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A Chatbot System to Support Mine Safety Procedures during Natural Disasters

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Abstract: This study developed a chatbot to improve the efficiency of government activation of mine safety procedures during natural disasters. Taiwan has a comprehensive governmental system dedicated to responding to frequent natural disasters, and the Bureau of Mines has instituted clear procedures to ensure the delivery of disaster alarms and damage reports. However, the labor- and time-consumption procedures are inefficient. In this study, we propose a system framework for disaster-related information retrieval and immediate notifications to support the execution of mine safety procedures. The framework utilizes instant messaging (IM) applications as the user interface to look up information and send messages to announce the occurrence of disaster events. We evaluated the efficiency of the procedures before and after adopting the system and achieved a time-cost reduction of 55.8 min among three types of disaster events. The study has proven the feasibility of adopting novel techniques for decision-making and assures the improvement of the efficiency and effectiveness of the procedure activation.

Keywords: disaster risk reduction; chatbot; mine safety; decision-support; conversational agent

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1. Introduction

Frequent natural disasters in Taiwan include earthquakes, typhoons, and heavy rain caused by severe weather events (e.g., thunderstorms) and synoptic-scale systems [1–3]. With the mountainous terrain and complex geology of the Taiwan island, disasters are intensified and cause safety issues. For example, the 7.3-magnitude Chi-Chi Earthquake in 1999 severely damaged Taiwan, causing over 2000 deaths [4,5] and destroying over 50,000 households [5]. In 2009, Typhoon Morakot killed over 600 people, left 60 people missing, caused over 1050 injuries, and destroyed 600 buildings [5]. The August 23 flood, which was caused by a tropical depression in 2018, resulted in seven deaths, and almost 8500 residents were evacuated to temporary shelters [6]. Because floods, typhoons, earthquakes, and landslides caused over 4000 deaths in Taiwan between 1994 and 2019 [5], governmental disaster management has been prioritized. After the Chi-Chi Earthquake in 1999, the Disaster Prevention and Protection Act [7] of Taiwan, which establishes how the governmental system protects the safety of people's lives and properties, was instituted.

The Bureau of Mines of the Ministry of Economic Affairs (MOEA) in Taiwan has developed procedures for alerting mines of potential risks when a natural disaster occurs. For example, the *Procedures for Notification of Earthquakes, Typhoons, and Torrential Rain* ensure mines in affected areas are notified and damage information is collected. The Disaster Prevention and Protection Act of Taiwan requires central and local governments to implement measures depending on the functional authorities. Such measures include (a) disaster alarm announcement and delivery, (b) response and alert, (c) people evacuation, (d) rescue and refuge advice, (e) information collection of disaster situations, and (f) survey reports of loss. Hence, the Bureau of Mines has instituted procedures to activate the mechanism of information delivery and collection. When the Central Weather Bureau (CWB) issues warnings based on hazardous meteorological or seismological phenomena, the Mine Safety Division of the Bureau of Mines determines whether to activate the procedures in accordance with the severity. When the procedures are activated, the five Mine Safety Centers of the Mine Safety Division and the Eastern District Office are notified, and the mines in their jurisdictions are alerted via short message service (SMS) or instant messaging (IM) applications. During the disaster, the mines should execute emergency response measures. After the disaster, the Mine Safety Division requires the five Mine Safety Centers and the Eastern District Office to collect information on the mines to understand the situation.

The procedures clarify the activation timings and response. However, the Mine Safety Division encounters two key difficulties during implementation:

- Labor consumption: Shift work is necessary for the Mine Safety Division to be aware of warnings from websites or applications on smart devices.
- Decision time cost: It takes time to determine whether the severity of an alarm meets the activating conditions and whether there are mines in the affected area.

Thus, although a comprehensive governmental system is dedicated to responding to frequent natural disasters, and the Bureau of Mines has instituted clear procedures to ensure the delivery of disaster alarms and damage reports, inefficiencies remain that could be mitigated.

This study aims to improve the efficiency of the government activation of mine safety procedures during natural disasters by reducing the labor and time consumption during emergency operations for information delivery. By adopting smart device technology, we develop a novel solution featuring immediate notifications, direct indications, and an intuitive interface for disaster information retrieval to support effective decision-making. Section 2 reviews related works, and Section 3 clarifies the research objective. Section 4 introduces the system framework and design method, and Section 5 describes the system implementation. Section 6 discusses the effectiveness evaluation of the system adoption. Section 7 describes the major advantages achieved in this study, including feasibly utilizing novel techniques for decision support and improving efficiency and effectiveness of procedure activation during disaster events.

2. Related Works

Barriers to information accessibility have declined along with the enhancements made to information and communication technology (ICT). Electronic devices continue to become more powerful [8]. Meanwhile, due to the evolution of wireless protocols and techniques, connections to the Internet are no longer bound to time and location. The fusion of faster networks, efficient applications, improved operating systems, better user interfaces, enhanced display technology, and the extending ecosystem of application markets have made modern smartphones successful [9]. Effortless access, process, and production of information are now possible using smartphones.

Following the widespread use of smartphones, the growth of messaging applications has resulted in conversational agents, also called chatbots in the industry, becoming a trending solution for trivial problems. Conversational agents are software applications that interact with users for different purposes using conversations [10]. Chatbots are widely used in various areas, such as business, medical and healthcarefields, and disaster management. Bavaresco et al. [11] reviewed recent studies and found that chatbots have been most explored in the commerce domain, covering subareas such as e-commerce, sales, shopping, and flight booking. Sun et al. [12] adopted chatbots to personalized recommendation systems for building a virtual sales agent by utilizing deep learning technologies. Jusoh [13] proposed a method to persuade e-customers to buy products through recommendation and negotiation. Majumder et al. [14] built a chatbot to help customers with category-sensitive retrieval techniques and obtained quality improvements. Koetter et al. [15] investigated the potential usage of chatbots in insurance companies and developed a prototype for an exemplary insurance scenario. Cui et al. [16] developed a customer service chatbot taking advantage of product descriptions and user-generated content from e-commerce websites. Laranjo et al. [17] observed that recent studies of chatbots in the medical field are commonly related to mental health and suggested that the utilization of chatbots for health-related issues is an emerging research field. Vaidyam et al. [18] noted that the mental health field could adopt chatbots in psychiatric treatment with proper approaches. Mavropoulos et al. [19] presented a context-aware system framework by combining monitoring and chatbots to benefit ailing patients and assist clinical experts to retrieve information about patients. Griol et al. [20] presented a multimodal conversational coach for physical activity training with sensors to provide meaningful coaching and feedback during sessions. Tsai et al. [21] stated that the advance of smart devices and social networking contributes to a trend of using chatbots for disaster prevention and emergencies.

