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BANJIR RESCUE: IOT-BASED FLOOD EVACUATION CENTER

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ABSTRACT

One of the important processes involved when a disaster happens is to allocate the victims to the navigation center. Current evacuation practices may cause further damage as the victims must wait for the rescue team to come. A self-navigation system, called Banjir Rescue, would allow the victims to save their lives and belongings sooner by determining the appropriate evacuation center. In this approach, the appropriate evacuation center is determined based on two critical parameters, which are the water level and distance. First, the near-real-time data retrieved from the water level sensor set up at the evacuation centers is sent to the system and compared with the evacuation centers' water threshold value. The algorithm will then proceed with the second phase, that is, checking for the distance between the victim's current location and the evacuation center if the water level found in the first phase is less than the threshold. Finally, the selection is made where the algorithm will choose the nearest evacuation center to the victims. The system will get the coordinates of the appropriate evacuation center that passes both phases and send the coordinates to the installed navigation applications on the mobile phone, such as Google Maps and Waze. The desired navigation app will be launched with the coordinates passed from the system to guide victims to reach the appropriate evacuation center. The result shows that the proposed approach could provide a near-real-time water level reading of each sensor and near-accurate distance calculation to the system to determine the appropriate evacuation center.

Keywords*: Flood, Banjir, Disaster Management, Navigation System.*

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1. Introduction

The disaster that takes place on Earth is categorized into two, which are natural and human-caused disasters. Malaysia is often hit by floods, droughts, landslides, pollution, and disasters triggered by humans (Parker, 1997), which commonly happen on a large scale, causing loss of lives and properties (Rosmadi et al., 2023; Yunan, 2020). Since Malaysia receives rain most of the time throughout the year, according to Chan (2014), floods are considered to be the most serious of all catastrophes in Malaysia, especially during the monsoon change. During the monsoon change, Malaysia experiences heavy rain, which usually causes flash floods in cities like Kelantan, Terengganu, and Pahang. Hence, preparation is one of the ways to survive natural disaster and their aftereffects.

Mobile applications have been helping people in every possible way, including in disaster management. By having a disaster management mobile application, flood victims can be notified of the situation and get shelter at an evacuation center. To minimize the potential loss, many researchers have tried to develop an early alert, prevention, during, and post-disaster system. As the human lifestyle is evolving to '*the Internet is everything century'*, the mobile phone has eventually changed the way of communication. This can be supported by Lamberg et al. (2012), who said that research found that cell phones were the priority that the victims took while escaping to safer locations. Having disaster management on a mobile phone could be one of the initiatives to ensure victims' safety. Evacuation is described as a risk reduction technique that can be used to minimize a community's effects of an emergency. This includes transferring people to a safer place and returning them. Bradley et al. (2013) mentioned in their research that it has to be properly prepared and implemented for an evacuation to be successful. In Malaysia, for example, the responsible authority on the advice of the organization managing or organizing the emergency may identify the evacuation centers through specific jurisdictional emergency management plans. The ability to identify the appropriate evacuation center could assist victims in locating themselves at an available shelter.

The current evacuation practice may cause delays as the victims must wait for the rescue team to come. This will eventually cause further damage to their properties and loss of lives. Besides, the current system does not consider near-real-time water levels at the evacuation center. Near real-time updates are important to provide accurate information about the current situation so that appropriate action can be taken immediately. When a disaster happens, one of the conditions for the evacuation center is that the building itself should be in a location that is unaffected by the floods. Determining the appropriate evacuation center is quite challenging because its condition, which is the center's water level, should be appropriately identified as the affected area varies according to the earth's surface (Daud et al., 1995). Hence, a solution of setting up a water level sensor at each evacuation center is highly recommended to determine whether the evacuation center is affected by the flood or if it is safe for the victims to stay temporarily. The solution also considers the distance from the victim's location to the evacuation center to find the nearest and unaffected evacuation center.

2. Related Work

This section provides background information and also the related work to the study and development of Banjir Rescue.

2.1 Disaster

A disaster is defined by the World Health Organization (WHO) as any event that causes devastation, ecological damage, loss of human life, and degradation of health and health services on a scale sufficient to warrant an extraordinary response from outside the affected community. Disasters can be classified into natural and human-caused disasters (Li et al., 2019). A natural disaster is defined as any occurrence caused by the earth's natural forces. Hurricanes, earthquakes, tsunamis, mudslides, avalanches, and floods, for example. On the other hand, it is understood that human-made disaster has a dimension of social purpose, negligence, or mistake that involves a human-made system's failure. Examples of human-made disasters are fire, road accidents, terrorism, and biological or chemical hazards. Malaysia is not exempt when it comes to experiencing a disaster. This can be supported by Parker et. al. (1997), who stated that geologically, Malaysia is a stable nation free from major catastrophes such as earthquakes, volcanic activity, and strong winds. However, Malaysia is not entirely spared from natural disasters and calamities as it is still struck by floods, droughts, landslides, pollution and disasters caused by man.

