Paper:

Development of Science-Based Decision Support System for Evaluating the Safety of Evacuation Facilities in Case of Torrential Rains

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Torrential rains have been increasing in frequency. There have been instances in which residents were caught up on their way to evacuation shelters. It is important to check on hazards caused by conditions, on the adequacy of evacuation facilities, and on water levels and weather advisories. When taking appropriate action in torrential rains, it is necessary to assess weather and water information based on the preliminary survey of evacuation. To improve the quality of decision making, a science-based procedure should utilized by public agencies to judge the situation. We propose a procedure manual and web-based system for take appropriate action as disaster response.

Keywords: heuristics, torrential rain, science-based procedure, procedure manual, web-based system

1. Introduction

Torrential rains have been on the increase, as evidenced by the fact that the frequency of observed rainfall of 50 mm or 80 mm per hour has gone up [1]. Torrential rains have caused damage almost every year, and prompt judgment and decision making are required because such damage occurs in relatively limited areas and situations proceed in a short period of time. Administrative agencies issue evacuation information to the public when damage is assumed. During typhoon No.9 in 2009 and the torrential rains in Niigata in 2004, some people were affected by the heavy rainfall as they evacuated on foot [2, 3]. In addition, in the case of the typhoon No.12 in 2011, evacuation facilities were damaged [4], making appropriate evacuation an issue. In response, the Committee on Disaster Evacuation established in the Central Disaster Management Council carried out a study between 2010 and 2012. It was reported that people deemed "evacuation" as meaning "movement to shelters"; thus shelters for emergency evacuation and those for temporary livelihood should be identified and separated [2]. This report led to the Disaster Countermeasures Basic Act amended in 2013, which stipulated evacuation actions such as indoor refuge taking depending on situations and defined evacuation sites ("designated emergency evacuation site" in the Act) [5], and shelters ("designated shelter" in the Act) [6]. However, existing designated shelters are assumed to be used for temporary livelihood in many cases, so whether they are appropriate as evacuation sites should be checked.

It is important during heavy rainfall for residents to obtain reliable information, judge based on scientific findings and procedures, and determine appropriate evacuation actions. Similarly, administrative agencies should select appropriate responses. However, the usage of disaster-related information, such as rainfall amount, water level, and sediment disaster warning information, requires technical knowledge, making the information difficult for most residents to use effectively. In addition, time is of the essence during torrential rains, and proper judgments must be made based on minimal information. The use of heuristics is therefore considered effective. Heuristic is a simple procedure that helps find adequate, though often, imperfect answers to difficult questions that are used in individual daily lives [7]. However, judgment process models of heuristics have not been sufficiently addressed. The authors believe such models can be created effectively using the findings of administrative agencies because they judge responses to fronts and typhoons every year and use scientific findings for these judgments.

For the purpose of evacuating residents appropriately, it is necessary and the responsibility of administration to prepare evacuation judgment processes, arrange evacuation methods, and check evacuation facilities to allow administrative agencies to issue evacuation information, and it is the responsibility of residents to select appropriate evacuation actions. Therefore, targeting torrential rains, this research considers establishing standard processes and tools for integrated evaluation that focuses on evacuation facilities. This is to check evacuation facilities for appropriate evacuation and judge rainfall situations as well as to judge responses, such as appropriate evacuation procedures. These processes place the highest priority on improving the response capacity of administrative agencies and also improve self- and mutual-assistance of residents by making the concept understood.

2. Evacuation Concept and Necessity of Checking Evacuation Facilities Based on Scientific Findings

2.1. Definition of Evacuation Concept

Evacuation has been often understood as movements to public facilities such as the gymnasiums of primary or junior high schools [2], and many cases in which people have been injured during their movements to such facilities have been reported. The Disaster Countermeasures Basic Act was therefore amended in June 2013, and evacuation actions were defined as follows: 1) movements to designated evacuation sites, 2) movements to safe places, 3) movements to nearby high buildings, and 4) refuge in safe places in buildings [8]. Each individual should properly select from among these actions, depending on situations during disasters.

2.2. Necessity of Checking Evacuation Sites Related to Evacuation Facilities

The selecting of evacuation sites is a vital part of evacuation action in terms of protecting lives, but many problems have arisen because municipalities generally consider evacuation sites as shelters. During the heavy rainfall brought by typhoon No.12 in September 2011, 50 shelters were submerged or half destroyed in Wakayama Prefecture [4]. Also, according to Ushiyama et al. (2006), during heavy rainfall in July 2006, sediment and driftwood flowed into a primary school designated as a shelter in the city of Okaya, Nagano Prefecture [9]. These are examples of improper shelters designated as evacuation sites.

After the amendment of the Disaster Countermeasure Basic Act in June 2013, evacuation sites for emergency evacuation in urgent situations and shelters for temporary livelihood for a certain period of time were made distinct [6]. Evacuation sites are required to have safe places and structures against hazards, while shelters should be appropriate for accommodating evacuees and transporting supplies [10]. Emergency evacuation sites have possibly been regarded as shelters, so facilities designated as shelters should be checked to make sure that they satisfy the requirements for evacuation sites. In order to confirm safety against hazards, the use of scientific findings such as hazard maps and the classification of sediment disaster risk areas is needed.

3. Check Procedure Manual for Evaluating Shelters

3.1. Use of Fast and Frugal Heuristics

Gerd Gigerenzer (1999) stated that human beings have limited rationality because there are limitations to their

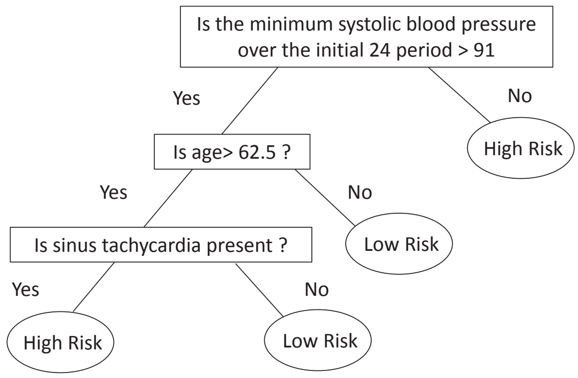

Fig. 1. A simple decision tree for classifying incoming heart attack victims as high-risk or low-risk patients.

information processing capacity and knowledge usage. Labor and time can be saved by using Fast and Frugal Heuristics (FFH), a method of prompt and simplified information processing [11]. FFH seems to correspond to "standard tactics" based on little information. **Fig. 1** is an example of FFH for emergency physicians to the judge the risks to patients who have suffered heart attacks.

In activities with limited time, such as responses to torrential rains, FFH judgment procedures are considered to be effective. This paper therefore elaborates on the judgment procedures of FFH to create a highly practical procedure manual.

3.2. Requirements of a Procedure Manual for Checking Shelters

It is desirable to formulate an evacuation judgment model as a procedure manual included in disaster response manuals. In addition, since administrative agencies accumulate experiences of judging disaster situations in their regular business, the use of such experiences is considered effective. Findings obtained from experiences of administrative agencies are listed in guidelines regarding judgments in terms of evacuation advisories or similar. This paper utilizes these findings and establishes a judgment model by adding checklist items and necessary information to create a procedure manual for checking shelters, one that allows residents and administrative agencies to make judgments. For the abovementioned reasons, the judgment procedures of administrative agencies are studied as a model.

Yamada et al. (2008) pointed out the following three factors as reasons for inadequate disaster response manuals. 1) The descriptions in manuals differ from writer to writer, and necessary information is sometimes missing. 2) Most writers lack disaster experience and cannot create manuals based on their experience since disasters rarely occur. As a result, manuals are based on cases of affected areas and do not correspond to the organization structures and climate of the relevant region 3) It is difficult to create detailed manuals under clear rules because disasters are highly uncertain and depend on regional characteristics and individuality [12]. Furthermore, Hayashi et al.

