Implementation and Evaluation of Evacuation Shelter Support System

Yuta Seri[1], Masaya Takezaki[2], Tomoyuki Ishida[2]

[1]Graduate School of Engineering, Fukuoka Institute of Technology, Japan

[2]Department of Information and Communication Engineering, Fukuoka Institute of Technology, Japan

Received: March 14, 2025; Revised: May 31, 2025; Accepted: June 30, 2025; Published: July 23, 2025

Abstract

This paper discusses the implementation and evaluation of an evacuation shelter support system. The proposed evacuation shelter support system comprises an evacuee arrival/departure registration management system that utilizes facial recognition technology and an evacuation shelter management system for local government staff. In the proposed system, facial recognition is performed using a camera-equipped tablet device installed at the evacuation shelter to manage the arrival and departure of evacuees. In addition, the proposed system visualizes the congestion status of the evacuation shelters in real time and automatically calculates the required amount of relief supplies from the real-time evacuee information acquired at each evacuation shelter. To evaluate the proposed system, we surveyed 31 participants regarding the system's usability and effectiveness, and the proposed system received high evaluation scores in many evaluation categories.

Keywords: Evacuation Shelter Support, Facial Recognition, Congestion Status Visualization, Relief Supplies Automatic Calculation.

1 Introduction

1.1 Background

Japan is one of the world's most disaster-prone countries, and large-scale disasters, e.g., typhoons, heavy rains, earthquakes, and tsunamis, occur nearly every year. As a recent example, the Noto Peninsula earthquake occurred on January 1, 2024 [1]. In addition, it is predicted that there is a high probability of a Nankai Trough megathrust earthquake and a Tokyo metropolitan earthquake occurring within the next 30 years, and preparations for these events are an urgent issue.

In times of disaster, evacuation shelters play an extremely important role. Such shelters provide a temporary place of refuge for disaster victims and serve as a base for providing basic life support and information. However, there are many challenges associated with operating an evacuation shelter. For example, with conventional paper-based management methods, it is difficult to grasp the arrival and departure of disaster victims at evacuation shelters and their individual needs. As a result, delays in the provision of needed supports, mistakes, and duplication and omission of information are likely to occur. In particular, there is a high risk of delays in understanding the situation and providing critical support to people needing special consideration, e.g., the elderly and individuals with disabilities.

In light of these considerations, the introduction of evacuation shelter management systems that utilize information and communication technology has progressed in recent years. For example, the evacuation shelter management system "Rakuraku Hinan Kun" [2] provided by Telenet Corporation digitizes evacuee lists, which

speeds up reception processes and makes it possible to grasp the situation inside the evacuation shelter. In addition, Iwate Prefecture is working on a system to digitize evacuation shelter management using the LINE app [3], and a demonstration experiment verified that this reduces administrative burdens and improves support for evacuees compared with conventional paper-based work. However, these systems still have issues. For example, they are inadequate in terms of supporting residents who do not own information devices, e.g., smartphones, or those who are not familiar with using such devices; thus, these systems are not equipped to handle those with limited access to information. In addition, traditional management methods make it difficult to determine the congestion conditions at evacuation shelters in real time and calculate the demand for relief supplies accurately. To address these issues, we propose a system that facilitates smooth information sharing between evacuees and disaster response headquarters staff via a web-based system. Specifically, the arrival and departure of evacuees at evacuation shelters is managed using cameras installed at a shelter and a facial recognition system that utilizes image recognition technology. In addition, the congestion status of the shelter is visualized on a map in real time using a geographic information system (GIS). This enables us to understand the population density in the shelter and the details of the evacuees (ratio of males to females, age, etc.), and we aim to realize a system that can respond quickly to evacuees as required.

The remainder of this paper is organized as follows. Related work is discussed in Section 2, and the purpose of this study is described in Section 3. The system configuration of the proposed evacuation shelter support system is discussed in Section 4, and the proposed system is described in detail in Section 5. Section 6 evaluates the proposed evacuation shelter support system. Finally, the paper is concluded in Section 7.

2 Related Work

Kitsuya et al. [4] developed the Real-time Evacuation Support System (RESS) to reduce the loss of human life during natural disasters. The RESS system can share the location information of people requiring support, provide support, and detailed information about the status of evacuation shelters in real time.

In addition, Miura et al. [5] developed an information transmission system to address manpower shortage problems in evacuation shelters. This system facilitates easy reporting and understanding of the situation at evacuation shelters using a web browser, and the busyness of evacuation shelter managers can be estimated from their step count and location information. In addition, requests for assistance can be registered automatically using the web-based system.

Abe et al. [6] proposed an information management system that links the evacuation behavior of victims with personal information, which allows evacuation shelters and disaster response headquarters to clearly understand the situation and confirm the location and congestion of evacuation shelters. This system comprises a victim system, an evacuation shelter system, and a disaster response headquarters system. The victim system includes several functions, e.g., evacuation shelter arrival procedures, evacuation shelter congestion confirmation, and evacuation status confirmation for family members. The evacuation shelter system manages evacuation shelter information registration and evacuation information management processes, and the disaster response headquarters system has functions to grasp the evacuation situation, procure supplies, provide human support, and assist with rescue activities.

Gonzalez-Villa et al. [7] proposed an evacuation management system to address the difficulties associated with predicting appropriate evacuation routes and managing evacuees during disasters. This system has a GIS-based real-time decision support function and can simulate optimal evacuation routes, evacuation shelters, and assembly points. In addition, this system can manage multiple simultaneous evacuations and provide optimal evacuation strategies.

Agoylo et al. [8] developed the Municipal Emergency Response System, which incorporates Google Maps and short messaging services (SMS) to facilitate communication during disasters and reduce loss of life, property damage, other negative effects of emergencies, and response times. This system displays the location

of an accident on Google Maps and has a function to report emergencies via SMS.

Diaz Intal et al. [9] focused on the user experience design of a mobile application intended to improve disaster management in the province of Marinduque, Philippines. They adopted a design process comprising five phases, i.e., empathy, define, ideate, prototype, and test, and they conducted a workshop with 30 participants. Here, the participants shared their experiences and problems during disasters, and they identified the required functions as announcements, safety guidelines, evacuation information, request for aid, incident reporting, rescue monitoring, household information, risk index, and facilities maps, and prototypes of these functions were constructed.

Handayani et al. [10] described the implementation of mobile technology to improve the reporting process during disasters and emergencies, and they proposed a system that allows people to send information in real time and share important data and evidence through a mobile application.

In addition, Gallera et al. [11] proposed a digital information system to improve governance and community development in barangays, which are the smallest local administrative units that make up cities and towns in the Philippines, and they evaluated the effectiveness of the system. This system attempts to manage information in a manner that is easily accessible for residents and to increase the efficiency and effectiveness of local governance and community development.

Mardaid et al. [12] proposed a flood emergency response system that utilizes facial recognition technology and CCTV cameras installed at evacuation centers to manage flood victims in Malaysia, which is prone to flood damage. This system analyzes the faces of victims captured by the CCTV cameras, and the system's dashboard monitors and visualizes flood-related data in real time, including the number of floods, the number of victims, the duration of floods, and the estimated losses.

Hayashi et al. [13] proposed a system to support the identification and management of evacuees by distributing radio frequency identification (RFID) tags to evacuees to improve the efficiency of evacuee roll calls, food distribution management, and other evacuation shelter operations during large-scale disasters. This system makes it possible to manage evacuees by matching evacuee information with RFID tags in a database.

Ogawa [14] developed an attendance management system for university classes using facial recognition technology. Using a Python environment and the "Face Recognition" library, which is an open source library for facial recognition, the system captures and recognizes students' faces in real time, compares the captured facial images with the facial photos registered in the academic affairs system and on student ID cards, and manages attendance automatically.

3 Research Objective

Existing evacuation shelter management systems are configured to assume that users possess a smart device, e.g., a smartphone or tablet. However, this reduces fairness and convenience for information-poor residents, e.g., individuals without smartphones or those who are not familiar with using information devices. Thus, we propose the following two systems.

A) Facial recognition-based evacuee arrival/departure registration management system

The facial recognition-based evacuee arrival/departure registration management system is based on the concept of utilizing the facial photographs and personal information of residents managed through the Individual Number System and the Basic Resident Register. With this system, the evacuees perform facial recognition using a camera-equipped tablet device installed at the reception desk of an evacuation shelter. Once the facial recognition process is complete, the evacuee confirms their identity on a confirmation screen. Then, the evacuee enters information about the damage to their home (e.g., total destruction or partial destruction),

damage to infrastructures (e.g., power outage and water outage), and other special circumstances (e.g., pregnancy status, pets, and disabilities) into the terminal to complete the arrival registration. Facial recognition is also performed when departing from the evacuation shelter, and the evacuees are registered to leave.

B) Evacuation shelter management system for local government staff

The evacuation shelter management system for local government staff is used by disaster response headquarters and staff working in evacuation shelter operations to grasp real-time information about evacuation shelters in a unified system. This system has the following functions.

- Registration and deletion of evacuation shelters.
- Visualization of the real-time congestion status at each evacuation shelter.
- Displaying detailed information for each evacuation shelter, e.g., the age groups and gender ratio of the evacuees.
- Automatically calculate the required amount of relief supplies based on the detailed information of each evacuation shelter.

This system eliminates the need for handwritten input, as is the case with evacuee cards, and it does not require physical individual cards or digital devices, e.g., My Number cards or smartphone and tablets. This system facilitates smooth arrival and departure registration using facial recognition technology for evacuees and efficient evacuee management by disaster response headquarters.

4 Configuration of Evacuation Shelter Visualization System

The configuration of the evacuation shelter visualization system is shown in Figure 1. This system comprises a evacuee agent, a local government staff agent, an application server, and a database server.

4.1 Evacuee Agent

The evacuee agent targets residents who are evacuating to evacuation shelters. Figure 2 shows the flow of the system, assuming its use in an actual evacuation shelter. The evacuee agent performs facial recognition using the camera on a tablet device installed at the evacuation shelter. Then, the evacuee follows the instructions displayed on the screen to register their arrival at the evacuation shelter. The arrival and departure registration flow is summarized as follows.

1) The evacuees use the tablet device installed at the evacuation shelter to perform facial recognition.
2) The evacuees confirm their identity based on the facial recognition results.
3) The evacuees select the required item of damage to their house (completely destroyed, partially destroyed, partially damaged, no damage, etc.) as additional information.
4) The evacuees enter the optional items of damage to infrastructures (e.g., power, water, gas, and telephone outages) and other special notes (e.g., pregnancy status, accompanying children, and disabilities).

4.2 Local Government Staff Agent

The local government staff agent manages the following information.

- Registration and deletion of each evacuation shelter.
- Monitoring the evacuation status of evacuee agents at each evacuation shelter.
- Understanding evacuation information, including the personal information of the evacuees.
- Understanding the evacuation history of evacuees and the congestion status of each evacuation shelter.
- Understanding the age groups and gender composition of each evacuation shelter.
- Understanding the required amount of relief supplies determined from the above information.

