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Design and Development of ER MineTracer: A Mobile Emergency Response Application for Mining Industry

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ABSTRACT: Most of the industries, especially mining companies, are facing nowadays an exciting future with growing demand as well as severe challenges. Several innovations in technology as well as in the organizational process and methods are developed in order to cope with the continuously advancing technologically-driven society and to address pressing issues that industries are facing, including emergency response-related problems. This study aimed to improve information access by developing ER MineTracer mobile emergency response application which combines web and mobile applications designed for reporters and rescuers in responding to employees' emergency requests. It uses GPS to determine an employee's current position and communicates the user's name and present location straight to a web application installed in a command center for quick dispatching of emergency units. Descriptive-developmental research was employed in the study utilizing an object-oriented modeling tool in designing the ER MineTracer mobile application. Thirty (30) participants were purposefully chosen to assess the performance of the system and it was revealed that the developed ER MineTracer mobile application was efficient in terms of accessibility, accuracy, and usability. Hence, it is recommended to utilize ER MineTracer and optimize smartphones to assist individuals in saving lives during emergencies and accidents, especially in mining industries.

KEY WORDS: Descriptive-Developmental Research, Emergency Response, Frequency Radio, Mobile Application, Object-Oriented Modeling Tool, Taganito Mining Corporation, Philippines

1. INTRODUCTION

1.1 Background

The twenty-first century is a time of massive innovation which brings significant contributions to any companies, especially for mining industries. Inevitably in any companies, emergency which is an unanticipated and frequently hazardous circumstance can arise at any point of time. Its first minutes are usually critical and so it needs for a prompt response [1]. Hence, requests for assistance from emergency teams should be unambiguous in order to help dispatchers send the right personnel and equipment.

Emergency response is about coordinating and directing resources to respond to various events and controlling the emergency. Among these are GPS technology for tracking rescuers and resources, translators for communication, and field examiners for damage assessment. Smartphones and web applications help improve the emergency system. Geolocation plots the user's location on a map and sends it to the command center [2]. With the rapid growth of technology, particularly the proliferation of smartphones, there is a need to develop a system that would give employees an additional option or means to call for help.

The mining industry is inherently hazardous, and communications play a crucial role in enhancing worker safety and maximizing operational efficiency [3]. With technological advancements, active surveillance and remote monitoring are now possible which helps provide better medical responses following significant incidents. Moreover, reliable communication systems reduce risks by providing constant two-way communication between miners and their support teams to monitor conditions and ensure a timely emergency response.

In the case of Taganito Mining Corporation (TMC) in Claver, Surigao del Norte, Philippines, a Walkie-Talkie two-way radio has been used by miners and the emergency response team for information access, but unfortunately, its performance is limited due to certain factors such as distance, location, etc. With this challenge, the researchers were prompted to conduct a study that would

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improve the information access by designing and developing an ER MineTracer mobile emergency response application in order to revolutionize the way emergency services call for help, making it more efficient and reliable especially for employees in TMC.

1.2 Conceptual Framework

This research was anchored on two studies which utilized Google maps to plot equivalent latitude and longitude coordinates and optimized the user interface using PhoneGap and secondly, developed an emergency notification system with several built-in sensors for notifying emergency organizations, utilizing the basic sensors found on modern mobile devices and the users' aptitude [2, 4]. Figure 1 shows the flow of the study with input, process, and output used in the design and development of the system.

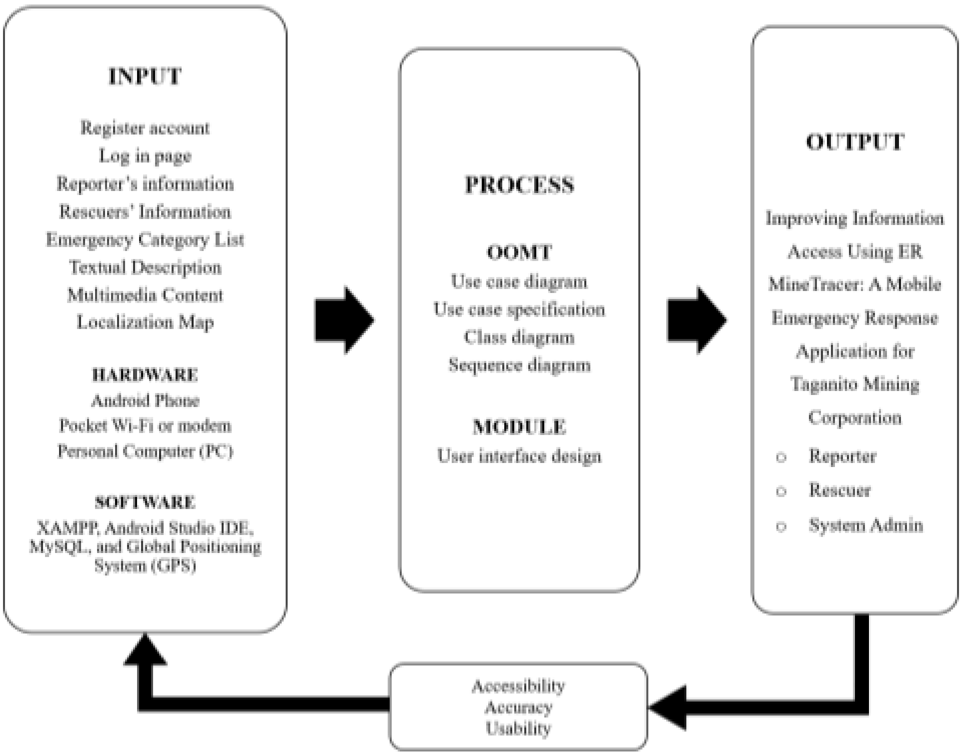

Figure 1. Flow of the Design and Development of the ER MineTracer Mobile Emergency Response Application

1.3 Objectives

This research aimed to answer the following questions:

1.3.1 What are the components and factors considered in the design and development of the mobile application?

1.3.2 What are the performances of the walkie-talkie and the developed mobile application in terms of accessibility, accuracy, and usability?