An overview of Malaysian natural disaster events from 1998 to 2018 shows in a study conducted by Zurairi (2018) that flood is the most frequent disaster faced by Malaysians, with 38 cases within ten years. In addition, in reality, Malaysia has undergone quite a few extreme weather and climate events over the last few decades, including El Nino in 1997, La Nina in 2011, and 2012, freak thunderstorms nearly every year, monsoon floods, and haze (Chan, 2015). According to Glago et al. (2021), a situation becomes a disaster when it causes damage or adverse effects to human lives, livelihoods, and/or properties. A recent 2010 flood in Kedah and Perlis is among the worst floods Malaysia has ever experienced. The total economic loss and the government's financial burden have been tremendous.Locals should expect floods when warning signs are present. According to Parker (1997), there are some common warning signs of floods. The first sign is the intense rainfall. Locals should be expecting floods if they keep receiving heavy rain for a few days or if a dam or levee failure occurs. They should, therefore, take note of these warning signs and be prepared for the worst. For example, at the end of November 2019, heavy seasonal rains began to make their mark in northern states, causing flooding in cities like Pahang, Terengganu, and Kelantan, which are also known as the cities frequently hit by flash floods. Hence, according to Pillay et al. (2023), this has inspired everyone to concentrate on technical solutions for people facing this disruptive catastrophe.

2.2 Disaster Management

According to Che Hamid (2019), Malaysia’s current government has formed a national disaster management agency to deal with disaster-related issues in a rapid, organized, structured, and coordinated manner. Muzzamil et al. (2022) suggest that proper flood management schemes be planned and flood forecasting be strengthened. Furthermore, coordination includes incorporating technologies and modules from all related agencies, such as police, fire forces, civil defense, healthcare, and public health services. Wang et al. (2022) suggest that integrating the concept of resilience into the framework of risk management is a better approach in future flood management directions. Prevention is better than cure and should also be applied in surviving any disaster events. Everyone is responsible for taking precautionary measures to overcome incoming disasters to save themselves and their loved ones. According to Hong et al. (2023), preparedness is the systematic incorporation of disaster risk management, which includes prevention and mitigation. Preparing, planning, and staying informed are the three elements that must be presented in readiness (Shariff et al., 2019). It later creates a cycle of disaster (Figure 1). One of the preparedness measures for flood is evacuation which should be planned early by the responsible party. However, a study on the level of preparedness among the communities that was conducted by Diyana et al. (2020) indicated that the other factors above were moderate to high, and the overall preparedness level was found to be moderately low (a case study among communities in Segamat).

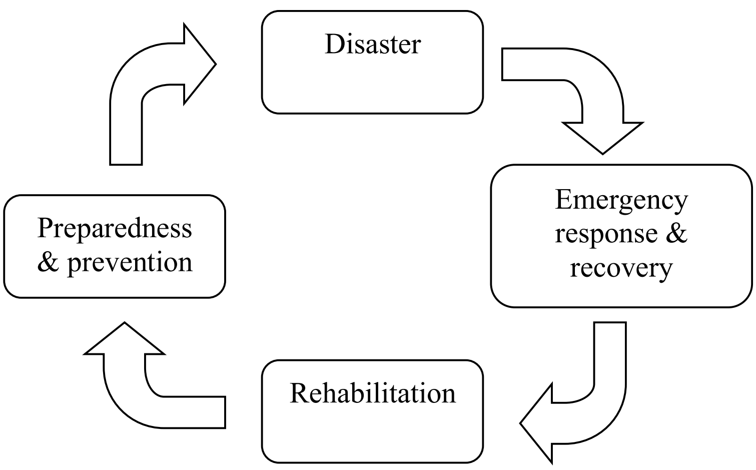


Figure 1. Cycle of Disaster.

