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Paper:

The Standardized Disaster-Information Products for Disaster Management: Concept and Formulation

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The purpose of this paper is to consider the essential concept by which to formulate standardized information that supports effective disaster response. From the experiences of past disasters, we have learned that disaster response organizations could not work effectively without information sharing. In the context of disaster response, the purpose of "information sharing" is to ensure common recognition of the disaster situation being confronted. During the Kumamoto earthquake, we provided a set of disaster information products to disaster response organizations to support their relief activities. Based on the real disaster response experience, we extracted issues of information sharing between various organizations. To resolve these issues, we discuss the concept of information sharing first, and then consider the quality of information that supports disaster response activities by referring to the information needs of emergency support organizations such as the Disaster Medical Assistance Team (DMAT). We also analyze the Basic Disaster Management Plan published by the Central Disaster Management Council and extract a common disaster-information set for governmental organizations. As a result, we define the "Standard Disaster-information Set" (SDS) that covers most disaster response information needs. Based on the SDS, we formulate intermediate information products for disaster response that provide consistent information of best-effort quality, named the "Standardized Disaster-information Products" (SDIP). By utilizing the SDIP, disaster response organizations are able to consolidate the common recognition of disaster situations without consideration of data availability, update timing, reliability, and so on.

Keywords: information sharing, disaster management, disaster information, emergency response

1. Introduction

The purpose of this paper is to consider the essential concept by which to formulate standardized information that supports effective disaster response.

From the experiences of past disasters, we have learned that disaster response organizations could not work effectively without information sharing. In the context of disaster response, the purpose of "information sharing" is to ensure common recognition of the disaster situation being confronted. Since many teams dispatched by various organizations join together at the disaster response site, sharing common recognition of the disaster situation is a crucial factor of an effective and rapid response.

Especially, at the time of the Great East Japan Earthquake, many affected municipalities experienced serious "information blackout" [1]. The Japanese government was shocked by this fact and has aimed to prevent the same situation from occurring in future disasters. Since the information blackout during the Great East Japan Earthquake had been so serious, the major information-related problem at disaster sites has been mainly understood to be a technical problem of the telecommunication systems. In order to solve this problem, improvement of the emergency communication systems and development of a data communication network that is resistant to disasters have been promoted by both the public and private sectors. These technical approaches are producing results, and the problem of the loss of telecommunication at the time of a large-scale disaster can be expected to improve in the future.

However, this approach merely solves the technical problem of information sharing wherein information does not reach the disaster response site. Information sharing itself is a particular type of information usage comprising such fundamental operations as information collection, processing, exchange, delivery, and so on. In other words, the term information sharing indicates a user experience in which the same information is being utilized among different organizations.

Let us assume that telecommunications at the time of a disaster are secure and that a sufficient amount of information can be provided to the disaster response site. Under such circumstances, will information be shared spontaneously at the disaster response site and be utilized to take effective actions?

This is actually not just an assumption. The communication systems were not lost for a long period of time during the Joso city flood and the Kumamoto earthquake; nonetheless, we found that necessary information had not been shared at the disaster response sites, and confusion was experienced among the disaster response teams. We believe that this is not a problem of the information's delivery or quantity.

In this paper, we discuss the concept of information sharing first, and then consider the quality of information that supports disaster response activities. Finally, we offer a draft of the information set that will best ensure the realization of common recognition between disaster response organizations.

2. Background and Previous Research

The term, "information sharing" is useful for expressing a form of information utilization. While the term is used broadly, the concept of information sharing is still under discussion.

In the United States, after the World Trade Center Disaster (September 2001), information sharing among crisis response agencies came into focus. After the disaster, various surveys or studies have examined the inter-organizational coordination and information sharing in extreme disasters [2, 3]. In addition, the Department of Homeland Security (DHS) released the first version of the National Incident Management System (NIMS) in 2006. The NIMS is "a systematic, proactive approach" to guide various response organizations in working together seamlessly, and it is essentially designed for managing all hazards regardless of cause, size, location, or complexity. The Incident Command System (ICS) is a core tool of the NIMS, and it provides practical methods and a system for managing incident responses based on the NIMS. Information management is an important component of the NIMS, and "Common Operating Picture," "Interoperability," "Reliability, Scalability, and Portability," and "Resiliency and Redundancy" are described as its fundamental concepts [4, 5]. These concepts of information management are reflected in the ICS and also implemented in products for incident management, such as "WebEOC," which is the most popular Web-based incident management system among local governments in the United States. While the NIMS provides a standardized framework for information sharing, the specification of information is not defined in it.

In 2012, the National Information Sharing Consortium (NISC) was launched to improve the state of public safety, emergency management information sharing, and interoperability [6]. The NISC has been gathering information on best practices and guidance on the essential elements of information (EEIs) (see **Table 1**). The EEIs are defined by a bottom-up process according to the information requirements before a decision is made [7].

Current (2017) EEIs have been developed based on the result of a great exercise, "CAPSTONE-14," in 2014. In the after-action report of CAPSTONE-14, the Central United States Earthquake Consortium, the organizer of the exercise, recommended the following:

> "Establishing common EEIs significantly supported regional information sharing and situational awareness. [...] In the future, DHS may consider adapting these EEIs for data sharing as a best practice and part of the NIMS accreditation" [8].

Table 1. The NISC's Essential Element of Information (EEI).

Essential Element of Information	Description
Electricity Grid	Operational status of Electricity Grid
Natural Gas Grid	Operational status of Natural Gas Grid
Water Grid	Operational status of Water Grid
Road Status (including bridges)	Operational status of roadway transportation network, especially pre-defined emergency supply routes critical for response and recovery efforts
Rail Network (including bridges)	Operational status of railway transportation network
Navigable Waterways	Operational status of navigable waterway transportation network
Air Transportation Infrastructure	Operational status and capabilities of airports and airspace
Area Command Locations	Location and activation status of area command (often overlaps with state emergency operation centers)
Staging Areas	Location, status, and type of staging areas, which are used to temporarily store resources required for emergency response and recovery
Points of Distribution (PODS)	Location, type, and operation status of PODs for distribution of food, water, and other bulk commodities
Joint Reception, Staging, Onward Movement and Integration (JRSOI) Sites	Location, status, and points of contact for JRSOI sites, established by the State branch of the National Guard to coordinate emergency response efforts
Evacuation Orders	Areas under current evacuation orders, and the details concerning the orders
Injuries and Fatalities	Confirmed number of injuries and fatalities
Shelters	Location and operational status of sheltering facilities
Communications	Operational status of landline, cellular, and internet access
Hospital Status	Operational status of hospitals, including beds available, supply status, etc.

Things we can learn from the NIMS approach regarding information sharing can be summarized as follows:

1 Information needs should be considered by a use-case-based approach rather than a supply-side approach.

2 A well-structured set of information like the EEI is necessary to the accomplishment of interoperability between organizations.

3 The Common Operational Picture is a key component of realizing information sharing.

The Japanese government does not have a unified incident management system such as the NIMS. The Basic Disaster Prevention Plan that was released in 1968 by the Central Disaster Management Council is the only fundamental document for disaster response in Japan [9]. While it has been revised at each occurrence of a great disaster, the basic structure has not been changed. The plan is designed using a disaster-specific and top-down approach that is in contrast to the all-hazards and bottom-up approach of the NIMS, and it describes only the principle disaster response of ministries and other designated organizations in a traditional, vertically segmented manner. The specification of each essential component, such as information management or resource management, is left to each responsive organization.

Since the Great Hanshin-Awaji Earthquake (the 1995 Southern Hyogo Prefecture Earthquake), many researchers have challenged effective information sharing in disaster management.