1.3.3 Is there a significant difference between the performance of the Walkie-Talkie and the ER MineTracer mobile application?

1.4 Review of Related Studies

Conventional methods of data collection use printed forms. The collected data is then transcribed from documents into spreadsheets or statistical packages. Costs implied in this process are expenses on paper, printing, and transcribing. Mobile phone-based data can be directly sent to the database. One doesn't need specialized mobile devices for simple data collection; further, almost all of us routinely use mobile phones for communication. The cost-effectiveness of handheld-based data collection has been reported by researchers, and illustrations of savings in terms of money, carbon dioxide emissions, and trees are also available. Practically, data can be transcribed and stored moments after it is collected, which allows timely analysis and rapid dissemination of findings [5].

Developing and deploying a reliable communication infrastructure at a crisis location is a complex research problem. Failures in communication infrastructure and information exchange thwart early response efforts, resulting in significant loss of life and economic consequences. Reliability, robustness, interoperability, and minimal interdependence are all characteristics of communication technology required for emergency applications. The importance of communication, information sharing, and interoperability in an emergency response scenario has risen recently based on the frequency of disasters worldwide and the wide range of severities and degrees of impact [6].

Accessibility essentially describes an individual's ability to engage users' activities in design by iterative prototyping – collectively, 'opportunities.' Accessibility is closely related to but not similar to mobility. Accessibility is the ultimate aim of mobility and it is closely related to the purpose of facilitating the user to develop and maintain his views of the information space. The accessibility challenge is to enable users to understand the overall structure of the system, like the similarities and differences between its components and portions [7, 8].

Smartphones are utilized in experience sampling designs to collect data from participants at specified times in a diary study or when events occur in their lives. In addition to subjective measurements, smartphones feature readily available and readily accessible physical sensors [9]. These include GPS, Bluetooth, and spatial orientation data, among others. Data from these sensors can be collected via apps and browsers, and the behavioral, social, and health sciences are finding more and more uses for this data. Studies have demonstrated that smartphones can recognize physical activity with the same precision as dedicated devices, such as smartwatches and heart rate monitors [10, 11].

Due to mobile phone usage, communication has become very easy, and it has changed the lifestyles of the common users of mobile phones. With increasing accuracy, GPS technology permits the localization of the receiver with increasing accuracy, using complex methods that can reach a few meters. Applications for mobile phone terminals with localization capabilities in many areas are potentially very high, and the high success rate of these systems is easy to predict. The real benefits of mobile phones with localization for disabled and older users will depend to a great extent on their requirements being considered during the evaluation phase [12, 13].

According to Margaret Rouse's Theory, usability measures the user's potential to achieve their goals. In information technology, the term is frequently used to determine the usability of software applications. Usability testing is a fundamental concept in information technology and involves testing software products, interfaces, or technologies on end-users. Usability testing is necessary to develop strategies for determining how systems actually function once they have been delivered to customers. Usability testing is merely one of several general types of the software product and system testing. Usability testing, on the other hand, focuses on creating a positive environment for users, ensuring that critical information is not buried in a dashboard, and ensuring that using the product or system is a pleasurable and empowering experience [14, 15].

2. METHODS AND MATERIALS

This study used descriptive-developmental research approach and was conducted from January to May 2022 at Surigao del Norte, Philippines. The design of the system was guided by the following object-oriented modeling tool. The purpose of the various tools was to organize and plan the procedure, represent the system's activities, and present the system's attributes, particularly the operations' process and the system's organization, to design and work in step-by-step procedures [16].

Object-Oriented Modeling Tools (OOMT)

Use Case Diagram. This is a graphic depiction of interaction among the elements of a system. It is used to identify and organize the system.

Use Case Specification. This is a written document that outlines the actors, preconditions, and flow of events, as well as alternative flows of using the case.

Class Diagram. This is a type of static structure of a system that shows the system classes, their attributes, operation, and relationship among objects.

Sequence Diagram. This is an interaction diagram that shows how objects operate with one another.

Thirty (30) participants were purposefully chosen to assess the performance of the ER MineTracer mobile application which includes 15 dump truck drivers, 6 supervisors, 7 emergency team personnel all from Traganito Mining Corporation, and lastly, 2 experts in IT. The performance of the mobile application was assessed in terms of accessibility, accuracy, and usability utilizing a researcher-made instrument which was validated by selected three experts in the field.

To describe the performance of the mobile application based on the results of the assessment from the participants, the descriptive statistical tools mean and standard deviation were used in the study. These tools are appropriate since the data gathered are continuous and every data contributes to the calculation of the mean and standard deviation [17]. Moreover, since the data failed the normality test, the non-parametric Wilcoxon Signed-Rank Test was used to examine the significant difference of the performance of the Walkie-Talkie and ER MineTracer mobile application.