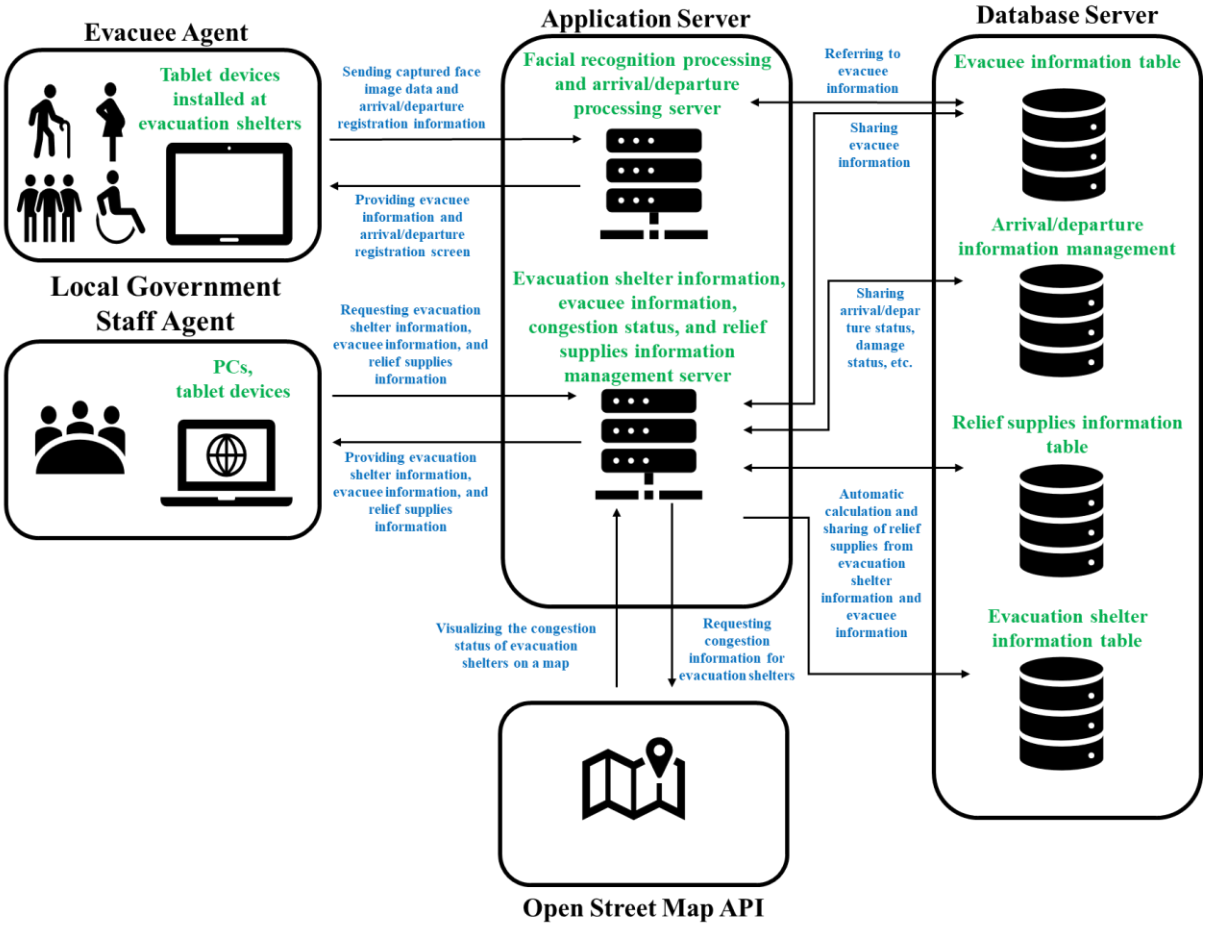


Figure 1: Configuration of proposed evacuation shelter visualization system

Figure 2: Flow assuming use in an actual evacuation shelter

4.3 Application Server

The application server comprises two distinct servers, i.e., a facial recognition processing and arrival/departure processing server, and a shelter information, evacuee information, congestion status, and relief supplies information management server.

4.3.1 Facial Recognition Processing and Arrival/Departure Processing Server

The facial recognition function is executed on the facial recognition processing and arrival/departure processing server using the browser operated by the evacuee agent. The face photo data captured from the browser are received by this server. Then, the server compares the facial feature set obtained from each evacuee's facial image stored in the evacuee information table on the database server with the facial features obtained from the captured facial photo data. The server then returns the facial recognition result to the evacuee agent.

When entering the evacuation shelter, the evacuee agent is asked to enter the personal information from the evacuee information table and displayed on the browser. Then, the evacuee agent is asked to select the required information about any damage to a house (total destruction, partial destruction, partial damage, no damage, etc.) and other optional items, e.g., damage to infrastructures (power, water, gas, and telephone outages), and any special notes (e.g., pregnancy status, with child or children, and disabilities). When departing the evacuation shelter, the evacuee agent is asked to press the exit button on the browser and the departure process is performed.

The arrival and departure status of the evacuees is determined based on the presence or absence of corresponding data in the arrival date and time field in the arrival/departure information management table. For example, if there is no arrival date and time information, the system is requested to proceed to arrival processing, and if arrival date and time information exists, the system is requested to perform to departure processing.

4.3.2 Evacuation Shelter Information, Evacuee Information, Congestion Status, and Relief Supplies Information Management Server

The evacuation shelter information, evacuee information, congestion status, and relief supplies information management server have the following functions.

- Providing a list of each evacuation shelter.
- Providing the arrival and departure status of the evacuee agent.
- Providing detailed information about the evacuation shelters.
- Providing congestion status information for each evacuation shelter on a map via the Open Street Map API.
- Providing relief supplies information based on the evacuee information for each evacuation shelter.

4.4 Open Street Map API

The map information provision API uses the Open Street Map API. In addition, the congestion rate is calculated from the number of evacuees and the capacity of each evacuation shelter obtained from the evacuee information and evacuation shelter information tables. Then, the congestion situation is visualized on a map. Local government staff is able to grasp congestion information in real time.

4.5 Database Server

The database server contains four tables, i.e., the evacuee information table, the arrival/departure information management table, a relief supplies information table, and an evacuation shelter information table. An overview of these tables is presented in Table 1.

5 Evacuation Shelter Support System

We implemented the proposed system using the Django Python framework and MySQL, which is an open source SQL database management system.

Table 1: Overview of Tables in the Database Server

Table name	Tables overview
Evacuee information table	Manages basic information of evacuees (name, date of birth, address, etc.), face photos, and encoding values obtained from the face photos
Arrival/departure information management table	Manages basic information of evacuation shelters (shelter name, capacity, address, number of evacuees, congestion rate of each shelter, evacuee age ratio in each shelter, etc.)
Relief supplies information table	Manages the arrival and departure dates and times of the evacuees and additional information required at the time of arrival (damage to houses, damage to infrastructures, special notes)
Evacuation shelter information table	Manages the required amount of relief supplies calculated automatically based on the evacuee information for each evacuation shelter

5.1 Facial Recognition-based Evacuee Arrival/Departure Registration Management System

The proposed system uses facial recognition technology to register evacuees as they arrive at and depart from the evacuation shelter. The evacuees use a tablet device at the evacuation shelter reception desk to register their arrival and departure. Figure 3 shows the top screen of the evacuation shelter arrival/departure management system. When an evacuee presses the “Start facial recognition” button, the system transitions to the facial recognition page.

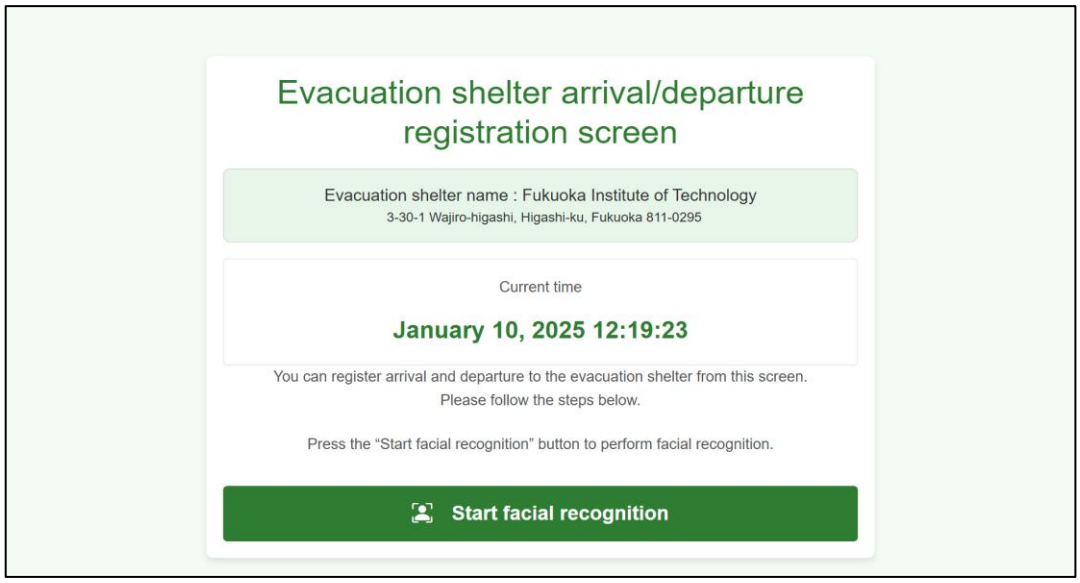


Figure 3: Top screen of the evacuation shelter arrival/departure management system

Figure 4 shows the facial recognition screen of the evacuation shelter arrival/departure management system. As can be seen, the face of the evacuee captured by the camera is surrounded by a blue frame. Here, a program recognizes the face of the evacuee from the real-time image acquired by the camera. The evacuees can perform facial recognition by pressing the “Perform facial recognition” button.

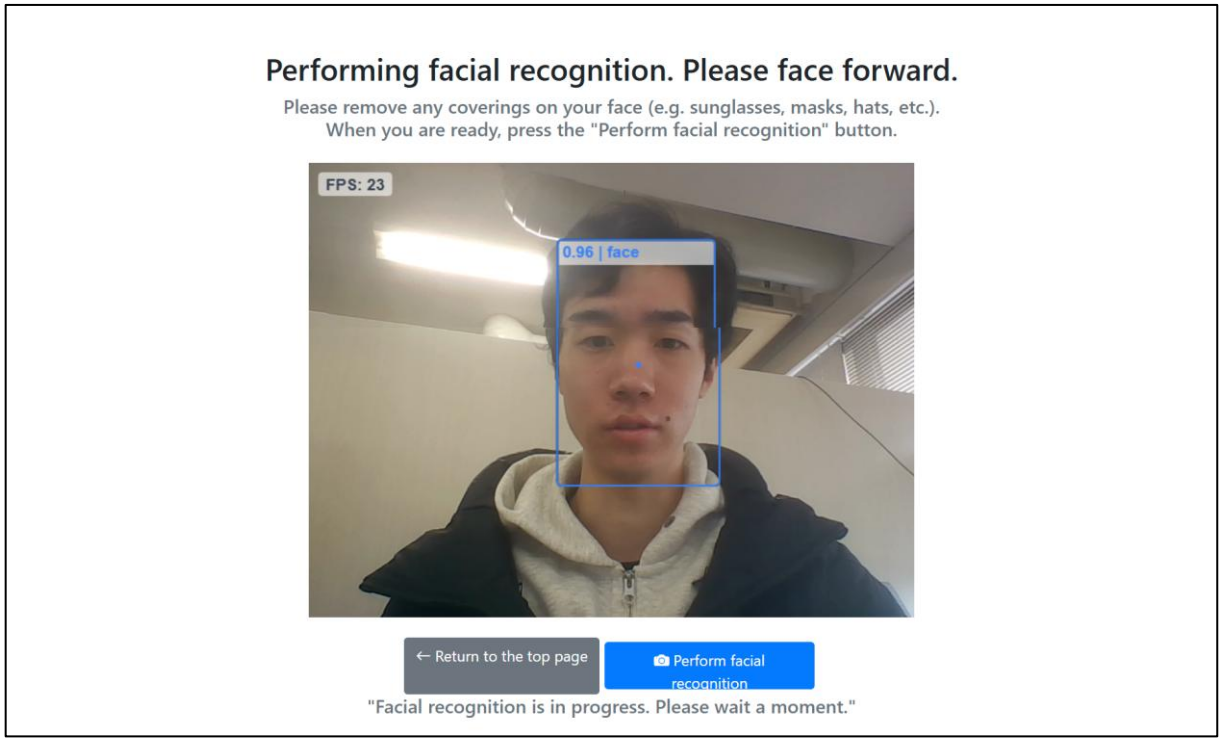


Figure 4: Facial recognition screen

Figure 5 shows the facial recognition result screen. If the facial recognition process is successful, the screen automatically changes to show the name of the evacuee. When the evacuee presses the “Next” button, the screen transitions to the additional information registration screen to register the relevant additional information. In addition, when the evacuee presses the “Confirm personal information” button, a modal window appears that displays their personal information, e.g., their name, the facial photo, date of birth, and address (Figure 6).

