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Paper:

Effects and Issues of Information Sharing System for Disaster Response

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In disaster response, wherein many organizations undertake activities simultaneously and in parallel, it is important to unify the overall recognition of the situation through information sharing. Furthermore, each organization must respond appropriately by utilizing this information. In this study, we developed the Shared Information Platform for Disaster Management (SIP4D), targeted at government offices, ministries, and agencies, to carry out information sharing by intermediating between various information systems. We also developed a prototype of the National Research Institute for Earth Science and Disaster Resilience (NIED) Crisis Response Site (NIED-CRS), which provides the obtained information on the web. We applied these systems to support disaster response efforts in the 2016 Kumamoto Earthquakes and other natural disasters. We analyzed the effects of and issues experienced with the information sharing systems. As effects, we found 1) the realization of increased overall efficiency, 2) validity of sharing alternative information, and 3) possibility of using the system as a basis for information integration. As future issues, we highlight the needs for 1) advance loading of data, 2) machine readability of top-down data, and 3) identifying the common minimum required items and standardization of bottom-top data.

Keywords: disaster response, disaster information, information sharing, WebGIS, standardization

1. Introduction

In Japan, which is at high risk of various natural disasters such as earthquakes, tsunamis, and torrential rains, the realization of a disaster-resilient society has been a long-time thesis. As social vulnerability to disaster has increased in recent years, because of the declining birthrate, aging population, urban congestion, and depopulation of rural areas, it is predicted that disasters with nationwide repercussions such as earthquakes with epicenters directly below Tokyo or the Nankai Trough earthquakes are likely to occur in the near future. Thus, improving our disaster-response capacity is an urgent national priority.

Since many organizations must act simultaneously in parallel in disaster response initiatives, it is important to construct and share a common operational picture (COP) to grasp the disaster situation, share a common recognition of the overall situation, and for individual organizations to respond appropriately [1].

In 2014, the Council for Science, Technology and Innovation (CSTI), Cabinet Office, established the Ministerial Strategic Innovation Promotion Program (SIP) [2], transcending the frameworks or conventional jurisdictional areas of government offices and ministries. One objective was to "strengthen the functions of resilient disaster prevention and reduction." A related issue is the "research and development of an ICT-based information-sharing system and technologies that disaster-response agencies can use to effectively use this system." In response, we proposed the "research and development of a Coordinated Ministry-Agency Disaster Prevention Information Sharing System and technology for its utilization," which was approved upon screening and is currently being undertaken [3]. In this paper, we use the term "Sharing Information Platform for Disaster Management" (SIP4D) to refer to the Coordinated Ministry-Agency Disaster Prevention Sharing System.

In April 2016, the National Research Institute for Earth Science and Disaster Resilience (NIED) established the Center for Comprehensive Management of Disaster Information to improve social resilience by collecting and disseminating information related to disaster resilience. In response to the Kumamoto Earthquakes, which occurred immediately after its establishment, the Center immediately undertook disaster-response support actions by collecting disaster-related information issued by various agencies through SIP4D, and set up the NIED Crisis Response Site (hereafter NIED-CRS) on the web to disseminate relevant information to the public and disaster-response agencies.

This undertaking to support disaster response based on the use of SIP4D and NIED-CRS as the information-sharing system was implemented following the Kumamoto Earthquakes and in several natural disasters that subsequently occurred. In this paper, we discuss the effects and issues of the information-sharing system to support disaster response by analyzing the experience of supporting disaster-response efforts based on information sharing during the Kumamoto Earthquake.

2. Current Status and Issues of Information Sharing During Disaster Response

The need for information sharing during disaster response initiatives has been highlighted numerous times in the past [4]. Central Disaster Management Council "Investigation Committees of information sharing for disaster management" (2003) pointed out four concrete measures regarding disaster-prevention information handled by disaster-prevention organizations. These are the fast and accurate collection of information, high-reliability broadband communication for disaster prevention, sharing and standardization of information, and effective use of information by integration [4]. Usuda (2008) noted that since disaster response is accompanied with uncertain or unconfirmed events, it is important to make "an integrated use of information" by sharing information to ensure appropriate decision-making. Furthermore, it is essential to ensure "mutual operability" among information systems to this end [5].

Regarding the response to actual disasters, Urakawa et al. (2007, 2008), Hayashi et al. (2007), and Tamura et al. (2010) showed that following the 2007 Chuetsu Offshore Earthquake, the Niigata Prefectural Disaster Response Headquarters compiled various thematic diagrams to unify the recognition of information among personnel charged with disaster response. This demonstrated the validity of compiling digital maps for disaster response. Furthermore, they pointed out the need to recognize the compilation of thematic maps as an essential task in disaster response, and to set up a system that allows the relevant agencies and personnel to mobilize quickly when a disaster occurs [6–9]. In the response to the 2011 Tohoku Earthquake and Tsunami, based on activities at the Cabinet Office conducted over a 45-day period beginning on the day following the disaster to assist a unified recognition of the situation among government ministries and agencies, Inoguchi et al. (2011) contended the possibility of using technology for a mash-up of spatial information [10]. Meanwhile, in view of their finding that useful information issued by many organizations failed to reach affected disaster sites, and that disaster sites do not have the necessary resources to receive diverse information and convert it into a usable form, Taguchi et al. (2015) proposed using a standard interface for information sharing and communication. As such, they demonstrated the validity of information conversion and integration through WebGIS [11].

Regarding the status of information systems, Kawada (2002) noted his failed efforts to persuade the authorities to construct an interface to enable interaction between the disaster prevention information systems of nine prefectures in the Kinki region. He found that the information systems managed by local governments employ different operating systems and use different formats for the map information systems. This indicates the lagging state of the regional response system and support among local governments [12]. Kimura et al. (2011) reported that when they were engaged in activities based at the Cabinet Office in response to the 3.11 Tohoku Earthquake and Tsunami, the network-based centralized information collection system was barely used. Information sharing was conducted mostly through written messages or paper notes attached to whiteboards. On-site personnel found this system difficult to handle, as they were not used to it [13]. Ise et al. (2015) conducted a survey on the status of the disaster-prevention information systems of local governments in Japan, noting that although they are widely used, many consist of systems that collect information only according to format no. 4 of the Fire and Disaster Management Agency. They emphasize the desirability of implementing systems that can handle information in a flexible manner and organize and share the damage status as map information [14].

Although there have been discussions on inter-organizational sharing and utilization of information, as seen above, these have not resulted in a concrete undertaking to construct a nationwide information-sharing system. This absence of an active cross-organizational information-sharing mechanism has caused issues such as the considerable time spent by individual organizations on information collection or the difficulty of coordinated inter-organizational response. It is vital to construct a mechanism for disaster response today, when information communication technologies for inter-organizational information sharing and utilization such as cloud technology or the interoperation technology of geospatial information are maturing.