3. RESULTS AND DISCUSSION

3.1 Technical Specifications of ER MineTracer

Table 1 shows the technical specifications of the hardware tool used as well as the external behavior of the system. Personal computer was used by the administrator of the system to maintain and update the application. It is also used as the server to run the ER MineTracer. Mobile phone is a device used by the reporter and rescuer to operate the application. Since it is a mobile application, the mobile user needs a mobile phone and with a good specification to have a good performance on the application.

Table 1. Hardware Specification

Hardware	Specification
Personal Computer	Processor: Intel Core i3 or higher RAM: 4GB or higher Display: 1370x768 or higher HDD: 200GB or higher
Mobile Phone	Processor: Android Android version: Android 5.0 lollipop RAM: 3GB or higher
Pocket Wi-Fi	At least 3 Mbps or higher

Table 2 shows the specification of software that should be used to run the system. Operating system is used to run the mobile emergency response application, while application software is used to build the system using different kinds of software.

Specifically, MySQL is an open-source relational database management system which generates a database for data storage and manipulation by defining the relationship between each table. XAMPP Control Panel is a platform that works well in both Windows and makes transitioning from the local test server to the live server extremely easy as well. Android Studio IDE is an integrated development environment designed specifically for Android development. Global Positioning System (GPS) enables one to view the map of a certain place. A navigational system uses signals to fix the location of a radio receiver above the earth's surface. GPS is useful in our system, especially in rescuing.

Table 2. Software Specification

Software	Specification
Operating System	Windows 7 or higher
Application Software	My SQL database, XAMPP, Android Studio IDE, and GPS

3.2 Process

In Figure 2, the use case diagram is presented which illustrates the step-by-step process of the interaction of the user, administrator, and the system. To access the application, the mobile user must register an account and must be approved by the administrator to log in to the registered account. After logging in with the reporter, they will see the emergency preparedness plan right away in the homepage menu. The application then can send a report to the rescuer and system administrator. The rescuer and system administrator will receive the report, and the rescuer can open the GPS while the system administrator can also view the report. The system administrator was the one who would manage information and view the accounts, and the crucial is to update the application.

Use case specification is a document that outlines the system's activities and data flows. Table 3 presents the activity of how registering an account and presents the detailed flow of the registered account. Table 4 presents the activity on how to log in to the account and presents the detailed flow of the login account. Table 5 explains the process in logging-in the account registered. Table 6 presents the information presented on the homepage of the application. Table 7 presents the activity on what are the categories the reporter can choose from. Table 8 presents the activity of how the reporter can send to the rescuer and system administrator. Table 9 presents the activity of how the rescuer views the reporter's information and presents the detailed flow of it. Table 10 displays the event of how the rescuer opens the GPS. Table 11 presents the activity of the system administrator updating the system. Table 12 presents the activity of how the system administrator views the accounts. Table 13 presents the activity of a system administrator managing information.

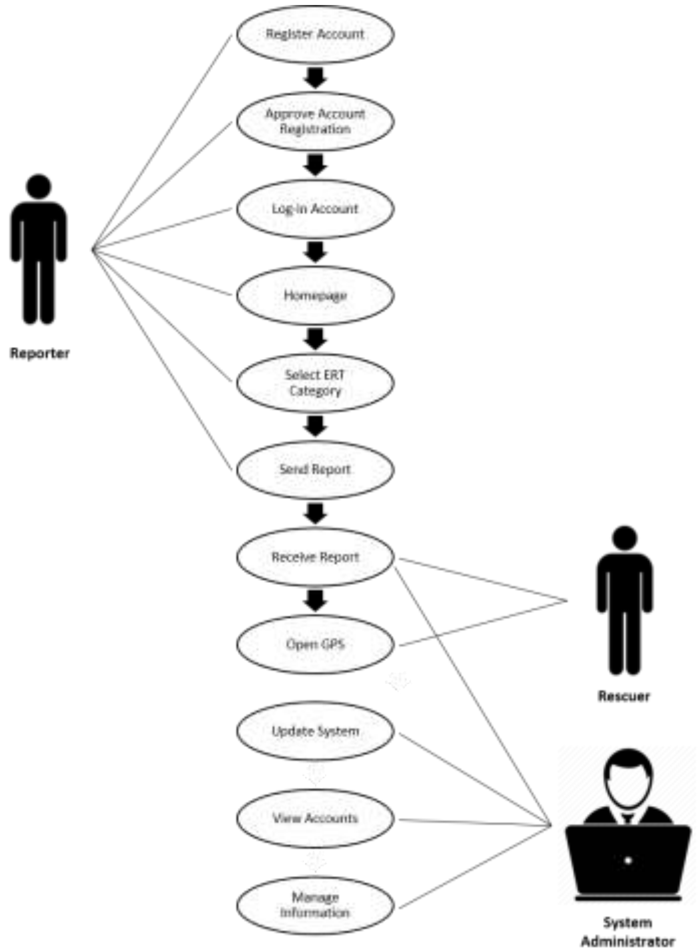

Figure 2. Use Case Diagram

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Table 3. Use Case 1: *Register Account*

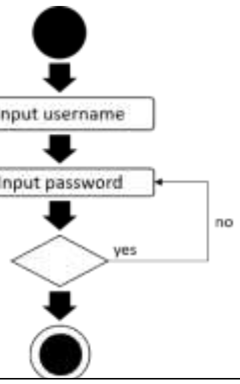
Use case name	Registration Approval
Description	This process describes the approval of account registration.
User goal	To approved registration
Actor	System Administrator
Pre-condition	The reporter must fill up a registration form.
Scenario	1. Input username 2. Input password 3. Tap Log-in Alternative course: 1. If a password is invalid, pls try again until the password is correct.
Workflow	
Post-condition	The mobile user can now access the application.