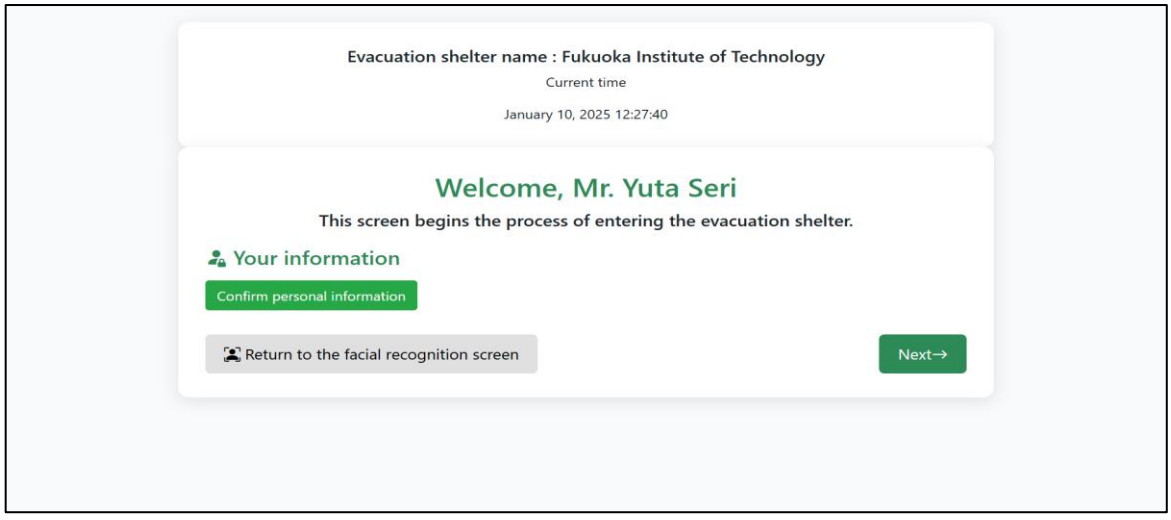


Figure 5: Facial recognition result (evacuee information) screen

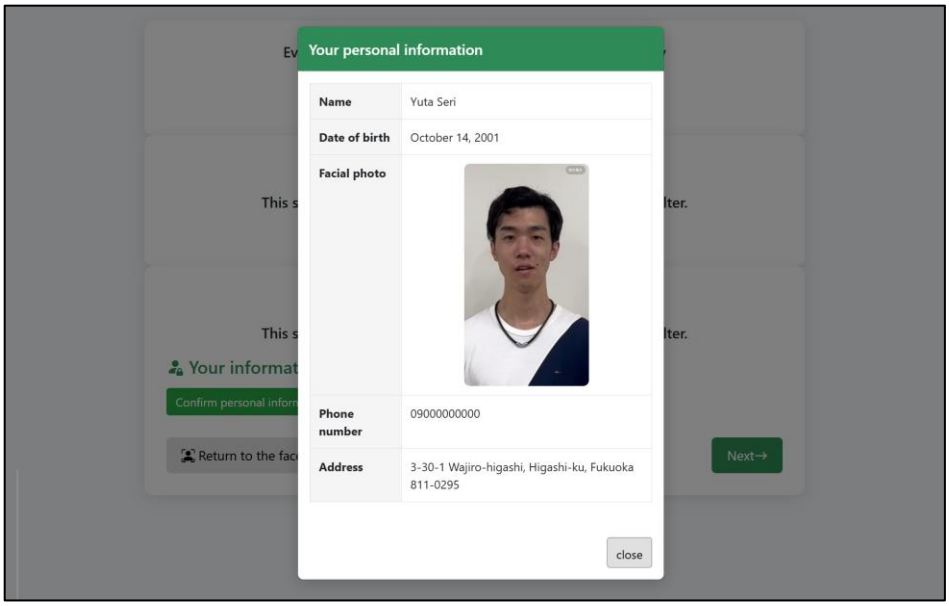


Figure 6: Evacuee information screen in a modal window

Figures 7 to 9 show the additional information registration screen, which is used to select and input damage to houses, damage to infrastructures, and other special notes. Figure 7 shows the house damage status selection screen. Here, the evacuees must select one of the options to describe the damage to the house they live in, e.g., completely or partially destroyed. After selecting an option, the evacuees can select the "Next" button to transitions to the lifeline damage status selection screen.

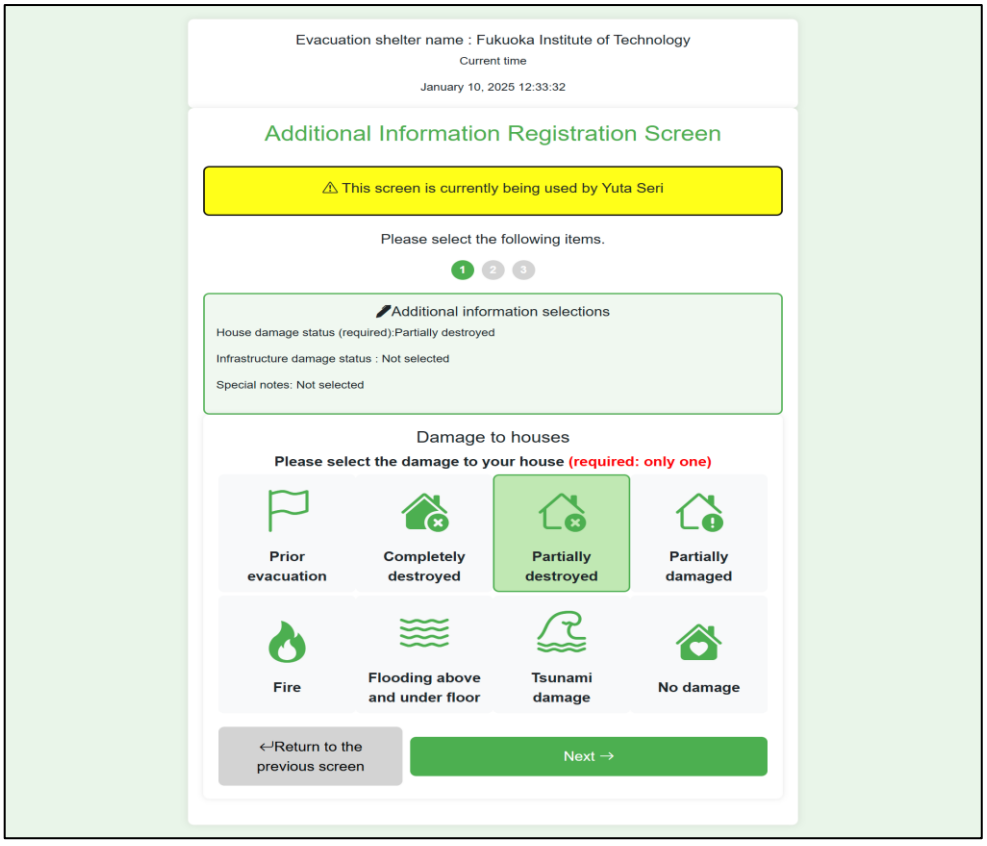


Figure 7: Additional information registration screen (house damage status selection screen)

Figure 8 shows the lifeline damage status selection screen. Here, the evacuees can optionally select multiple items, i.e., power outage, water outage, gas outage, and telephone outage. When the evacuees select the “Next” button, the screen transitions to the special notes selection and input screen.

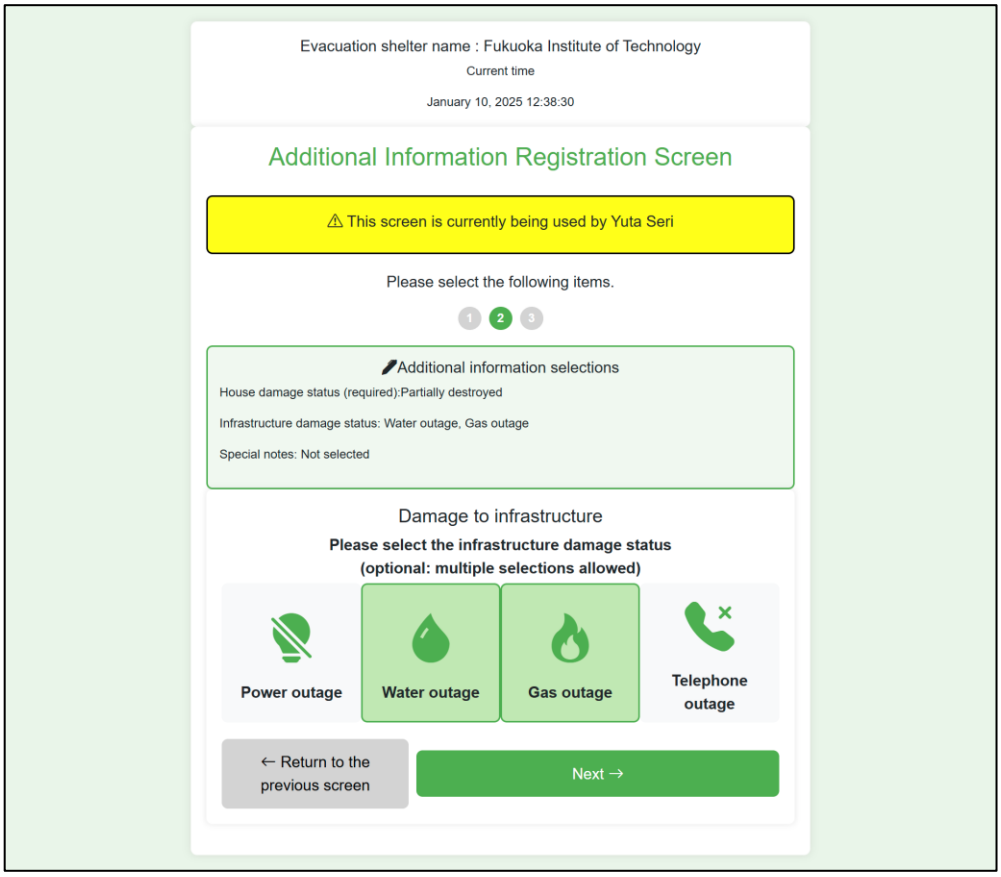


Figure 8: Additional information registration screen (lifeline damage status selection screen)

Figure 9 shows the special notes selection and input screen. Here, the evacuees can optionally select multiple items: pregnancy status, people with infants, people with pets, and others. Then, when the evacuees select the “Register” button, the registration for arrival to the evacuation shelter is complete.

Figure 10 shows the arrival registration completion screen. Here, the arrival date and time and the name of the evacuee are displayed with the message “Arrival registration completed.” After 10 s, this screen automatically switches to the top screen (Figure 3).

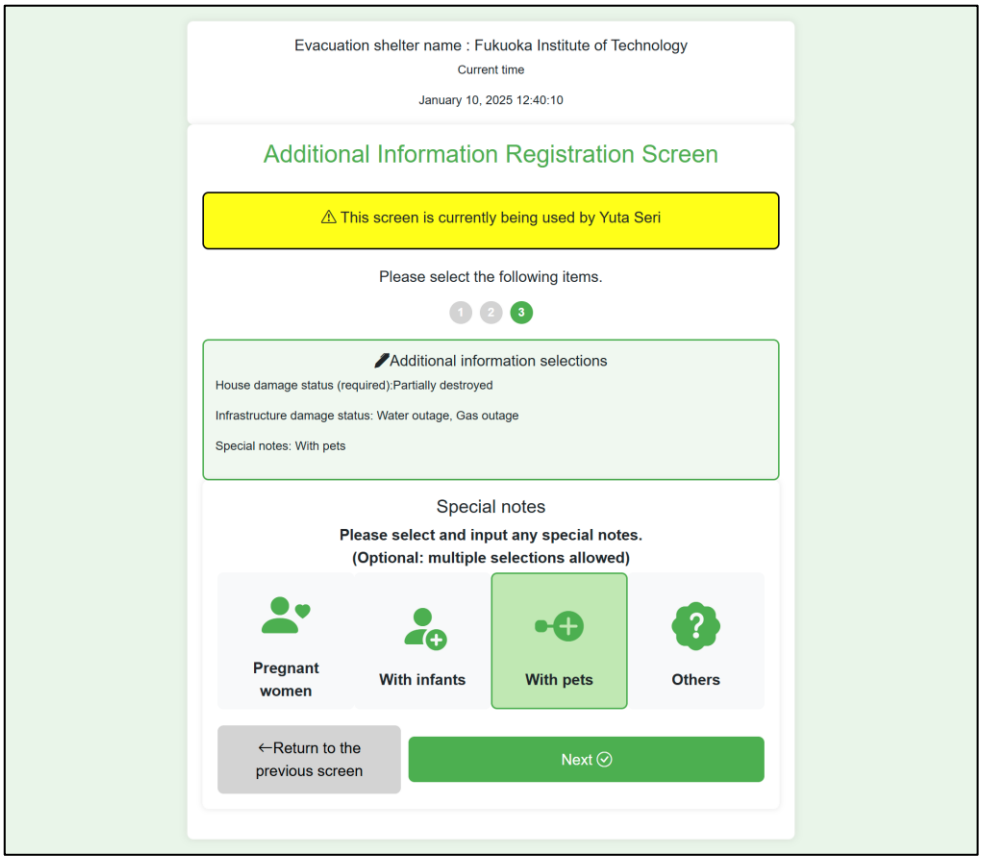


Figure 9: Additional information registration screen (special notes selection and input screen)

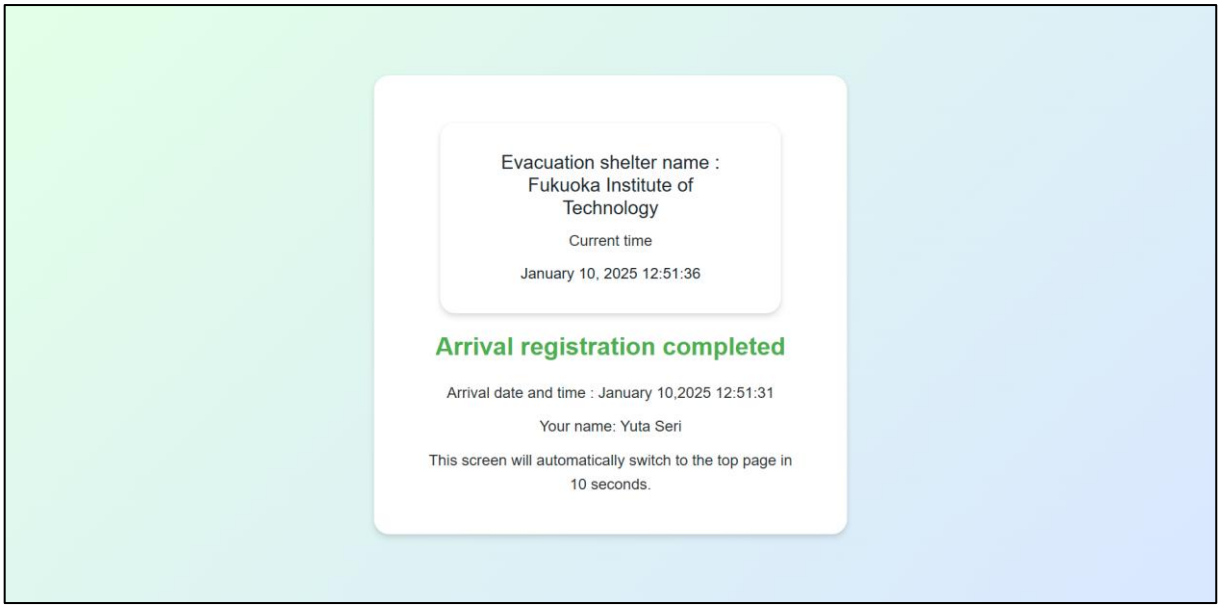


Figure 10: Arrival registration completion screen

In the following, we describe the flow of registering to depart the evacuation shelter. As with the arrival registration, the evacuee selects the “Start facial recognition” button on the top screen (Figure 3). If the facial recognition process is successful, the departure registration confirmation screen (Figure 11) is displayed, which shows the evacuee’s name, the arrival date and time, and their facial photo. When the evacuee selects the “Exit”

button, the departure registration is complete, and the exit registration completion screen (Figure 12) is displayed.