Several governmental agencies in Taiwan have developed public servicing chatbot products for the general Taiwanese population, and some of the products provide disaster-related information. For example, the National Science and Technology Center for Disaster Reduction (NCDR) developed a chatbot providing over 30 types of public alerts, covering severe weather events, hydrology, traffic, and other issues [22,23]. The Agriculture Department of the New Taipei City Government presented the Landslide Guardian 2.0 to provide instructions on landslides and send notifications to warn users against impending landslides and other severe weather events [24]. In addition, some local governments, including the Taipei City Government, provide local disaster information via their official channels.

In addition to alerts or information dissemination, some institutions and studies have adopted chatbots for collecting damage information and providing advanced services. In Japan, Weathernews Inc., the National Research Institute for Earth Science and Disaster Resilience (NIED), and the National Institute of Information and Communications Technology (NICT) developed a chatbot to collect damage information, summarize the collected information, and provide customized advice to help victims [25,26]. In Taiwan, Tsai et al. [27] proposed a three-module conversation-based system framework, implemented as a chatbot to notify and support school building managers completing damage inspections and report submissions after earthquakes. Kung et al. [28] adopted transfer learning to automatically extract information from the collected damage reports and provide analysis for decision-makers to understand the situation.

Some institutions have adopted chatbot products for decision support in the field of disaster management. For example, Tsai et al. [21] developed a chatbot for water-related disaster decision-makers, enabling users to retrieve requested information for decision-making by directly acquiring the chatbot; the system has been validated through a six-month field test and proven its effectiveness. Furthermore, Chan and Tsai [29] enabled disaster decision-makers to retrieve both static and real-time information directly in natural language with the integration of semantic and temporal term types, improving the capacity of question analysis.

Although several disaster-related chatbot products exist, such products are not feasible for the difficulties that the Bureau of Mines is facing. Most only provide basic severe weather alerts; they seldom provide further instructions for the following procedures. In addition, they are typically designed for the general population rather than experts and decision-makers. Although basic information more or less informs government officers and disaster responders to activate emergency operations, officers often need to look up additional documents, especially for institutions with complicated procedures. Tsai et al. [21] developed the water-related chatbot for another governmental agency with different authorities, and it focused on information retrieval for decision support; thus, they did not discuss the need for a notification to activate the safety procedures.

On the other hand, decision support systems (DSS) are commonly adopted and discussed in various aspects of disaster management. Wallace and De Balogh [30] conceptualized a framework for adopting DSS in the field of disaster management. Fogli and Guida [31] designed a knowledge-centered DSS for emergency managers responding to critical situations, overcoming some limitations of user-centered and activity-centered design in the specific context of DSS. Yoon et al. [32] prototyped a computer-based DSS tool to train emergency responders of governmental transportation agencies for their capacities. Zhou et al. [33] observed that new technologies were contributed to the recent development of DSS, and some studies brought advanced information techniques, geographic information systems (GIS), and agent-based designs to enhance emergency decision making. In Taiwan, many governmental agencies developed computer systems considering respective functional authorities during disaster events to support information gathering and decision-making. For example, the Water Resources Agency and the National Fire Agency utilize different systems to fulfill their tasks [34,35]. However, the Bureau of Mines does not have a specific DSS for disaster management.

Thus, we find that the Bureau of Mines lacks the integration of notifications for operations, which is both labor- and time-consuming, and no existing solutions target this issue.

3. Research Objectives

This study aims to improve the efficiency of the government activation of mine safety procedures during natural disasters by reducing labor and time consumption. We focus on the following four goals:

- providing immediate announcements of severe disaster events to enhance the efficiency of activating the safety procedures;
- providing accurate indications to follow the activated procedures in different situations to enhance the effectiveness of the safety procedures;
- ensuring decision-support information, such as real-time observations, charts, documents, and alerts, are available and sufficient for decision-making; and
- ensuring the retrieval of decision-support information is intuitive to improve information accessibility.

4. Method

In this study, we propose a system framework for disaster-related information retrieval and immediate notifications to support the execution of mine safety procedures. The framework utilizes IM applications as the user interface to look up information and send messages to announce the occurrence of disaster events. The proposed system has the following features:

- Question-answering about both real-time information and static documentation
- User permission management to ensure the security of sensitive government information
- Immediate announcement of severe disaster events

Figure 1 illustrates the comprehensive system framework. The three major parts are the core system providing essential utilization, the IM application as the user interface, and the external data sources providing immediate disaster alerts, including earthquake reports, torrential rain warnings, and typhoon alerts. The core system consists of the database and three modules: (1) the search module (S-module), (2) the user module (U-module), and (3) the notification module (N-module). All three modules connect to the database, containing user data, interaction logs, and past notification records. The S-module provides the disaster-related information via an information architecture and a series of mapping keywords as the entries to the information. The U-module manages the user's permission to access sensitive data and provides registration forms for the user to apply for authentication. The N-module retrieves immediate alerts from an external data source, sends announcements to users via IM applications, and saves past notification records.