Table 4. Use Case 2: *Registration Approval*

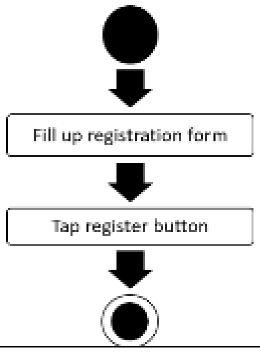
Use case name	Register Account
Description	This process describes when the mobile user register for an account.
User goal	The mobile user can have an account in the application.
Actor	Reporter
Pre-condition	The mobile user must have a username and password.
Scenario	1. Fill up the registration form 2. Tap the register button
Workflow	
Post-condition	The mobile user now has an account.

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Table 5. Use Case 3: *Log-in Account*

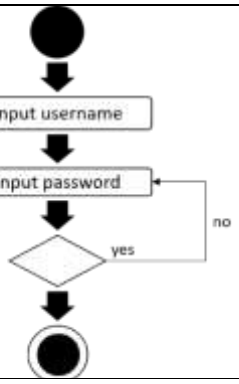
Use case name	Log-in Account
Description	Logging-in process
User goal	Log-in account
Actor	Application user
Pre-condition	Account must be registered and approved by the administrator
Scenario	1. Input username 2. Input password Alternative course: 1. Password is invalid. Please try again until the password is correct.
Workflow	
Post-condition	Application users can access the Application.

Table 6. Use Case 4: *Homepage*

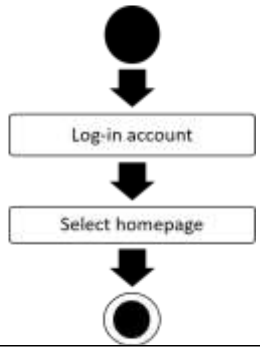
Use case name	Homepage
Description	This process shows the emergency preparedness plan for the reporter and rescuer.
User goal	To make the reporter aware of the emergency preparedness plan of the company.
Actor	Reporter
Pre-condition	The reporter must log-in account to the homepage.
Scenario	1. Log-in account 2. Select the homepage
Workflow	
Post-condition	The reporter viewed the emergency preparedness plan.

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Table 7. Use Case 5: *Select ERT Category*

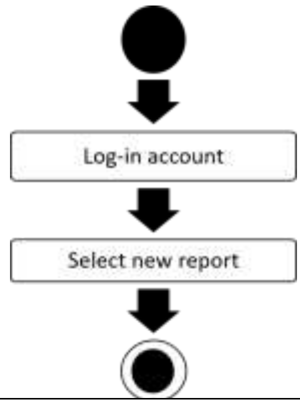
Use case name	Select ERT Category
Description	This process shows the menu of the homepage and selects an option.
User goal	Select and open the chosen button in the menu
Actor	Reporter
Pre-condition	The reporter must log-in account to the new report menu.
Scenario	1. Log-in account 2. Select a new report in the menu
Workflow	
Post-condition	The reporter viewed the chosen button.

Table 8. Use Case 6: *Send Report*

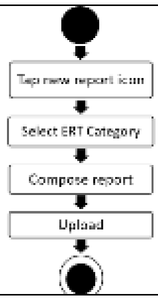
Use case name	Send report
Description	This process shows how the reporters send their reports.
User goal	To send report
Actor	Reporter
Pre-condition	The reporter must enter the message and reference point.
Scenario	1. Tap the new report icon 2. Select the ERT category 3. Compose the report 4. Upload
Workflow	
Post-condition	The application can compose a report.

Table 9. Use Case 7: *Receive Report*

Use case name	Receive Report
Description	This process shows how the application receives the report.
User goal	To receive report

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Actor	Reporter
Pre-condition	The application user must tap the reports button.
Scenario	1. Choose the reports icon 2. Tap or open the report being received 3. Received report
Workflow	
Post-condition	The reporter can now view the report and open the GPS.

Table 10. Use Case 8: *Open GPS*

Use case name	Open Global Positioning System
Description	This process displays the map and location of the reporter.
User goal	To open and view the map and location.
Actor	Rescuer
Pre-condition	The rescuer must tap or open the report being received to view the location of the reporter.
Scenario	1. Choose the reports icon 2. Tap or open the report being received 3. Open the GPS
Workflow	
Post-condition	The rescuer can now view the map location of the reporter.

Table 11. Use Case 9: *Update System*

Use case name	Update System
Description	This process explains how the administrator updates the system.
User goal	To update the system or application.
Actor	System Administrator
Pre-condition	The administrator must access the system.
Scenario	1. Open the program of the system 2. Update the program 3. Save update

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Workflow	
Post-condition	The application was now updated.