A sequence diagram of the evacuee arrival/departure registration management system is shown in Figure 13. This system uses facial recognition technology to manage the arrival and departure of the evacuees. As can be seen, the evacuees perform facial recognition on a tablet device, and when arriving at the evacuation shelter, they enter detailed information, e.g., damage to their homes and infrastructures, to register for arrive to the evacuation shelter.

Here, facial recognition is achieved using the Python face_recognition library using the following techniques.

1) Facial features are quantified as a 128-dimensional vector face encoding value, where each element is expressed in the range of ?1 to 1.

2) The similarity between two faces is measured according to the Euclidean distance, and a match or mismatch is determined by comparing it with a set threshold. Note that a smaller threshold value increases the strictness of the recognition process, and a larger threshold value increases the recognition tolerance.

3) To process large amounts of face data efficiently, we employed the K-dimensional Tree (KD-Tree) algorithm. This enables faster searches than linear searches (with a computational complexity of O(n)). In addition, efficient data storage and search are realized by dividing the space recursively using the KD-Tree algorithm.

First, a facial image acquired by the camera on the tablet device is sent to the application server, and the face encoding value is extracted on the server side. Then, the face encoding value of the evacuee information stored in the database is compared using the KD-Tree algorithm, and the result is returned. This mechanism enables efficient facial recognition processing even for a database with thousands to tens of thousands of evacuees.

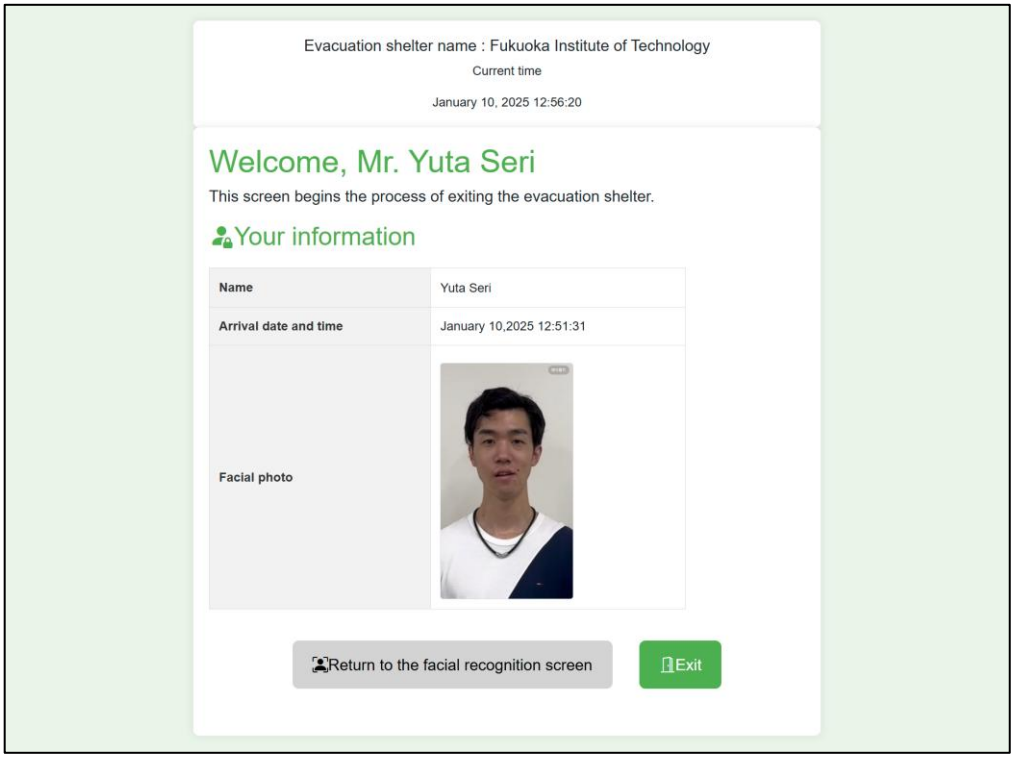


Figure 11: Departure registration confirmation screen

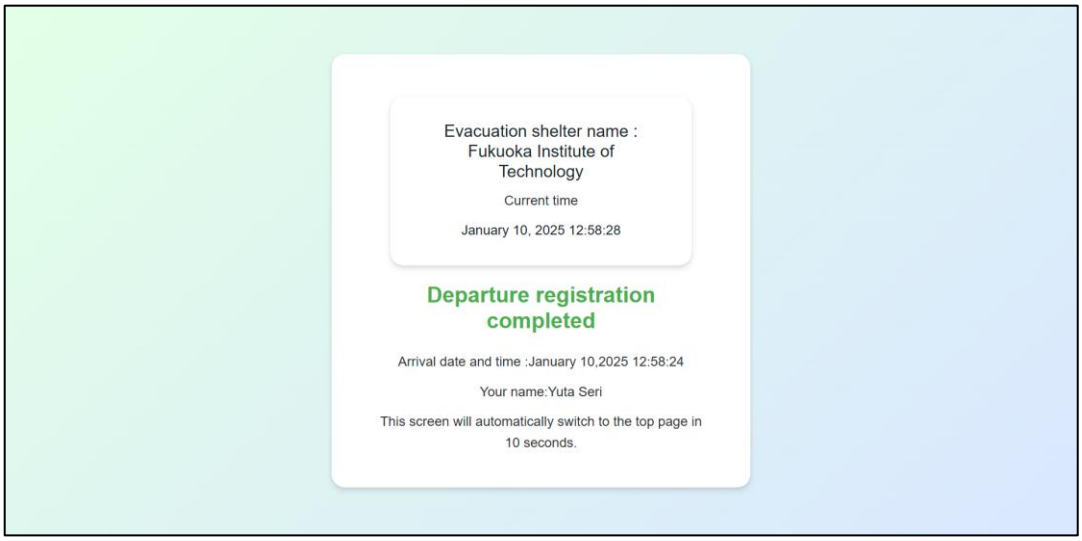


Figure 12: Departure registration completion screen

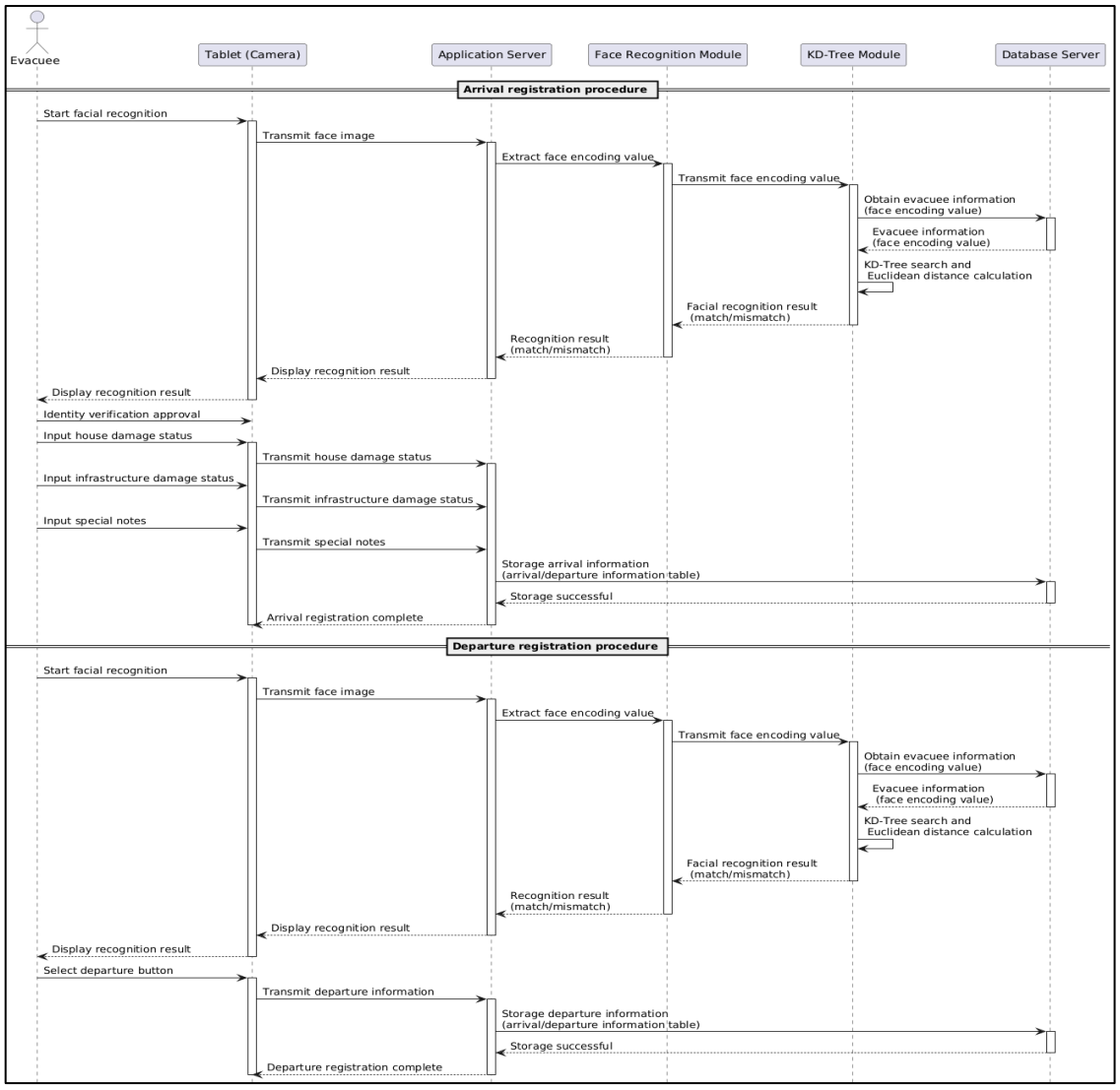


Figure 13: Sequence diagram of the evacuee arrival/departure registration management system

5.2 Evacuation Shelter Management System for Local Government Staff

The evacuation shelter management system allows local government staff at the disaster response headquarters to view and manage important information about evacuee arrivals and departures at evacuation shelters, as well as other relevant information registered in the evacuee arrival/departure registration management system.

The home screen of the evacuation shelter management system is shown in Figure 14. As can be seen, the home screen includes the following buttons.

- The “Evacuation Shelter List” button transitions to a screen where evacuation shelters can be added or deleted from the system.
- The “Congestion Status Visualization” button transitions to a screen where the congestion status of each evacuation shelter is visualized on a map.
- The “Detailed Information” button transitions to a screen where the gender ratio, age group, and number of people at each evacuation shelter can be confirmed.
- The “Relief Supplies Calculation Results” button transitions to a screen that shows the calculated required amount of relief supplies based on the age group and gender ratio at each evacuation shelter.
- The “Log/History” button transitions to a screen where the log of work done by local government staff can be confirmed.