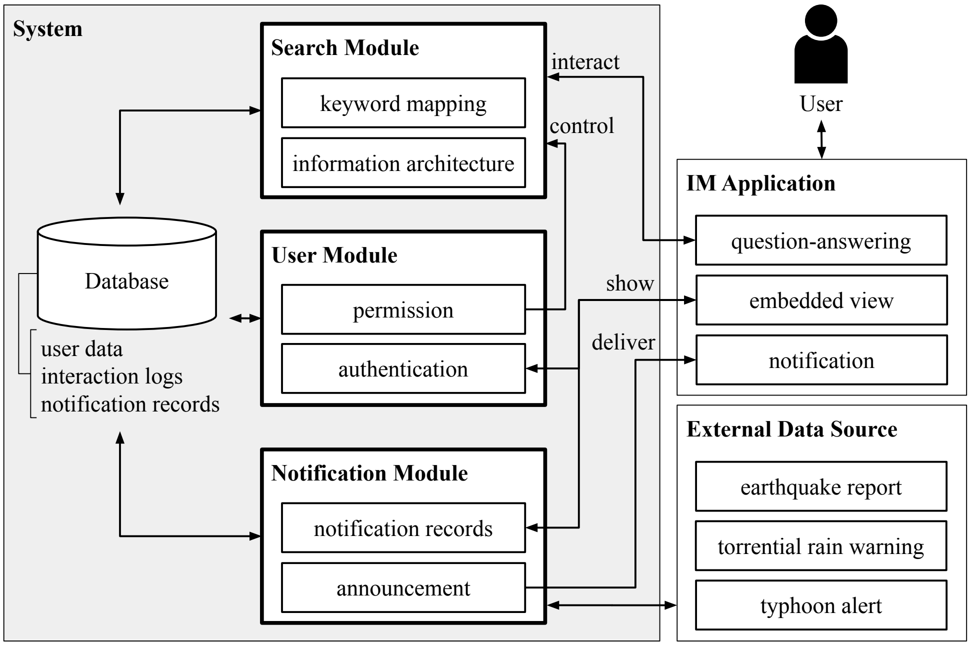

Figure 1. The system framework.

The S-module consists of a keyword mapping list and an information architecture. The keyword mapping provides a list of entries for the disaster-related information that supports the user's decision-making. The information architecture structures the decision-support information based on the domain knowledge of disaster management to assist the user in searching for requested information. The question-answering process operates on the IM application in the form of a chatbot. To retrieve the requested information, the user asks the chatbot questions via the IM application by sending text messages. The system processes the user's input text by trimming, compares the trimmed text with the keyword mapping list, finds the requested information of which the keyword matches the text from the information architecture, and replies to the user. The system also stores the user's message text in the database.

The U-module applies user authentication and permission management. Since sensitive information may be required for governmental decision-makers, authentication and permission management are necessary to ensure information security. Permission management controls the accessibility to information in the information architecture of the S-module. Users that are not yet authenticated or have low permissions cannot retrieve sensitive data from the system via the IM application. This module also provides the authentication application form to authenticate and grant proper permissions to users. Users may fill in the application form via the in-app web browsers embedded in the IM application.

The N-module notifies users of the occurrence of disaster events and displays past notification records. When the N-module detects updates of alerts from the external data source, it retrieves the original data and determines whether the announced disaster events meet the activation standard given in the procedures. If the standard is met, the system continues to determine the related users as receivers and generate messages using predefined templates based on situations. The system sends the announcing message to the selected users via the IM application and stores the announcing record in the database. Similar to the authentication application of the U-module, users may check the notification records via the in-app web browser embedded in the IM application.

4.1. Search Module (S-Module)

The search module provides disaster-related information based on user demand and the domain knowledge of disaster management. It consists of an information architecture and a keyword mapping list. The information architecture is designed referring to the domain knowledge and the user requirements for decision support. The keyword mapping list contains entries to the content of the information architecture. By asking the chatbot via the IM application, the system processes the user's input text, compares the text with the keyword mapping list, retrieves the information from the information architecture, and generates an appropriate response to the user.

To clarify the user demand for information retrieval and notification, we interviewed nine personnel of the Bureau of Mines, including the director general, the deputy director general, the chief secretary, the director of the Mine Safety Division, the director of Technical Assistance Division, the staff of the Mine Administration Division, the staff of the Mine Safety Division, and the staff of the Eastern District Office, as shown in Figure 2. Figure 3 shows the organization of the Bureau of Mines and describes the essential roles of some of the personnel/units during natural disasters. The director general, the deputy director general, and the chief secretary are the top decision-makers. The Mine Safety Division performs mine safety inspection, management, and promotion. The Eastern District Office and the Mine Safety Centers deliver information for notifying the mines in the affected areas to take precautions at the start and collecting reported damage from the mines at the end. Hence, the interview focused on the personnel of these roles/units.

Figure 2. Pictures of the interviews.

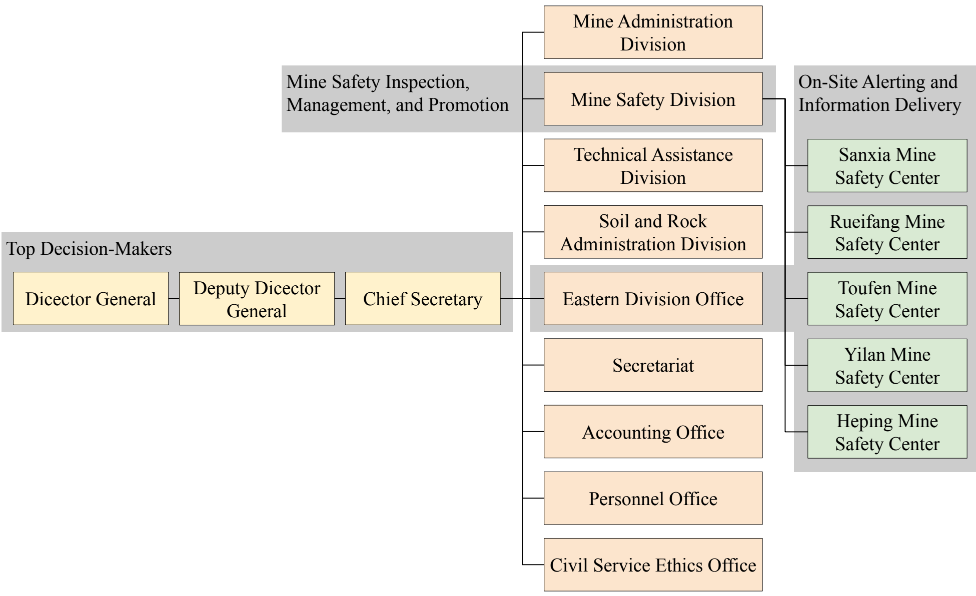

Figure 3. The organization chart of the Bureau of Mines (adapted from Bureau of Mines, Ministry of Economic Affairs [36]).

We identified 12 demands, summarized into three major topics, as shown in Table 1. For the topic of the information architecture, users pointed out that real-time rainfall, landslide alerts, river water level alerts, road alerts, and websites of other emergency-related agencies, such as the National Fire Agency (NFA) of the Ministry of the Interior, are required. Regarding alerts, users specified the detailed activation conditions of torrential rain events and suggested that direct indication for each Mine Safety Center should be included in alert messages. For the topic of operation records, users suggested that records of operation and feedback should be collected for performance evaluation and further system improvement.