3. New Undertaking: the Information-Sharing System

Considering the status as reviewed above, we outline SIP4D and NIED-CRS as prototypes of systems for inter-organizational information sharing during disasters, as mentioned in Section 1.

3.1. Shared Information Platform for Disaster Management (SIP4D)

SIP4D is an information-sharing system to realize information sharing between organizations centered on the Cabinet Office, Ministries, and Agencies.

One of its objectives is to "realize intermediary information sharing that enables mutual information exchange among various information systems." Since many organizations have already constructed and are operating individual information systems, it is unrealistic to newly construct a separate extensive system that covers all aspects of disaster response. On the other hand, the conventional approach in which two organizations are individually connected requires adjustment and development for each connection. In response, the approach has been proposed in which different systems mutually enter/output, share, and utilize information via a common interface. However, this approach has not yet been adopted nationwide. Therefore, in this study, we developed an information system

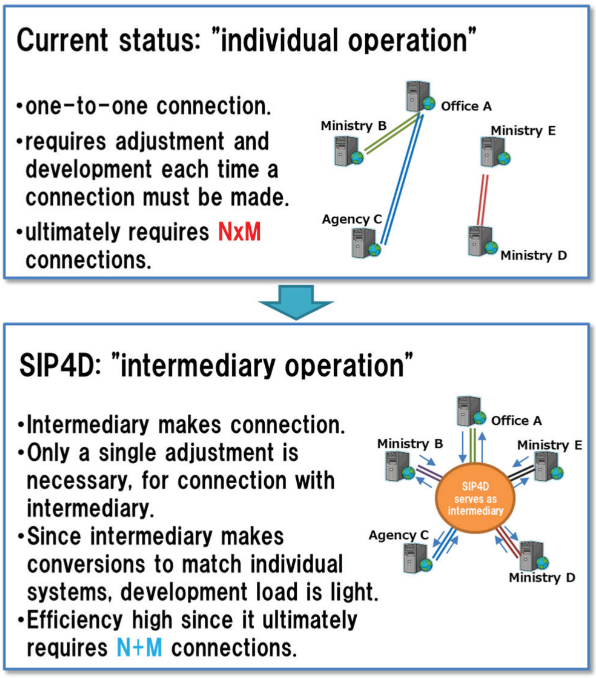

Fig. 1. Concept of the intermediary information-sharing system SIP4D.

that connects existing information systems and serves the intermediary role of facilitating the flow of information between systems (**Fig. 1**).

Specifically, the system receives N types of disaster-related information issued by various information systems, automatically converts them to M types of formats required by the various information systems, and provides them. Thus, higher efficiency is achieved by reducing the number of combinations of information sharing from N×M to N+M. Individual information systems constructed in the future can also be connected to this system and incorporated into the overall information-sharing network. The goal is to reduce the load of making adjustments for connections and development, and thus allow efficient overall information sharing. To this end, the system must possess functions to collect and provide information wherein a variety of information in various formats is received and suitably converted, and integrally process it as needed. A prototype equipped with these functions is under development (**Fig. 2**).

SIP is a five-year research and development project. In conjunction with the research and development programs for the "disaster health-care support system" administered by the Ministry of Health, Labor and Welfare and the "water reservoir disaster-prevention support system" administered by the Ministry of Agriculture, Forestry and Fisheries, the validity of the information-sharing and utilization technology is to be verified through training-based demonstration experiments. Ultimately, the objective is to realize coordination among government offices, ministries, and agencies in the form of information sharing and utilization in Japan. In Japan, many government offices, ministries, agencies, and related organizations exist, each having different jurisdictional functions regarding disaster prevention or response. It is necessary to achieve nationwide unification of situation awareness, so that each organization can quickly and effectively respond to a disaster, maximizing the disaster response capacity of the nation.

3.2. NIED Crisis Response Site (NIED-CRS)

As stated above, SIP4D is designed and constructed as an intermediary-type system based on the premise that each organization involved in disaster response possesses and operates its own information system. Thus, it assumes that users will not directly access it. This premise represents an ideal situation; however, the reality is that information utilization systems are not well established, although there are many information transmission systems. Even when installed, they may lack a mechanism for receiving information from external sources. Furthermore, many are incapable of integrating information for use, thus displaying a wide variety among individual systems. Therefore, we developed a system where various users who carry out activities at the disaster site or are about to be dispatched to the site can access, refer to, select, superimpose, print, and output the data of information collected by SIP4D. This system is NIED-CRS (**Figs. 3** and **4**).

Based on the e-community platform, [15] developed NIED as a technology to support information sharing at local disaster prevention sites. NIED-CRS is customized so that the released disaster information, which changes from moment to moment, can be archived according to the release number. The website is configured so that a single disaster is covered on a single page (URL), where text-based information is listed in links and geospatial information is integrally displayed as WebGIS, centered on public information. The release of the first page constitutes release No.1, and new releases are subsequently issued whenever information is added or updated, enabling time-series management.

4. Information Sharing Support Following the Kumamoto Earthquake

Starting with the Kumamoto Earthquake, Japan was subject in 2016 to multiple natural disasters including earthquakes, tsunamis, volcanic eruptions, typhoons, and heavy snowfalls. In response, the authors responded to five disaster types, 12 events in total, by operating SIP4D and NIED-CRS. In this section, we describe our response to the Kumamoto Earthquake.

Immediately following the earthquake at 21:26, April 14, 2016, the NIED-operated J-RISQ earthquake early warning system automatically launched, releasing the estimated status of ground shaking according to municipality and the populations subject to various seismic-intensity levels. Release no. 1 was issued at that time, and updated releases were issued by adding seismic-intensity information obtained from the Japan Meteoro-