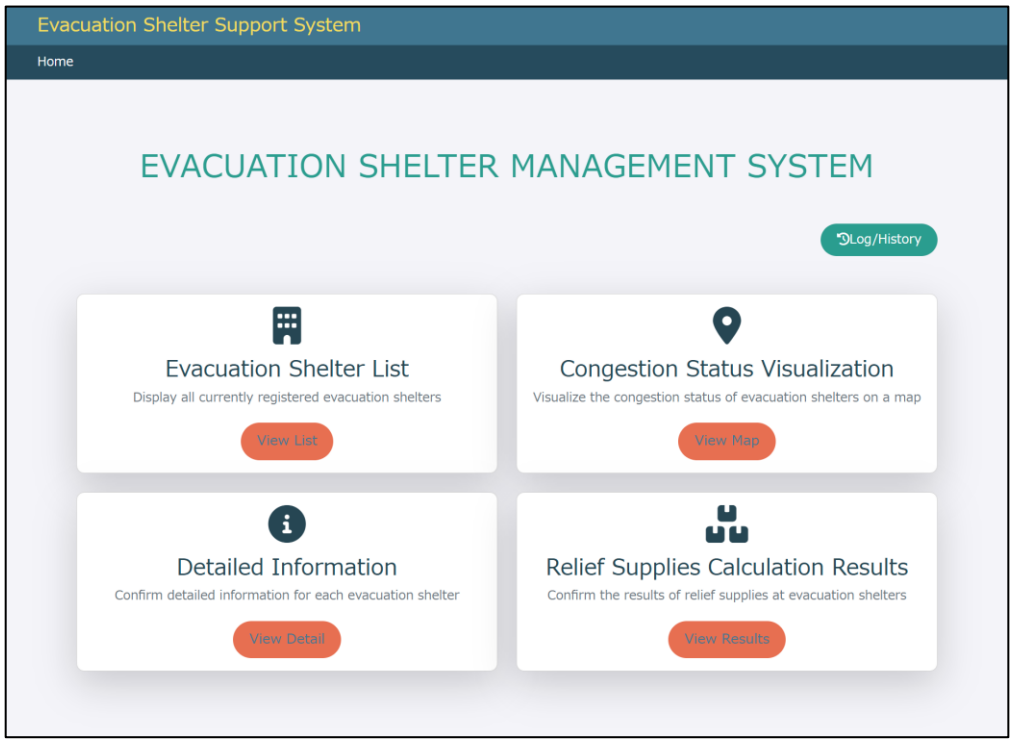


Figure 14: Home screen of the evacuation shelter management system

Figure 15 shows the evacuation shelter list screen, which displays the evacuation shelter ID, evacuation shelter name, postal code, address, capacity, and congestion rate (i.e., the current number of evacuees at the shelter). Local government staff can add, delete, and update evacuation shelters from this screen, and the congestion rate can be viewed as a progress bar.

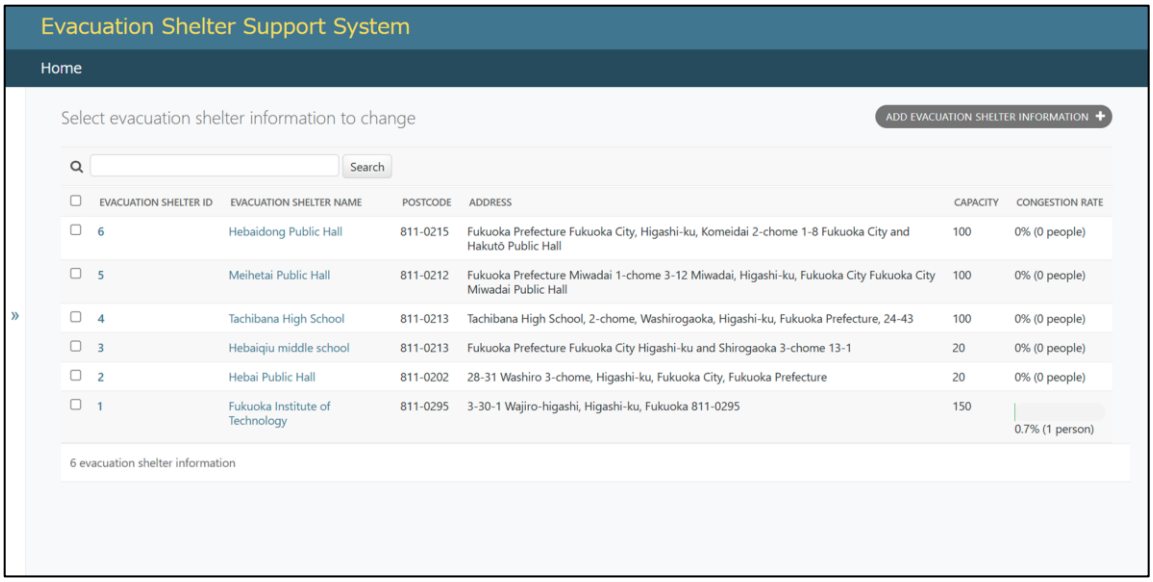


Figure 15: Evacuation shelter list screen

Figure 16 shows the congestion status visualization screen for each evacuation shelter. Here, local government staff can confirm the congestion status of each evacuation shelter visualized in real time on a map. In the sidebar on the right, local government staff can confirm the address, capacity, current number of evacuees, number of male evacuees, number of female evacuees, and the congestion rate of each evacuation shelter in a list. In addition, Figure 17 shows how the congestion status is displayed. As the congestion rate increases, the color becomes increasingly dark, thereby making it possible to visualize the congestion status on the map effectively.

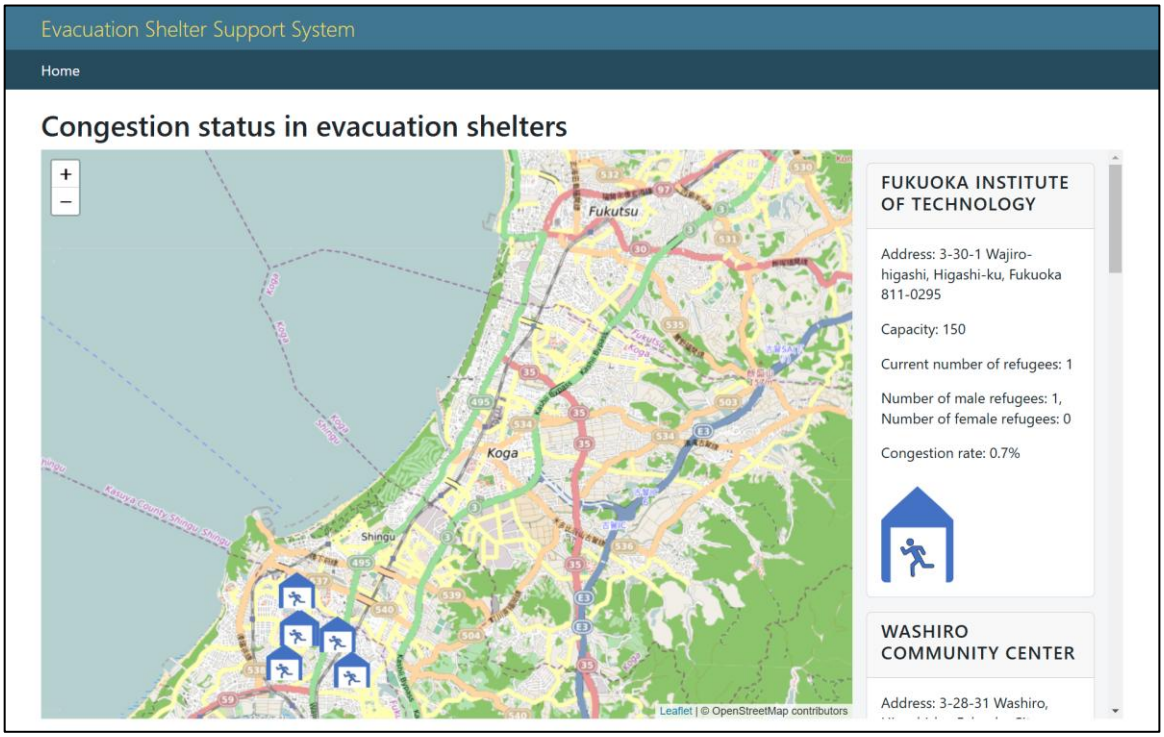
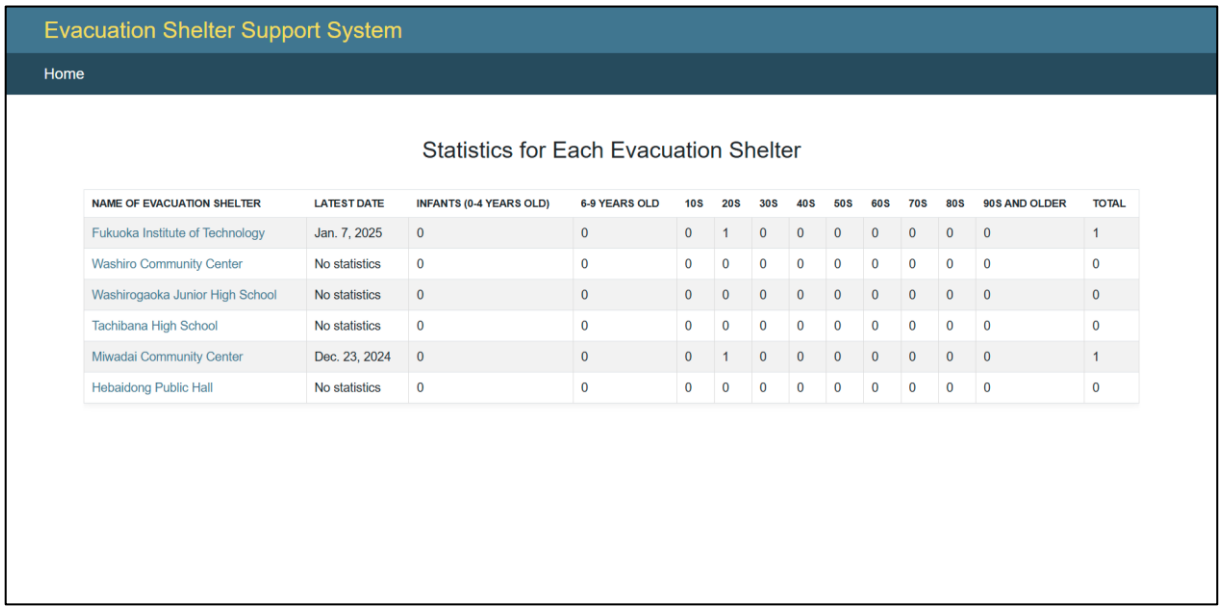


Figure 16: Congestion status visualization screen for each evacuation shelter

Congestion rate	Illustration
0%~20%	
21%~40%	
41%~60%	
61%~80%	
80%~	

Figure 17: Congestion status display

Figure 18 shows the statistical information screen for the evacuation shelters, and Figure 19 shows the detailed information screen for a single evacuation shelter. Figure 18 shows a list of the age groups currently at each evacuation shelter. When the local government staff selects the evacuation shelter name from the screen shown in Figure 18, the screen transitions to the detailed information screen for the evacuation shelter (Figure 19), which shows the gender ratio, age distribution, and number of evacuees at the specific evacuation shelter. At the bottom of this screen, the local government staff can view basic information about the evacuation shelter, information about the evacuees currently at the shelter, and information about previous evacuees.



NAME OF EVACUATION SHELTER	LATEST DATE	INFANTS (0-4 YEARS OLD)	6-9 YEARS OLD	10S	20S	30S	40S	50S	60S	70S	80S	90S AND OLDER	TOTAL
Fukuoka Institute of Technology	Jan. 7, 2025	0	0	0	1	0	0	0	0	0	0	0	1
Washiro Community Center	No statistics	0	0	0	0	0	0	0	0	0	0	0	0
Washirogaoka Junior High School	No statistics	0	0	0	0	0	0	0	0	0	0	0	0
Tachibana High School	No statistics	0	0	0	0	0	0	0	0	0	0	0	0
Miwadai Community Center	Dec. 23, 2024	0	0	0	1	0	0	0	0	0	0	0	1
Hebaidong Public Hall	No statistics	0	0	0	0	0	0	0	0	0	0	0	0

Figure 18: Statistical information screen for each evacuation shelter

Figure 20 shows the relief supplies automatic calculation screen for each evacuation shelter. The relief supplies include water and the eight basic items of push-type relief supplies defined by the Cabinet Office [15], i.e., food, blankets, portable toilets, adult diapers, toilet paper, sanitary products, infant milk, and infant diapers. The daily required amount of each relief supply is set as shown in Table 2. Using this information, the amount of relief supplies required for each evacuation shelter can be calculated automatically according to the age

group and gender. In addition, by selecting the CSV output button, it is possible to export the supply calculation results in CSV format.