Evacuation is a response to an imminent or projected flood hazard expected to present a danger to life, health, or well-being. It is a risk reduction technique that can be used to minimize the impacts of an emergency on a community. This includes transferring people to a safer place and returning them. Evacuation is necessary when there is a danger to building occupants' safety from the environment inside a structure and leaving the facility is a better choice than staying. Evacuation should occur through the nearest exit, but an alternate or secondary escape route may be required, depending on the circumstances. Based on Ahmadi et al. (2022), few studies have comprehensively and qualitatively addressed flood response, especially evacuation. In placing more emphasis, Bradley et al. (2013) claimed that it must be adequately prepared and executable for an evacuation to be successful. The measure of preparedness, such as evacuation, is necessarily increasing to avert the negative impacts of floods (Ao et al., 2020). An evacuation center is a location at a reasonable distance from a flood-affected area. One of the conditions for the evacuation center is that the building itself should be in a location that is protected from the area impacted by the floods. Some of the evacuation centers pass the requirements, but some are not appropriate because of the location of the building itself. These claims can be contended by Helderop et al. (2019), saying that during a large-scale flood, the official evacuation center could be disrupted at the same rate as the flood-affected area, making them useless to be used by residents of flood-affected neighborhoods. Hence, there is a high need to determine the most appropriate evacuation center for victims that meets the criteria.

2.1 Sensors

Early disaster warning, which is the SMS notification, is a very comprehensive disaster management system in disaster-prone areas, and many studies show that the SMS approach is commonly used. However, a notification may only alert the victims of current situations, where they need to be transferred to an evacuation center as soon as possible. There are a few methods and approaches for disaster management, like Disaster Management Server (DMS), Android mobile disaster management, IOT-based alert, the best path to the nearest evacuation center, the use of Google Maps API, and more.

A few solutions have been proposed by Mahmud et al. (2019), and Siddique et al. (2023), which focused on sending a Short Message Service as a warning system. This system only sends messages without standard evaluation to the subscribers because no databases are being used. It may cause network congestion, as a large amount of SMS needs to be sent from the server. One of the ways proposed to reduce network congestion is to provide a mobile broadcast service that sends messages directly to subscribers in certain areas only. However, these solutions only focused on notification, and a notification may only alert the victims of current situations, where they need to be transferred to an evacuation center. Besides alerting subscribers of the disaster, determining and assisting victims to the appropriate evacuation center is another crucial process. Zain et al. (2020) developed a personal flood monitoring system that can call and send warnings via SMS. The warning was sent not only to system users but also directly to the Fire and Rescue Station as floodwaters rose rapidly to dangerous levels.

Zain et al. (2020) developed a flood warning and monitoring system (FWMS), using an Arduino Uno microcontroller, ultrasonic sensor (HC-SR04), and GSM SIM900A module. Using FWMS, users can apply for flood status in their area in real-time via SMS. Fajardo et al. (2010) use Android Mobile Development Environment for the disaster management system. The solution determines the best path along with different geographical areas that the volunteers and rescuers could take to serve people within the shortest period. The traveling salesman problem (TSP) approach is used in determining the most optimum route with several algorithms like dynamic, linear, Monte Carlo, and heuristic search methods.

Gosavi et al. (2014) proposed the solution of notifying flood-threatening residents and local authorities utilizing SMS. Arduino microprocessor is used for monitoring the whole setup. This is interfaced with a GSM modem and pressure sensor. The pressure sensor monitors the height of the water level and the Arduino microcontroller is used to measure the height value of water according to Pascal's law. The measured water level will then be compared to the defined threshold, and if the level exceeds the threshold value, the microcontroller will send an SMS to the residents to notify them via the GSM module.

Indriasari et al. (2017) used a built-in GPS to get the volunteers' location coordinates. They mentioned that the location data sending could be done in two modes, which are manual and automatic mode. This application mainly focuses on locating volunteers that can reach the affected area by presenting a marker with the names and distance between the volunteers and victims. The location data obtained would then be shown in Google Maps. The disaster management coordinators can manage volunteers by seeing the location of volunteers on a digital map and sending messages to volunteers using the Google Cloud Messaging service. Meanwhile, Sikder et al. (2017) aimed to warn people before the disaster and inform the best path to the nearest evacuation center via SMS or voice call. His solution divided the whole application into some modules. One is a database of the subscriber's information, and the area's likelihood of being hit by disaster is calculated. The other focused on those areas where the information is taken from an official weather website. This information is converted to a JavaScript Object Notation (JSON) file. Based on the information, the system would be able to grasp the possibility of a disaster occurrence and then inform about the nearest evacuation center information to the subscribers.

3. Methodology

Banjir Rescue was developed based on the Waterfall Methodology involving six phases of requirement analysis, system design, implementation, testing, deployment and maintenance.