From July 2004 through March 2007, The Ministry of Education, Culture, Sports, Science and Technology (MEX) conducted a joint research project, "The Research on Disaster Reduction using Crisis-adaptive Information Sharing Technologies [10]." In this project, the National Research Institute for Earth Science and Disaster Resilience (NIED), Tokyo University, and cooperative organizations developed a disaster mitigating information sharing platform that was effective for disaster response activities, mainly for local governments. The project team investigated the usage of disaster information using the observation data of disaster exercises that used the information-sharing platform in several municipalities, proved the advantages of the platform, and extracted the issues of disaster-information sharing. Notably, this research project clarified that to accomplish effective information sharing, it was necessary not only to use the ICT system but to have an adequate information set that was suitable for the actual disaster response activities. In several disaster-response exercise cases, it became difficult for the disaster-response staff of municipalities to handle the abundant information provided by the system, even if they determined that the information-sharing system was worth using. To resolve this issue, the research team proposed an "Information Recipe" that was a conceptual framework by which to compose the set of usable information according to the disaster-response phases [10, pp. 26–39]. This concept was precious to the utilization and standardization of disaster-information sharing, but its social implementation was left for further research.

Right after this project, when the Niigataken Chuetsu-oki Earthquake occurred in 2007, Urakawa and Hayashi organized the Emergency Mapping Team (EMT) for the Niigata Prefectural Disaster Response Headquarters and provided the Common Operational Pictures (COP) for sharing situational awareness between responders [11]. Through this activity, they researched the manner in which to efficiently integrate information based on the information needs of disaster responders. It was the first case of the systematic information management and sharing held by the Emergency Operation Center (EOC) in an actual disaster situation in Japan, and it proved the efficiency of common information sharing between disaster response organizations. They analyzed the usage of disaster information in local governments and sorted disaster information according to the thematic maps in which said information was used. The result of the analysis is conceptually similar to the EEI, which is also notable.

It can be said that these empirical studies examined the effectiveness of the three points we have mentioned above in actual disaster response sites. However, these studies focused on the prefectural or municipal level, since the targeted disasters were limited to a rather narrow area. Therefore, inter-governmental or inter-jurisdictional information sharing has not yet been examined in reality.

At the Great Eastern Japan Earthquake in 2011, many organizations, researchers, private companies, and NPOs provided various disaster information via the internet [12], but most of them did not reach affected areas. When a large, wide-area disaster such as the Nankai Trough Earthquake occurs, affected areas might lose the ability to "pull" the information needed, even if the telecommunication system is alive. In that case, the national government or supporting organization should "push" a set of appropriate information to local governments and disaster response organizations in affected areas. We suppose that the three points mentioned above suggest the issues that we should discuss and resolve in preparation for large-scale disasters.

In this paper, we discuss the issues based on the three points above mainly, focusing on the information sharing between disaster-response organizations at the nationwide level. Currently, we engage the research project of the "Cross-ministerial Strategic Innovation Promotion Program" (SIP) to realize inter-organization information sharing between ministries, agencies, and designated public organizations. We have already developed a prototype of the Sharing Information Platform for Disaster Management (SIP4D) and are implementing its functions based on the conceptual design of information sharing that is discussed in this paper.

3. Essential Information Sharing Strategy

The primary purpose of disaster-information sharing is to build common recognition of a disaster situation that is being confronted. It facilitates disaster response activities in the affected area and enables effective collaboration between related organizations. The common recognition of disaster situations will be composed of the fundamental information needs in response activities. Thus, we should consider the essential concepts in order to determine the set of information that is needed by disaster response sites.

Most disaster response actions are carried out to solve problems that occur in the disaster area. Only a few actions are done by a single team, and a large portion of the actions need collaboration between two or more teams dispatched from different organizations. Information sharing is necessary to establish common recognition of the disaster situation between these organizations and their teams. Needless to say, it is not worth sharing information that is not useful in the disaster response. Therefore, we should consider a set of information that is required to solve the problems that occur in the disaster-response process.

	Specific Set of Information	Common Set of Information
New Problems	① not predictable	② partially predictable
Programmatic Problems	③ not enumerable	④ enumerable

Fig. 1. Matrix of information sharing strategies.

Generally speaking, disaster response problems can be classified into two categories: "Programmatic Problem" and "New Problem" [13, 14].

A programmatic problem is a predictable and possible problem that has been learned about in past experiences. While disaster response problems vary between each disaster, most of them can be predicted at some level regarding such elements as disaster type, scale of damage, population density, geographical characteristics, and so on. Therefore, disaster response organizations are able to plan operational procedures for these problems before disasters occur and to prepare an effective response.

The other type, a new problem, is unpredictable and occurs suddenly. Since it is impossible to prepare an exact solution for this sort of problem before the disaster, decision makers are required to provide a creative response. Planning is also needed for this type of problem.

If we define a set of information that covers all possible problems, the amount of information set might be huge. Theoretically, it is possible to prepare in advance a set of information that is needed for each programmatic problem. However, since the programmatic problems are defined individually by each disaster response organization, preparing all sets of information in a unified way is not feasible. Moreover, nobody can precisely predict the information that will be needed to solve new problems.

We suppose that the most feasible way is to define a set of information that covers the minimum requirements of most problems. This issue can be summarized as a simple matrix, as shown in **Fig. 1**. The rows of the table indicate the categories of problems, and the columns indicate the information set type. Each domain indicates the following: Domain 1 is "not predictable," Domain 2 is "partially predictable," Domain 3 is "not enumerable," and Domain 4 is "enumerable." For the first step, we start from Domain 4, the most feasible target. That is, we define the "common information set" based on the minimum requirement of programmatic problems.

Based on this essential strategy, we discuss the common information set that should be shared among stakeholders in a disaster response.

4. Empirical Approach to Defining the Common Information Set

Suzuki [15], Urakawa and Hayashi [11], and Inoguchi et al. [12] have already researched the information set required in disaster response. We refer to their research results to grasp an overview of the information needs of disaster response activities. In the United States, the NISC's EEIs are becoming the de facto standard, but unfortunately, Japan does not have such a standardized information set.

We referred to the building process of the EEI, which is a good example of the bottom-up process, to define the information set based on the actual needs of emergency response organizations. However, it is not appropriate to apply the EEIs directly to the disaster response in Japan because the risk governance of the United States is different than that of Japan. Since the EEIs are designed to be compliant with the NIMS, each EEI can be defined by a standardized procedure; however, we do not have such a framework in Japan.

Each EEI is a set of information that is selected based on use cases of Emergency Supporting Functions (ESF); thus, the large dataset of disaster related information exists in the background of the EEIs [16, 17].

Therefore, we have to consider the structural way in which to construct the common information set. **Fig. 2** shows our construction process for the common information set named the "Standardized Disaster-information Products" (SDIP).

At the first step, we enumerated the common disaster information by referencing the damage reports that were published by the Cabinet Office after past natural disasters.

This information set can be considered as the standard set of disaster information that is required in the government's disaster-response process; thus, we named this information set the "Standard Disaster-information Set" (SDS) (see **Table 2**). While it is not the complete enumeration of disaster information, it is expected to cover the most commonly used information in the natural disaster response process. The damage reports are built up from formulaic reports (such as the "No.4 form" of the Fire and Disaster Management Agency) submitted by governmental agencies, local governments, and designated public organizations. The SDS is the essential material by which to establish common recognition of a disaster situation.

At the second step, we extracted the tasks that are supposable as information sharing related to the Basic Disaster Prevention Plan, and we sorted them by relationship between the collaborative organizations. This mainly targets the prospective programmatic problems in the government's general disaster response scenario. Sometimes descriptions are unclear and ambiguous, but it is the most authorized disaster response material. The result of this sorting is presented as a large matrix in **Fig. 2**.