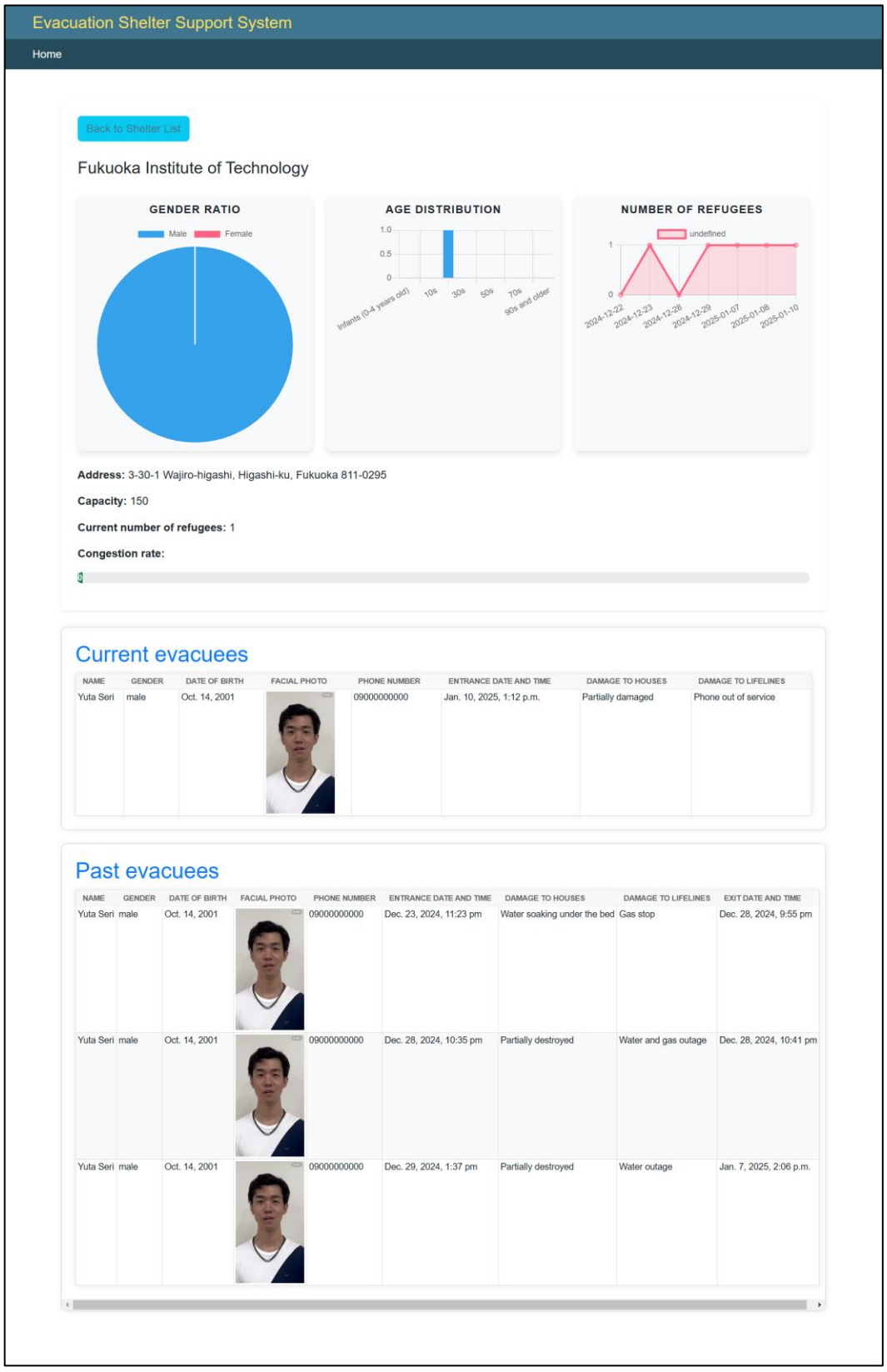


Figure 19: Detailed information screen for an evacuation shelter

Table 2: Daily required amount of each relief supplies

Name of item	Unit	Male (standard amount)	Female (standard amount)	Infants (standard amount)	Elderly (standard amount)
Food	Serving	3	3	0	0
Blankets	Sheet	1	1	-	-
Portable toilets	Unit	6	6	-	-
Adult diapers	Sheet	0	0	-	6
Toilet paper	Roll	1	1	-	-
Sanitary products	Pack	0	1	-	-
Infant milk	Can	0	0	1	-
Infant diapers	Sheet	0	0	6	-
Water	Liter	3	3	-	-

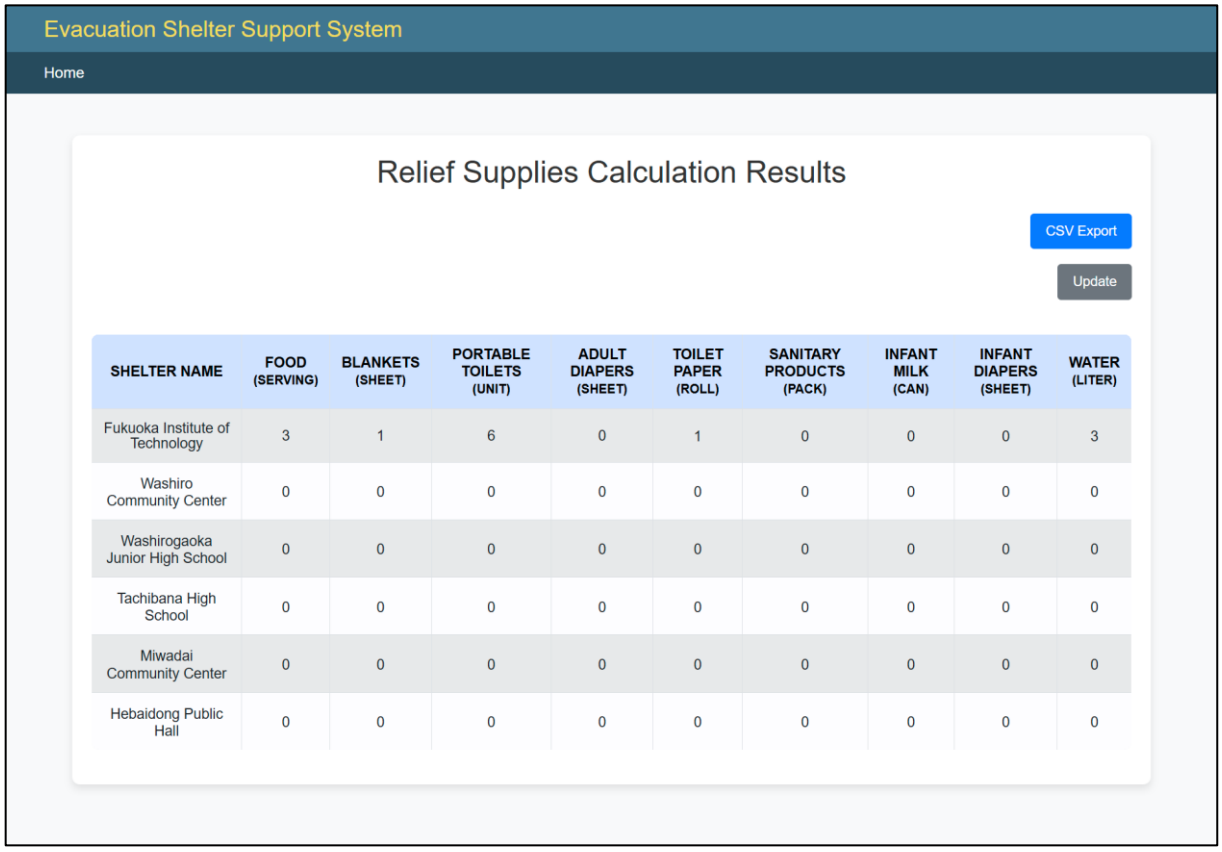


Figure 20: Relief supplies automatic calculation screen for each evacuation shelter

Figure 21 shows the evacuee arrival/departure log and the history screen of the evacuee management system. This system visualizes this information in chronological order.

Figure 21: Evacuee arrival/departure log and history screen

The sequence diagram of the evacuation shelter management system is shown in Figure 22. This system comprises six main functions. Local government staff can access the following functions from the home screen: a list of the evacuation shelters, visualizations of the congestion status, detailed information, relief supplies calculation results, and log/history. Note that these functions are implemented by accessing the database via the server from a web browser, and the system allows local government staff to manage information on the evacuation shelters and evacuees.

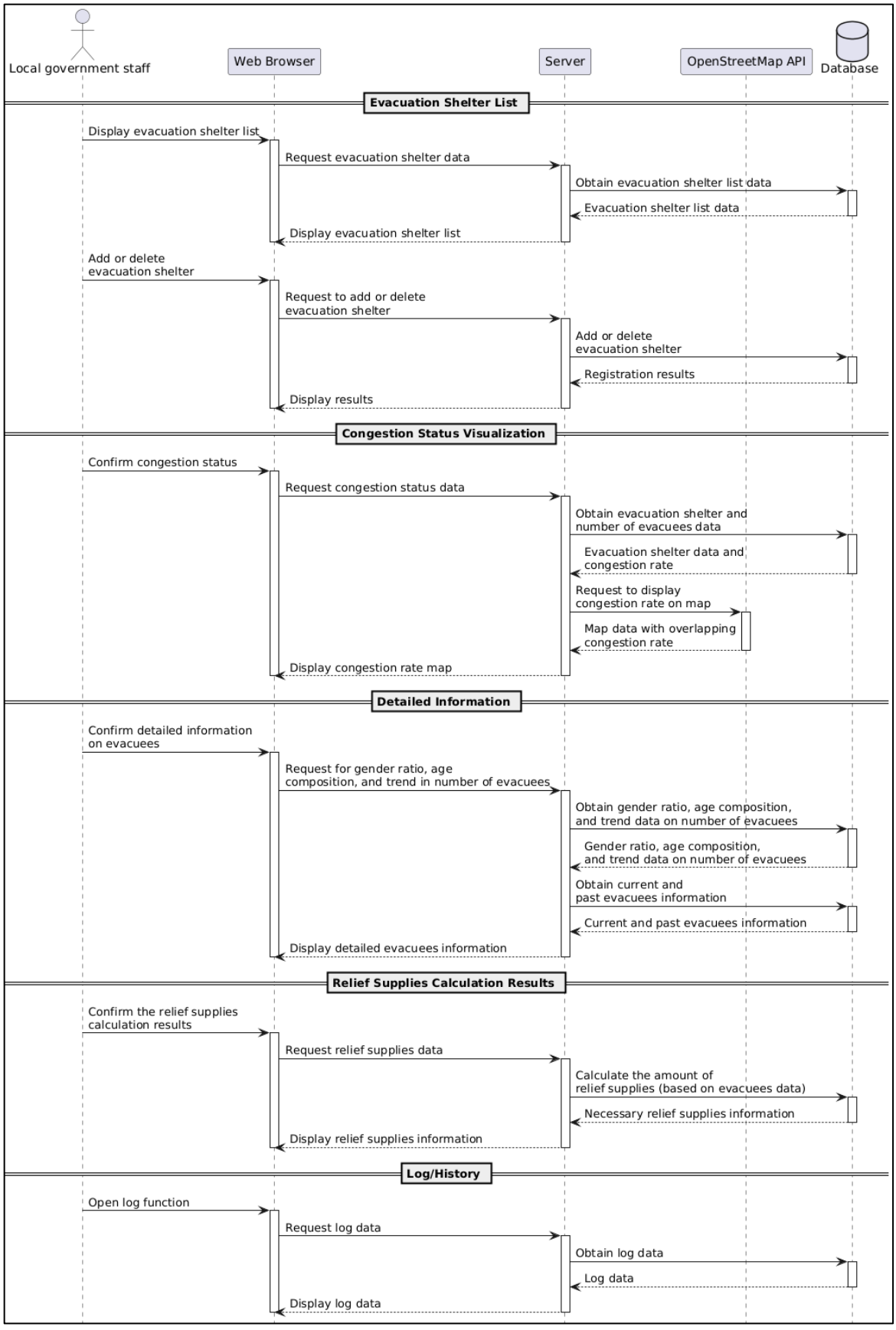


Figure 22: Sequence diagram of the evacuee management system

6 Evaluation of Evacuation Shelter Support System

To evaluate the proposed evacuation shelter support system, which comprises the evacuee arrival/departure registration management system and the evacuation shelter management system, we administered a questionnaire to 31 participants. We also evaluated the processing capabilities of the proposed system's facial recognition function.

- Convenience of registering arrivals and departures using facial recognition

Figure 23 shows the evaluation results regarding the convenience of registering evacuee arrivals and departures using facial recognition technology. As can be seen, 23 participants (74%) answered "convenient," seven participants (23%) answered "somewhat convenient," and one participant (3%) answered "no opinion." These results confirm the high convenience of registering evacuee arrivals and departures using facial recognition technology in the proposed system.