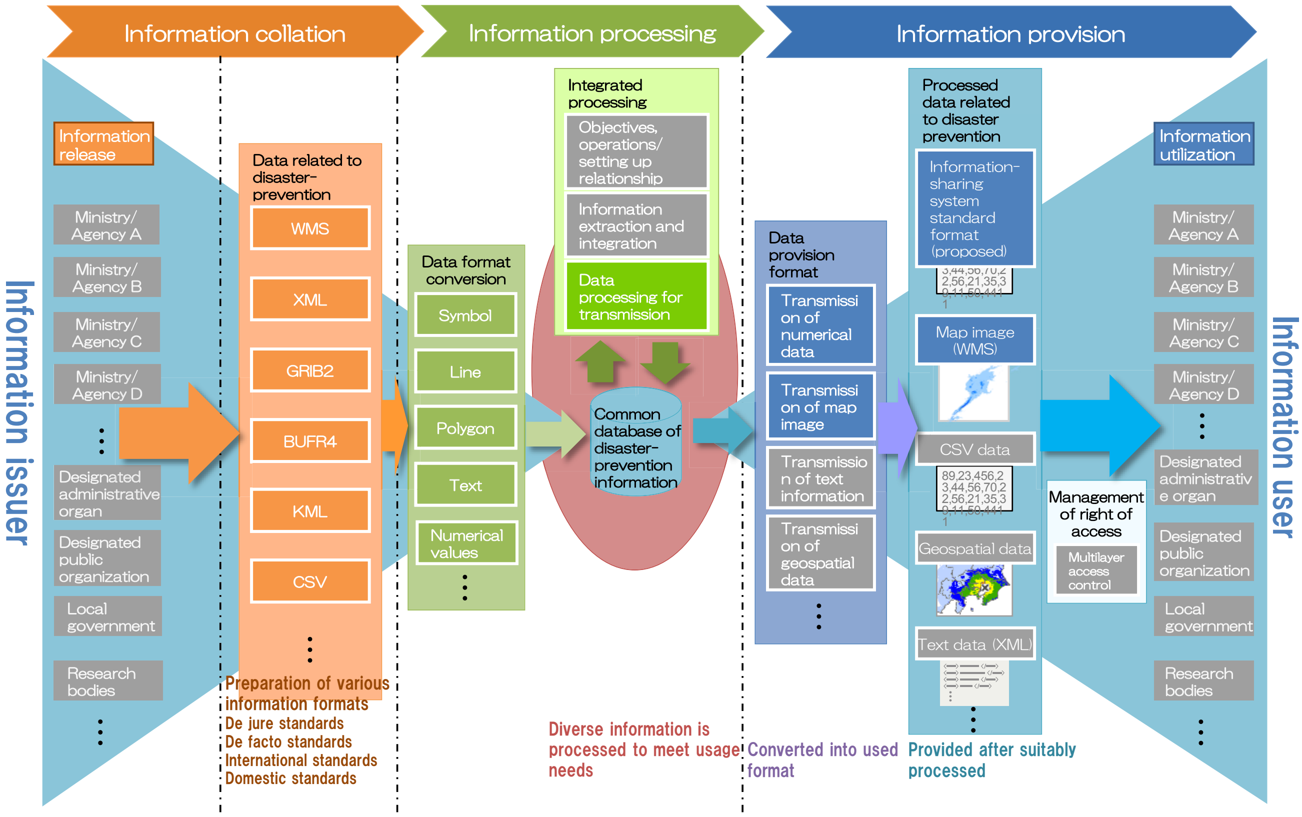

Fig. 2. Functional structure of the intermediary information-sharing system SIP4D.

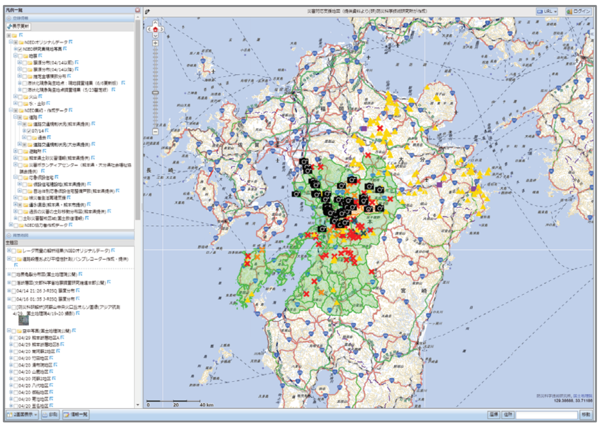

Fig. 3. NIED-CRS WebGIS screen.

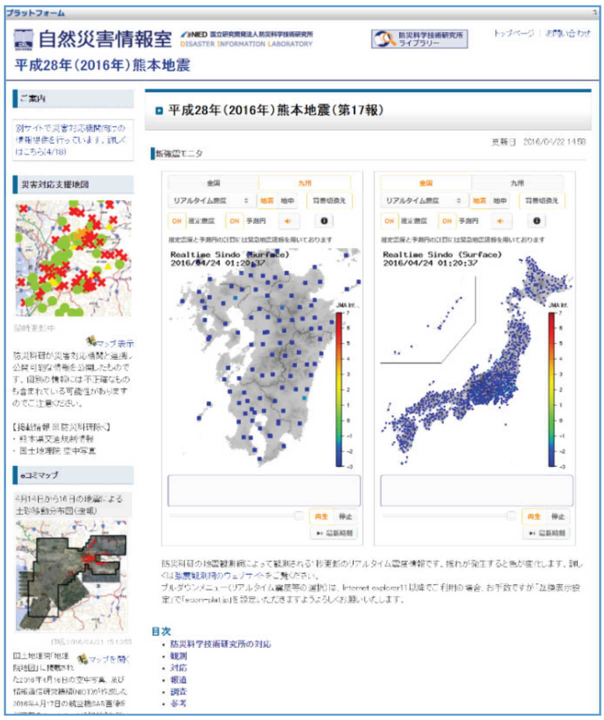

Fig. 4. NIED-CRS screen.

logical Agency and local governments, ending with release no. 7. The last release included all available seismic-intensity information about 10 minutes later. Simultaneously, the Real-Time Earthquake Damage Estimation System (provisional version), developed as part of the SIP program, compiled data on the distribution of the estimated number of totally destroyed buildings (**Fig. 5**).

SIP4D provided this information automatically and in real time to the "disaster health-care support system" and "water reservoir disaster-prevention support system," also part of the SIP program. In addition, to provide this information to systems and organizations outside the SIP context, the Kumamoto Earthquake version of NIED-CRS was set up by NIED [16].

The data on distribution of the estimated number of to-

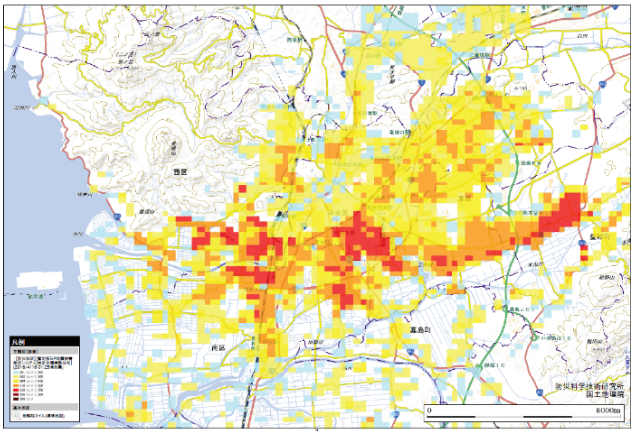

Fig. 5. Distribution data of estimated number of totally destroyed buildings.

tally destroyed buildings mentioned above was released on NIED-CRS at 3:59, April 15. Although this type of information was usually withheld in the past, it was released to the public in this case to assist as rapid a response as possible. This made it possible to identify areas of concentrated damage based on the observed data against earthquakes for which the damage scale or distribution cannot be determined from information on only the epicenter and magnitude.