Since it is difficult to extract all of the information needs from this matrix at once, we focused on disaster-response activities related to medical support (Sub-matrix

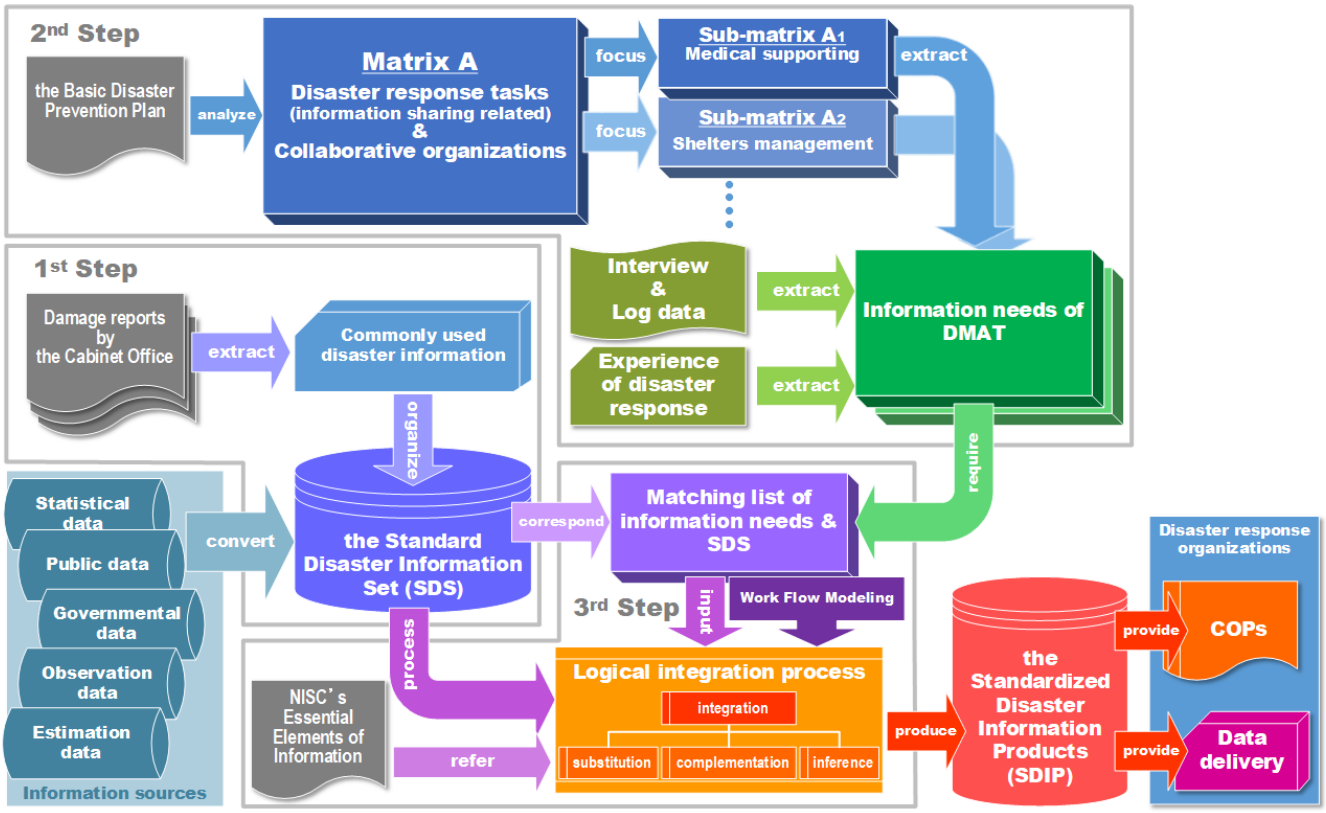

Fig. 2. Construction process of the Standardized Disaster-information Products (SDIP).

Table 2. The Standard Disaster-information Set (SDS, partial).

Standard disaster-information set			Information items	Geospatial feature type	Supervisory authority / Information provider	Available Information system, etc.	In Damage reports
Casualties	Records in damage reports	Casualties	Dead, missing, injured (serious, minor, degree unknown)	Municipality	FDMA	Form No. 4	○
	Landslides etc. (MLIT)	Casualties - debris flow	Dead, missing, injured	Municipality	MLIT	DiMAPS	○
		Casualties - earth slide	Dead, missing, injured	Municipality	MLIT	DiMAPS	○
		Casualties - rockfall	Dead, missing, injured	Municipality	MLIT	DiMAPS	○
	Real-time damage estimates	Estimated casualties caused by an earthquake	Dead, seriously injured	Mesh	NIED	SIP 5	
Structural damage	Records in damage reports	Residential damage	Totally destroyed, half destroyed, slightly damaged, totally burned, half burned, flooded above floor level, flooded below floor level	Municipality	FDMA	Form No. 4	○
		Non-residential damage	Public buildings, other	Municipality	FDMA	Form No. 4	○
		Fires	Number of fires	Municipality	FDMA	Form No. 4	○
	Landslides etc. (MLIT)	Residential damage - debris flow	Totally destroyed, half destroyed, slightly damaged	Point	MLIT	DiMAPS	○
		Residential damage - earth slide	Totally destroyed, half destroyed, slightly damaged	Point	MLIT	DiMAPS	○
		Residential damage - rockfall	Totally destroyed, half destroyed, slightly damaged	Point	MLIT	DiMAPS	○
	Real-time damage estimates	Estimated residential damage caused by an earthquake	Totally destroyed, half destroyed	Mesh	NIED	SIP 5	-
		Estimated damage caused by heavy rain	Under development	Mesh	NIED	SIP 5	-
		Estimated damage caused by a tsunami	Under development	Mesh	NIED	SIP 5	-
Road Status	Road damage	Highways	Information on vehicular travel bans for highways	Restricted section	MLIT	DiMAPS	○
		National roads (MLIT)	Information on vehicular travel bans for national roads (nationally managed roads; nationally subsidized, regionally managed roads)	Restricted point	MLIT	DiMAPS	○
		National roads (prefectures, ordinance-designated cities)	Information on vehicular travel bans for national roads (nationally managed roads; nationally subsidized, regionally managed roads)	Restricted point	Prefectures, ordinance-designated cities	L Alert, Prefectural disaster management systems, etc.	○
		Prefectural roads	Information on vehicular travel bans for prefectural roads	Restricted point	Prefectures, ordinance-designated cities	DiMAPS	○
		Municipal roads	Information on vehicular travel bans for municipal roads	Road section	Municipalities	Municipality's Disaster management system, etc.	-
		Farm roads	Information on vehicular travel bans for farm roads	Road section	MAFF	N/A	-
		Other roads	Roads managed by public road corporations and road operators	Road section	MLIT	DiMAPS	○
	Information on traffic congestion and restrictions	Vehicle information and communication system (VICS)	Information on traffic congestion and restrictions	Road section	JARTIC	VICS Center or JARTIC Web Site	-

A1 in **Fig. 2**) and shelter management (Sub-matrix A2 in **Fig. 2**). Here, we explain the information needs analysis process in the case of the medical support activities.

Table 3 shows the extracted portion that is related to the Disaster Medical Assistance Team's (DMAT) dispatch of the matrix. In **Table 3**, symbol "C" indicates the organiza-

Table 3. Medical-related disaster response activities and responsible organizations.