(2005) clarified in the study the cause of human injury during the flood in Niigata in July 2004 and stated that the when a model for information transmission concerning wind and flood damage as well as evacuation support for people requiring assistance during a disaster is being established, the following five points should be investigated to mitigate damage: i) assume indoor refuge as an evacuation method, ii) include in the disaster prevention system helpers who support the evacuation of those who require nursing care, iii) set the self-determination of appropriate evacuation actions as a disaster prevention goal, iv) set numerical criteria for issuing evacuation advisories and directives so that municipal personnel can easily make judgments, v) make arrangements for the observation of rainfall and of water levels of small- medium-sized rivers over their basins [3].

As this paper studies judgment procedures, we believe that a) the check procedure manual should be standard and allow for a certain judgment without technical knowledge from 1) and iv). In addition, b) check procedure manual should include items to be considered and information to be referred to be based on past experiences and is also necessary from guidelines and 2). Based on iii), c) check procedure manual should be available to different actors such that residents can learn evacuation judgment procedures was established. Assuming usage as FFH, d) check procedure manual should be easily understood logically and visually is prerequisite. These items are described below.

a) Check procedure manual should be standard and allow for a certain judgment without technical knowledge

The issuing of evacuation information is a major municipal activity during heavy rainfall. Higashida et al. (2004) pointed out that the issuing of evacuation advisories has been left to the judgment of municipal personnel and based on situations and experiences. Higashida et al. (2004) also pointed out that municipalities issued evacuation advisories at different times, and some did not issue any at all during the heavy rainfall in Tokai in September 2000 [13]. Not all personnel have a lot of experience and knowledge, and chief executives may be unavailable. In addition, "disaster information literacy" is required for effectively utilizing information provided by disaster related agencies, such as the Japan Meteorological Agency (JMA). This indicates the effectiveness of a system for judging when to issue evacuation information by collecting information following predetermined procedures and making judgments based on the results.

b) Check procedure manual should include items to be considered and information to be referred and should be based on experiences.

Items to be considered should include standard procedures among reliable, useful items in the abovementioned guidelines, and it is important to judge based on issued warnings and comparisons of observed and reference values of rainfall amounts and water levels. Past responses and disaster experiences should be utilized because disaster responses are to be based on the characteristics of the relevant region. An understanding of past damage and situations in the relevant region can be used for judgments.

c) Check procedure manual should be available to different actors such that residents can learn evacuation judgment procedures.

Administrative personnel can quickly make judgments and improve their skills by learning model procedures making evacuation judgments. As judgment procedures are the same among residents, it is assumed that residents can take prompt evacuation actions before evacuation information is issued by administrative agencies by learning the concept of judgment. In particular, in heavy rainfall in which situations change rapidly, appropriate safety activities may not be performed after the issuance of evacuation advisories or similar by administrative agencies. As Hayashi et al. (2005) put forth, therefore, it is important for residents to determine appropriate evacuation actions by themselves [3]. A procedure manual should also be useful for actors other than administrative agencies.

d) Check procedure manual should be easily understood logically and visually

Information design should also be investigated because operation is likely to be improper if manuals and procedures are difficult to understand when multiple pieces of information are referred to and multiple judgments are combined. According to Kimura (2012), the following five elements should be considered in infographics: 1) attractive: attract viewers, 2) flow: follow the flow of eyes, 3) clear: clarify intended information, 4) simple: simplify and focus on required information, 5) wordless: make understood without words [14]. These elements are effective when adopted to each component, arrangement, and relationship of procedure manuals. Donald A. Norman (2002) described design principles for making difficult tasks easier: 1) use both knowledge in the world and in the head, 2) simplify the structure of tasks, 3) make things visible: bridge the gulfs of Execution and Evaluation, 4) get the mapping right, 5) exploit the power of constraints, both natural and artificial, 6) design for error, and 7) when all else fails, standardize [15]. This study considers these points. Simplifying the flow and clarifying relationships are especially important in this procedure manual, and this accord with heuristics construction.

4. Checklist Items and Flow of Procedure Manual for Shelters

4.1. Information for Guidelines or Similar Regarding Evacuation Judgment

The work "Guidelines for Producing a Decision and Dissemination Manual for Evacuation Advisories and Orders" [16], promulgated in March 2005, details proce-

Table 1. Information to be considered (Guidelines for Producing a Decision and Dissemination Manual for Evacuation Advisories and Orders (March 2005) and the Report of the Research Committee for Evacuation during Heavy Rainfall).

Item	Wind and flood disasters	Sediment disasters
Organization of elements for judging evacuation advisories and similar, etc.	• Information on past inundations Inundation charts, photos of flood scenes, water levels and climate during previous floods, hydraulic data • Information on assumed inundations Assumed inundation distribution, landform classification map for flood control, simulation results for flooded lands and waterways • Information on the maintenance of river management facilities Discharge capacity chart, important flood prevention locations, levee maintenance, drainage pump stations and water gates • Information on risks of human injury Arrival time and flow speed of floodwaters, water depth resulting in severe flooding and possible collapse of housing	• Information on past sediment disasters Sediment disaster distribution and damage, climate data • Information on assumed sediment disasters Sediment disaster caution distribution, sediment disaster risk distribution, maintenance regions • Information on maintenance of sediment control facilities Maintenance map for sediment control levees, facilities for preventing the collapse of steep slopes, and landslide control facilities
Organization of judgment criteria for issuing evacuation advisories or similar	• Weather warnings, weather advisories, weather information, typhoon information • AMEDAS, short-term precipitation forecasts, precipitation nowcasts, water levels and flood forecasts for specific rivers • Maintenance of river management facilities • Past inundation map, assumed inundation map, hazard map • Information on current and predicted water levels • Information on current and predicted water levels • Information on small- and medium-sized rivers, inland waterways, inundations • Information on pump operation, levee deformation, inundation, information from water fighters, damage of upstream municipalities.	• Weather warnings, weather advisories, weather information, typhoon information • AMEDAS, short-term precipitation forecasts, precipitation nowcasts • Sediment disaster information (sediment disaster caution mesh information) • Information on current and predicted water levels • Information on neighboring sign phenomena • Information on sediment control facilities • Past sediment disaster maps, assumed sediment disaster maps, hazard maps • Information from patrolmen and residents, and sediment disaster monitoring devices

dures for creating manuals regarding the evacuation judgments of municipalities. This guideline advises municipalities to prepare manuals for 1) target disasters, regions, and places at risk, 2) areas to evacuate, 3) judgment criteria and concepts for issuing evacuation advisories and similar, and 4) transmission methods for evacuation advisories and similar. However, short-term, heavy rainfall is not assumed, and the flow of evacuation judgment is not exemplified. These disadvantages were investigated in the "Research Committee for Evacuation during Heavy Rainfall." In the report released in March 2010, checklists and flowcharts related to the issuance of evacuation information in standard procedures were exemplified [17]. The checklists organize 1) elements for judging evacuation advisories and similar as well as 2) judgment criteria for issuing evacuation advisories or similar. The flowcharts contain the following: 1) confirm the possibility of disaster occurrence, 2) collect information for judging the necessity of evacuation, 3) judge the necessity of issuing evacuation preparation information, 4) prepare the issuance of evacuation preparation information, and 5) announce the evacuation information. In addition, items to be considered when establishing manuals for evacuation judgment are shown, as listed in **Table 1** [16, 17].

These guidelines were amended in April 2014, based on amended laws, system changes, and lessons from disasters such as the Great East Japan Earthquake. They were then published as the "Guidelines for Producing a Decision and Dissemination Manual for Evacuation Advisories and Orders" [7]. The main purpose of this amendment was to indicate specific disaster prevention weather information that could be used for municipalities in judg-

Table 2. Major information for judgment of the disaster prevention system and evacuation advisories and similar (Guidelines for Producing a Decision and Dissemination Manual for Evacuation Advisories and Orders (September 2014)).