Table 1. The demands identified in interviews with the Bureau of Mines personnel.

Topic	Demand
Information architecture	Real-time rainfall
	Landslide alerts
	River water level alerts
	Road alerts
	Websites of other agencies
	Architecture rearrangement based on disaster management phases
	Consideration of sensitive information
Alerts	Specification of torrential rain announcement timings
	Direct indication for different Mine Safety Centers
Operation records	Operation timeline for further analysis
	User feedback collection for system improvement
	User log collection for further analysis

4.2. User Module (U-Module)

The user module manages user authentication and permissions. The process of decision making may require sensitive information. To ensure the security of sensitive information, we establish five types of users: decision-makers, safety staff, other staff, system maintainers, and the public. Definition and examples are designed based on different Bureau of Mines roles and are described in Table 2. Users except for the public have permission to access all sensitive information. By controlling the accessibility to the content of the information architecture, sensitive information is protected.

Table 2. The description of user permissions.

Type	Description
Decision-makers	Core decision-makers of the Bureau of Mines, e.g., the director general, the deputy director general, the chief secretary, and directors of the divisions
Safety staff	Personnel providing immediate response to the emergency, e.g., the staff of the Mine Safety Division, the staff of the Mine Safety Centers, and the staff of the Eastern District Office
Other staff	Personnel that do not need to immediately respond to emergency
System maintainers	Maintainers of the system
Public	Users not yet authenticated or not working for the Bureau of Mines

The system provides an application form for users to submit their profiles to gain proper permissions. Users may fill in the application form via the in-app web browsers embedded in the IM application. The system maintainers routinely collect the applications and send them to the Bureau of Mines. The decision-makers at the Bureau of Mines determine the given permission by reviewing each profile.

4.3. Notification Module (N-Module)

The target receivers of the announcement include the decision-makers and the safety staff, as defined in Table 2, since the procedures assign specific tasks to them. Hence, users who are granted the permission of decision-makers or safety staff receive notifications when the conditions are matched. Timings, conditions, and indications vary for different types of disasters. For a typhoon or a torrential rain event, the personnel are notified at both the start and the end of the warning period; the staff should notify the mines in the affected areas to take precautions at the start and report the damage at the end.

For an earthquake, the personnel are only notified after the earthquake to report the damage. Messages are delivered when any earthquake station in at least one of the jurisdictions of the Mine Safety Centers or the Eastern District Office observes an intensity greater than or equal to 5. The personnel of the Mine Safety Centers and the Eastern District Office with the largest intensity in the jurisdictions meeting the alerting criteria should inspect the mines in the jurisdiction and report the damage to the decision-makers.

For invading typhoons, messages are delivered both at the start and the end of a sea and land warning. When a warning is issued, the personnel of all the Mine Safety Centers and the Eastern District Office should notify the mines in the affected jurisdictions to take precautions. After the warning is lifted, the personnel of all the Mine Safety Centers and the Eastern District Office should inspect the mines in the affected jurisdictions and report the damage to the decision-makers.

For torrential rain events, messages are delivered both when the torrential rain warning is issued and when it is lifted in any town in at least one of the jurisdictions of the Mine Safety Centers or the Eastern District Office. The personnel of all the Mine Safety Centers and the Eastern District Office should notify the mines in the affected jurisdictions to take precautions when a warning is issued. After the warning is lifted, the personnel of all the Mine Safety Centers and the Eastern District Office should inspect the mines in the affected jurisdictions and report the damage to the decision-makers.

5. Implementation

The system is implemented with LINE, the most popular IM application in Taiwan [37]. LINE features the Messaging API to build bots for providing customized services to users. The Messaging API passes requests from the LINE Platform to bots by sending them over HyperText Transfer Protocol Secure (HTTPS) [38]. For implementation, Python 3 is used for programming with PostgreSQL as the database. The operating system (OS) is Ubuntu 18.04 deployed on an Amazon Web Service (AWS) virtual machine. Flask, a Python micro-web-framework library, was adopted to implement the system as a HyperText Transfer Protocol (HTTP) service to control the interaction process between users and the chatbot and to host additional web pages. To enable HTTPS, we retrieved certifications from Let's Encrypt.

5.1. Keyword-Information Mapping

Based on our research of the topic, including the interviews, we implemented 108 sets of keyword information. Of the sets, 107 are classified as "weather," "disaster management information," "laws and documents," and "other utilities," and the other set is the entrance menu to access the four major classes. The classification forms the basis of the five-layer information architecture, which is simplified in Figure 4 and summarized in Table 3. Over half of the sets are classified on the topic of weather, which provides various meteorological and seismological information to support decision-makers in understanding the situation. Locations of emergency medical stations, real-time alert statuses, notification records, and the *Procedures for Notification of Earthquakes, Typhoons, and Torrential Rain* can be found in the topic of disaster management information. Other regulations and documents are in laws and documents. Other utilities include the authentication application form and the feedback form.