Responsive organizations / Emergency response activities	Government H.Q. for Disaster Management	On-site Disaster Management Headquarters	Cabinet Office	National Police Agency	Fire and Disaster Management Agency	Ministry of Education, Culture, Sports, Science and Technology	Ministry of Health, Labor and Welfare	DMAT, DPAT, etc.	Ministry of Economy, Trade and Industry	Ministry of Land, Infrastructure and Transport	Japan Meteorological Agency	Technical Emergency Control Force (Tec-Force)	Japan Coast Guard	Ministry of Defense	Japan Self Defense Force	Affected Prefectures	Non-affected Prefectures	Prefectural Police	Affected Municipalities	Non-affected Municipalities	Fire Departments	Medical Services	Private Sector
Rescue and emergency activities by local governments and national organizations outside the afflicted area	C	C		S	S					S			S	S	P	S	P		S	P			S
Procurement of organization's equipment related to rescue and emergency			P	P	P					P			P	P		P	S		P	S			S
Coordination of activities, information sharing and support between rescue units	P	P		P	P			P				S	P	P	P	P		P	P		P		
Implementation of medical activities by medical institutions in affected areas		C				P	P	P						P		P			P			P	
Dispatch of DMAT from outside the affected area	C			S	S	P	P	P		S			S	S	P	P	P		P	P		P	
Implementation of extensive posterior medical care activities	C			S	S	S	S			S			S	S		P	P					S	

C Coordinator　P Primary Organization　S Supporting Organization

Edited by R. Sato based on the "Basic Disaster Prevention Plan" [2]

tion that is accountable for coordination, "P" the primary organization responsible to each action item, and "S" the supporting organization. For example, we can see that thirteen organizations are related to the action item in the row titled "Coordination of activities, information sharing and support between rescue units." From the matrix, it is clear that more than ten organizations should collaborate with each other in the disaster-affected area and share information. This also means that more than ten kinds of information must be shared. This document mentions that information sharing is necessary in disaster response operations, but it does not specify the set of information to be shared.

To clarify the information needs of disaster response organizations or responders, we interviewed the core members of the DMAT administration office about their actual disaster response experiences in the following cases:

1 Mt. Kiso-Ontake explosion in 2014

2 Joso city flood in 2015

3 Kumamoto earthquake in 2016

We focus on the DMAT because it is an early response team that has experience getting into affected areas without sufficient information. Additionally, we have been collaborating with the DMAT administration office in the research project of the SIP since 2014. We are approved to access their activity log and reported information via the Emergency Medical Information System (EMIS); thus, some data that verify the interview record were obtained from the EMIS. At the Kumamoto Earthquake, we also directly communicated with the staff members of the DMAT Coordination Headquarters, and provided a prototype of the COP that reflects their information needs.

Table 4. DMAT's Disaster response information needs.

ID		Information needs of DMAT
D01	Roads	Road damages, Passable roots, Recovery status
D02		Closed section by weather conditions
D03	Road Traffic	Traffic jam
D04		Traffic restriction other than emergency vehicles
D05		Traffic restriction by fire
D06		Traffic control due to people going home
D07	Fuel	Location of available gas stations
D08		Waiting time for filling
D09	Weather	Overview of weather
D10		Weather warning, Alert information
D11		Typhoon
D12		Snow accumulation
D13		Flood
D14	Earthquake & Tsunami	Seismic intensity
D15		Tsunami inundation
D16	Rivers	River water level
D17	Volcanos	Volcano observation
D18	Lifelines	Electricity supply
D19		Gas supply
D20		Water supply
D21		Telephone
D22		Mobile-phone
D23		Internet
D24	Helicopters	Number of helicopters
D25		Intensity of flight
D26		Flight roots (departure point, arrival point)
D27	J.S.D.F. Activity	Location of dispatched squadrons
D28		Type of activities
D29		Location of command post
D30	Police	Status of dispatch
D31	Fire Department	Number of dispatched teams (aerial, surface)
D32	Medicine	Location of staging base
D33		Available medicines
D34	Damage	Human damage
D35		Building damage
D36		Medical facilities

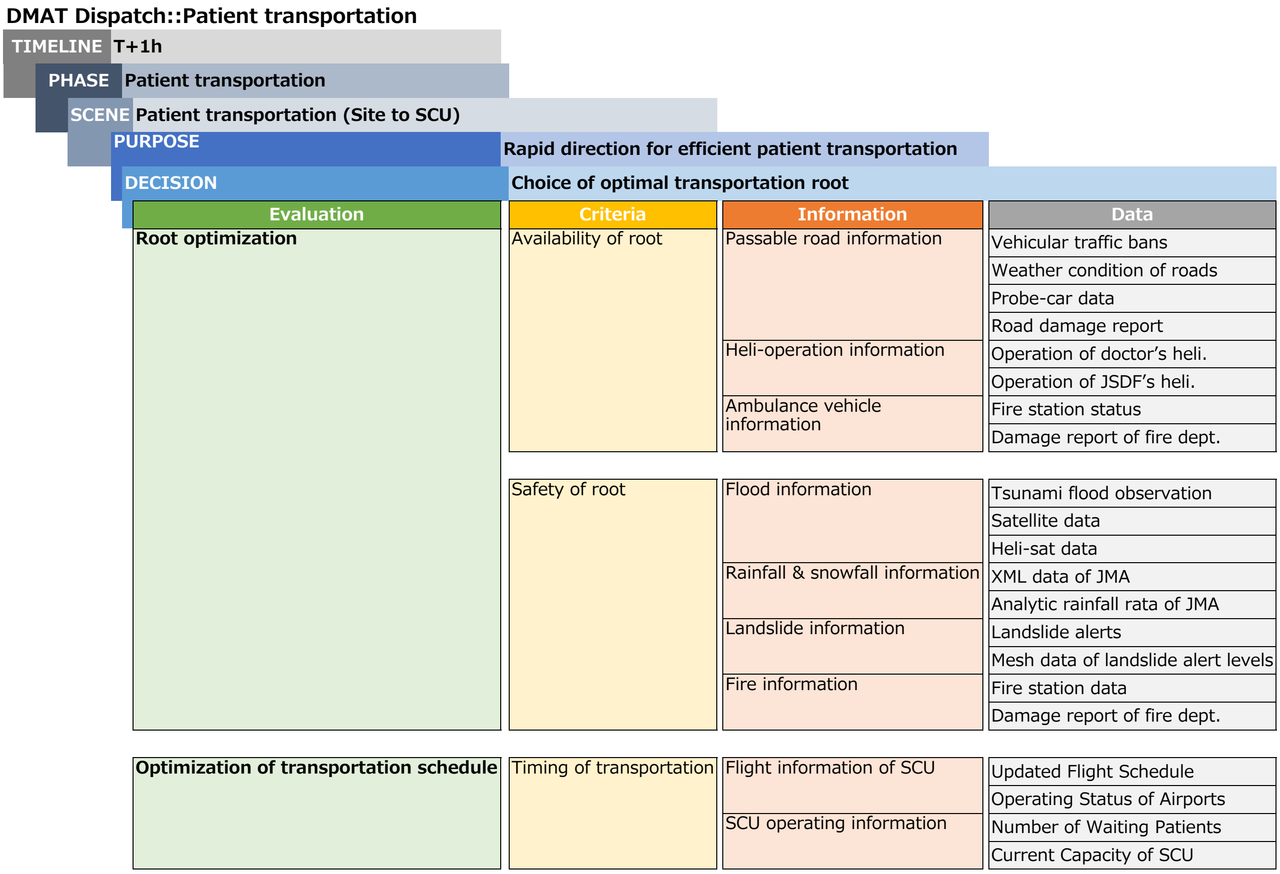

Fig. 3. The task-information model of DMAT'S patient transportation task (partial).

Through collaborative research with the DMAT, we studied their work flow and required information. Based on the research, the correspondence between each task and the required information is described as the "Task-Information Model," shown in **Fig. 3**.