Weather information, advisories, warnings, emergency warnings		
	Weather information	Typhoon information
		Prefectural weather information
		Record short-term heavy rainfall information
	Weather advisories, warnings, emergency warnings	Advisories (heavy rainfall, flooding, strong winds, waves, storm surge)
		Warnings (heavy rainfall, flooding, storms, waves, storm surge)
		Emergency warnings (heavy rainfall, storms, waves, storm, wave, storm surge)
Rainfall information		
	Point rainfall	AMeDAS
		Telemeter rainfall
		Real-time rainfall
	Basin rainfall	Average basin rainfall
	Area rainfall	Radar and rainfall nowcast
		Radar rainfall
		X-band polarimetric (multi parameter) RAdar Information Network rainfall information
		Real-time radar
		Analyzed rainfall
		Short-term predicted rainfall
Water level information		
		Telemeter water level
		Predicted water level
Water disaster information		
		Predicted flooding in specific rivers
		Water level arrival information
		Rainfall index for basins
		Standardized basin rainfall index
Sediment disaster information		
		Sediment disaster caution mesh information
		Detailed information on sediment disaster risks provided by prefectures
		Sediment disaster caution information

ing when to evacuate. **Table 2** presents major information related to the judgment of the response system and evacuation advisories, etc.

As these guidelines utilize scientific findings based on disaster occurrence and investigation, this study discusses procedures based on scientific findings. The flowcharts included in these guidelines are schematic, so more specific information and procedures are required. The information in these guidelines should be divided into that referred to before and during rainfall, and we check important information based on the concept of FFH.

4.2. Checklist Items for Evacuation Sites

The following items are checked beforehand, referring to guidelines to evaluate evacuation facilities. Those items must be easy to understand and use comparisons of values as much as possible.

a) Basic Shelter Information

Basic information, such as name, address, structure, number of target evacuation households, and people requiring assistance, should be provided because users can understand shelters as "houses" or similar, and voluntary disaster prevention organizations and residents other than administrative agencies can also utilize these procedures.

b) The Maximum Disaster Observation Values (Extreme Values)

It is important to understand the maximum observation values (extreme values) from past disaster records at the relevant point. If rainfall above the extreme values is observed, risks of unprecedented situations are high. The comparison between the extreme values and observed values serves as a basis for judgment. For example, during the torrential rainfall in Tokai in September 2000, daily rainfall amounts set records, and hourly rates equaled past maximum values [18]. Typhoon No.23 in 2004 set new highs for rainfall per hour and per 24-hour period, at one and thirty points, respectively [19].

c) Criteria using Rainfall, Water Levels, and Soil Rainfall Index

The vulnerability of the relevant area can be determined by researching reference values for amounts of rainfall, water levels, and the soil rainfall index predetermined for weather warnings, etc. and identifying observation values at danger levels. Reference values are determined based on scientific findings and damage situations, and they are compared to observation values during periods of heavy rainfall.

d) Damage Assumption and Facilities that may be Affected

The vulnerability of the relevant area and risks to shelters are studied by checking sediment disaster caution zones and assumed inundation damage using the inundation hazard map. If inundation is assumed, whether or not basements are flooded and whether refuge to upper floors is possible should be considered depending on the depth of inundation. The possibility of inundation damage to shelter facilities should also be investigated.

4.3. Checklist Items During Rainfall

Because weather conditions and water levels vary from hour to hour during periods of heavy rainfall, appropriate actions should be taken by collecting information and judging situations. Dynamic information such as announced advisories and warnings as well as rainfall and water levels is checked during periods of rainfall. In addition, sediment disaster caution information and sediment disaster caution levels (unique to Kyoto Prefecture) are announced for the purpose of providing information on which to judge disaster risk (urgency). The sewage system has been constructed assuming rainfall per hour of 50 mm [20], but various disasters may incur precipitation above that value [21]. Thus, 50 mm of rainfall per hour is the caution value for the flooding of inland. The reaching of flooding risk water levels in large rivers can also be used as a basis for when to respond.

4.4. Response Criteria

During periods of rainfall, risks are judged depending on observed rainfall and water levels. In order to make prompt responses, reference observation values should be determined for response actions based on facility characteristics and rainfall criteria. Administrative agencies issue evacuation information and set up shelters. From the viewpoints of evacuation actions to shelters and the effectiveness of response activities, it is appropriate to review response criteria for each evacuation area. Residents are required to select from among four defined evacuation actions, depending on the conditions of houses and evacuation facilities. These settings should incorporate past responses and evacuations and the time required for evacuation responses.

Appropriate evacuations can be performed by confirming evacuation sites before and during periods of rainfall and then selecting actions that correspond to response criteria.

4.5. Examination Flow for Check Procedure Manuals of Shelters

a) Examination Procedures

All items are connected using arrows to examine check procedures based on relationships. The arrows are followed from top to bottom, and blanks are filled or checked. The procedure manual uses A3 paper.

b) Title, Frame Color, and Arrangement of each Element

Sediment disasters and inundation disasters are assumed during periods of torrential rainfall, and items are checked before and during periods of rainfall. As different title colors (sediment disaster: orange, flood disaster: light blue) and frame colors (checked beforehand: green, checked during rainfall: yellow) are used, the characteristics of each item are easily understood. Each item is arranged so that examination processes are easily understood when viewed.

c) Information Sources

Assuming various users, including municipal personnel responsible for disasters, the sheet contains the website addresses of information sources.

Figure 2 shows a check procedure manual created for shelters.

5. Evaluation of Procedure Manual for Checking Shelters

This procedure manual was evaluated in the retrospective workshop held on September 11, 2014. The workshop was on typhoon No.18, which struck in 2014. This workshop was held as a part of the Kyoto disaster prevention lectures, and a lecture on torrential rain (characteristics of recent torrential rains and their countermeasures) was given on the morning of the same day. This workshop called for participants from municipal personnel for disaster prevention and members of voluntary disaster prevention organizations in the disaster prevention divisions of municipalities in Kyoto, and a total of 35 (6 municipal personnel from 6 municipalities and 29 members of voluntary organizations) participated. Participants collected information using PCs following the workflow put forth in the procedure manual, and then they evaluated the procedure manual, listing its advantages and disadvantages. A questionnaire survey was also performed afterward to evaluate the manual, and 72 comments were obtained.

The comments obtained were structured using the KJ method. This method, introduced by Jiro Kawakida, clarifies the structure of collected information and processes qualitative information from the bottom up [22]. This method includes the following procedures: 1) arrange all comment cards and read them, 2) give groups of similar cards a heading and repeat grouping to make a larger group, 3) consider the spatial arrangements of groups and their relationships, and 4) schematize the relationships of