- Usability of facial recognition function

Figure 24 shows the evaluation results regarding the usability of the facial recognition function. As shown, 19 participants (61%) answered "easy," nine participants (29%) answered "somewhat easy," two participants (7%) answered "no opinion," and one participant (3%) answered "difficult," thereby confirming the high usability of the facial recognition function.

- Effectiveness of evacuee arrival/departure registration management system

Figure 25 shows the evaluation results regarding the effectiveness of the evacuee arrival/departure registration management system. As can be seen, 27 participants (87%) answered "effective," three participants (10%) answered "somewhat effective," and one participant (3%) answered "no opinion." These results confirm the high effectiveness of the evacuee arrival/departure registration management system.

- Effectiveness of evacuation shelter registration and deletion function

Figure 26 shows the evaluation results regarding the effectiveness of the evacuation shelter registration and deletion function. As shown, 24 participants (78%) answered "effective," six participants (19%) answered "somewhat effective," and one participant (3%) answered "no opinion," thereby confirming the high effectiveness of the evacuation shelter registration and deletion function.

- Effectiveness of the congestion status visualization function

Figure 27 shows the evaluation results for the effectiveness of the congestion status visualization function. Here, 26 participants (84%) answered "effective," four participants (13%) answered "somewhat effective," and one participant (3%) answered "no opinion." These results confirm the high effectiveness of the congestion status visualization function.

- Effectiveness of the evacuation shelter detailed information management function

Figure 28 shows the evaluation results regarding the effectiveness of the evacuation shelter detailed information management function. As shown, 22 participants (71%) answered "effective," eight participants (26%) answered "somewhat effective," and one participant (3%) answered "no opinion," thereby confirming the high effectiveness of the evacuation shelter detailed information management function.

- Effectiveness of the relief supplies automatic calculation function

Figure 29 shows the evaluation results regarding the effectiveness of the relief supplies automatic calculation function. As can be seen, 27 participants (87%) answered "effective," three participants (10%) answered

"somewhat effective," and one participant (3%) answered "no opinion," thereby confirming the high effectiveness of the relief supplies automatic calculation function.

- Changes in total processing time by number of data

We also measured the processing time when the number of evacuee data items increased stepwise from 100 to 10,000. Here, we performed facial recognition five times for each number of data items and calculated the average processing time. Table 3 and Figure 30 show the processing time results for each number of data items and their corresponding trends. As can be seen, the processing time increased linearly in proportion to the number of data items because the face encoding value is a high-dimensional vector with 128 dimensions. Therefore, as the amount of data increases, the search time becomes longer, and when handling high-dimensional vectors, the search time tends to approach a linear search. However, we believe that this increase in processing time is within a sufficiently practical range, taking into consideration the performance of the facial recognition system.

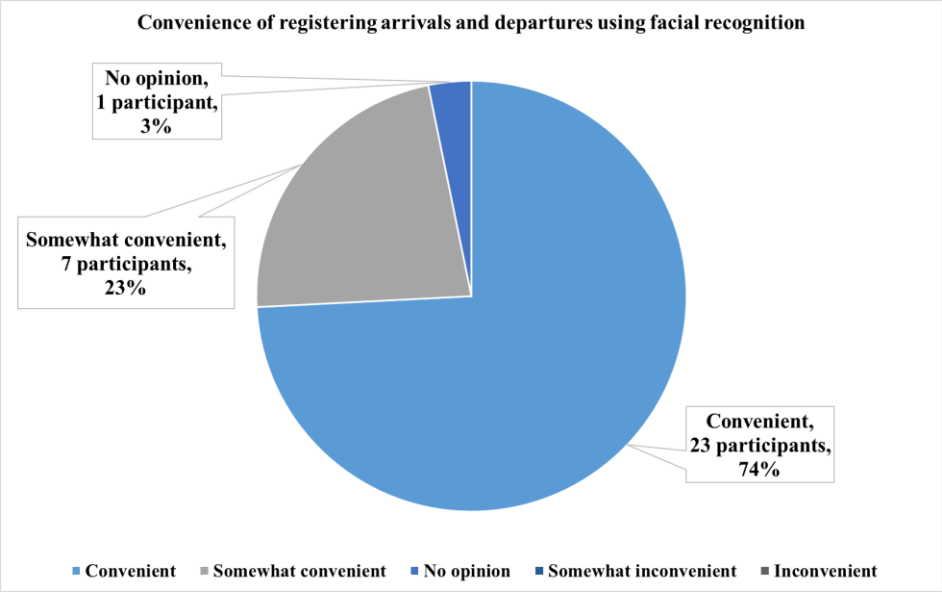


Figure 23: Convenience of registering evacuee arrivals and departures using facial recognition (n = 31)

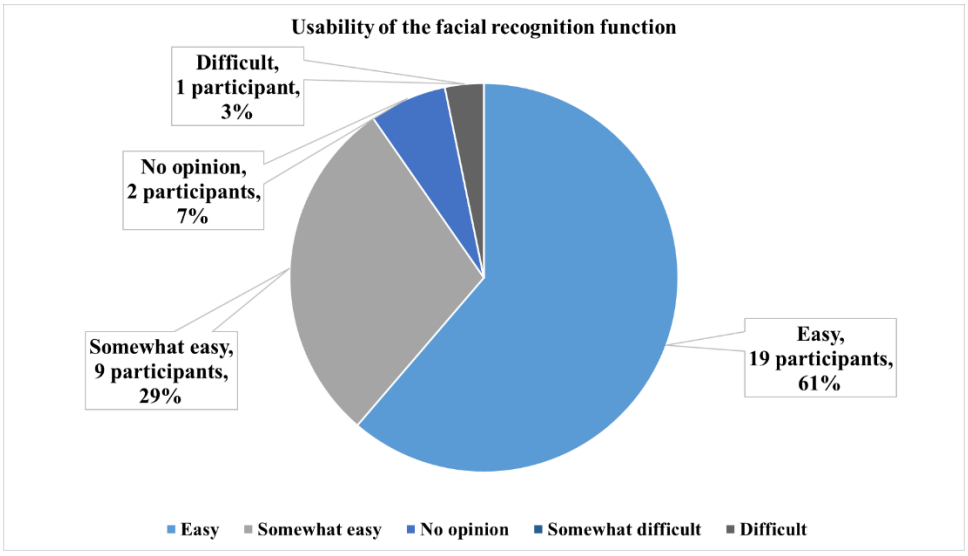


Figure 24: Usability of the facial recognition function (n = 31)

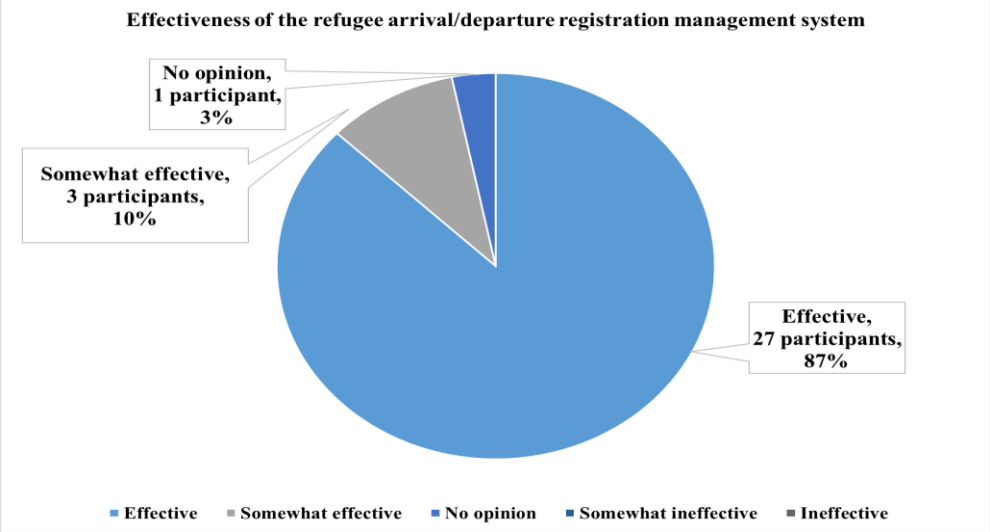


Figure 25: Effectiveness of the evacuee arrival/departure registration management system (n = 31)

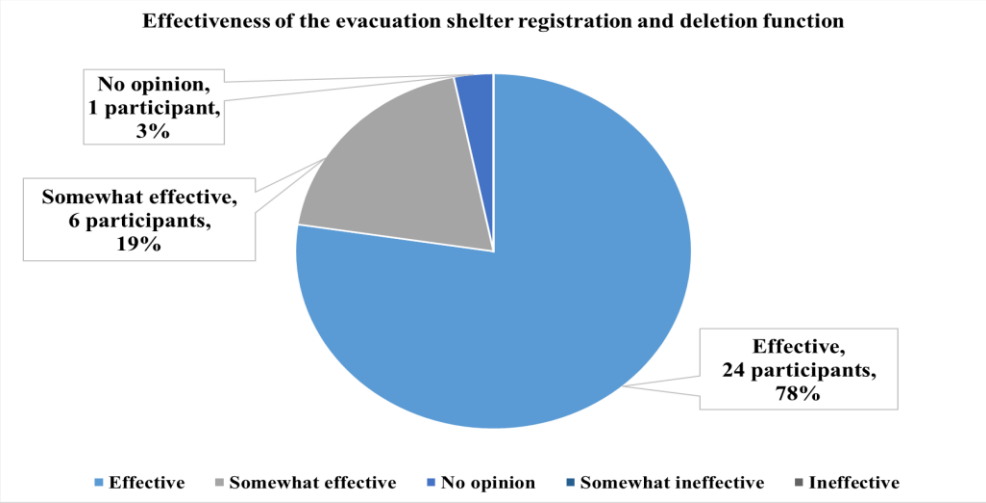


Figure 26: Effectiveness of the evacuation shelter registration and deletion function (n = 31)

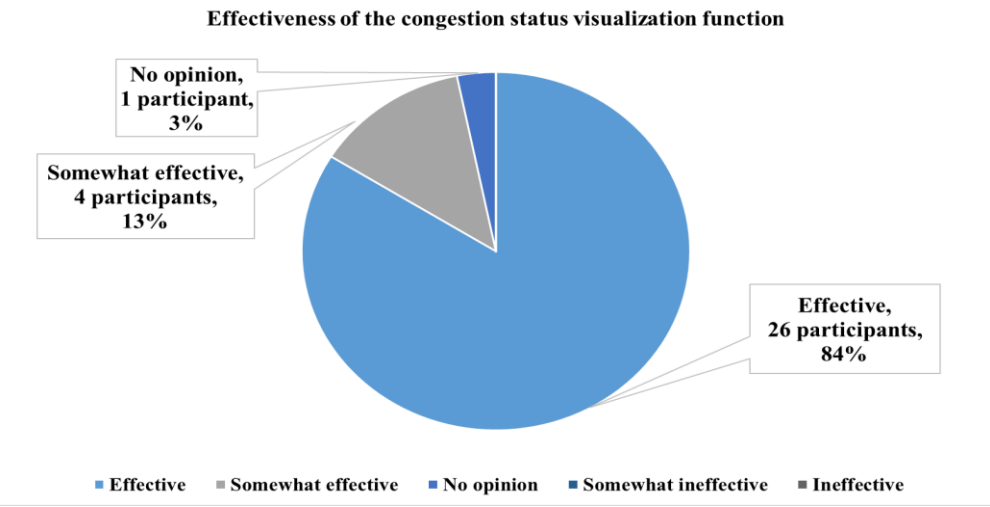


Figure 27: Effectiveness of the congestion status visualization function (n = 31)

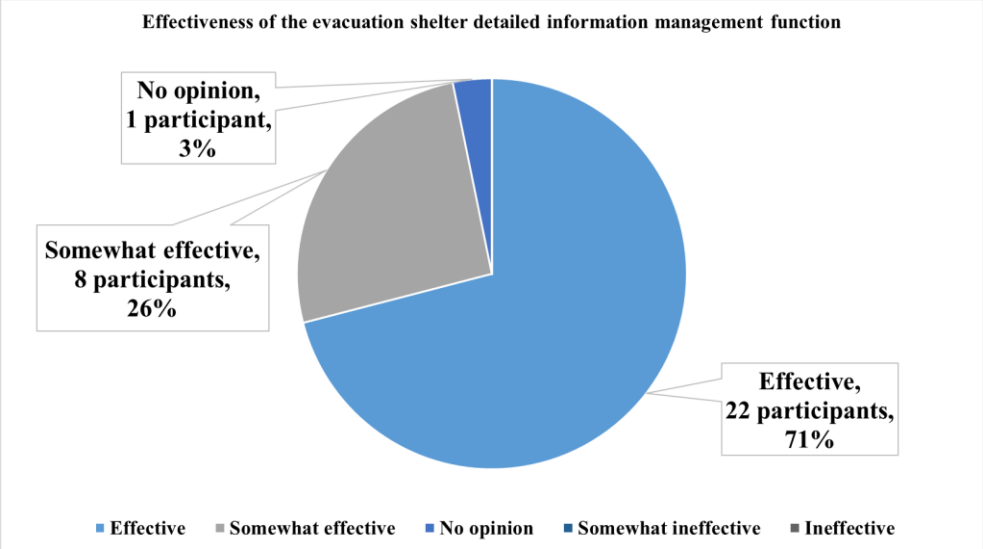


Figure 28: Effectiveness of the evacuation shelter detailed information management function (n = 31)