Table 4 shows the summarized list of the DMAT's information needs based on the Task-Information Model. As we can see in the table, the information needs include not only medical-care-related information but also such information as life lines, infrastructure, road traffic, and so on [18].

While these 36 items include currently unavailable information, most of them can be linked to the existing information. The correspondence between the information needs and specific information sources is shown in **Table 5**. Almost all information was sourced from organizations other than the DMAT. This means that the DMAT cannot access most of the necessary information without information sharing. In reality, they struggled to collect information themselves in past disaster responses. Even if the team at the next desk has useful information for the DMAT, there is no certain way to ensure that they are aware of that fact. Therefore, the DMAT must spend their precious manpower and time in the process of seeking information. While it sounds exaggerated, similar situations often occurred at the disaster-response sites of the Joso city flood and the Kumamoto earthquake. To avoid repeating this situation in future disasters, the information set above should be prepared and provided in advance. Information items that are marked as high necessity, such as passable road information, shelter location information, and medical facilities information, should be categorized as a minimum requirement for DMAT activities.

5. Standardized Disaster-Information Products

As mentioned in the DMAT example, more than 30 items of information are needed for DMAT activities in the disaster response process.

In the Basic Disaster Prevention Plan, each response activity is described in organization based. For example, the prefectural government in the affected area is accountable for the task, "Grasp the road traffic situation." In order to complete this task, the response person has to get information about the damage to the national roads (from MLIT), damage to the prefectural and municipal roads (from the civil engineering department), damage to the highway (from road management companies), landslides (from MLIT), traffic control (from the prefectural police office), and traffic jams. While this information is included in the SDS, for an ordinary staff member of the local government, it will not be easy to collect the appro-

Table 5. The Standard Disaster-information Set corresponding with the DMAT's information needs (partial).

Contents of information	Correspondence to DMAT's information needs	Government H.Q. for Disaster Management	On-site Disaster Management Headquarters	Cabinet Office	National Police Agency	Ministry of Public Management, Home Affairs, Posts and Telecommunications	Fire and Disaster Management Agency	Ministry of Agriculture, Forestry and Fisheries	Ministry of Education, Culture, Sports, Science and Technology	Ministry of Health, Labor and Welfare	DMAT, DPAT etc.	Ministry of Economy, Trade and Industry	Ministry of Land, Infrastructure and Transport	Japan Meteorological Agency	Geographical Survey Institute	Technical Emergency Control Force	Japan Coast Guard	Ministry of Defense	Japan Self-Defense Forces	Affected prefectures	Non-affected prefectures	Prefectural police	Affected municipalities	Non-affected municipalities	Fire departments	Medical services	Private sector
Highway	D1/D2												○														
National road	D1/D2												○														
Prefectural road	D1/D2																			○			○				
Municipal road	D1/D2																						○				
Information on traffic regulation and jam	D3/D4/D5																										○
Other roads	D1/D2												○														
Traffic result	D1/D2																										○
Forecast of analyzed amount of rainfall and short-term precipitation	D9													○													
Information on typhoon	D11													○													
Information on earthquake	D14													○													
Observation of volcanic activities	D17													○													
Weather emergency warning, warning and advisory	D10													○													
Designated river flood forecast	D16													○													
Sediment disaster warning information	D10													○													
Volcanic alert and forecast	D17													○													
Information on mobility of helicopter	D24/D25/D26/D31						○																				
Damage to persons	D34						○																				
Damage to dwelling houses	D35						○																				
Damage to non-dwelling houses	D35						○																				
Information on power failure nationwide	D18											○															
Information on each electric power company	D18											○															

priate information, even with the complete SDS list.

As Suzuki mentioned in the research report, if all of the information is delivered directly to the disaster response site, it might create confusion and problems handling so much information at the site. In this case, the response teams have to assign each information set to programmatic problems in order to utilize the information delivered. They also have to consider the availability, update timing, and reliability of each information set, since it is not certain that all delivered information is usable without exception. These tasks are unsurprising, but they might spend the extra time and manpower of the response team. In a practical sense, it is quite infeasible.

This issue is rooted in the situation that both information management and information utilization are handled by the disaster response site. We suppose that both functions should be clearly divided in the case of disaster response. More precisely, information management should be handled outside the disaster-affected area, and only information utilization should be handled at the disaster-response site.

To realize such a function distribution, we designed intermediate information products that provide consistent information of best-effort quality, the SDIP. In this term, "standardized" indicates the set of processes that adjust the update timing of raw data, complement the lack of information, and manifest the reliability (See **Table 6** for the draft version). By utilizing SDIP, it is unnecessary for the disaster response team to handle such information management tasks as data availability control, complementation of information, and reliability check. The SDIP is produced by the "logical integration process."

The logical integration process is constructed from three adjustment processes and one integration process. The three adjustment processes, "substitution," "complementation," and "inference," work to produce the information products as completely as possible based on the currently available SDS.

For example, "Passable Road Information" is sourced from DiMAPS (the public disaster information service by MLIT) in principle. When DiMAPS' information is not available, Passable Road Information will be substituted by such alternative sources as municipalities' damaged-road information, ITS Japan's probe-car data, and so on. Moreover, at the time of the flood, the passable road section is inferenced by using estimated flooded-area data. This processed information is added to the metadata according to the standardized criteria and titled as the unique name, "Passable Road Information." For disaster response organizations, it is good enough to refer to the particular information products titled "Passable Road Information" any time (see **Fig. 4**). Needless to say, attribute information, such as updated timing, reliability, spatial coverage, etc., are described in the metadata of the SDIP.

We are developing an automated logical integration process as one of core functions of the SIP4D. In 2017, at the time of the Kumamoto Earthquake and the Disaster Medical Activities Exercise in Tokai Area, we activated the prototype system of SIP4D and verified that the implemented parts of the logical integration process functioned

Table 6. The draft version of the Standardized Disaster-information Products (SDIP).