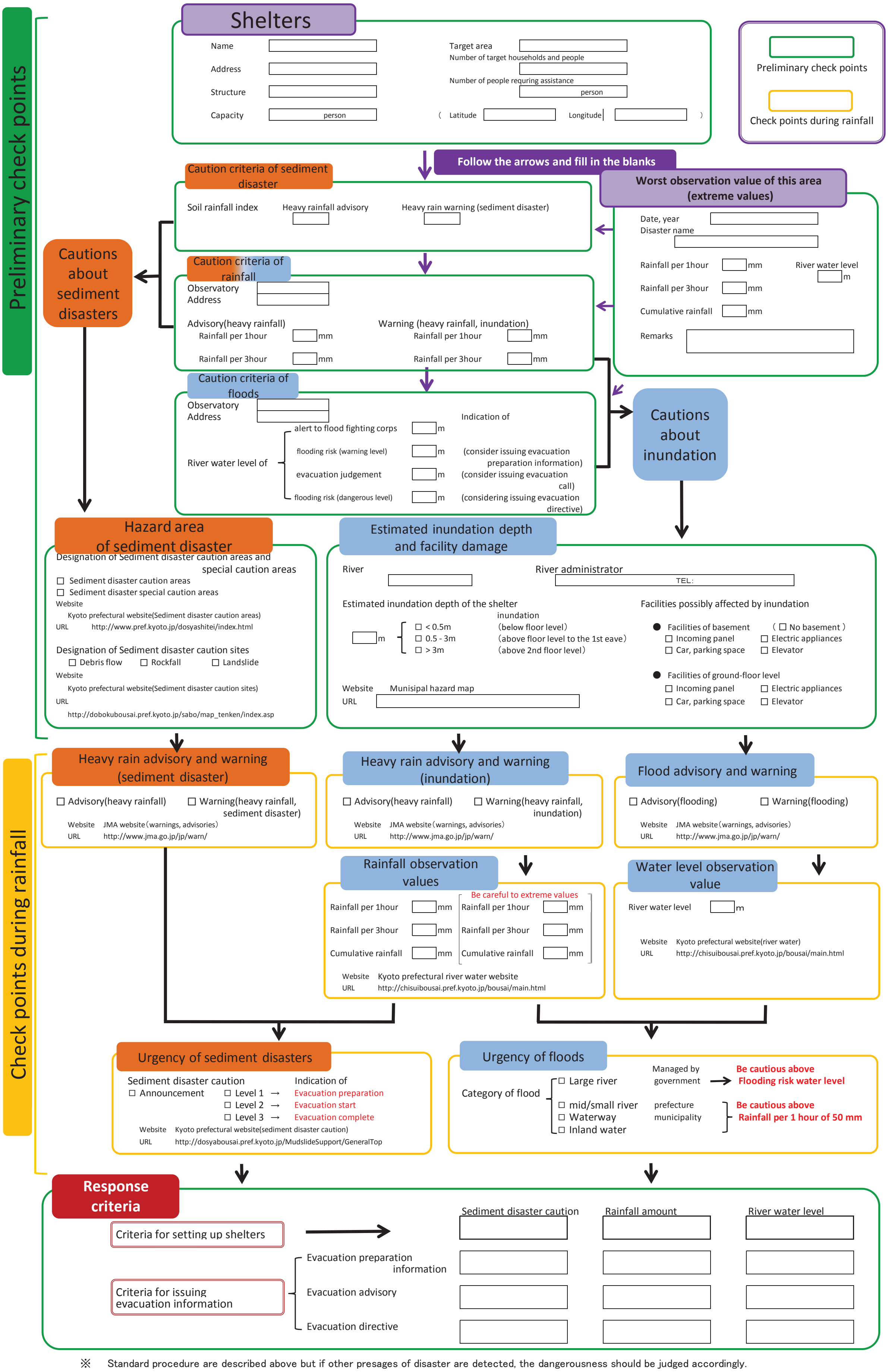

Fig. 2. Procedure manual for checking shelters.

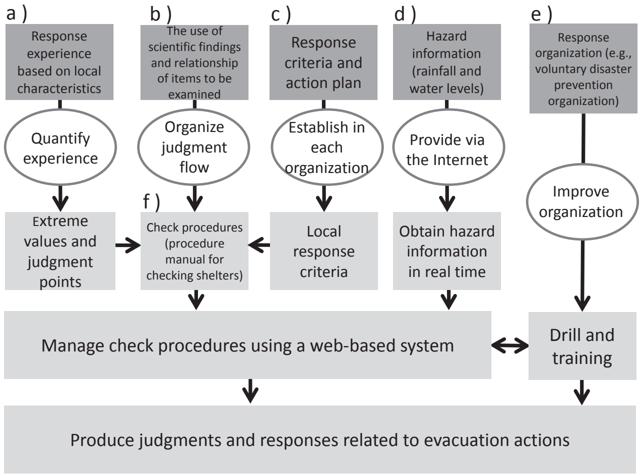

Fig. 3. Evaluation results for the procedure manual for checking shelters.

groups [23]. This method proved useful in the collecting and analyzing of comments for the purpose of evaluating the procedure manual.

Figure 3 shows the structure, obtained using the KJ method, of the evaluations of the procedure manual for checking shelters.

a) Response Experience based on Local Characteristics

Observed rainfall and water level values are useful for comparisons during heavy rainfall. It is also necessary to quantify response experience based on local characteristics into extreme values and judgment points and to incorporate them in the procedure manual.

b) The Use of Scientific Findings and Relationship of Items to be Examined

Objective judgment procedures using reference and observed values are reasonable, and an overall picture of the examination can be obtained using the procedure manual. However, the manual includes many items and small blanks, so it is desirable to promote labor-saving by using a web-based system.

c) Response Criteria and Action Plan

Response organizations can begin work on their own before obtaining information from administrative agencies if response criteria are prepared beforehand. Response criteria should be established based on discussions with administrative agencies and local residents. Response criteria with the least examination are preferable.

d) Hazard Information (Rainfall and Water Levels)

Hazard information is available on the web in real time during rainfall. However, local disaster response organizations mainly consist of elderly citizens not skilled at obtaining information on the web. It is therefore preferable to make information collection less labor intensive.

e) Response Organizations, e.g., Voluntary Disaster Prevention Organizations

It is important to improve organizations through training and workshops because organization systems are insufficient and the judgments made by members using the procedure manuals are not sure.

f) The Use of the Procedure Manual

The procedure manual aids in the understanding of current situations and issues of shelters and the relevant area as well as in the performance of preliminary countermeasures and the making of judgments during disasters.

a) and c) are included in check procedures, and a)–d) lead to the conclusion of using a web-based system in the structure of evaluation. Considering the above, the evaluation comments show that the procedure manual should be managed using a web-based system and that judgments and responses related to evacuation actions should be improved through training and workshops in settings such as voluntary disaster prevention organizations. Judgment procedures were understood for the most part, but respondents desired more simplified procedures because there were so many items. Some pointed out that the efforts of response organizations were required for the linking of judgments and responses, and the authors wish to address this issue in the future.

6. Development of Check Procedure System for Facilities (Shelters)

6.1. Management in a Web-Based System for Check Procedures

A "Check procedure system for facilities (shelters)" (hereinafter referred to as "system") on the web was created because the procedure evaluation led to a web-based system for collecting hazard information in real time. The system confirms rainfall and water levels around each facility during rainfall, and the levels are compared to predetermined caution criteria. It can draw and display observed rainfall values from related websites, saving the labor it would take to check. Related information such as hazard maps can be viewed from linked websites. Registered facility information and reference values, along with observed values, can be checked in the event of an emergency, integrating the management of reference and observed values.

6.2. System Configuration and System Usage Flow

Figure 4 shows the system configuration. A database is created by inputting user and facility information, including the facility, extreme and reference values, observation stations for rainfall and water levels, and responses in case of disaster. Master information, such as information on observation stations for rainfall and water levels and shelter facilities, is available in the database. Information on

