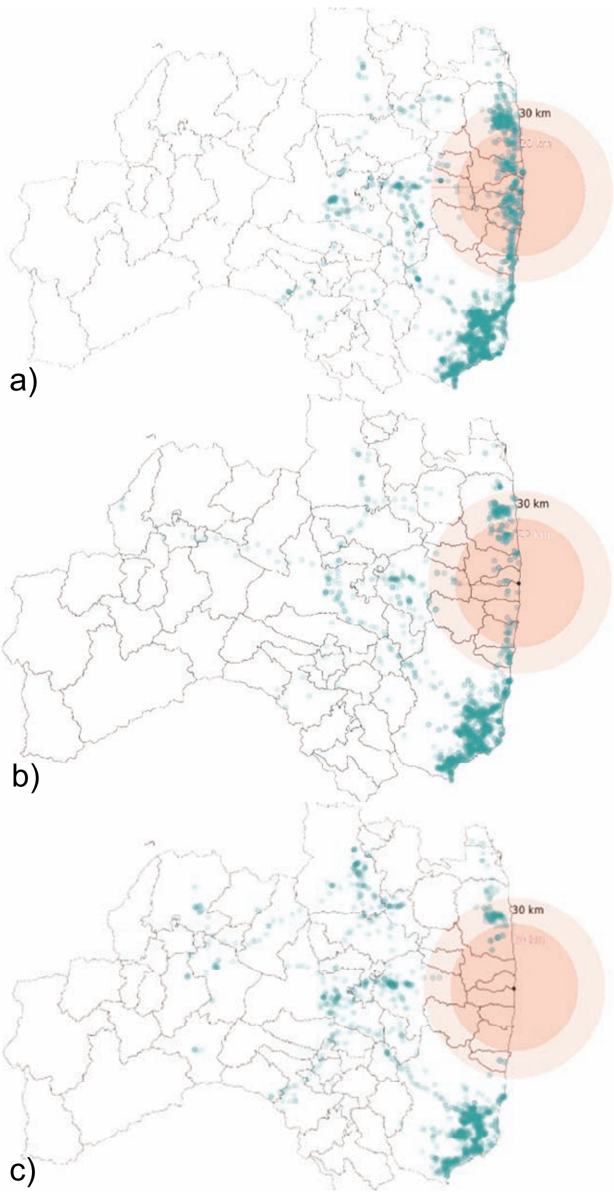

Fig.11 Evacuation scenario within a week after the nuclear accident (provided by Dr. Teerayut Horanont as project researcher, University of Tokyo): (a) March 11, the situation before the disaster; (b) March 12, a day after the Tokyo Electric Power Company (TEPCO) announced the failure of the Fukushima DNPP backup power and cooling system; (c) March 14, the situation after the second explosion of the third reactor.

5. TOWARD A COMPACT INFRASTRUCTURE THAT INCLUDES ICT

Japan has witnessed considerable growth, in spite of a diversification of values, low birth rate, aging population, global warming, and instability of international society's progress; yet the experience of this earthquake made me realize in general terms that it may be time for us to accept that there will be no time in the future when people protected by civil engineering structures will be absolutely safe. As a matter of fact, by visiting developing countries, we can realize that people who live in such areas accept the fact that congestion and floods occur, and they still live happily in spite of the threat of these disasters. As one means of coping, younger generations in particular make use of mobile phones, linking themselves to Twitter and Facebook and ensuring that they can make phone calls to take active action based on the situation.