Table 12. Use Case 10: *View Account*

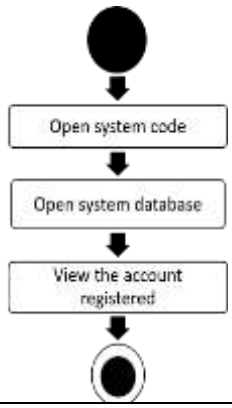
Use case name	View Account
Description	This process explains how the administrator views a registered account.
User goal	To be able to view the registered account.
Actor	System Administrator
Pre-condition	The administrator must open the database of the system.
Scenario	1. Open system code 2. Open system database 3. View the account registered
Workflow	
Post-condition	Admin manages the account information secured.

Table 13. Use Case 11: *Manage Information*

Use case name	Manage Information
Description	This process explains how the administrator manages the information.
User goal	Manage the information in the system and account information.
Actor	System Administrator
Pre-condition	The administrator must open the system code and the database of the system.
Scenario	1. Access the system 2. Open system code 3. Open the system database 4. Manage the information 5. Save

Workflow	
Post-condition	Admin manages the account information secured.

The class diagram, in Figure 3, shows the structure of the application consisting of its attributes and operation. It also shows the relationship of other classes of the ER MineTracer. Furthermore, the application process and report transmission from the applicant to the organization's Emergency Response Team (ERT) is displayed in Figure 4 which shows the sequence or arrangement of the ERT and process.

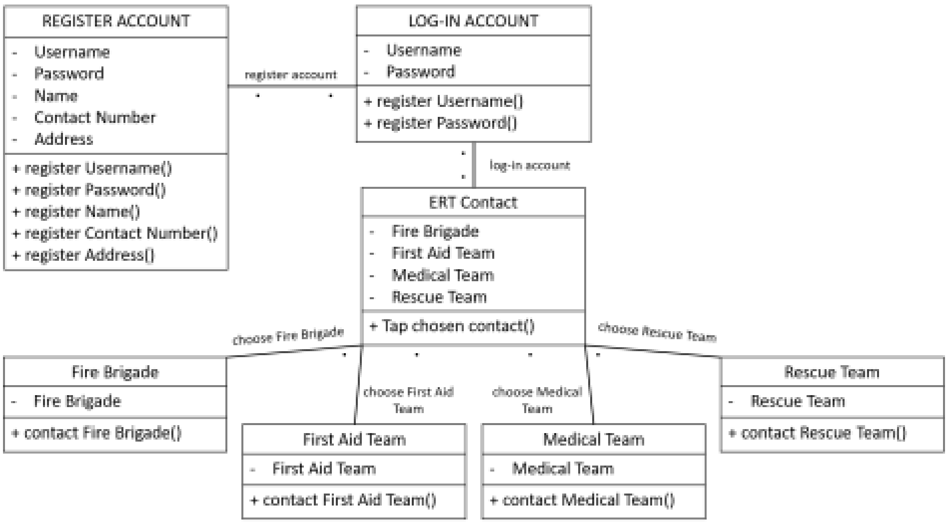


Figure 3. Class Diagram

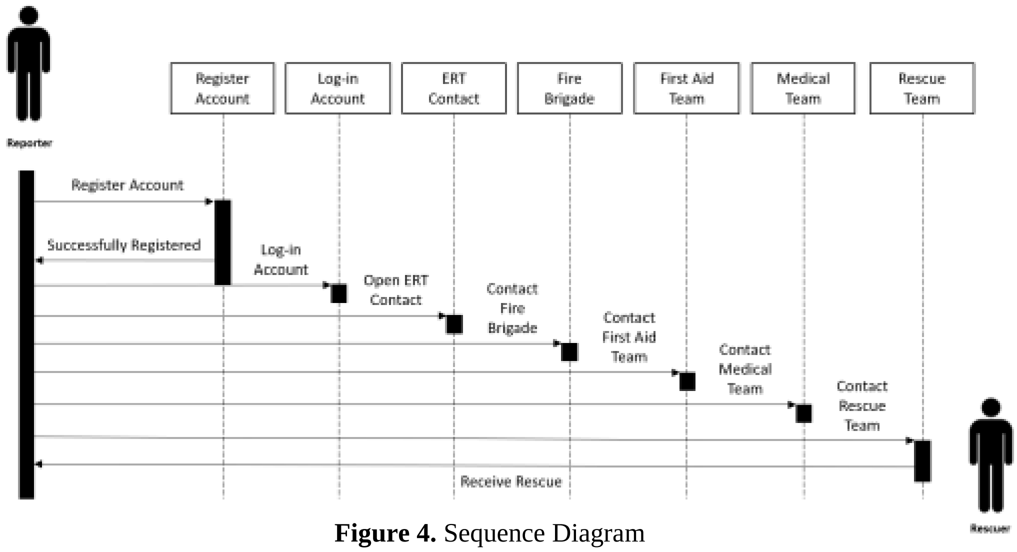


Figure 4. Sequence Diagram

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3.3 User Interface Design

Figure 5 shows the interface that the reporter-user can see in the application with logo of ER MineTracer Application as the first interface. Next is the *register interface* where the user can fill up the system required to be registered in the application and followed by *log-in interface*. After the users logged in their account, they may now proceed to *homepage interface, my reports interface, ERT contact interface, send report interface*, or *user settings interface*. The *homepage interface* contains the emergency preparedness plan of the company; *my report interface* is the inbox of the application where the user can see the list of their reports; *ERT contact interface* is the section where the reporter can choose from four different categories to send reports, even offline; *send report interface* is the page where the reporter composes their reports, such as the description, location, and photo of the accident; and *user settings interface* is the reporter user settings where the information of the user can be seen.