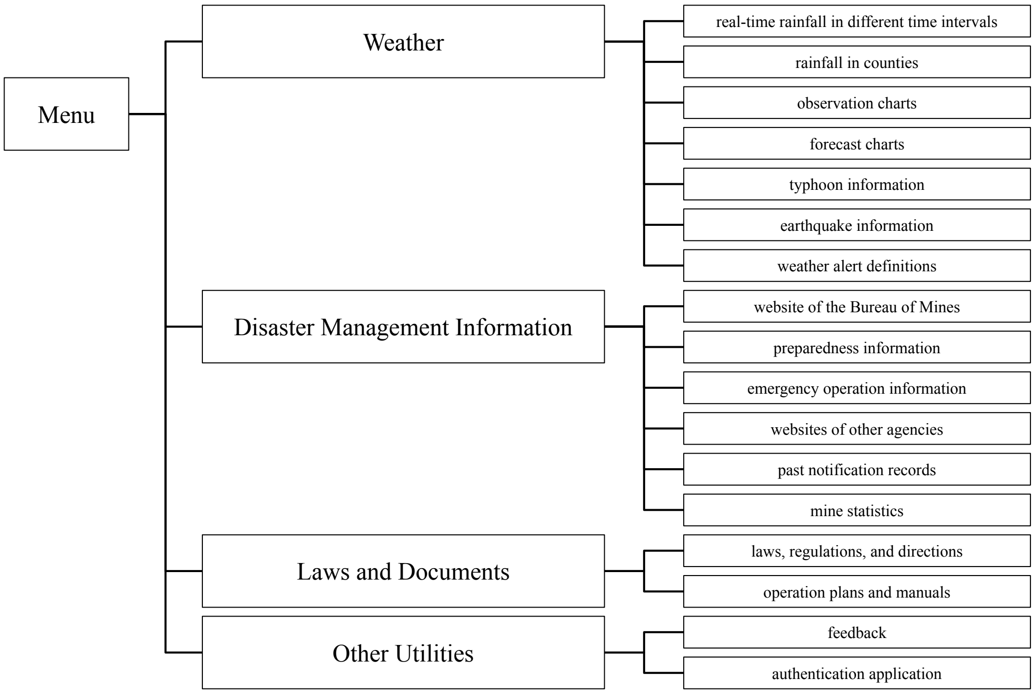

Figure 4. Top three layers of the information architecture.

Table 3. Summary of information in the four major classes.

Topic	Number of Keywords	Examples
Weather	57	Real-time rainfall, weather charts from different institutions, radar charts, satellite images, typhoon information, earthquake information, definitions of weather alerts
Disaster management information	28	Locations of emergency medical stations, the *Procedures for Notification of Earthquakes, Typhoons, and Torrential Rain*, real-time alert statuses, notification records, links to websites of the other agencies
Laws and documents	19	The Disaster Prevention and Protection Act, the *Operation Plan of Disaster Prevention and Protection for Mining*, the *Manual of Disaster Prevention and Protection Operation for Mining*
Other utilities	3	Authentication, feedback

5.2. Data Source

Most of the static documentation, including the locations of mines, the contact information of mine safety centers, and the procedures and regulations are provided by the Bureau of Mines. To clarify the accurate definitions of different weather alerts, the descriptions of the definitions are collected from the CWB website. Other information is collected from the Internet, such as from related agencies' websites. For weather charts (such as observation and forecast charts) and alerts that do not directly activate procedures (such as landslides, river water levels, and roads), we collect real-time information from web pages hosted by at least 10 agencies for the user to access via in-app web browsers.

Severe weather alerts, earthquake reports, and rainfall observations are obtained from the Open Weather Data Platform hosted by the CWB. The Open Weather Data Platform, hosted over HTTPS, provides more than 250 types of data covering various topics, including observations, weather forecasts, earthquakes, climate information, alerts and warnings, numerical weather predictions, and astronomy. Most data types, such as real-time rainfall observation records and earthquake reports, are provided following the CWB Open Data Protocol [39], which was specified by the CWB in 2015. The others are provided following the Common Alerting Protocol (CAP) [40] specified by the Organization for the Advancement of Structured Information Standards (OASIS) in 2010, such as torrential rain warnings and typhoon alerts. Both the CWB Open Data Protocol and the CAP adapt Extensible Markup Language (XML) and specify a unique identifier for every single report or warning message. For system implementation, we developed a timer to check if there are updates from the Open Weather Data Platform. We also developed parsers for earthquake reports, torrential rain warnings, and typhoon alerts to extract essential information. The database records the extracted identifiers of such information to identify whether the data is updated.

5.3. Immediate Notification

Following the timer for checking alert updates every 2 min, we implemented the procedures and the activation conditions via programming. When the information extracted from retrieved data meets the conditions, the system generates appropriate text messages based on the templates given by the Bureau of Mines and sends the messages to the decision-makers and the safety staff defined in Table 2 as a notification. Figure 5 shows a notification example in the chat for a torrential rain event. The text message states the alert type, announcement time, affected areas, the Mine Safety Center with impacted jurisdictions, and the relevant procedures. In addition, a hyperlink to the website of the CWB is attached to the message for the user to retrieve detailed information. The system also records the messages sent to users and displays the messages via web pages, as shown in Figure 6. Even though users may find some notification records in their IM application, recent users cannot retrieve past notifications prior to the time they befriend the chatbot. Thus, an additional panel for looking up past notifications is required.

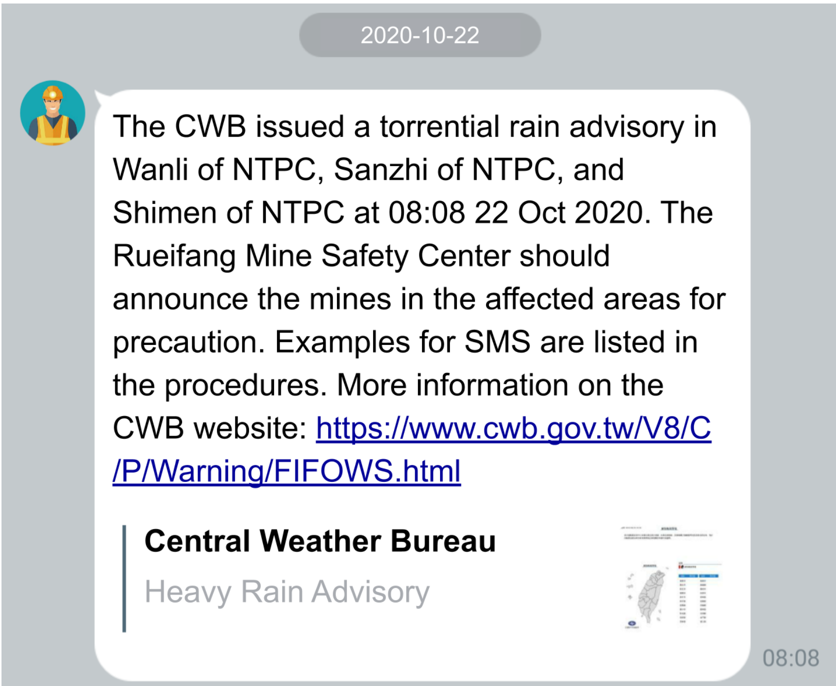

Figure 5. An example of a torrential rain announcement in the chat.