Subsequently, NIED updated NIED-CRS as needed, with SIP4D acting as its core system and serving the intermediary role of sharing information obtained from various sources. The J-RISQ Earthquake Early Warning System and Real-Time Earthquake Damage Estimation System (provisional version) were started again when the main shock occurred at 1:25, April 16, while the operations of SIP4D and NIED-CRS continued.

NIED dispatched researchers to the site early in the morning of April 15, arriving at the Kumamoto prefectural office at 11:50. Subsequently, they served as the onsite response team, collecting information and identifying needs on the site centering on the national government's On-site Disaster Response Headquarters and Kumamoto Prefectural Government Disaster Response Headquarters. They also made efforts to achieve rapid information sharing among disaster response agencies and organizations, while a remote support team carried out information collation, processing, and dissemination off the site.

Onsite information sharing took place exclusively in the form of verbal explanations in conferences and through the distribution of paper documents. However, this was not suitable for activities based on the exchange of information between organizations, as organizations considering support activities from the outside had no access to this information. Therefore, it was decided to produce digital versions or maps from the paper documents distributed on site and share them to achieve a unified awareness of the situation among the organizations active on site and those attempting to provide support from the outside. The production of data took place as follows. After the onsite researchers obtained information printed (or written) on paper and photographed it, they emailed it to the remote team, which was on standby. It was then converted into digital versions by several staff researchers or cooperating institutions, collated for SIP4D, and released to the public on NIED-CRS, which was accessed by onsite staff for referencing or printing. This was possible because of the use of a cloud-based information sharing system.

The collated data was transmitted to various information systems for their respective usage, and was provided via NIED-CRS to the onsite Disaster Response Headquarters and other agencies as data or paper printouts. The flow of information sharing in response to the Kumamoto Earthquakes is shown in **Fig. 6**.

5. Discussion

Based on the experience of information sharing for disaster-response support for the Kumamoto Earthquakes, we discuss the effects of the information sharing system and future issues.

While the response actions for the Kumamoto Earthquakes began on April 14, 2016, and continue as of March 31, 2017 in the form of restoration and reconstruction support. We consider the period up to August 31, 2016, when the continued stay of the onsite researchers was terminated. The types, amount, and registered time and date of the data shared during this period were recorded by SIP4D and NIED-CRS, and used for the analysis. Meanwhile, the requests and responses obtained from disaster response agencies as verbal transmissions, documents, and email during this period were recorded by the authors in the daily reports and request list according to agency, which is also used in the analysis. In addition, we conducted in interviews on February 20 and March 3, 2017 on the usage of shared information during this period at the divisions of the Kumamoto prefectural government of Crisis Management and Disaster Prevention, Health and Welfare Policy, Sediment Control, Road Maintenance, and Urban Planning. The recorded verbal responses were used for the present analysis. By analyzing this data inductively, we determine and discuss the effects of the information sharing system and issues pertaining to achieving these effects in future disasters.

5.1. Effects of the Information Sharing System

The following three effects of the information sharing system were derived from the obtained data.

(1) Increased Overall Efficiency of Information Sharing

The information shared via SIP4D for the Kumamoto Earthquakes in terms of the number of layers in NIED-CRS was 631 (**Table 1**). Meanwhile, 40 organizations cooperated in terms of information sharing at the disaster site, centered on the onsite Disaster Response Headquarters (**Table 2**).