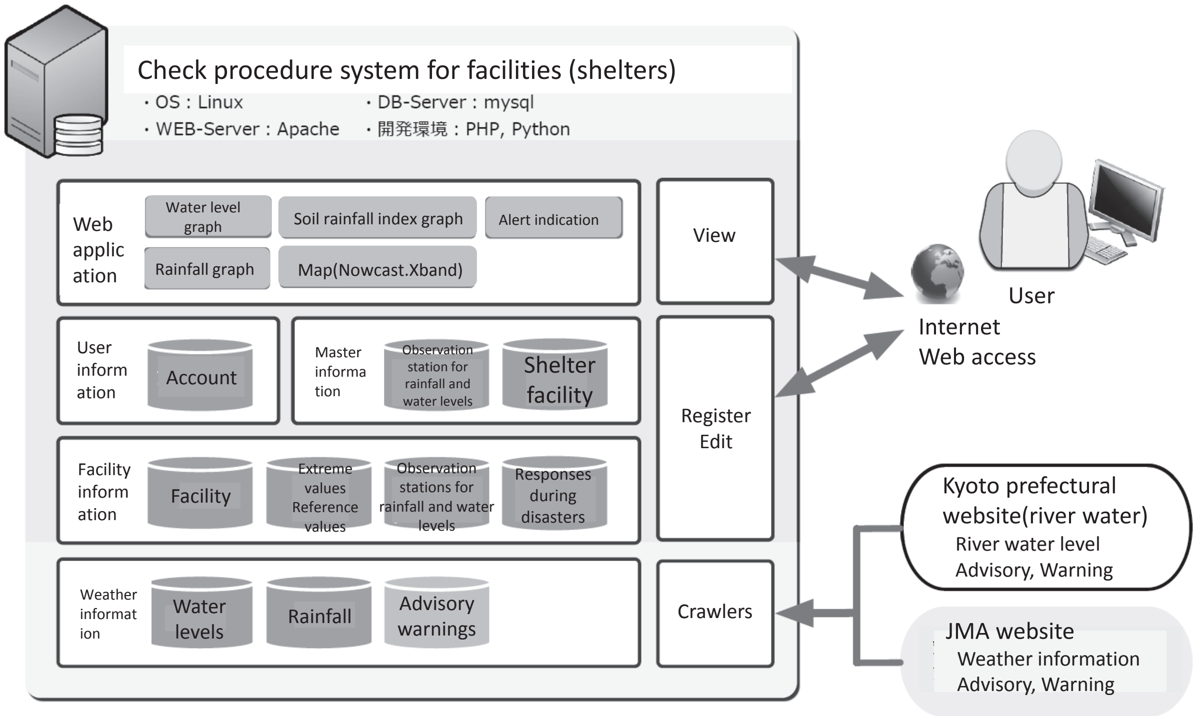

Fig. 4. Check procedure system for facilities (shelters).

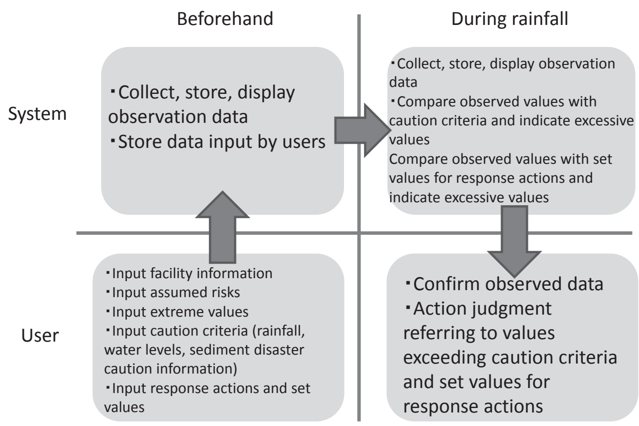

Fig. 5. Outline of system usage.

rainfall and water levels is obtained from the website for Kyoto river information and processed using a web application to output water level, rainfall, and soil rainfall index graphs as well as alerts based on registered action criteria. In addition, X band MP radar rainfall information, rainfall nowcasts, sediment disaster caution mesh information are obtained from the website of the Japanese Meteorological Agency (JMA) of the Ministry of Land, Infrastructure, Transport, and Tourism, and processed and displayed using a web application.

Figure 5 is an outline of system usage. Users resister facility information, risks assumed based on hazard maps, extreme values, caution criteria, response activities, and set values with the system beforehand. The system stores input information and collects observation data. During rainfall, the system indicates observation data and comparison results along with registered caution criteria and set values for response actions. Users determine actions based on information from the system, such as changes in observed values and observed values exceeding reference values, which exceed set values for response actions.

Figure 6 shows the examination flow. The degrees of freedom of item size and arrangement were increased by shifting from a paper manual to the web-based system. At that time, items were arranged from small to large in the order of facility information, hazard maps as surrounding land shape information, high-risk areas for sediment disasters, extreme values, water level criteria related to larger areas, and rainfall and soil rainfall index criteria in municipalities. Map-based information, such as radar information, was added to the monitoring by virtue of its easy information access. Examination starts with the registration of shelter information, followed by river, rainfall, and sediment disasters. Information on geography and geology, the observed worst disaster values, caution criteria, and response criteria are input in that order, and rainfall is monitored using related websites. The system requires a web browser, such as Internet Explorer.

Main pages of the system are the new registration page for facilities (shelters) (**Fig. 7**) and the top page indicating rainfall and similar information (**Fig. 12**). If users log in from the initial login screen, they can check information on registered facilities. The system can be used following instructions on the facility information registration page (**Fig. 7**), instructions based on the examination flow. Input screens appear when users select the buttons for each item. The colors of the buttons change sequentially, and only colored buttons can be selected. **Fig. 7** shows the screen when information related to extreme values is in-

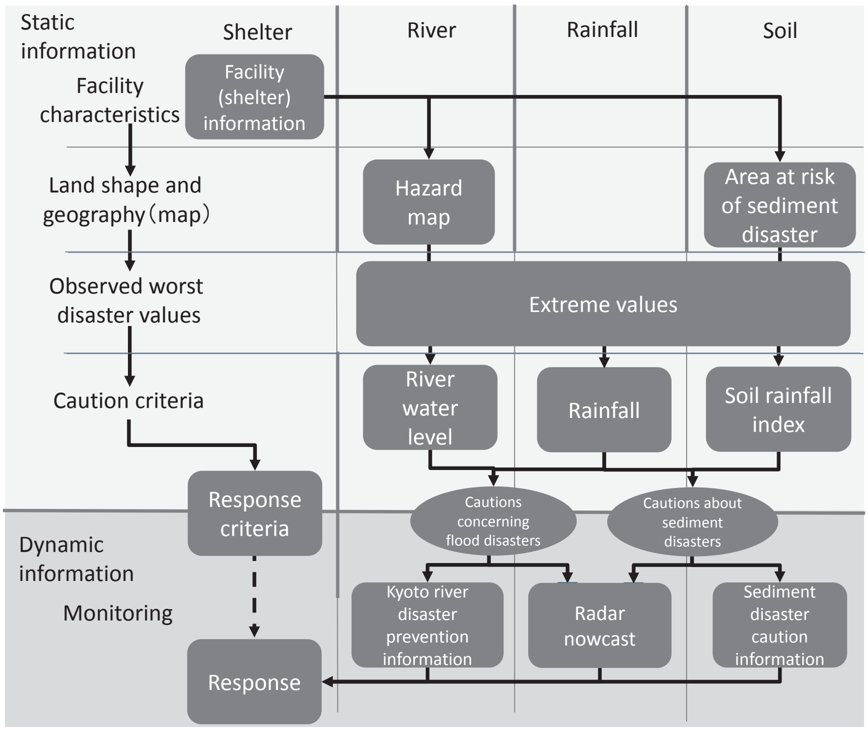

Fig. 6. System examination flow.