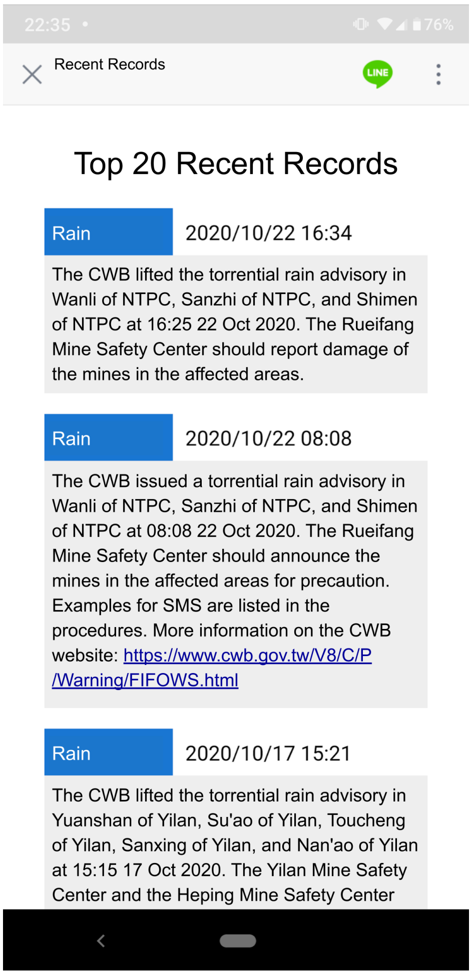

Figure 6. The past notification look-up web page viewed with the in-app browser.

5.4. User Interface

For the user interface, two interactive modes, "by-text" and "by-click," are provided. Using the by-text mode, users interact with the chatbot via a process mimicking conversation with a real person. This starts with a user acquiring specific information from the chatbot by sending a text message. The chatbot receives the text message, processes the input, and looks up the keyword-information mapping for the most probable answer. Then, the chatbot responds to the user with the information fetched from the information architecture. Users can also interact with the chatbot by clickable images or buttons in the by-click mode. Clickable images or buttons send text messages on behalf of the user, triggering the chatbot to respond like in the by-text mode or opening the in-app web browser to an external website. Users familiar with the system can directly acquire the information using the by-text mode. Users unfamiliar with the system can retrieve the information using the by-click mode. Both modes provide access to the keyword-information mapping and the information architecture.

Figure 7 shows a series of screenshots of the LINE chat on Android 9. The user clicks one of the buttons in the menu at the bottom of the screen. The chatbot sends a text message on behalf of the user. Next, the chatbot retrieves the requested information from the information architecture, generates an appropriate response, and replies to the user. The information may be a specific description, a link to an external website, or a topic of some information in the architecture. For a specific description, the chatbot replies in the form of a text message. For links, the chatbot replies in the form of buttons. For a topic, the chatbot replies with a clickable image composed of the entries covered in this topic as constructed in the information architecture.

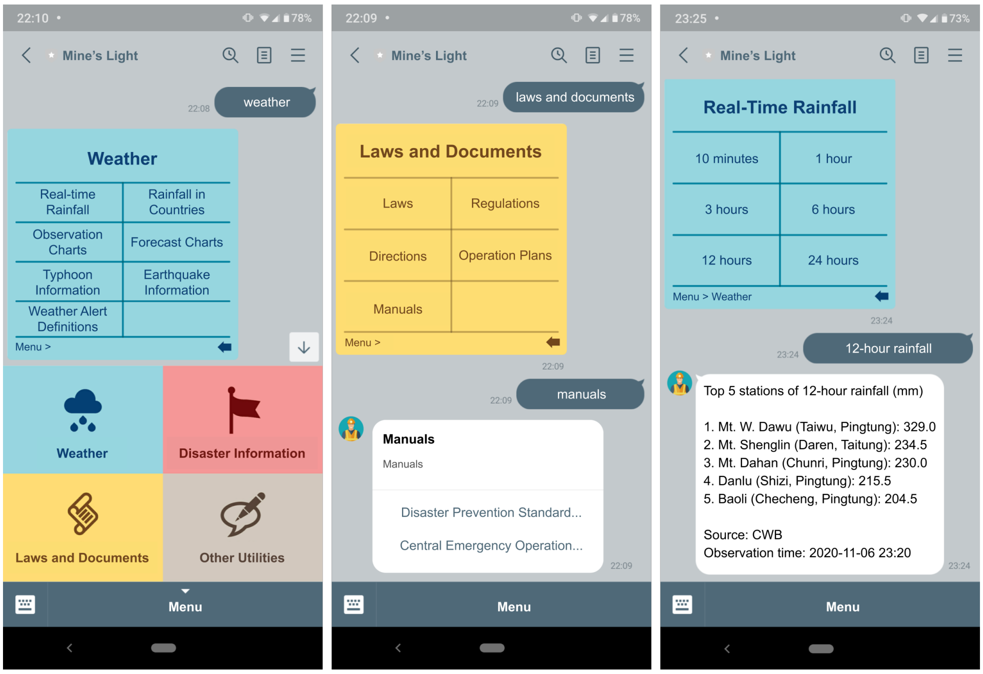

Figure 7. Screenshots of the user interface of the LINE chat on Android 9.

6. Effectiveness Evaluation

We evaluated the effectiveness of the implemented system by the change in the efficiency of the procedures before and after adopting the system. We collected the operation records from the Bureau of Mines before and after the system was adopted in the field. For the three different types of disaster specified in the procedures, 31 notification records were collected, covering 21 events from 9 April 2019 to 1 November 2019.

6.1. Processes

Figure 8 illustrates the processes before and after the adoption of the system. The processes start from the observation or the forecast of a disaster event. The CWB provides disaster alerts in multiple ways, such as e-mails, SMS, updates of the Open Weather Data Platform, and announcements on the official website. In the original process, the staff of the Mine Safety Division received the notification and determined whether the *Procedures for Notification of Earthquakes, Typhoons, and Torrential Rain* should be activated. If the procedures were activated, the staff notified the personnel of the Mine Safety Centers and the Eastern District Office in the affected area(s). For the adapted process, the implemented system retrieves the alert information from the CWB, automatically determines the activation and the affected areas based on the retrieved information, and directly notifies the personnel of both the Mine Safety Division and the Mine Safety Centers or the Eastern District Office with impacted areas. Finally, in both processes, the personnel of the Mine Safety Centers and the Eastern District Office notifies the mines located in the area(s).