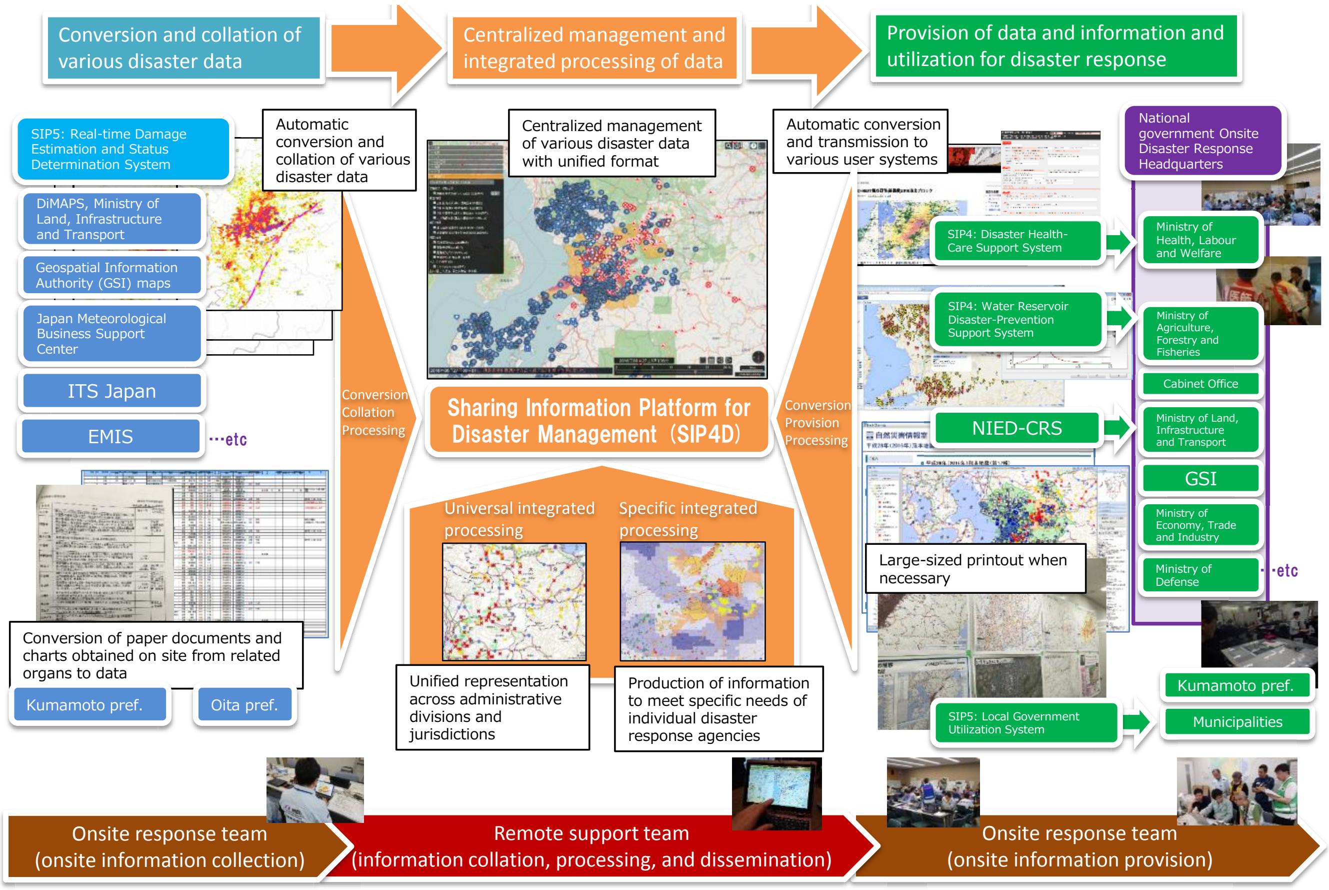

Fig. 6. Flow of information sharing to support disaster response after Kumamoto Earthquake.

It is difficult to accurately determine the total number of organizations that shared information, as NIED-CRS was accessible to the public on the web. Therefore, restricting ourselves to the increased efficiency of the government offices, ministries, and agencies targeted by SIP4D, we determined that 11 agencies shared information. One objective of SIP4D was to increase efficiency by reducing the number of patterns to obtain information from "N×M to N+M." Using a simple calculation based on the figures $N = 631$ and $M = 11$, the combination of patterns was reduced from $N \times M = 6941$ to $N + M = 641$. Although the efficiency did not actually increase by this amount in the response to the Kumamoto Earthquakes, as these figures represent the maximum values, we note it as a quantitative index.

To increase overall efficiency, we asked the national government Onsite Disaster Response Headquarters and the divisions of the Kumamoto prefectural government what their respective needs were, then compiled a single data set to cover data for which there was high across-the-board demand. We printed multiple copies of these data sets and delivered them to the parties requiring them. For example, it was found later that the information on evacuation centers was compiled not only by the local governments, which are charged with this task, but also individually by the Self Defense Force, Japan Disaster Medical Assistance Team (DMAT), communication infrastructure companies, nonprofit organizations (NPOs), and volunteer groups, all of whom required this information for their activities. When we presented the unified data set to these organizations, we received comments that "it would have been more efficient if we had known this." As the information was effectively used, the validity of information sharing was confirmed.

Furthermore, when we conducted the hearing survey of the Kumamoto prefectural government Road Maintenance Division, we were told that they received numerous phone inquiries about road information following the earthquake. The frequency of these inquiries remained high for about a month following the earthquake disaster, and often included inquiries about how to reach evacuation centers. Since the Road Maintenance Division did not have on hand information on evacuation centers, they used the information on evacuation centers provided on NIED-CRS to check the locations and any landmarks or signs in the vicinity. As demonstrated here, the organization that possesses the original data receives many inquiries. Therefore, if the information sharing system is clearly recognized by all parties and it becomes well-established knowledge that data can be obtained from this system, it will be possible to increase overall efficiency and reduce the number of inquiries to the data-holding organization, lightening the load on the personnel in charge. This effect can only be achieved if the

Table 1. List of shared data.

NIED original data	
Onsite survey photos	11
Earthquake	
– Hypocenter distribution (prior to April 14)	15
– Hypocenter distribution (from April 14)	137
– Seismic intensity distribution (April 14 and 16)	2
– Hypocenter destruction process (April 16)	1
– Estimated distribution of totally destroyed buildings (April 14 and 16)	2
– Originating location of liquefaction: onsite survey results (May 23, June 6)	2
Volcano	
– Observation point	1
Water and soil	
– Effective rainfall, cumulative rainfall (updated every 5 minutes)	
– – On-the-spot rainfall intensity	1
– – Effective rainfall with 1.5-hr. half-life period	1
– – Effective rainfall with 72-hr. half-life period	1
– – 24 hr. cumulative rainfall	1
– Slope movement distribution maps	10

NIED-collated and -produced data	
Volcano	
– Mount Aso volcanic alert level (source: Japan Meteorological Agency)	1
– Mount Aso Volcano disaster prevention map (source: Kumamoto pref.)	3
Sediment Disaster Alert Areas (source: Ministry of Land, Infrastructure and Transport)	2
Landslide disaster (source: DiMAPS)	6
River facility damage status (source: DiMAPS)	3
Road	
– Road traffic restriction status (source: Kumamoto pref.) from April 16	92
– Road traffic restriction status (source: Oita pref.) from April 22	6
– Road traffic restriction status (source: DiMAPS) from May 9	5
Evacuation centers	
– Status of evacuation centers (source: EMIS) from April 17	4
– Status of evacuation centers (source: Kumamoto pref.) from April 21	4
– Status of evacuation centers (source: Kumamoto City) from April 21	3
– Status of evacuation centers (source: Kumamoto pref.) from May 1	4
– Status of evacuation centers (for Mashiki Town only; source: medical rescue team) May 9 only	1
– Designated evacuation centers (National Land Numerical Information)	1
Restoration of water supply (sources: Kumamoto pref. and Kumamoto City)	27
Disaster Volunteer Center (Source: Social Welfare Councils, Kumamoto and Oita prefs.)	29
Temporary housing	
– Construction sites of temporary housing (source: Kumamoto pref.)	21
– Number of temporary housing units according to local government (source: Kumamoto pref.)	6
Support of livelihood reconstruction of disaster victims	
– Progress status of building damage certification survey (source: Kumamoto pref.)	7
Medical institutions (source: EMIS)	2

Data provided by NIED cooperating parties	
National census (2010; sources: Ministry of Public Management, Home Affairs, Posts and Telecommunications and Ministry of Land, Infrastructure and Transport)	3
Statistical data (source: Pasco Corp.)	1
Basic data (compiled and provided by Kyushu Univ.)	
– Facilities (municipal offices, public facilities, assembly facilities)	3
– Municipal administrative districts	1
– Promotion Bureau classification	1
Mount Aso central cone ortho-image (sources: Asia Air Survey Co., Ltd.; Geospatial Information Authority (GSI))	1
Kumamoto prefecture Landslide disaster information (source: Kumamoto pref.; released May 13 and July 6, 2016)	
– Landslide disaster emergency inspection	14
– Landslide disaster hazardous locations	16
– Landslide disaster special alert areas	24
– Landslide disaster alert areas	24
Slope movement distribution (1990 and 2012, source: Kumamoto pref.)	2
Road bumps and flatness measurements (source: BumpRecorder Co.)	3
Automatic extraction of blue-sheeting houses (source: Pasco Corp.)	3
Water reservoirs (National Agriculture and Food Research Organization)	1
Survey on water reservoirs (source: Pasco Corp.)	2
Mobile phone free charging service (source: Pasco Corp.)	1
Bathing facilities (source: Pasco Corp.)	1