No	Disaster-information products			Integrated items	Main data sources (SDS items)	Feature type and legend of COP	
	Category		Title				
1	Hazard	Earthquake	Hypocenter-related information	Time hypocenter location and depth magnitude maximum seismic intensity	·JMA disaster prevention information XML (earthquake information)	point	Icon indicating the hypocenter
2			Information on seismic intensities	Information on seismic intensities	·JMA disaster prevention information XML (earthquake information) ·Strong seismic motion indicator measured at observation points (NIED SIP 5)	polygon	Different colors for different seismic intensity levels
3				Distribution of seismic intensities	·Areal seismic information (NIED SIP 5)	mesh	Stepwise display of estimated seismic intensity
4		Tsunami	Tsunami alert and advisory	Alerts/advisories issued or not issued in tsunami report areas	·JMA disaster prevention information XML (tsunami information)	line	1: Alert large tsunamis; tsunami alert 2: Tsunami advisory 3: — 4: —
5			Tsunami information	(Expected) time of a tsunami's arrival at tsunami report areas; height of the tsunami			
6			Information on tsunami-caused floods	Tsunami-caused flood areas flood water levels	·Estimated levels of tsunami-caused floods (SIP 5) ·Satellite images, aerial photos	mesh	Stepwise display of flood depth
7		Volcano	Eruption alert and forecast	Volcanic eruption alert level	·JMA disaster prevention information XML (volcano information: eruption alert and forecast)	point	1: Volcanic eruption alert levels 5 and 4 2: Volcanic eruption alert levels 3 and 2 3: Volcanic eruption alert level 1 4: —
8			Rapid reports on eruptions	Volcanic eruption alert level	·JMA disaster prevention information XML (volcano information: rapid reports on eruptions)		
9			Forecasts of ash falls	Amount of ash falls	·JMA disaster prevention information XML (volcano information: forecasts of ash falls)	polygon	Stepwise display of the amount of ash falls
10		Weather	Alert, advisory	Alerts/advisories issued or not issued; Content of announcement (storm, ocean wave, lightning, dryness, frost, snow accretion)	·JMA disaster prevention information XML (special weather alert, weather alert and advisory)	polygon	1: Alert issued 2: Advisory issued 3: No announcement 4: —
11			Precipitation (current)	Current precipitation (250-m mesh size)	·Online weather information (JMBSC (JMA)) ·High-Resolution Precipitation Nowcast (JMA)	mesh	Stepwise display of precipitation
12			Precipitation forecast	6-hour precipitation forecast (1km mesh size) 9-hour precipitation forecast (2km mesh size) 39-hour precipitation forecast (5km mesh size)	·Online weather information (JMBSC (JMA))	mesh	Stepwise display of precipitation at given times
13			Total precipitation	Total precipitation for the past 24 hours (1-km mesh size)	·Online weather information (JMBSC (JMA))	mesh	Stepwise display of total precipitation
14			Snow accumulation	Snow accumulation at observation points	·Snow Accumulation List (JMA website)	point	Stepwise display of snow accumulation
15		Typhoon	Typhoon information (current)	Current typhoon information (name, size, strength, location of the eye, atmospheric pressure, radius, radius of the highest wind	·JMA disaster prevention information XML (typhoon information)	point	Eye, high wind region, highest wind region (circle)
16			Map of typhoon track	Track information for the first five days (name of the typhoon, hourly location of the eye	·JMA disaster prevention information XML (typhoon information)	point	Eye, high wind region, highest wind region (circle, forecast)
17		Flood	Information on river floods	Flood risk at water level observation points (flood advisory, alert, imminent risk, occurrence), water levels	·Flood forecast for designated rivers (JMA) ·River information (MLIT FRICS) ·Dam-related measurements (MLIT FRICS) ·Dam/weir water level (MAFF)	point	1: Occurrence, imminent risk 2: Alert, advisory undefined 4: —
18			Reservoir information	Risk of reservoir failure (advisory, alert, imminent risk, occurrence)	·Risk of reservoir failure (MAFF)		
19			Flood (inland water inundation) information	Flood areas in inland water inundation	·Estimated flood areas (MLIT DiMAPS) ·Estimated flood areas resulting from reservoir flooding (MAFF) ·Satellite images, aerial photos	polygon mesh	Flood area (polygon); stepwise display of flood depth (mesh)
20		Landslide	Landslide alerts	Landslide alert information released or not released	·Landslide alerts (JMA) ·Landslide alerts (MLIT DiMAPS)	polygon	1: Announcement in effect 2: — 3: No announcement 4: —
21			Mesh information for landslide alert levels	Landslide risk (extremely likely, very likely, alert, caution) (5-km mesh size)	·Online weather information (JMBSC (JMA))	mesh	Stepwise display of risk
22			Landslide location	Landslide location, type (rockfalls, earth slide, debris flows, etc.), circumstances	·Landslide, etc. (MLIT DiMAPS)	point	Icon indicating occurrence location

No	Disaster-information products			Integrated items	Main data sources (SDS items)	Feature type and legend of COP	
	Category		Title				
23	Damage	Casualties, missing persons	Casualties	Number of people confirmed or presumed dead, missing, or injured	·Damage report (FDMA Form No. 4) ·Landslide, etc. — casualties (MLIT DiMAPS) ·Real-time damage estimates (NIED SIP 5)	polygon	1: Death(s) occurred 2: Injury occurred 3: No casualty reported 4: Deaths estimated; no report
						mesh	Stepwise display of the scale of damage
24			Status of isolation	Number of people and households	·Isolated areas (municipalities)	polygon	Polygon indicating isolated area
25			Distribution of people	Estimated people flow	·People flow data	mesh	Stepwise display of density
26		Building	Status of residential damage	Number of structures totally/half destroyed, flooded above/below floor level	·Damage report (FDMA Form No. 4) ·Landslide, etc. — residential damage (MLIT DiMAPS) ·Real-time damage estimates (NIED SIP 5)	polygon	1: Major damage occurred (100 structures or more) 2: Damage occurred 3: No damage 4: Unknown
27			Status of non-residential damage	Number of structures totally/half destroyed, flooded above/below floor level			
						mesh	Stepwise display of the scale of damage
28		Facility	Status of government buildings	Government buildings usable or unusable Their attributes	·Damage report (FDMA Form No. 4) ·Damaged local government buildings (MIC) ·Location data of public facilities (MLIT)	point	1: Unusable 2: Damaged but usable 3: Usable 4: Unknown
29			Status of Educational facilities	Educational facilities usable or unusable Their attributes	·Damage report (FDMA Form No. 4) ·Educational facilities (MEXT)		
30			Status of facilities for social welfare	Damage status of facilities for the elderly, the disabled, and children	·Status of facilities for the elderly (MHLW) ·Status of facilities for the disabled (MHLW) ·Status of facilities for children (MHLW)		
31			Status of rivers and dam facilities	Location and details of damage on riverine/dam facilities	·Flood forecast for designated rivers - flood incidence (JMA) ·Information on river-related damage (MLIT DiMAPS) ·Information on damage to dams/weirs (MAFF)	point	Icon indicating damage location
32			Status of agricultural facilities	Location and details of damage on agricultural facilities (irrigation channel, water gate,	·Information on damage to agricultural facilities (MAFF) ·Risk of reservoir failure (MAFF SIP 4)	point	Icon indicating damage location
33			Status of industrial facilities	Location and details of damage on industrial facilities (factories, industrial complexes, etc.)	·Information on damage to industrial facilities (METI) ·Information on damage to nuclear power plants (METI)	point	Icon indicating damage location
34			Status of fuel supply	Gas stations open or closed; their attributes (name, address, etc.)	·Information on gas station availability (METI) ·Information on gas station availability (company websites)	point	1: Operation suspended 2: Open with limitation 3: Open 4: Unknown
35		Traffic	Status of roads	Information on vehicular travel bans for roads Restricted sections Restricted spots (damaged spots) Previous vehicle traffic Restriction details Causes Attributes of roads (name, section name)	·Roads (highways, national roads, prefectural roads, municipal roads, farm roads); damage information (MLIT DiMAPS; damage reports from prefectural and municipal governments; public road corporations; road operators, MAFF) ·VICS-based information on traffic congestion and restrictions (JARTIC) ·Previous road traffic (ITS Japan) ·Live cameras on roads (MLIT) ·Satellite image, aerial photo (JAXA, MLIT, aero survey companies) ·Digital Road Map (DRM) ·Hazard information (MLIT, NEXCO, local gov.)	line	1: Closed 2: Open with limitation 3: Open 4: Unknown
36			Status of railroad operation	Operation status of railroads (suspended; restricted; normal) Their attributes (line name, section)	·Railroad service information (MLIT DiMAPS) ·Railroad service information (railroad companies)	line	1: Operation suspended 2: Operated with limitation 3: Normal operation 4: Unknow
				Damage status of station buildings and rails		point	Icon indicating damage location