Information technology is not just convenient, but it

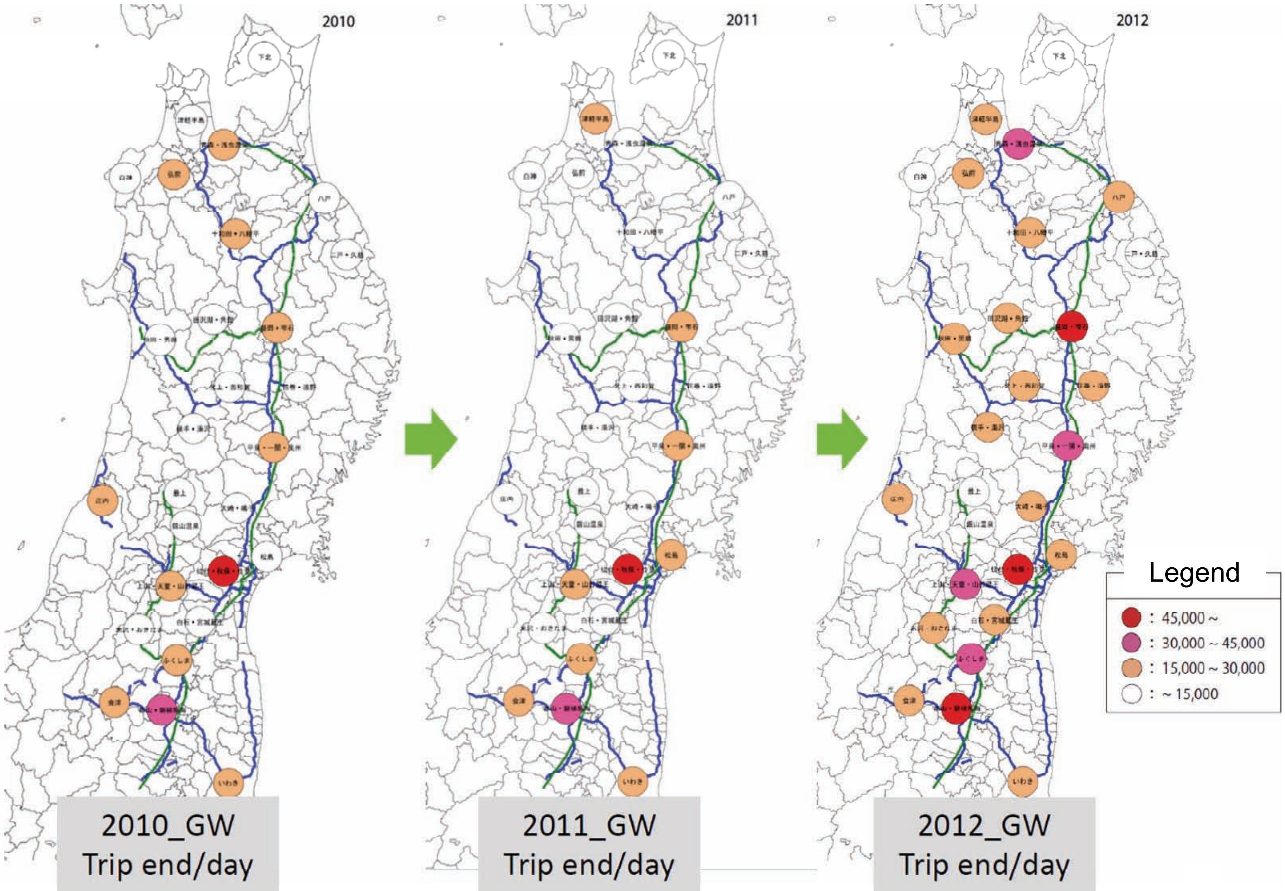

Fig.12 Comparison of trips to Tohoku district during Golden Week (GW) in 2010, 2011 and 2012 (provided by Mr. Ubukata as collaborative researcher, University of Tokyo). The number of trips is worst in GW of 2011, that is, just after the earthquake. The number of trips in GW of 2012, after the earthquake, is greater than in 2010, before the earthquake.

is also capable of connecting the emotions of people and so function as an invisible safety net and, as a result, I believe, it can reduce the amount of investment in infrastructure to a certain extent. I realize that this is an overused expression, but it may just be necessary to consider rebuilding society as a whole from the perspective of how each individual can maintain his/her ties and how he/she can adapt to circumstances and live on, as well as consider what the infrastructure should be.

If it is possible to create an infrastructural design that is lightweight, smart, and suitable for the Digital Native era, I am hopeful that such a technology may also be exportable.

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