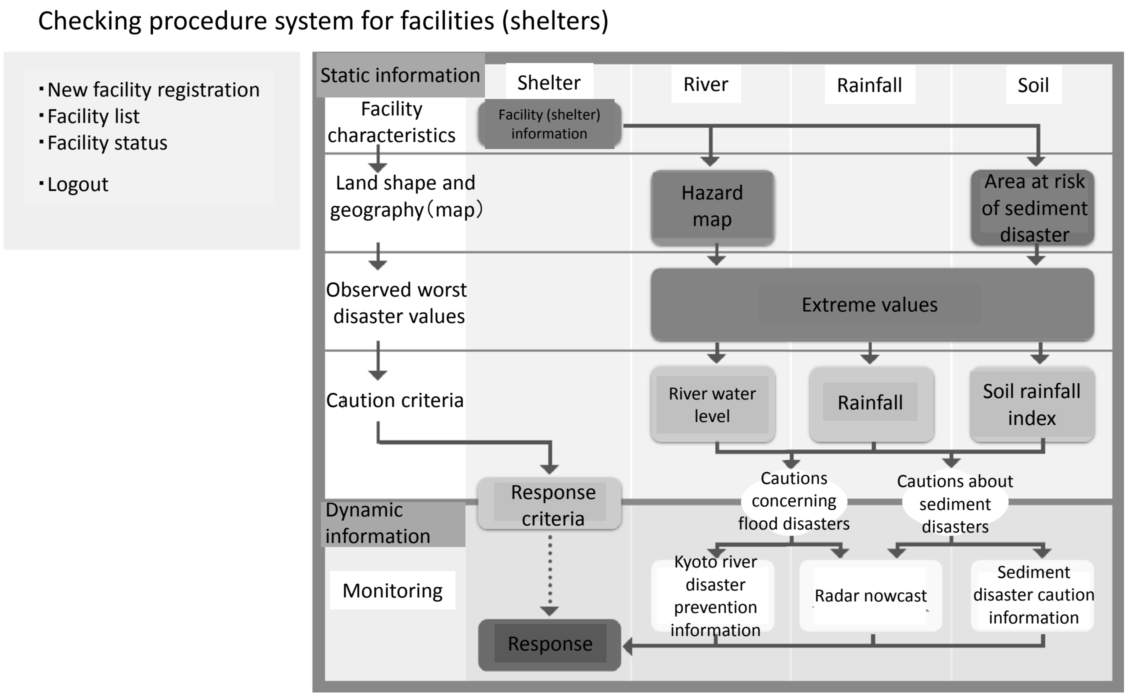

Fig. 7. Registration screen for basic facility information.

put. Progress can be confirmed as the values are input. Input items are as follows.

6.3. Preliminary Input

a) Facility characteristics (facility information): target facility information is registered beforehand in the new registration page of facilities (shelters). Shelters in Kyoto Prefecture are registered in the system and can be selected from the map screen and municipal shelter list. Facility name, address, structure, capacity, the number of target households in the target area / the number of persons, those who need special care, and latitude/longitude are registered. With

Fig. 8. Registration screen for facility information.

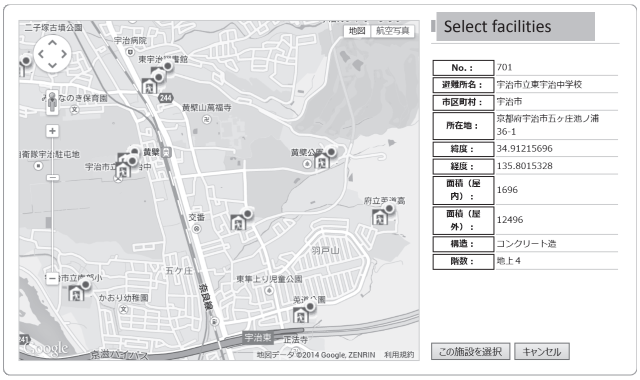

Fig. 9. Selection screen for shelters (map).

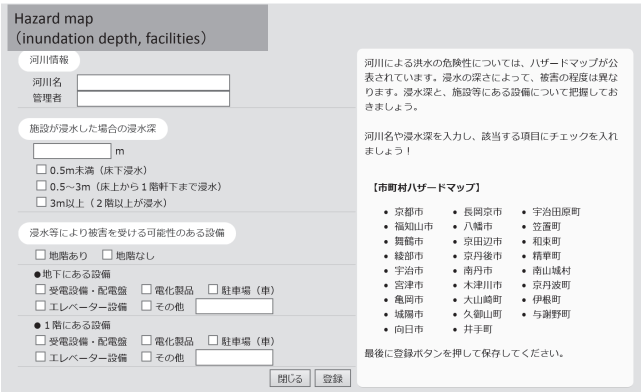

Fig. 10. Registration screen for hazard map.

the aim of facilitating appropriate input, instructions for input and related links appear on the right in the preliminary input screen. The registration screen for facility information is shown in **Fig. 8**; the screen for selecting facilities on a map is presented in **Fig. 9**.

b) Geography and geology (map) (hazard map, high-risk areas for sediment disasters): river name, river administrator, inundation depth, and facilities at risk of damage are input. The instructions for input include a link to local government websites that include hazard maps and at-risk areas for sediment disasters. **Fig. 10** shows the registration screen.

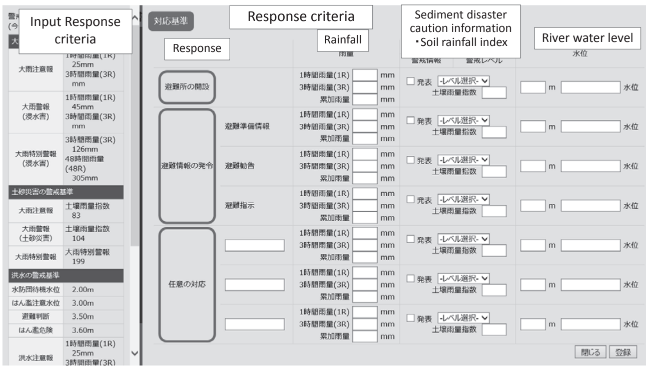

Fig. 11. Registration screen for response criteria.

c) Observed worst disaster values (extreme values): disaster date, name, observed rainfall, and water levels are input. The extreme values can be input using links to Kyoto Prefecture's website (disaster record page), municipal disaster prevention plan, and observed value search page of Automated Meteorological Data Acquisition System (AMeDAS) of the JMA.

d) Caution Criteria (river levels, rainfall, and soil rainfall index): Caution criteria are input by registering water level and rainfall indicators. In the map screen, registered water level and rainfall indicators in Kyoto Prefecture can be selected. Caution criteria for the selected water level indicator are automatically reflected. Caution criteria for rainfall and sediment disasters can be confirmed using a link to the JMA website. The top page indicates observed values once rainfall and water-level indicators are registered.

e) Response Criteria: based on criteria registered in d), response actions and corresponding rainfall values are registered. Arbitrary responses include setting up shelters and issuing evacuation information can be registered. **Fig. 11** shows the registration screen.

6.4. Emergency Monitoring

The status of each shelter is confirmed on the top page (**Fig. 12**) during rainfall and utilized for response judgments. Water levels, radar information on rainfall, and mesh information for sediment disaster cautions can be confirmed in real time on the top of the screen. The rest of the screen consists of information on registered shelters, listed in the order of water levels, rainfall, and soil rainfall index, from left to right. On the top of information on the registered shelter, caution criteria based on advisories and similar and comparison results with registered response criteria are shown.

Changes in water levels, rainfall, and soil rainfall index are shown in the graphs in the center. The rainfall graph includes rainfall per hour, over three hours, and cumulative rainfall. Caution values, such as those of advisories,

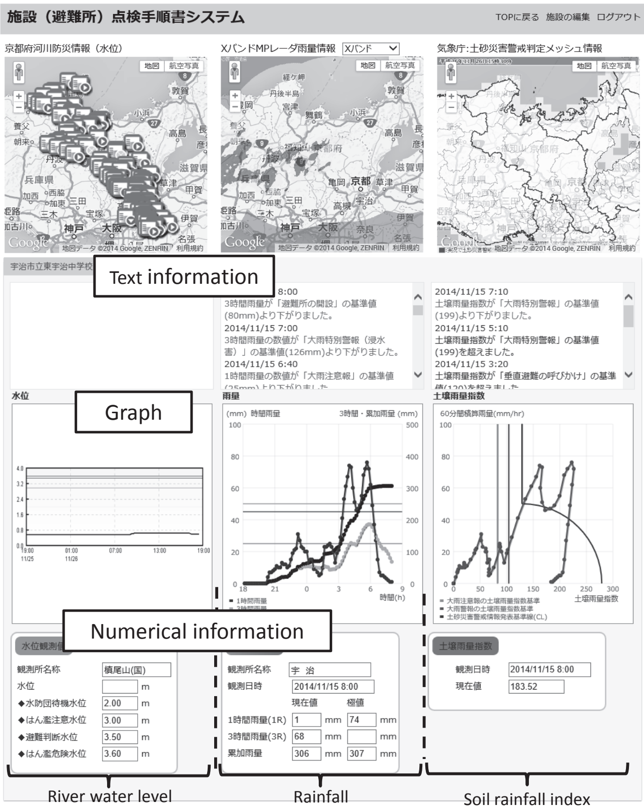

Fig. 12. System top page (demo version).

are indicated in each graph. Observed water levels, rainfall, and soil rainfall index values are shown on the bottom. Water level values can be compared to reference values and rainfall values with extreme values.