On the other hand, the interface for the rescuer-user is shown in Figure 6. They almost have the same interface; only that for rescuers, after they logged in their account, they only have options such as *homepage interface, reports interface, user settings interface*, or *GPS interface*. The *reports interface* is the inbox of the application where the user can see the list of the reports, while the *GPS interface* is basically where the rescuer can see the exact location of the reporter whenever they ask for rescue.

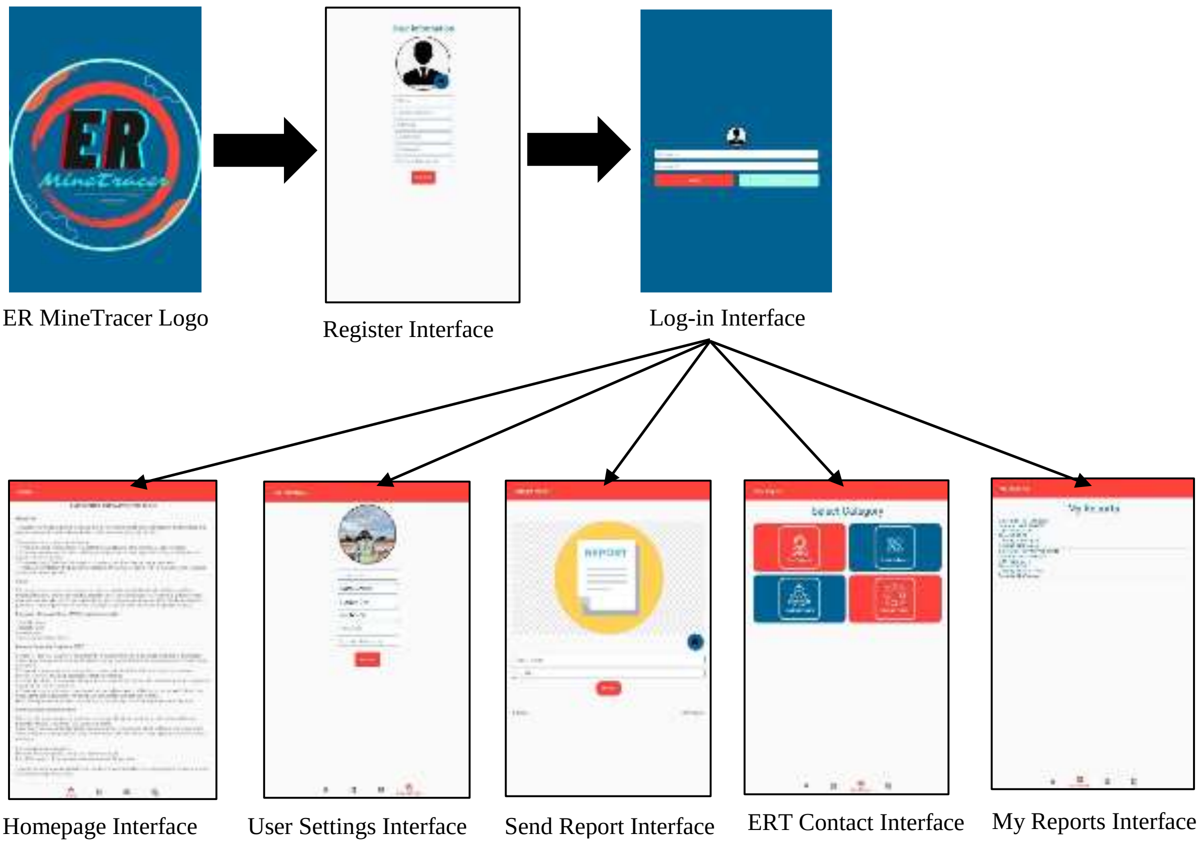

Figure 5. User Interface for Reporter

For system administrator, the first interface they can see is the *log-in interface* of ER MineTracer App where they must log in their account to access the application. After the log-in interface, new incidents, resolved incidents, user settings, and log-out sections can be seen. After the *homepage interface*, the incidents that the reporter sent can be seen in the new incidents section, as shown in Figure 6.