Data released by external agencies	
Road passage maps (released by ITS Japan) *discontinued May 10	
– Passenger car passage record (line data, updated daily)	1
– Passenger car passage record (point data, updated daily)	1
– Light truck passage record (point data, updated daily)	1
– Medium and heavy truck passage record (point data, updated daily)	1
Active fault map (released by Headquarters of Earthquake Res. Promotion, Ministry of Education, Culture, Sports, Science and Technology)	1
Ground fissure distribution map (released by GSI)	1
Standard maps (GSI)	1
Light-colored maps (GSI)	1
Blank maps (GSI)	1
Aerial photographs (GSI)	1
Aerial photographs of 1970s (GSI)	1
Aerial photographs 1961-1964 (GSI)	1
Aerial photographs 1945-1950 (GSI)	1
Color altitude maps (GSI)	1
Aerial photographs after disaster (GSI)	25
Maps (Geospace CDS)	1
Aerial photographs (Geospace CDS)	1
Google Maps (maps and photos)	1
Google Maps (maps)	1
Google Maps (photos)	1

Total 631
(As of August 31, 2016)

Table 2. List of agencies that cooperated onsite at the Disaster Response Headquarters.

Agencies that collaborated at onsite Disaster Response Headquarters (total 40)	
National government Onsite Disaster Response Headquarters (11)	Kumamoto Prefectural Government (16 divisions)
Cabinet Office	Disaster Prevention and Crisis Management Division, Executive Office of the Governor
Ministry of Public Management, Home Affairs, Posts and Telecommunications	Public Relations Division, Executive Office of the Governor
Ministry of Land, Infrastructure and Transport	Road Maintenance Division, Department of Civil Engineering
Ministry of Health, Labor and Welfare	River Policy Division, Department of Civil Engineering
Ministry of Agriculture, Forestry and Fisheries	Sewage System and Environment Division, Department of Civil Engineering
Ministry of Education, Culture, Sports, Science and Technology	Erosion Control Division, Department of Civil Engineering
Ministry of Economy, Trade and Industry	Urban Planning Division. Department of Civil Engineering
Ministry of the Environment	Housing Division, Department of Civil Engineering
Japan Coast Guard	Construction Division, Department of Civil Engineering
Geospatial Information Authority	Health and Welfare Policy Division, Department of Health and Welfare
Japan Ground Self-Defense Force	Health Promotion Division, Department of Health and Welfare
	Fire Prevention and Industrial Safety Division, Department of General Affairs
Other agencies (13)	Municipalities Division, Department of General Affairs
Japan Disaster Medical Assistance Team (DMAT) secretariat, Japan Medical Association, etc.	Agricultural Land Improvement Division, Department of Agriculture, Forestry, and Fisheries
	Traffic Policy Division, Planning and Promotion Department
	Environment Division, Department of Commerce, Industry, Tourism, and Labor

information-sharing system is assigned a clearly established role and known to all parties, which present important social issues that must be resolved in the future.

(2) Validity of Sharing Alternative Information

Information for which there was demand from various interlinking organizations after the earthquake disaster pertained to whether the roads to reach the disaster sites were passable. Based on the experience of flooding in Joso City the previous year, SIP4D was linked to the Integrated Disaster Information Mapping System (DiMAPS), making it possible for various parties to share information on road damage released by the latter system. However, only information on highways was released in the early stages following the earthquakes, and the information on general roads was released only from release no. 14 on April 21. Meanwhile, the Kumamoto Prefectural Government Disaster Response Headquarters released as the road traffic regulation status locations in Kumamoto prefecture with no or restricted thoroughfare as of April 16 as a list and map. Since this information was provided in a chart and pdf file, it was unusable in its original form by other systems. Therefore, it was converted to digital form and map data, then shared (**Fig. 7**). The map data of the road traffic regulation information was first shared at 16:00, April 16, and then updated up to seven times a day. Sharing alternative information when the originally planned official information was unavailable made it possible to support organizations engaged in activities, particularly in the hyper-acute phase.

A similar circumstance occurred with the information on evacuation centers. Although data on evacuation centers was to be compiled by the local governments, this information was found immediately after the earthquake disaster. We received a notice from DMAT, with which a link-up with SIP4D had been established as an information sharing organization, that they were uploading the data on the evacuation centers they had visited to the Emergency Medical Information System (EMIS). Although we were unable at that point to verify the completeness or accuracy of this data, in view of the importance of speed, it was converted to map data and shared with various parties. The first data was shared on April 17. This data was provided via the Cabinet Office to DMAT and disaster volunteer groups that supported evacuation centers, and utilized as basic information to allocate visi-

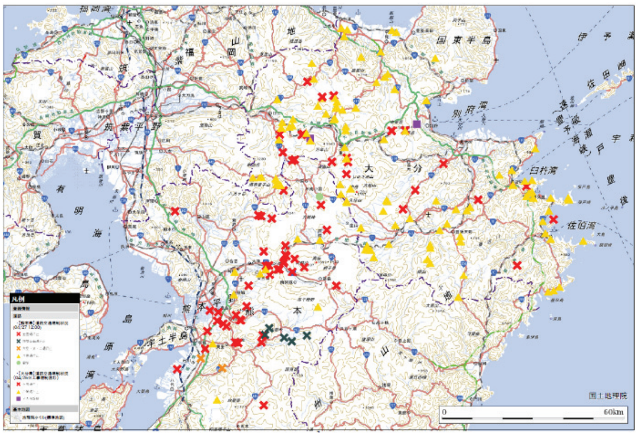

Fig. 7. Integrated map of road traffic regulation data.

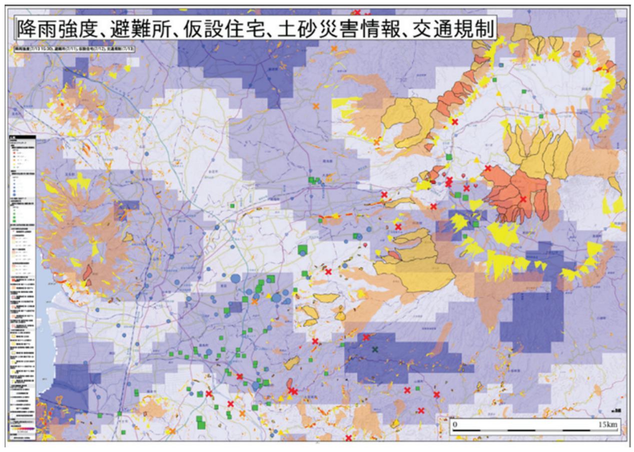

Fig. 8. Example of information package integrating various data.

tations. While official information was obtained from the prefectural government and shared as data beginning on April 21, the fact that we were able to support response activities with early unofficial data during the preceding period suggests the validity of sharing alternative data.