No	Disaster-information products			Integrated items	Main data sources (SDS items)	Feature type and legend of COP	
		Category	Title				
37			Status of bus operation	Operational status of bus and highway bus Route name Operational route	·Unavailable route (MLIT DiMAPS) ·Location of bus terminal (MLIT)	line	1: Operation suspended 2: Operated with limitation 3: Normal operation 4: Unknow
38			Status of port facilities	Port facilities availability Their attributes Operational status of water transportation	·Port/airport information (MLIT DiMAPS) ·Operational status (transportation company's websites) ·Location of port (MLIT) ·Location of airport and heliport (MLIT)	point	1: Closed 2: Restricted (emergency use only) 3: Usable 4: Unknown
39			Status of airport facilities	Airport facilities usable or unusable Their attributes Flight status			
40		Lifeline	Status of electric power supply	Number and proportion of households experiencing power outage	·Nationwide information on power outage (METI) ·Power outage information (electric power companies)	polygon	1: Service suspended (80% or more) 2: Service partially suspended 3: Service provided 4: Unknown
41			Status of gas supply	Rate of suspended supply, number of households experiencing suspended supply	·Nationwide information on gas stoppage (METI) ·Gas supply information (each gas companies)		
42			Status of water supply	Rate of suspended supply, number of households experiencing suspended supply	·Nationwide information on water stoppage (MHLW) ·Information on water stoppage (municipalities)		
43			Status of sewers	Unavailability rate, number of households experiencing service unavailability	·Information on sewers (municipalities)	polygon	1: Assistance needed (usage rate: 20% or lower) 2: Assistance needed (some parts unusable) 3: Normal 4: Unknown
44		Communications	Status of landline phone services	Connection status of landline phone service (emergency use and commercial use)	·Damage status related to landline phones (MIC) ·Damage status related to landline phones (telecom companies)	polygon	1: Disruption for both emergency and commercial use 2: Emergency communication possible; commercial communication restricted or not possible 3: Normal operation 4: Unknown
45			Status of cellular phone services	Connection status of cellular phone service (emergency use and commercial use)	·Damage status related to cellular phones (MIC) ·Damage status related to cellular phones (telecom companies)		
46			Status of Internet access	Access status of internet service	·Access status of Internet service (MIC)		
47			Status of emergency radio broadcast system	Damage of emergency radio broadcast Recovery status	·Unavailable area and recovery status (MIC)		1: Unusable 2: Partially usable 3: Usable
48		Imagery of damage	Aerial photograph and satellite image	Aerial photograph Satellite image (optical) Satellite image (SAR)	·Heli-tele image (NPA, FDMA, MLIT) ·Aerial photograph (local gov., MLIT,) ·Satellite image (JAXA)	mesh	Aerial Photograph, Satellite image
49			Fixed-point live camera image	Live camera image (roads, rivers) TV Fixed-point live camera (local gov.)	·CCTV (MLIT) ·Live camera (local gov.) ·River monitoring camera (MLIT)	point	Live camera image

No	Disaster-information products			Integrated items	Main data sources (SDS items)	Feature type and legend of COP	
		Category	Title				
50	Response	Medical care	Status of medical facilities	Status of medical facilities (hospitals, medical aid units, SCUs, etc.) Acceptance capability for patients Support needs Their attributes (name, address, etc.)	·Information on medical facilities (MHLW EMIS) ·Simulated data of medical needs (MHLW H-CRISIS) ·Damaged medical facilities (MHLW)	point	1: Patients not acceptable 2: Patients acceptable, but assistance needed 3: Patients acceptable
51		Evacuation	Evacuation advisory/order	Evacuation advisory/order issued Details of advisory/order	·Evacuation information (issuance and lifting of advisories) (MIC L Alert) ·Status of evacuation advisory/order (MLIT DiMAPS)	polygon	1: Evacuation order in effect 2: Evacuation advisory in effect 3: No evacuation order or advisory 4: Evacuation order or advisory lifted
52			Status of evacuation shelters	Opening of evacuation shelters Number of evacuees Other attributes (names of shelters, addresses, etc.)	·Information on evacuation shelters (MHLW EMIS, H-CRISIS) ·Information on evacuation shelters (municipalities) ·Location of parks (MLIT) ·Information on Hazardous area (MLIT, NIED)	point	1: Impossible to set up a shelter 2: Shelter being set up; difficult to accept new evacuees 3: Shelter being set up; possible to accept new evacuees
53		Supplies	Status of supply logistics centers	Operational status of supply logistics centers Their attributes (name, address, etc.)	·Information on provision of supplies (Cabinet Office) ·Information on provision of supplies (municipalities)	point	1: Operation difficult 2: Operation in progress; assistance needed 3: Operation in progress 4: Unknown
54			Status of requests for supplies	Requesting entities (supply logistics centers, evacuation shelters) Request details Entities receiving requests (supply logistics	·Information on provision of supplies (Cabinet Office) ·Information on provision of supplies (municipalities)	point	ago) 2: Request received 3: Request met or no request 4: Unknown
55			Status of procurement of supplies	Requesting entities Request details Entities receiving requests (supply logistics centers, disaster response headquarters, etc.) Procurement details	·Information on provision of supplies (Cabinet Office) ·Information on provision of supplies (municipalities)	point	1: No action taken yet 2: In process 3: Delivery completed 4: Unknown
56		Waste	Status of garbage collection facilities	Garbage collection facilities usable or unusable Their attributes	·Status of waste disposal (MOE)	point	1: Unusable 2: Damaged but usable 3: Usable 4: Unknown
57			Status of waste generation	Amount of waste	·Status of waste disposal (MOE)	polygon	Stepwise display of the amount of waste
58		Personnel dispatch	Medical activity	Total size of support providers (organizations, dispatched teams/units) reporting at gathering points	·Response, status of team/unit dispatch, etc. (MHLW)	point	Icon indicating a gathering point
59			NPA (wide-area emergency rescue unit)	Dispatch destination (municipality) and dispatcher Number of dispatched teams/units and personnel	·Response, status of team/unit dispatch, etc. (NPA)	polygon	1: Team(s)/unit(s) dispatched 2: No dispatch
60			FDMA (fire department emergency		·Response, status of team/unit dispatch, etc. (FDMA)		
61			MOD (Self-Defense Force)		·Response, status of team/unit dispatch, etc. (MOD)		
62			MLIT (TEC-FORCE)		·Response, status of team/unit dispatch, etc. (MLIT)		
63			Local governments		·Response, status of personnel dispatch, etc. (prefectures,		
64			Disaster relief volunteers		·Information on disaster relief volunteers (Cabinet Office)		
65		Support for livelihood recovery	Status of disaster damage certification	Result of assessments for disaster damage certification (number of assessments, breakdown of damage types)	·Status of disaster victim certification (Cabinet Office, municipalities)	polygon	1: 1,000 or more structures totally 2: 100 to 1,000 structure totally destroyed 3: Less than 100 structure totally destroyed 4: Unknown
66			Status of issuance of disaster certifications	Number of disaster certifications issued	·Status of issuance of disaster certifications (Cabinet Office, municipalities)	polygon	1: 10,000 or more certificates 2: 1,000 to 10,000 certificates 3: Less than 1,000 certificates 4: Unknown
67			Supply of temporary housing	Supply rate, number of housing units provided (built structures, rented units treated as temporary housing units)	·Supply of temporary housing (Cabinet Office, municipalities)	polygon	1: No supply (20% or less) 2: Supply in progress 3: Supply completed 4: Unknown or supply not needed

correctly.

As we have mentioned in the previous section, the NISC is publishing sixteen EEIs for disaster and emergency response. While the Japanese government currently does not have an information framework like the EEI, we suppose that we can provide almost the same quality of information products using the SDIP. Since the current SDIP is just a draft, it should be examined by various stakeholders. We plan to propose the draft SDIP to the working group hosted by the Cabinet Office and discuss disaster-information sharing.