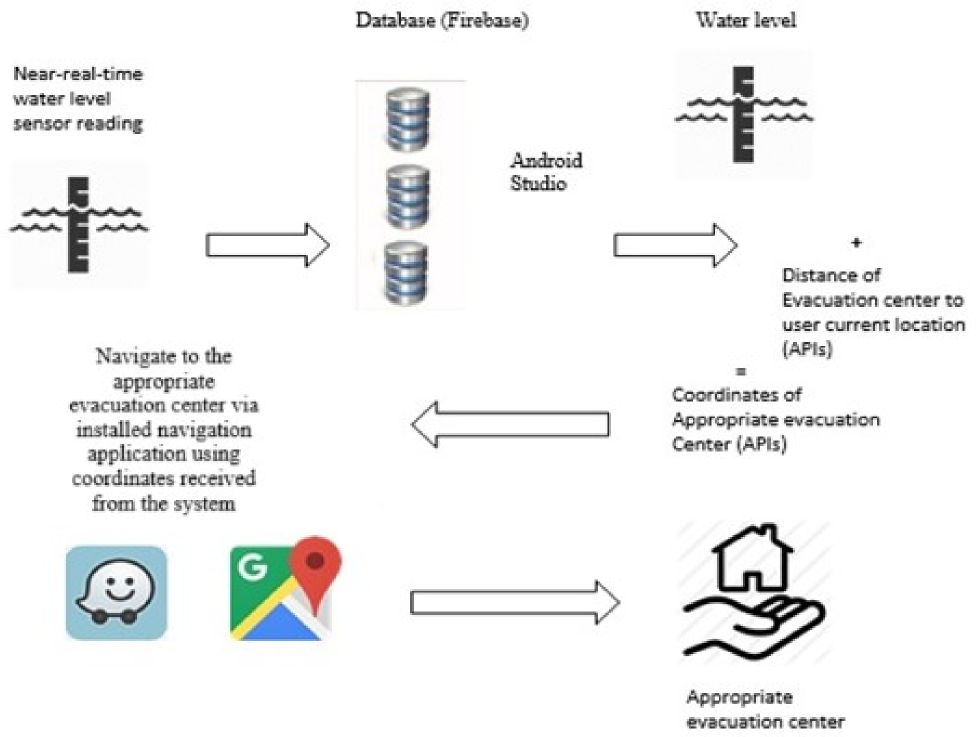


Figure 2. Overall diagram of the proposed system

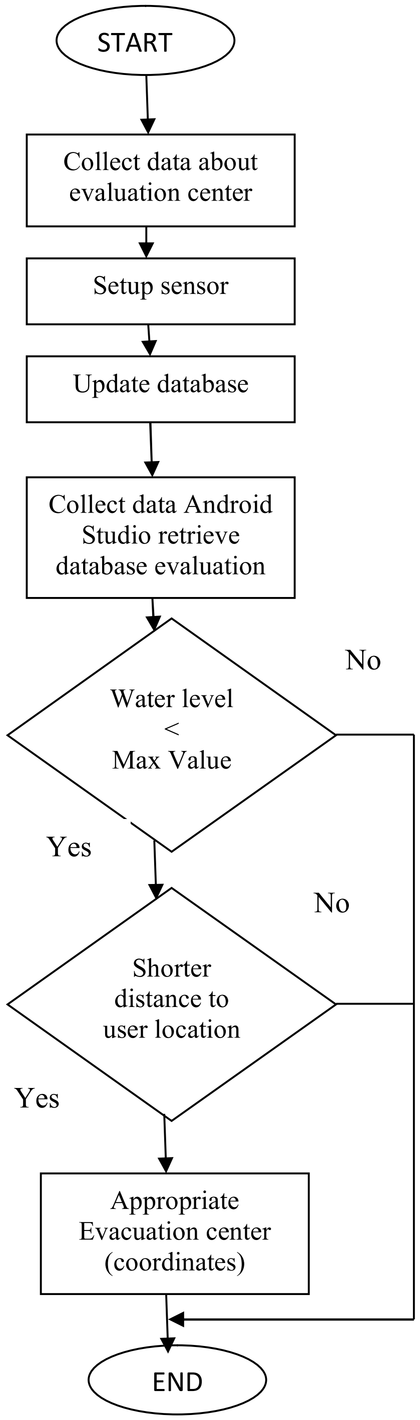


Figure 3. Flowchart to determine evacuation center

Figure 2 shows the overall diagram of the proposed system, and Figure 3 shows the flow chart to determine the evacuation center. The hardware used for the proposed system includes a Water level sensor in real-time, a Microcontroller board Arduino UNO board and a Wi-Fi Microchip ESP8266 Lua NodeMCU Wi-Fi Board. There are two software programs installed: Arduino IDE, for the back-end coding and Flutter, for the front-end coding. The Flutter environment is plugged into the Android Studio along with the Dart language. A simple database and user-friendly interfaces are then designed. Two algorithms were developed to compare the water level at the evacuation center with its maximum value and to calculate the distance between the user and to unaffected evacuation center. The water level sensor to read the water level at the evacuation center is set up.