(3) Possibility as Basis for Information Integration

Following the Kumamoto Earthquakes, the collated and compiled data were not just shared in their original form, but multiple data sets were integrated and formatted to meet the needs of the acting organizations. The overall picture of these needs is difficult to describe in an organized manner, as they varied by organization, individual cases, and the response phase. Thus, we restrict our discussion to presenting concrete examples and discuss the possibility of the system providing a basis for integrated processing and producing different representations.

As a concrete example of the road traffic regulation information, following the information released by the Kumamoto prefectural government, damage information for general roads was released on DiMAPS. Tabular data was then obtained from the Oita prefectural government beginning on April 22. Since these data sets were separately compiled by different organizations, they employed different attributes and were expressed in different formats. Thus, they were integrally processed and converted to a common format for sharing. This made it unnecessary for organizations using this data to integrate and format the three sets of road data expressed in different formats, enabling them to treat a single data set (**Fig. 7**).

Another example was when the Kumamoto Prefectural Government Disaster Response Headquarters expressed the need for a map to consider the response in case of heavy rainfall. We compiled information to provide a warning against secondary disaster risks by displaying the passage status of roads to be used to reach evacuation centers and temporary housing and integrating it with rainfall intensity and landslide-related information (**Fig. 8**).

As shown by the above examples, in addition to providing individual data sets, it is important to provide information packages that conform and directly connect to the operations of the organization to increase the effectiveness of onsite activities in terms of the role of information sharing during disasters that become prolonged and compounded. Although we leave a qualitative discussion of the effects to another occasion, this will require the unitary treatment of data and information packages. As such, the information sharing system may provide a platform.

5.2. Issues Pertaining to the Effective Functioning of the Information Sharing System

Considering the above, in terms of the shared data, we examine the issues that must be addressed for the system to exhibit its effects in future disasters. Specifically, the recent response to the Kumamoto Earthquake involved the manual registration of 631 layers to the system, a considerable workload. Therefore, we first discuss measures to minimize this load.

First, the 631 layers of data presented in **Table 1** were classified according to data type and organized in the order they were uploaded to NIED-CRS daily from April 14 to August 31. Then, to examine the possibility of reducing the load, the data were divided into two groups: 1) data available during normal times and 2) data generated after the occurrence of the earthquake. It was then further divided into a) static and b) dynamically updated data (including those that should have been updated but were not), to constitute four major categories (**Table 3**).

Based on this classification, it was found that 1) reducing the blank areas corresponding to "no data registered" and 2) achieving regular intervals in the data registration of b (dynamic data) are important items in reducing the workload in information sharing and effectively using the shared information. These factors are discussed from three aspects below.

(1) Advance Loading of Data

The data presented in ① consist of ①-a: static data that indicates the status at normal times and ①-b: data that are continuously updated. These data were manually registered and released in the recent Kumamoto disaster.

Table 3 Category and registered date of shared data (extract up to June 30, 2016).

Category		Data type
① Data that can be produced in advance of disaster	a) Static data	Standard maps (GSI)
		Blank maps (GSI)
		Light-colored maps (GSI)
		Color altitude maps (GSI)
		Aerial photographs (GSI)
		Aerial photographs of 1970s (GSI)
		Aerial photographs 1961–1964 (GSI)
		Aerial photographs 1945–1950 (GSI)
		Aerial photographs (Geospace CDS)
		Maps (Geospace CDS)
		Google Maps (maps and photos)
		Google Maps (maps)
		Google Maps (photos)
		Designated evacuation centers (National Land Numerical Information)
		Medical institutions (source: EMIS)
		Active fault map (released by Headquarters of Earthquake Res. Promotion, Ministry of Education, Culture, Sports, Science and Technology)
		Basic data (compiled and provided by Kyushu Univ.)
		Statistical data (source: Pasco Corp.)
		Mount Aso volcanic alert level (source: Japan Meteorological Agency)
		Statistics (National census, etc.)
		Hypocenter distribution (prior to April 14)
		Past slope movement distribution maps (source: Kumamoto pref.)
		Sediment Disaster Alert Areas (source: Ministry of Land, Infrastructure and Transport)
		Mount Aso Volcano disaster prevention map (source: Kumamoto pref.)
		Water reservoir distribution (National Agriculture and Food Research Organization)
	b) Dynamic data	Road passage maps (released by ITS Japan)
		Hypocenter distribution (since April 14)
		V-net observation points
		Effective rainfall, cumulative rainfall (NIED Contents)
②Data produced after occurrence of disaster	a) Static data	Seismic intensity distribution
		Estimated distribution of totally destroyed buildings
		NIED-captured onsite photos
		Aerial photographs (GSI)
		Ground fissure distribution map (released by GSI)
		Mount Aso central cone ortho-image (sources: Asia Air Survey Co., Ltd.; GSI)
		Slope movement distribution maps
		Automatic extraction of blue-sheeting houses (source: Pasco Corp.)
		Hypocenter destruction process
		Road bumps and flatness measurements (source: BumpRecorder Co.)
		Survey on water reservoirs (source: Pasco Corp.)
		Originating location of liquefaction
	b) Dynamic data	Road traffic restriction status (source: Kumamoto pref.)
		Road traffic restriction status (source: Oita pref.)
		Road damage information (source: DiMAPS)
		Status of evacuation centers (source: EMIS)
		Status of evacuation centers (source: Kumamoto pref.)
		Status of evacuation centers (source: Kumamoto City)
		Status of evacuation centers (Kumamoto City and Kumamoto pref. combined)
		Status of evacuation centers (for Mashiki Town only; source: medical rescue team)
		Disaster Volunteer Center (Source: Social Welfare Councils, Kumamoto and Oita prefs.)
		Restoration of water supply (sources: Kumamoto pref. and Kumamoto City)
		Mobile phone free charging service (source: Pasco Corp.)
		Bathing facilities (source: Pasco Corp.)
		Landslide disaster (source: DiMAPS)
		River facility damage status (source: DiMAPS)
		Progress status of building damage certification survey (source: Kumamoto pref.)
		Number of temporary housing units according to local government (source: Kumamoto pref.)
		Construction sites of temporary housing (source: Kumamoto pref.)
		Kumamoto prefecture Landslide disaster information (source: Kumamoto pref.)