7. Evaluation of Check Procedure System for Facilities (Shelters)

7.1. System Evaluation

A workshop related to the display and operation of the developed system and the method of presenting rainfall information, etc. was held on November 15, 2014. The target audience included municipal disaster prevention personnel and members of voluntary disaster prevention organizations. Five municipal disaster prevention personnel and 12 members of voluntary disaster prevention organizations from five municipalities in Kyoto Prefecture participated in the workshop. Each participant performed a demonstration of the system using observed rainfall data after completing preliminary registration items for shelters that may be used following the procedures. Response criteria were set by each participant based on caution criteria. Rainfall observation values of the Uji observation station (Ujiwakamori, Uji) from 6 M on August 14 to 8 AM on August 15, 2012 during a heavy rain in southern Kyoto were used as rainfall data. Participants were divided into four groups (A, B, and D had four members; C had five), and display items on the top screen were changed, as shown in **Table 3**. Then, a five-grade rating was performed for the 18 items listed in **Table 4** (with 5 being the most positive and 1 the most negative). Fifteen evaluation responses (four from A, B, and C, three from D) were collected. The average values of each evaluation group are presented in **Table 4**, and a graph of them is shown in **Fig. 13**.

Table 3. Information from each group during demonstration.

	Text information (values exceeding caution criteria)	Graph	Numerical information (observed and reference values)
A	○	○	○
B	○	○	×
C	○	×	○
D	○	×	×

* ○: Indicated, ×: Not indicated

The average total evaluation value was 3.8. The system as a whole was evaluated as being effective because the average value exceeded 3.0. The use of the system was favored, while the system specifications evaluation was moderate. Respondents seem to have thought that rainfall, water levels, and the soil rainfall index could be used for decision making.

Moreover, the effectiveness of numerical information and graph information was studied using a two way factorial analysis of variance. **Table 4** shows significant *P* values in evaluation questions. Significant tendency at a 10% level or similar could be observed in results of effectiveness of values and graphs for question 1, Those of values for question 4, those of mutual actions for question 15, and those of graphs for question 18. **Fig. 14** shows average values and standard deviation graphs for these items.

Considering the above, the following points can be assumed:

a) Question 1 (accuracy when using rainfall amounts to judge situations): values and graphs were evaluated highly when present, while they were not when not present.

b) Question 4 (accuracy when using water levels to judge situations): Effects increased when values were indicated.

c) Question 5 (whether or not water levels are useful for decision making): a significant tendency was observed in mutual actions; evaluation tended to be positive when both values and graphs were present and not so when only text information was present. Although information on water levels was not present in the demonstration, this tendency was shown.

d) Question 15 (system response): a significant tendency was observed in mutual actions; evaluation tended to be positive when both values and graphs

Table 4. System evaluation.

Question		A	B	C	D	Evaluation using P values		
						Effects of values	Effects of graph	Mutual effects
(1) Judgment based on rainfall amounts								
1	Accurate	4.75	4.00	4.00	3.33	*	*	
2	Useful in decision-making	5.00	4.25	4.00	4.33			
3	Effective in understanding situations	4.25	4.00	4.25	3.67			
	(Average of 1–3)	4.67	4.08	4.08	3.78			
(2) Judgment based on water levels								
4	Accurate	4.25	3.50	4.00	3.33	*		
5	Useful in decision-making	4.75	3.75	3.75	4.33			*
6	Effective in understanding situations	4.50	3.50	3.75	3.67			
	(Average of 4–6)	4.50	3.58	3.83	3.78			
(3) Judgment based on soil rainfall index								
7	Accurate	4.00	4.25	3.75	3.33			
8	Useful in decision-making	4.50	4.50	3.50	4.67			
9	Effective in understanding situations	4.25	4.50	3.75	4.33			
	(Average of 7–9)	4.25	4.42	3.67	4.11			
(4) Evaluation of system specifications								
10	Easy to operate	3.75	2.75	3.25	3.00			
11	Beautiful design	3.25	3.25	3.00	3.00			
12	Neat arrangement	3.00	3.50	3.75	3.67			
13	Reasonable procedure order	3.75	3.25	3.25	3.00			
14	Clear instructions	4.00	3.00	3.00	2.33			
15	Good response	4.00	3.00	2.50	3.67			*
	(Average of 10-15)	3.63	3.13	3.13	3.11			
(5) Evaluation of system usage								
16	Labor-saving information acquisition	4.50	3.50	4.00	3.67			
17	Useful	4.50	3.75	4.00	4.67			
18	Accessible to required information	4.50	4.25	3.75	3.67		*	
	(Average of 16–18)	4.50	3.83	3.92	4.00			

*: 10% significant and similar (P value for question 15, mutual actions: 0.109)

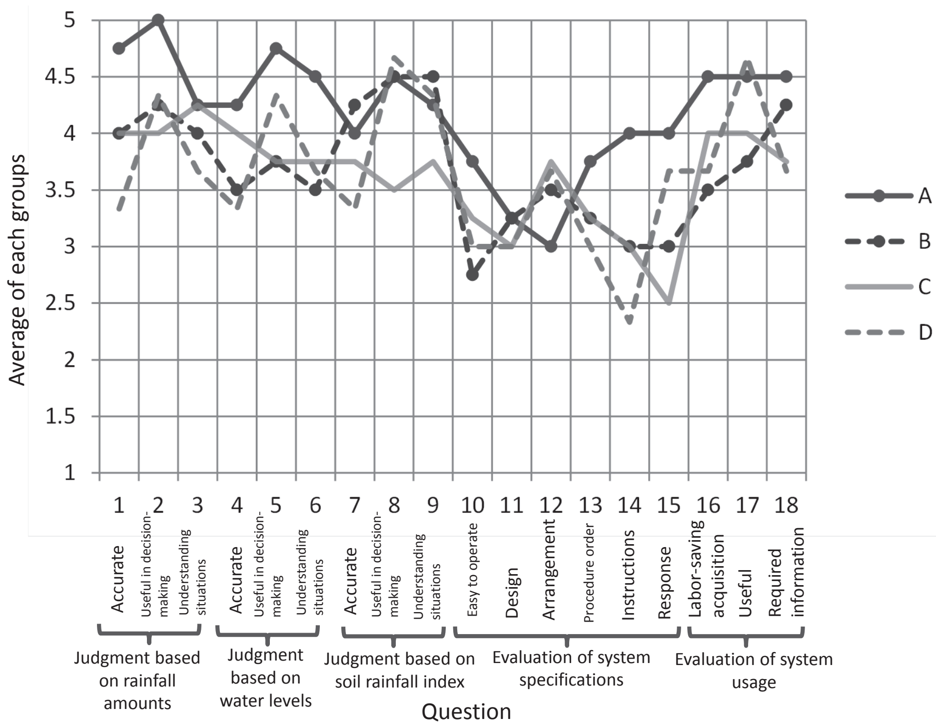

Fig. 13. System evaluation (graph).