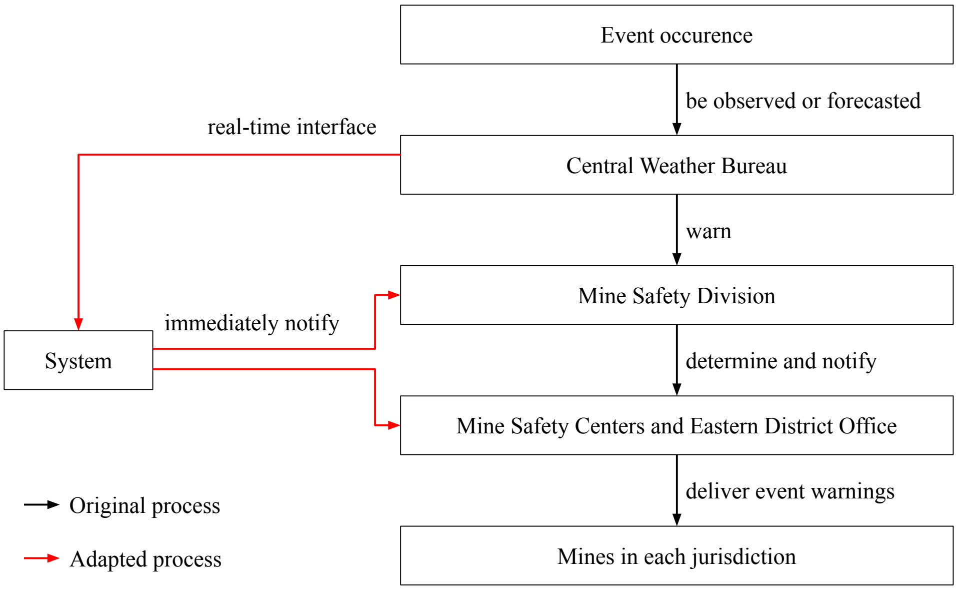

Figure 8. Comparison of the original process and the adapted process.

6.2. Cases

Three timings are recorded in a disaster event: the occurrence, the notification sent from the system, and the notification manually sent by the staff of the Bureau of Mines. To be precise, the occurrence of an earthquake is defined as the timing of the observation, while the occurrence of a typhoon event or a torrential rain event is defined as the timing of issuing or lifting the warning. For each announcement, we recorded the three timings and found the time span from the occurrence to the message delivery using the different processes. For the original process, we defined the time span of an announcement by subtracting the timing of the occurrence of the disaster event from the timing of the manual delivery of alerts to the staff of the Bureau of Mines. For the adapted process, we define the time span of an announcement by subtracting the timing of the occurrence of the event from the timing of message delivery to the Bureau of Mines personnel by the system.

To evaluate the effectiveness of adopting the system, we compared the time spans for the two processes and calculated the improvement in time cost before and after the adoption. Furthermore, considering the eventual lag for events at night, we marked the announcements published in the common rest period (i.e., from 00:00 to 07:00).

Ten earthquake events were selected for evaluation, with six occurring in the normal period and four in the rest period. Table 4 lists the three timings of the selected records. The adapted process achieved improved time in nine of the ten events, including all four in the rest period and five of the six in the normal period.

Table 4. Time evaluation for earthquake cases.

Occurrence	In Rest Period	Original Process		Adapted Process		Improvement (minutes)
		Notification Time	Time Span (minutes)	Notification Time	Time Span (minutes)	
9 April 23:13	no	9 April 23:39	26	9 April 23:22	9	17
10 April 04:24	yes	10 April 06:36	132	10 April 04:34	10	122
15 April 23:26	no	15 April 23:53	27	15 April 23:34	8	19
18 April 13:01	no	18 April 13:11	10	18 April 13:14	13	−3
17 May 00:26	yes	17 May 01:12	46	17 May 00:31	5	41
23 May 14:12	no	23 May 14:22	10	23 May 14:19	7	3
4 June 17:46	no	4 June 18:05	19	4 June 17:51	5	14
6 August 09:19	no	6 August 09:35	16	6 August 09:29	10	6
8 August 05:28	yes	8 August 05:40	12	8 August 05:42	14	−2
26 August 04:41	yes	26 August 06:53	132	26 August 04:49	8	124

Four typhoon events were selected for evaluation, including four warnings each being issued and lifted. One of the warnings was issued in the normal period and was lifted in the rest period, while the other warnings were all issued and lifted in the normal period. Table 5 lists three timings of the selected records. Some warnings were issued or lifted prior to the occurrence because the Central Weather Bureau sometimes published the announcements online earlier than the actual occurrence of an event, making the time spans negative.

Table 5. Time evaluation for typhoon cases.

Type	Occurrence	In Rest Period	Original Process		Adapted Process		Improvement (minutes)
			Notification Time	Time Span (minutes)	Notification Time	Time Span (minutes)	
issue	17 July 11:30	no	17 July 11:34	4	17 July 11:24	−6	10
lift	17 July 20:30	no	17 July 21:55	85	17 July 20:24	−6	91
issue	8 August 08:30	no	8 August 08:53	23	8 August 08:47	17	6
lift	9 August 20:30	no	9 August 20:36	6	9 August 20:33	3	3
issue	23 August 14:30	no	23 August 14:31	1	23 August 14:31	1	0
lift	25 August 08:30	no	25 August 08:48	18	25 August 08:25	−5	23
issue	29 September 20:30	no	29 September 20:44	14	29 September 20:43	13	1
lift	1 October 05:30	yes	1 October 06:09	39	1 October 05:26	−4	43

Seven torrential rain events were selected for evaluation, including seven warnings being issued and six being lifted; the lifting of one of the warnings was missing. One warning was issued, one was lifted during the rest period, and the others occurred in the normal period. Table 6 lists the three timings of the selected records.

Table 6. Time evaluation for torrential rain cases.