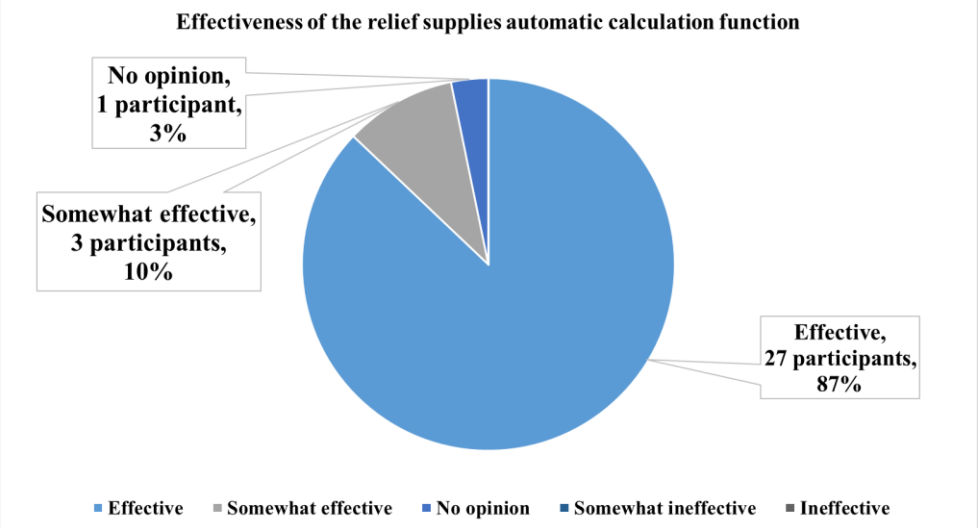


Figure 29: Effectiveness of the relief supplies automatic calculation function (n = 31)

Table 3: Processing time by number of evacuee data items

Number of evacuee data	Processing time [s]					Average processing time [s]
	1st time	2nd time	3rd time	4th time	5th time	
100	1.05	0.98	1.04	1.04	1.01	1.02
1,000	1.75	1.66	1.84	1.82	1.79	1.77
2,000	2.59	2.86	2.82	2.55	2.64	2.69
3,000	3.83	3.21	3.21	3.20	3.64	3.42
4,000	3.98	3.91	3.96	4.11	4.02	4.00
5,000	4.82	5.04	4.75	4.85	4.39	4.77
6,000	6.03	5.66	5.66	5.63	5.76	5.75
7,000	6.57	6.22	6.57	6.15	6.71	6.44
8,000	7.49	6.97	7.52	7.04	7.37	7.28
9,000	8.12	7.48	8.27	7.60	7.59	7.81
10,000	7.90	8.31	8.28	8.77	8.33	8.32

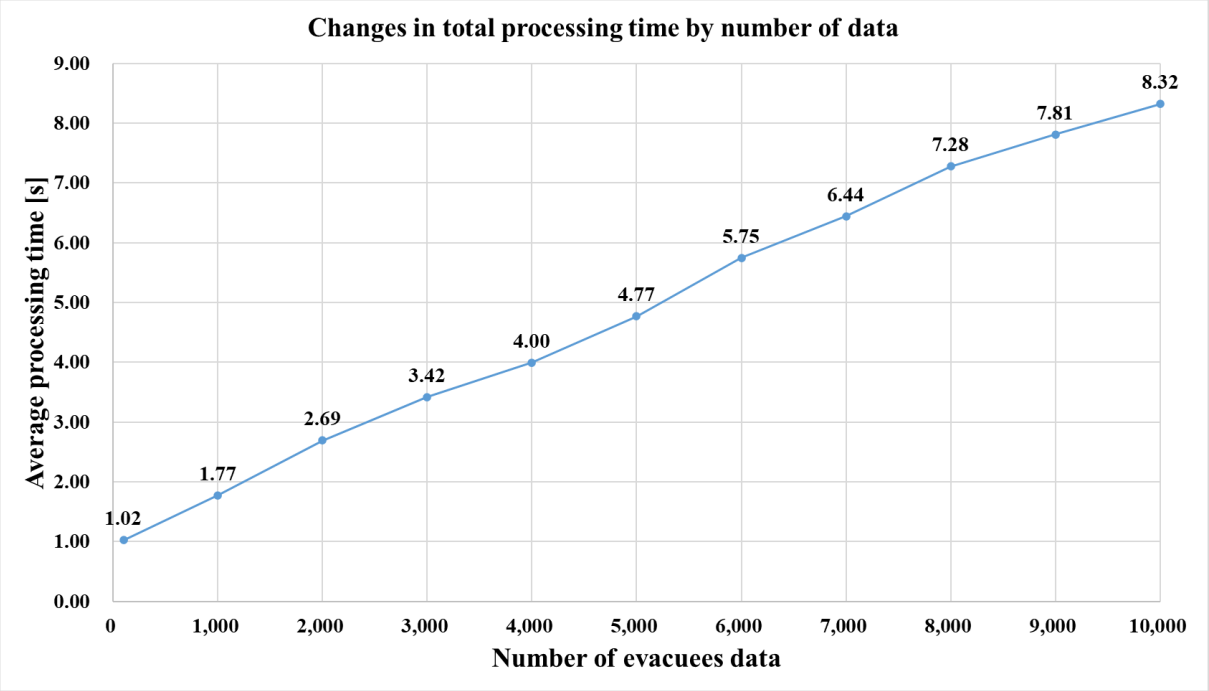


Figure 30: Changes in total processing time by number of data items

7 Conclusion and Future Works

This paper has described the implementation and evaluation of an evacuation shelter support system. The proposed evacuation shelter support system comprises an evacuee arrival/departure registration management system and an evacuation shelter management system.

Through the evacuee arrival/departure registration management system, the evacuees perform facial recognition using a camera-equipped tablet device installed at the reception desk of the evacuation shelter. Then, they enter the damage status of their house and relevant infrastructures, and the arrival registration is completed. In addition, when an evacuee departs from the evacuation shelter, facial recognition is performed again to register the departure.

Using the proposed evacuation shelter management system, local government staff can acquire real-time information about the evacuation shelters. This system has functions to register and delete evacuation shelters, visualize the congestion status of each evacuation shelter, view detailed information on the evacuation shelters, and calculate the required relief supplies automatically based on the detailed information of each evacuation shelter.

To evaluate the proposed evacuation shelter support system, a questionnaire survey was administered to 31 participants. The evacuee arrival/departure registration management system was evaluated in terms of convenience, usability, and effectiveness. In addition, the evacuation shelter management system was evaluated in terms of the effectiveness of each function. The evaluation results indicated that the proposed system was highly rated in all evaluation items. However, some participants requested that the evacuee arrival/departure registration management system be able to register the arrival/departure by household rather than by the individual; thus, in the future, we plan to implement a household registration function.

Acknowledgement

This paper is an extended version of the work [16] originally presented at the 8th International Conference on Mobile Internet Security, Sapporo, Japan, December 17-19, 2024.

References

[1] Geospatial Information Authority of Japan. List of past disaster-related information. https://www.gsi.go.jp/kohokocho/kakosai202001.html, [Online; Accessed in January 2025].

[2] Telenet Co., Ltd. Digital evacuation register management system for local governments -Rakuraku Hinan Kun-. https://telenet.co.jp/rakurakuhinan/, [Online; Accessed in January 2025].

[3] Iwate Prefectural University. Disaster Prevention and Reconstruction Support Center: We cooperated in a demonstration experiment (hosted by Iwate Prefecture) on the digitalization of evacuation shelter management. https://www.iwate-pu-bousai.jp/2024/09/19/699/, [Online; Accessed in January 2025].

[4] Kitsuya, M., Tsukahara, R., Sasaki, J. (2021). Development of Real-Time Evacuation Support System (RESS) to Reduce Human Damage in Natural Disasters. In Proc. of the 5th IFIP WG 5.15 International Conference, ITDRR 2020 (pp. 14-25), Sofia, Bulgaria, December 2020. https://doi.org/10.1007/978-3-030-81469-4_2

[5] Miura, Y., Kobayashi, M., Shin, K., Nishi, M. (2022). A Study on Information Transmission Systems to Solve Labor Shortages in Evacuation Centers. In Proc. of the 84th National Convention of IPSJ (pp. 525-526), Ehime, Japan, March 2022. (in Japanese)

[6] Abe, A., Kawai, Y. (2024). Information management system for evacuation status during disasters. In Proc. of the 86th National Convention of IPSJ (pp. 841-842), Kanagawa, Japan, March 2024. (in Japanese)

[7] Gonzalez-Villa, J., Cuesta, A., Alvear, D., Balboa, A. (2022). Evacuation Management System for Major Disasters. Applied Sciences, 12(15), 7876. https://doi.org/10.3390/app12157876

[8] Agoylo, J. J. C., Gula, R. O., Narciso, R. S., Ortega, J. G. D., Silvio, A. B. (2024). MUNICIPAL EMERGENCY RESPONSE SYSTEM (MERS) USING GMAPS AND SMS. Ignatian International Journal for Multidisciplinary Research, 2(5), 1121-1141. https://doi.org/10.17613/kard-k405

[9] Diaz Intal, G. L.,Senoro, D., Palaoag, T. (2021). User Experience Design for Disaster Management Mobile Application using Design Thinking Approach. In Proc. of the 2020 4th International Conference on Software and e-Business (ICSEB '20) (pp. 7-13), Osaka, Japan, December 2020. https://doi.org/10.1145/3446569.3446587

[10] Handayani, A., Hopipah, N., Fadhli, M. (2023). The Implementation of Mobile Technology in The Process of Reporting Disasters and Events. IJCCS (Indonesian Journal of Computing and Cybernetics Systems), 17(4), 405-416. http://dx.doi.org/10.22146/ijccs.87660

[11] Gallera, Jovie M., Salvador, Arvin S. (2023). Assessment of Digital Information Systems for Local Barangays. International Research Journal of Advanced Engineering and Science, 8(2),112-115.

[12] Mardaid, E., Zainal Abidin, Z., Asmai, S. A., Abal Abas, Z. (2023). Implementation of Flood Emergency Response System with Face Analytics. International Journal of Advanced Computer Science and Applications (IJACSA), 14(1), 400-406. http://dx.doi.org/10.14569/IJACSA.2023.0140143

[13] Hayashi, T., Watakabe, M., Tamari, Y., Tanaka, K.(2023). An Investigative Research on the Efficiency of Shelter Management Using Digital Technology During a Large-Scale Disaster. Bulletin of Hiroshima Institute of Technology, 57, 67-72. (in Japanese)

[14] Ogawa, T. (2022). Development and Evaluation of Face Recognition Attendance Management System Using CNN. Journal of Economics and Business Administration, 30(1), 15-22. (in Japanese)

[15] Cabinet Office, Japan. Regarding material support from the government. https://www.bousai.go.jp/taisaku/hisaisyagyousei/push.html, [Online; Accessed in January 2025].

[16] Seri, Y., Ishida, T. (2024). Development of a Shelter Control System for Refugees. In Proc. of the 8th International Conference on Mobile Internet Security (pp.1-11), Sapporo, Japan, December, 2024.

Author's Biography

Yuta Seri received the B.S. degree in Fukuoka Institute of Technology in 2024. Currently he is taking a master's course at Graduate School of Engineering, Fukuoka Institute of Technology. His research interests include Web Application System, Disaster Management System, Regional Disaster Prevention, Decision Support System, and Crisis Management.

Masaya Takezaki is currently taking the B.S. degree in Fukuoka Institute of Technology. His research interests include Evacuation Shelter Management System, Facial Recognition Technology, Safety Confirmation System, and Crisis Management.

Tomoyuki Ishida received the B.S. and M.S. degrees in Software and Information science from Iwate Prefectural University in 2004 and 2006, and Ph.D. degrees in the same University in 2010. Currently he is a professor in Department of Information and Communication Engineering, Fukuoka Institute of Technology, Japan. His research interests include Web Geographic Information System for local governments, Disaster Management System, Safety Confirmation System, Regional Disaster Prevention Planning, Virtual Reality and Tele-Immersion. He is a member of Virtual Reality Society of Japan (VRSJ), Information Processing Society of Japan (IPSJ) and Visualization Society of Japan (VSJ).