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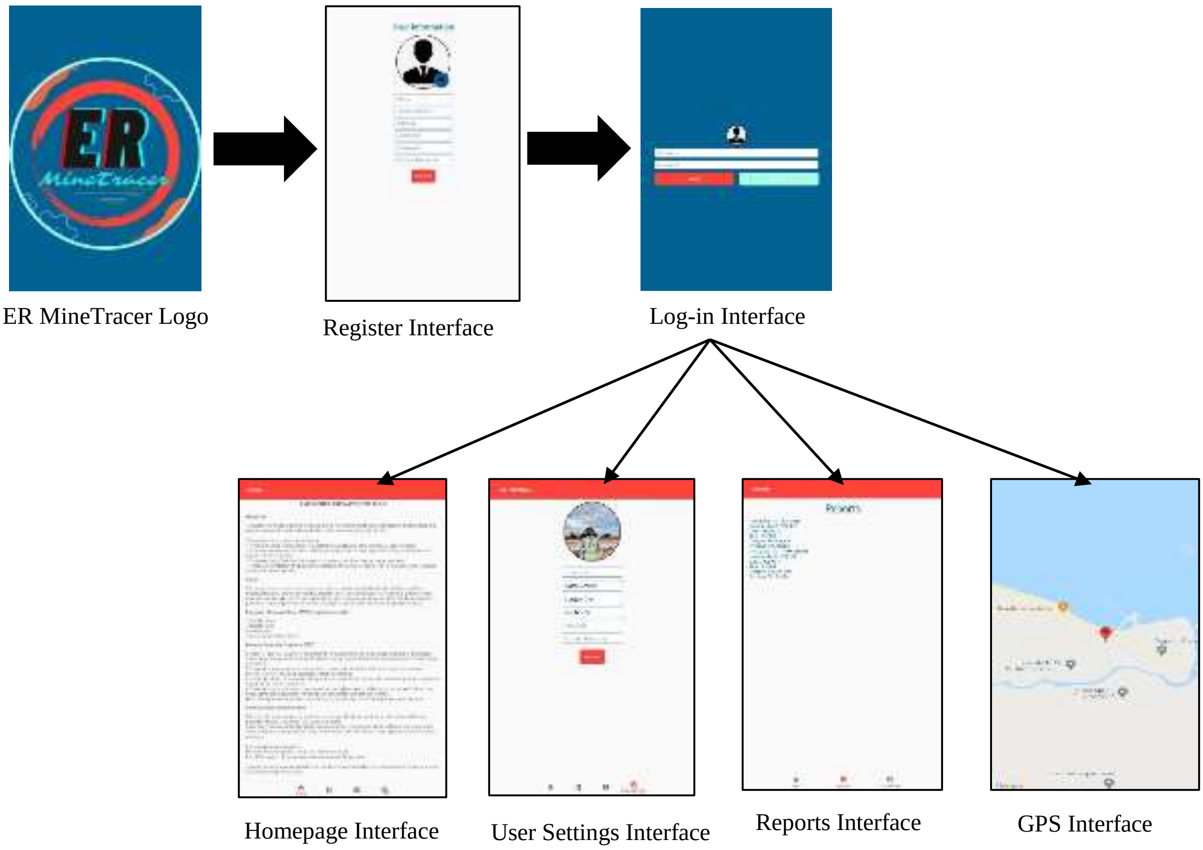

Figure 5. User Interface for Rescuer

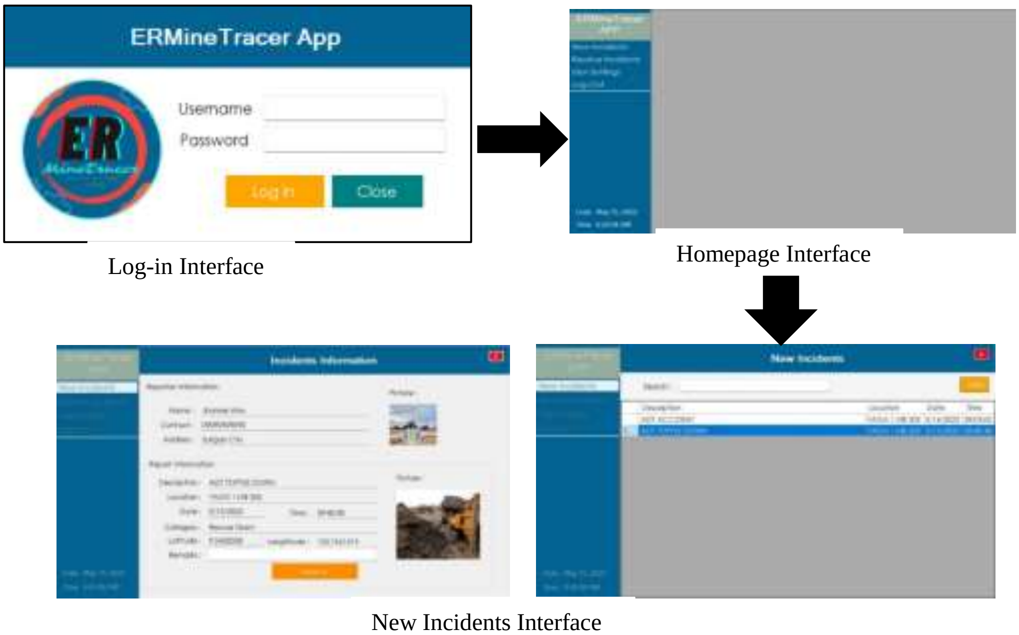

Figure 6. User Interface for Administrator

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Table 3. Performance of the Walkie-Talkie and ER MineTracer Mobile Application