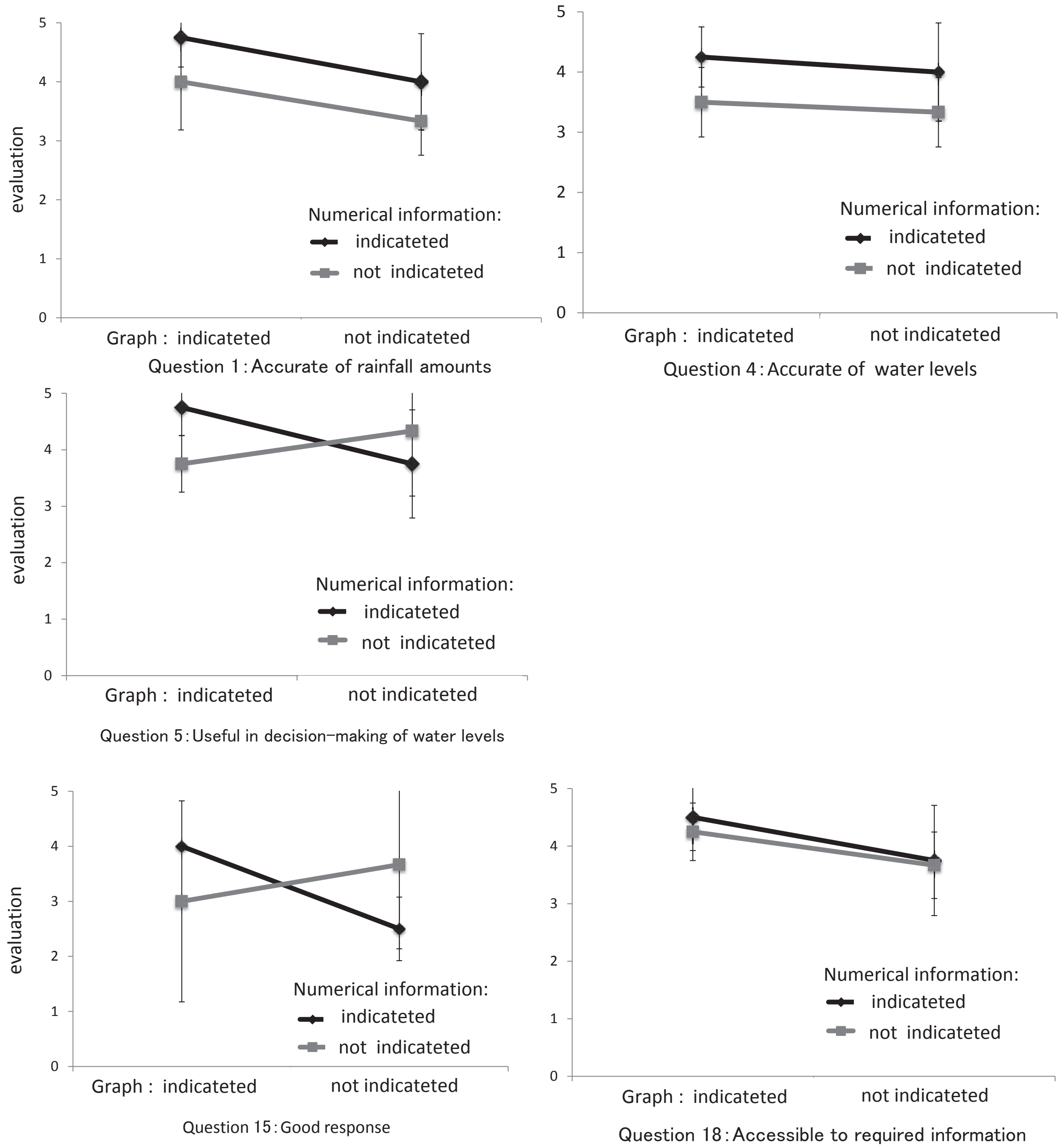

Fig. 14. Graphs for average values and standard deviation.

were present and not so when only text information was present.

e) Question 18 (Access to required information) a significant tendency was observed in the effectiveness of graphs; respondents preferred to have graphs present for confirming required information.

Both values and graphs were effective for rainfall, while only values were for water levels. The results suggest that presenting both values and graphs is effective in terms of information presentation; otherwise, presenting only text information is more useful than presenting either values or graphs. As the number of evaluation targets is low in the present evaluation, the authors wish to increase it in future studies.

7.2. Comments About the System

A questionnaire survey was performed after the workshop, and answers were obtained from 11 participants. Comments from the respondents are given in **Table 5**. 55% of respondents considered the system as "good," 36% of respondents as "useful under some conditions," and 9% of respondents as "difficult to use." Many respondents evaluated this system as useful during disasters, while the management of data such as hazard information and extreme values as well as the establishment of local response criteria remained as issues. In addition, some pointed out that using this system was difficult for elderly citizens, including executives of voluntary disaster prevention organizations, especially when extreme values

Table 5. System evaluation comments from the respondents.

Group	Comments	Evaluation
A Numerical information is indicated Graph is indicated	• If this system is understandable, it is useful when making a circumstantial judgement of the area. • This system is likely to be usable in the future. • Through the simulation, I felt it easy to use. Changes in circumstances will be represented as graphs and texts, so it is easy to understand. The rainfall graph of this system is easier to understand than common rainfall graph.	△ ○ ○
B Numerical information is not indicated Graph is indicated	• The system specification is good enough. But the management of data including local response criteria by the municipal governments is necessary to make the system usable. Though the contents or ranges of the information handled by the prefecture and the municipal are different, the data is equally needed. • When a shelter is assumed to be flooded, it seems effective.	△ ○
C Numerical information is indicated Graph is not indicated	• This system is difficult to utilize in the private sector. • This system is easy to use. Moreover, the improvement of material resources and human resources is needed. • I confirmed that it can be utilized sufficiently. • Using this system is difficult for elderly citizens, including executives of voluntary disaster prevention organizations. This system can be used at the disaster prevention education course of junior high school, etc.	× △ ○ △
D Numerical information is not indicated Graph is not indicated	• The impression of this system is good. I think it will be more reliable by inputting the terms and conditions. • This system is good and should be practicalized as soon as possible.	○ ○

Evaluation ○: good, △: useful under some conditions, ×: difficult to use

searched for via the Internet. Various data management efforts are being sought. Situation confirmation during rainfall needs to entail fewer operations, while the registration of facility information should be improved. In the course of disaster prevention education, this system can be operated by junior-high school students, etc. together with elderly citizens. The authors wish to improve the system by responding to these comments.

8. Conclusion and Future Prospects

This study has used scientific findings and the relationship of information obtained based on FFH to establish a procedure manual for determining response actions. FFH has been used for judgment procedures within administrative agencies that target torrential rainfall of increasing frequency. When this procedure manual was evaluated by municipal disaster prevention personnel and members of voluntary disaster prevention organizations in Kyoto, they understood the flow of the examination procedures outlined in the manual, and the management of the procedure by a web-based system was considered desirable considering the complexity of the procedures. Responses and judgments can be improved if training and workshops are provided to improve response organizations. Based on evaluation results, the authors studied a check procedure manual for shelters as a web-based system and developed a "check procedure system for facilities (shelters)." This system was evaluated by municipal disaster prevention personnel and members of voluntary disaster prevention organizations in Kyoto. Evaluation results for system specifications and operations, effective information presentation, and comments on usage were obtained. The authors will improve this system as an effective decision-making support tool based on evaluation results. In addition, a model area will be selected in Kyoto Prefecture, and response criteria in that area will be established based on agreements with disaster prevention response organizations, such as voluntary disaster prevention organizations. The authors wish to promote effective disaster responses based on scientific grounds and using study results.

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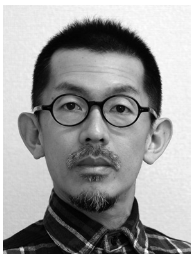

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