6. Common Operational Picture

The term, COP, is usually used in the military sense. COP is also known as a sort of tactical map that is used

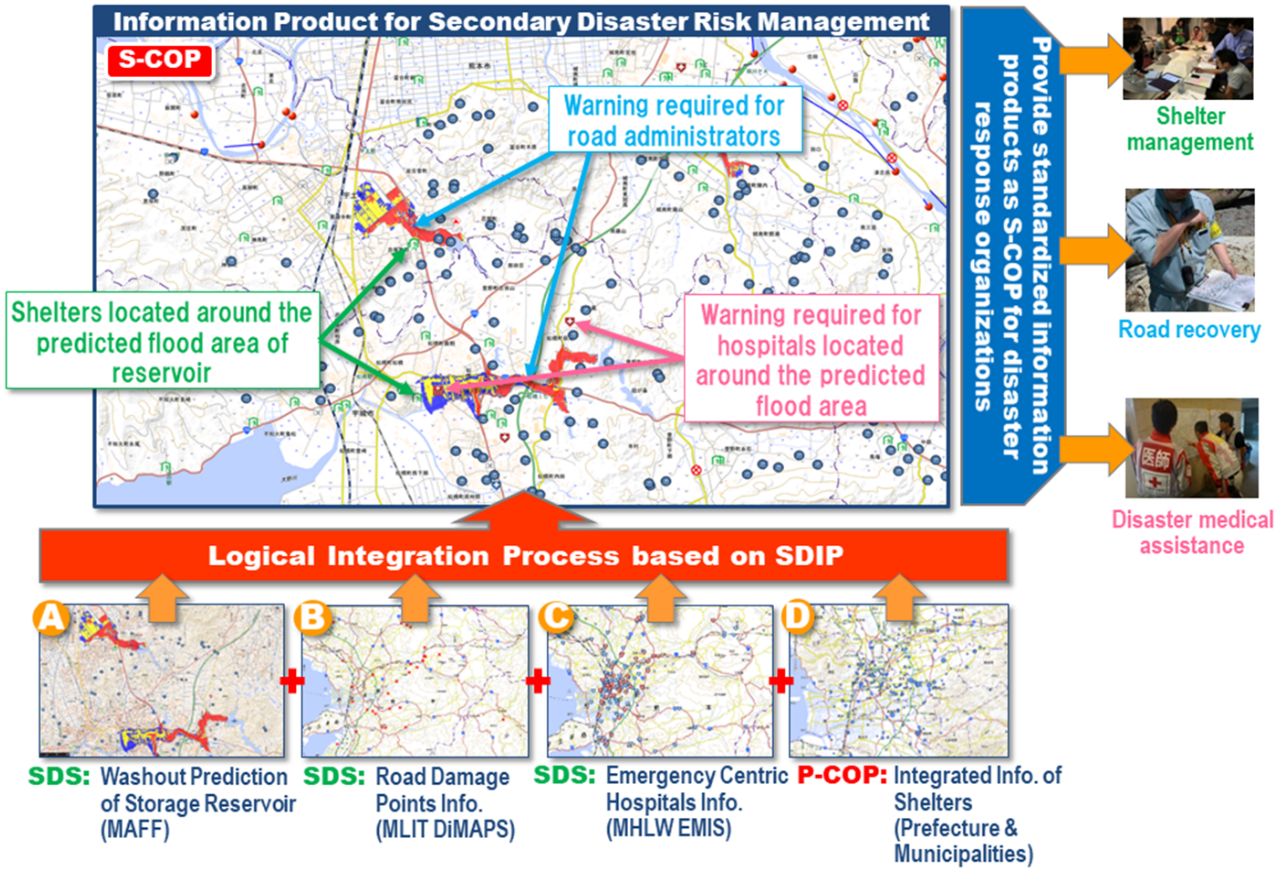

Fig. 4. Conceptual image of an information product as a service of S-COP based on SDIP.

for sharing an overview of a battlefield. On the other hand, in the field of disaster management, it means the set of information products (including maps) that is used to constitute the common recognition of the disaster situation between the disaster response entities [11]. At the time of disaster, maps are doubtlessly important information products, but there are many other types of information, such as tables, photos, movies, and chronologies, that are also important to the management of disaster response activities. COP is a concept that includes all of these necessary information products to be shared between various disaster response entities.

We have discussed SDIP in the previous section, and according to that, the COP is constituted from the SDIP. However, it is not feasible to cover all disaster-response activities with only one COP. We suppose that the COP principally should be constituted from such essential information products as passable road information, shelter information, and medical facilities information, which might be used to recognize the disaster situation by most disaster response organizations. We call this category of COP the “Primary COP” (P-COP). Additionally, particular groups of response organizations need the specific set of SDIP to sharing information that is required for professional purposes. For example, in the field of emergency medicine, such dispatched teams as DMAT, the Disaster Psychiatric Assistance Team (DPAT), the Japan Medical Association Team (JMAT), and the Disaster Health Emergency Assistance Team (DHEAT) must necessarily share information regarding the physical status of medical facilities, capacities of the core hospitals of disaster medicine, passable roots to Stage Care Units (SCUs), and locations of shelters. This information should be combined with the Primary COP to share common recognition of the general situation with other response organization groups. We call this category of COP the “Specific COP” (S-COP).

The P-COP set can be standardized across most disaster responses. On the other hand, the S-COP set might vary with the type of disaster and the purposes of the emergency response activities. If we create S-COPs responding to each activity, the number of S-COPs can become huge. Therefore, it is necessary to organize S-COPs according to some sort of disaster response information structure, such as SDIP.

We provided a COP for road status and for shelter status at the on-site disaster management headquarters in Kumamoto prefecture. **Fig. 4** shows the typical COP building process based on the SDIP concepts. In addition, we provided many S-COPs on the demands of the CAO, DMAT, DPAT, mobile-phone carrier companies, NGOs, and municipality’s offices. We created each COP by hand, which might easily cause a shortage of resources. If we consider the disaster response for such great disasters as the Nankai Trough Earthquake, it is necessary to prepare disaster-information systems that are capable of handling SDIP and COP.

7. Conclusion and Further Discussion

At the beginning of this paper, we mentioned that it is important to discuss the essential concept of information sharing prior to talking about the functions of information systems. We have discussed the SDS, SDIP, and COP, which are essential elements of accomplishing the purpose of information sharing. Now we are prepared to consider the design of disaster information systems. Since there are few spaces in which to mention this theme, we would like to point out only the issues with designing a disaster information system.

We suppose that the primary requirement of a disaster information system is that it provide useful disaster information, such as the SDIP and COP, to disaster response sites without carrying out unnecessary tasks. From the viewpoint of information technology, interoperability and a cloud-based system are necessary technologies in accomplishing this goal [19]. On the other hand, from the viewpoint of feasibility, the important point is that the value of the information is worth paying the cost (time and manpower). Additionally, the cost of obtaining the information must be equivalent or lower than other ways of doing so. Disaster response people want to get useful information on how to manage shelters, where to dispatch the DMAT, and which roads are passable, not on how to use information systems.

Therefore, there are two essential approaches that satisfy the primary requirements, as follows:

A) Improve the value of information
B) Reduce the cost of obtaining valuable (useful) information

Both the SDIP and COP belong to approach A. As we have discussed above, we need disaster information systems capable of handling a large amount of information at the time of a great disaster. Thus, the design of a disaster information system using approach B is a critical path to a truly useful disaster management system. It must be designed not from the supply side but from the viewpoint of the user who is responsible for disaster management. Our research on this issue is ongoing, and further discussion will be taken up in future papers.

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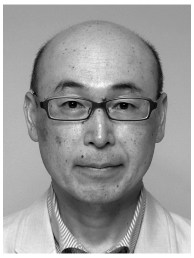

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- Society for Risk Analysis, Japan (SRA-Japan)
- Geographic Information System Association of Japan (GISA)
- Japan Society for Disaster Information Studies (JASDIS)