Indicators	Walkie-Talkie				ER MineTracer			
	M	SD	VI	QD	M	SD	VI	QD
Accessibility								
1. Capable of supporting multiple users concurrently.	1.23	0.43	SD	NAs	3.67	0.48	SA	VAs
2. Functions even though it is not connected to the internet.	3.87	0.35	SA	VAs	3.70	0.47	SA	VAs
3. User can access the medium only if they are permitted for security.	1.67	0.48	SD	NAs	3.83	0.38	SA	VAs
4. Features an intuitive interface that makes it simple to use.	3.77	0.43	SA	VAs	3.80	0.41	SA	VAs
5. Can share information with rescuers via photos and info.	1.93	0.37	D	LAs	3.80	0.41	SA	VAs
Sub-result	**2.49**	**0.41**	**D**	**LAs**	**3.76**	**0.43**	**SA**	**VAs**
Accuracy								
1. The message that the rescuer receives is identical to the message sent by the user.	2.23	0.82	D	LAr	3.70	0.47	SA	VAr
2. Capable of sending and receiving messages instantly.	2.87	0.78	A	Ar	3.77	0.43	SA	VAr
3. User Positioning is accurate.	1.20	0.41	SD	NAr	3.67	0.48	SA	VAr
4. The user can accurately access the medium anytime.	3.13	0.97	A	Ar	3.70	0.47	SA	VAr
5. The tool is appropriate for the task at hand.	3.70	0.60	SA	VAr	3.67	0.48	SA	VAr
Sub-result	**2.63**	**0.71**	**A**	**Ar**	**3.70**	**0.46**	**SA**	**VAr**
Usability								
1. It could be beneficial to both rescuers and users.	3.67	0.48	SA	VU	3.73	0.45	SA	VU
2. Can be used to assist users during times of emergency.	3.63	0.49	SA	VU	3.80	0.41	SA	VU
3. User has complete access to all data contained within the medium.	1.73	0.52	SD	NU	3.70	0.47	SA	VU
4. Beneficial when it comes to rescuing a victim.	3.33	0.88	SA	VU	3.73	0.45	SA	VU
5. It has a system that can assist in locating a person during an emergency.	1.33	0.66	SD	NU	3.77	0.43	SA	VU
Sub-result	**2.74**	**0.61**	**A**	**U**	**3.75**	**0.44**	**SA**	**VU**
Overall Result	**2.62**	**0.58**	**A**	**P**	**3.74**	**0.44**	**SA**	**HP**

Legend:

Scale	Range	Verbal Interpretation (VI)	Qualitative Description (QD)
4	25-4.00	Strongly Agree (SA)	Very Accessible (VAs) Very Accurate (VAr) Very Usable (VU) Highly Performing (HP)
3	50-3.24	Agree (A)	Accessible (As) Accurate (Ar) Usable (U) Performing (P)

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2	75-2.49	Disagree (D)	Less Accessible (LAs) Less Accurate (LAr) Less Usable (LU) Less Performing (LP)
1	00-1.74	Strongly Disagree (SD)	Not Accessible (NAs) Not Accurate (NAr) Not Usable (NU) Not Performing (NP)

3.4 Performance of ER MineTracer

Table 3 shows the performance of ER MineTracer (ERMT) as compared to the Walkie-Talkie (WT) two-way radio in terms of their accessibility, accuracy, and usability. Based on the table, the overall performance of WT is less accessible. However, the highest mean is 3.87 which implies that WT functions despite not being connected to the internet because it shares the radio-frequency band. On the other hand, WT was rated as accurate and usable which implies that it is still suitable for the task at hand because it is a portable tool that can be carried at any time, and it could be beneficial to both rescuers and users, making it beneficial to both parties. WT has a system that can help locate a person during an emergency.

Meanwhile, Table 3 also shows that ERMT was rated by the participants as very accessible, very accurate, and very usable. This implies that the application will be of great help to everyone, especially to TMC employees. It is capable of sending and receiving messages instantly due to its user-friendly interface, making it easier for the user to send a report.

The results support the claims that accessibility is cutting-edge information or resources and how it can be made accessible to all by providing resources to enhance accessibility and develop the system; that the system precision is crucial for determining whether or not a problem exists, and that, it is important to understand the system's accuracy to avoid making mistakes [8, 12].

Table 4 shows the summary results of Wilcoxon Signed-Rank Test for the difference of performance of the Walkie-Talkie (WT) and the ER MineTracer (ERMT). With p-values all less than 0.05 significance level, there is a significant difference between the performance of WT and ERMT. This implies that the ERMT mobile application significantly performed better than the WT in providing miners and emergency response team a better information access, a tool that is more functional and user-friendly, and a better description and illustration of the incident, so that the emergency response team can act appropriately to address the reported incident.

Table 4. Significant Difference between the Performance of ER MineTracer and Walkie-Talkie

Variables	Mean Rank	Sum of Ranks	Z-statistic	p-value
Accessibility	15.50	465.00	-4.890	0.0001
Accuracy	15.50	465.00	-4.813	0.0001
Usability	14.50	406.00	-4.465	0.0001

4. CONCLUSION AND RECOMMENDATION

Based on the findings, the ER MineTracer Mobile Application designed and developed by the researchers was generally rated as highly performing. The result was statistically significant implying that the new mobile application performs way better than the old one as to addressing emergency-related issues.

Hence, this study highly encourages mining companies to use the current trends in mobile and web technologies, especially the ER MineTracer, for improving information access and for fast and efficient dispatching of emergency units. This study aimed not to create a new protocol in emergency response but to maximize the use of smartphones to act as a medium and help people save their lives in case of emergencies and accidents. The proposed system was supposed to lessen the response time it takes to respond to emergency events and provide reliable information that might help in identifying what type of emergency team would respond.

Moreover, it is recommended to researchers to conduct further studies that develop more web-based mobile applications relevant for a fast and efficient work in industries. Researchers are also encouraged to better improve the system of the ER MineTracer to make it highly applicable in any industries.

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