□ … No data registration ■ … Data registration ▒ … Data holding

Note: "b) Dynamic data" includes data that are intrinsically dynamic in nature, but were not dynamic in the case of the Kumamoto Earthquakes. No data registered Data registered Data stored

Although it was possible to register the blank maps and aerial photographs that provide the background for various maps at the time the system was installed, the other data were compiled and entered when the need for them arose, which resulted in the blank zones.

Although the requirements vary depending on the type of disaster, the data of ① can be registered to SIP4D and NIED-CRS in advance if standard, common needs arising after the occurrence of a disaster can be grasped beforehand. To this end, it is necessary to standardize disaster-response operations, including the selection of the relevant data and advance loading of this data, which should reduce the workload in data entry during actual disasters. This requires continued support of disaster response into the future, and identifying data that will always be needed through accumulated experience.

Similar is the data of ②. By identifying data that must be compiled after a disaster occurs, it is possible to prepare in advance a framework for its registration, which should reduce the workload after the disaster and allow the estimation of figures in advance. This should increase the likelihood of sustaining the effects of the information sharing system.

Note that we were able to achieve, between the manual entries of data, registration at regular intervals of the data under ①-b to a certain extent. Future issues are to construct an information output system to achieve complete automation and further refinement of NIED-CRS.

(2) Machine Readability of Top-Down Data

The data under ②-a are static data compiled after the disaster occurs. An examination reveals that they consist of data obtained at some time representing the situation for the entire region. Furthermore, they tend to be data compiled and provided in a "producer-driven" manner, rather than compiled in response to onsite needs. Therefore, we call them "top-down data."

Because such top-down data are producer-driven, information-sharing parties cannot prescribe how they are compiled. Thus, to enable sharing of the data as soon as possible and reduce the "blank" zones, it is desirable to speed up the compilation process of the data producer and provide the data in a format technically conducive to sharing.

The Basic Act on the Advancement of Utilizing Public and Private Sector Data was enacted on December 7, 2016. It is designed to utilize data provided by the national and local governments, independent administrative institutions, and other businesses to contribute to realizing a safe and secure society and comfortable living environment, including the promotion of open data. It is desirable that open data is machine readable and suitable for secondary use; data with high machine readability can be shared effectively. Since information is often shared in map form following disasters, it is preferable that data is provided in a format suitable for incorporation into maps, which is an issue that requires adjustments at the level of individual organizations or society.

(3) Creating a Minimum-Item List and Standardization of Bottom-Up Data

The data under ②-b are dynamic and compiled after a disaster occurs. An examination reveals that they consist of data that change because of activity undertaken after the disaster. For instance, the passage of roads is regulated depending on the incurred damage or state of emergency response. The status of evacuation centers changes daily with the number of people sheltered, the occurrence of events, and specific needs. Since many of these data representing the situation following a disaster are compiled by collating figures determined at individual locations, we call them "bottom-up data."

As the table shows, the data under ②-b display extensive blank zones and their registration was often not performed at regular intervals. While data that undergo changes only occasionally have a low impact on disaster response activities, data that undergo frequent changes to represent the latest status has a direct bearing on activities. Furthermore, data that are irregularly and randomly updated are not conducive to automatic registration, and their manual registration after the Kumamoto Earthquake constituted a large workload. Thus, reducing the workload to increase the registration frequency of data under ②-b is an important issue for the future.

To this end, it is essential to determine the common items needed to convert the data collected in a bottom-up manner to maps or to integrate them. For example, the data on evacuation centers was compiled by collating and integrating data sets obtained from DMAT, the prefectural government, and city government. However, this collation/integration task was extremely difficult, because basic information that identifies the evacuation center such as its name and address differed depending on the organization or personnel collecting the data. Furthermore, accurate information on the location of the evacuation center such as latitude and longitude were unavailable, and the method of adding non-designated evacuation centers had not been established. Although the separate data sets were converted to maps and shared from April 21, they were integrated and shared as a single data set only from May 1.

Although the specific need for data differs among organizations, the locations and names of evacuation centers are locally known and fixed. Therefore, we feel that the collation process can be made more efficient and result in sharing accurate information by creating in advance a common list of the minimum necessary items that identify them. Thus, standardization of the minimum required items common among data sets is a future issue to be addressed.

In addition, in a subsequent hearing survey of the Health and Welfare Policy Division, we heard from personnel at the site that "we had some difficulty when making phone calls to evacuation centers to obtain their status, because the format was undecided. It would be effective if a standard format is available." The main objective of standardizing the information collection procedure is to minimize the load for information processing. Thus, creating a common minimum list of items needed for data collation or map conversion and standardizing the operation of organizations and personnel charged with disaster response to reduce the workload are important issues that must be resolved in the near future. Standardization of data formats and establishing common items are issues recognized in the past, and a considerable volume of experiences and discussions have resulted in the creation and release of guidelines [17] Although it includes recommendations for the preferred format of releasing data, the reality is that this information has not permeated society; consequently, the same problem surfaced when the Kumamoto Earthquake struck. Thus, it is essential to review the information items to be made common and set up a concrete program to establish them.

6. Conclusion

In this paper, we presented an overview of SIP4D, which is an intermediary information sharing system under development based on past discussions and responses to information sharing during disasters. We are also developing its "window" on the web, NIED-CRS, and in this paper, analyzed and discussed the effects and issues from the standpoint of an information sharing system using the case of its application to the Kumamoto Earthquakes. As effects, we identified 1) the realization of increased overall efficiency, 2) validity of sharing alternative information, and 3) possibility of using the system as a platform for information integration. As future issues, we highlight the need for 1) advance loading of data, 2) machine readability of top-down data, and 3) identifying the common minimum required items and standardization of bottom-top data.

In the recent experience of disaster response to the Kumamoto Earthquake, many scenes called for speed and flexibility in information sharing, rather than accuracy and completeness. This suggested the importance of an organization that can cut across multiple organizations, each of which are engaged in activities in their respective areas, and provide the function of information sharing. In the future, in addition to the data, information, and system, which were discussed in this paper, it will be necessary to set up an organization exclusively charged with information sharing among several organizations and the collaborative framework to support it, standardize disaster response operations, and address issues regarding the social implementation of this framework.

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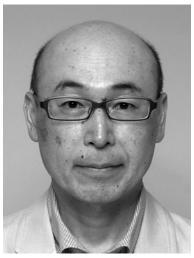

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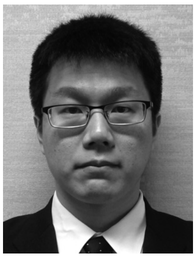

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