Type	Occurrence	In Rest Period	Original Process		Adapted Process		Improvement (minutes)
			Notification Time	Time Span (minutes)	Notification Time	Time Span (minutes)	
issue	27 April 15:50	no	27 April 16:06	16	27 April 16:11	21	−5
lift	28 April 04:20	yes	28 April 07:32	192	28 April 04:36	16	176
issue	17 May 09:40	no	17 May 09:51	11	17 May 09:54	14	−3
lift	17 May 15:10	no	17 May 19:02	232	17 May 15:19	9	223
issue	18 May 12:55	no	18 May 13:48	53	18 May 13:09	14	39
lift	18 May 22:25	no	19 May 06:38	493	18 May 22:45	20	473
issue	11 June 15:10	no	11 June 15:32	22	11 June 15:26	16	6
lift	11 June 18:50	no	11 June 19:19	29	11 June 19:11	21	8
issue	21 September 01:10	yes	21 September 08:07	417	21 September 01:20	10	407
lift	21 September 11:15	no	21 September 17:34	379	21 September 11:22	7	372
issue	26 September 23:10	no	26 September 23:30	20	26 September 23:22	12	8
lift	27 September 12:40	no	(missing)	(missing)	27 September 12:50	10	(missing)
issue	31 October 15:00	no	31 October 15:19	19	31 October 15:12	12	7
lift	1 November 07:30	no	1 November 08:01	31	1 November 07:40	10	21

6.3. Results

The average decrease in time cost after system adoption is evident for both the inclusion and exclusion of the rest period cases. Table 7 shows the average improvement in different types of disaster events. If the cases occurring in the rest period are included, an average reduction of 72.6 min of time cost was achieved among the three different types of disaster events. If the cases in the rest period were excluded, the average reduction was 55.8 min.

Table 7. Average improvements in different types of disaster events.

Announce Type	Rest Period Included				Rest Period Excluded			
	Number of Cases	Original (minutes)	Adapted (minutes)	Improvement (minutes)	Number of Cases	Original (minutes)	Adapted (minutes)	Improvement (minutes)
Earthquake	10	43.0	8.9	34.1	6	18.0	8.7	9.3
Typhoon event issue	4	10.5	6.3	4.3	4	10.5	6.3	4.3
Typhoon event lift	4	37.0	−3.0	40.0	3	36.3	−2.7	39.0
Torrential rain event issue	7	79.7	14.1	65.6	6	23.5	14.8	8.7
Torrential rain event lift	6	226.0	13.8	212.2	5	232.8	13.4	219.4
Overall average	31	81.7	9.2	72.6	25	65.2	9.4	55.8

Note that the comparison of including/excluding the rest period cases also shows the system's effectiveness in reducing labor costs. By excluding the rest period cases, the time cost of the original process decreases from 81.7 to 65.2 min, which is expected since the staff cannot immediately respond during the rest period. By contrast, the average time cost of the adapted process is less than 10 min, both including and excluding the rest period cases, indicating that the rest period does not affect the efficiency of the adapted process. If the Bureau of Mines wanted to eliminate inefficiency during the rest period, they would previously require continuous shift work. This is solved by the adoption of the system, thus reducing labor costs.

Among all announcement types, the torrential rain event lift and the typhoon event lift gain the most improvements. In contrast to the other announcement types, excluding the rest period cases does not visibly lower the time cost of the original process, according to Table 7. Thus, the improvements obtained in the torrential rain event lift and the typhoon event lift are not related to the rest period. On the other hand, the earthquake and torrential rain event gained fewer improvements in the adapted process. The difference between the improvements may come from higher awareness of the disaster occurrence or warning issue than the warning lift. The staff of the Bureau of Mines notice the announcement quicker after a disaster event occurs than when it is over. Hence, the adapted system saves relatively less but still plenty of time for the occurrence of disaster events, while the effectiveness of the system is significantly demonstrated for the lift of disaster event alerts.

7. Discussion

The major advantages of this study include the feasible utilization of novel techniques for decision support and the improvement of efficiency and effectiveness of procedure activation during disaster events. The study provides a solution by adopting a chatbot as an information retrieval interface and a channel to alert relevant personnel. Unlike other disaster-related products designed for the general population as we mentioned in Section 2, the chatbot in the present study specifically assists the decision-makers and other stakeholders in efficiently retrieving decision-support information via IM applications. In addition, the system consistently receives immediate announcements from the CWB and provides automatic determination based on the activating conditions, reducing labor and time costs for the safety staff of the Bureau of Mines. By enhanced retrieval and reduced consumption, our system improves the efficiency and effectiveness of decision-making.

However, the labor and time consumption of damage reporting is not completely eliminated in the present study. Since we focus on the activation of information delivery between the different personnel, case closure was not considered in the study. Currently, the system automatically notifies staff to collect and report the damage in each jurisdiction area. However, during the research interviews, we noticed that staff had to manually summarize the collected damages. The fundamental problem is that the current damage collection and report process is still based on phone or SMS; that is, there is no integrated system to collect the damage reports, and thus no chance for the developed chatbot in this study to automatize the summarization. Hence, we are unable to comprehensively reduce the labor and time cost of the procedures. To overcome the limitation, a system for damage collection and report process is required. In addition, techniques for unstructured report processing [28,41,42] may be adopted to enable automatic analysis and further reduce the labor and time cost.

8. Conclusions

We developed a chatbot to enhance the efficiency of government activation of mine safety procedures during natural disasters. Since natural disasters in Taiwan, including earthquakes, typhoons, and heavy rain, are frequent and impactful, a comprehensive government system is dedicated to disaster response. The Bureau of Mines has instituted clear procedures to ensure the delivery of disaster alerts and damage reports. However, there is an opportunity for improvement due to inefficiency associated with labor- and time-consuming procedures. In this study, we proposed a system framework for disaster-related information retrieval and immediate notifications to support the execution of mine safety procedures. The framework utilizes IM applications as the user interface to look up information and send messages to announce the occurrence of disaster events. We implemented the system in the form of a chatbot. The evaluation of the change in efficiency before and after system adoption demonstrated an average reduction of 55.8 min among the three types of disaster events. Although the lack of integrated systems to collect damage reports limits the overall reduction of the labor and time cost, the present study has proven the feasibility of adopting novel techniques for decision-making and assures the improvement of the efficiency and effectiveness of the procedure activation.

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Abbreviations

The following abbreviations are used in this manuscript:

AWS	Amazon Web Service
CAP	Common Alerting Protocol
CWB	Central Weather Bureau
DSS	decision support systems
GIS	geographic information systems
HTTP	HyperText Transfer Protocol
HTTPS	HyperText Transfer Protocol Secure
ICT	information and communication technology
IM	instant messaging
MOEA	Ministry of Economic Affairs
N-module	notification module
NCDR	National Science and Technology Center for Disaster Reduction
NFA	National Fire Agency
NICT	National Institute of Information and Communications Technology
NIED	National Research Institute for Earth Science and Disaster Resilience
OASIS	Organization for the Advancement of Structured Information Standards
OS	operating system
S-module	search module
SMS	short message service
U-module	user module
XML	Extensible Markup Language

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