- The pins at the water level sensor are connected to the Arduino Uno. This connection is established to read the data from the sensor.
- Arduino Uno is connected to the ESP8266 NodeMCU (Wi-Fi microchip) to connect to the Internet and Firebase. This connection is established to provide a connection to the Firebase to update the real-time database.

Android Studio is a platform used to develop a mobile app. Android Studio was installed and configured correctly to prevent future complications throughout the mobile application development. Arduino Software (IDE) is an open-source program that makes it easy to write code and upload it to the board.

4. Results

This section demonstrates the results gained using Rescue Banjir. The results in terms of connectivity and system reliability (workability) at three different locations were reported. Based on the water level and the distance from the current location to the evacuation systems, Banjir Rescue will calculate the shortest distance and navigate the victim to the nearest evacuation center. At the end, the interface of Banjir Rescue is shown.

4.1 Connectivity

The objective of this experiment is to test whether this application can run on real devices as during the development process, it has only been tested on an emulator. The process to debug on real devices is as follows:

- Connect the device to the desktop with a USB or Type C cable.
- The next step is to enable USB debugging on the real devices in the Developer Options window.
- Open the Settings app.
- Scroll to the bottom and select About phone.
- Scroll to the bottom and tap the Build number seven times.
- Return to the previous screen, scroll to the bottom and tap Developer options.
- In the Developer options window, scroll down to find and enable USB debugging
- In Android Studio, select the device to run the app. Then, click Run.

The application has been tested on 8 Android real devices. Table 1 shows the details of the devices, installed navigation applications and whether the navigation application received the coordinates of the shortest distance successfully. The result shows that this solution runs successfully and can process the system for every change of the sensor reading. The appropriate evacuation center is determined according to the near-real-time database. Also, both navigation applications successfully retrieve the appropriate evacuation centers' coordinates and show directions to the user.

Table 1. Result of Connectivity

	Installed Navigation Apps		**Successfulness**	
Phone Model	**Google Maps**	**Waze**	**Google Maps**	**Waze**
Huawei Nova 2i	Yes	Yes	Yes	Yes
Huawei P30 Pro	Yes	Yes	Yes	Yes
Samsung Galaxy A70	Yes	No	Yes	Unavailable
Oppo A5	Yes	No	Yes	Unavailable
Realme 5 Pro	Yes	Yes	Yes	Yes
Google Pixel 2	Yes	Yes	Yes	Yes
Samsung Note 7	Yes	Yes	Yes	Yes
Samsung Galaxy S8	Yes	Yes	Yes	Yes

4.2 Workability for three different current locations

The objective of this experiment is to determine the reliability of this system. This experiment is done by setting different users' current locations. It can be done using the emulator on Android Studio. The steps to change the current user location are as follows:

- In Android Studio, create an Android Virtual Device (AVD).
- If it is installed, click on Tools and select AVD Manager.
- Select the emulator and click on Cold Boot Now from the target device drop-down menu.
- After the emulator has successfully started, run the project.
- If the device is connected, the app will pop up on the emulator screen.
- Now, click on, and emulator extended controls will be displayed.
- In the search bar, enter the desired location and save.
- The save points are listed in the saved points section on the right side of the extended controls.
- To set the point as the current location, simply click on set location and the current user location is now changed.

Kelantan was chosen because it has been identified as one of the cities in Malaysia that is frequently hit by floods. This is because Kelantan has faced floods frequently, which means that Kelantan has a lot of evacuation centers to be used in this project. The evacuation centers in Kelantan are defined on the Malaysia Disaster official website. Table 2 shows the names of evacuation centers in Kelantan according to their area. However, the main area of the study is Bachok.

Table 2. The evacuation centers in Bachok, Kelantan

Name of Center	Name of Center
Balai KRT Kuau	Sek. Keb. Pak Badol
Balai Penggawa Daerah Tanjung Pauh	Sek. Men. Keb. Pak Badol
Balairaya Tepus	Sek. Arab Kg. Chap
Dewan SMK Beris Panchor	Sek. Keb. Bekelam
Madrasah Mohd Ismail	Sek. Keb. Jelawat
Masjid Kuala Melawi	Sek. Keb. Keting
Masjid Mahligai	Sek. Keb. Kubang Telaga
Masjid Nemen Kg. Baru	Sek. Keb. Kuchelong
Masjid Takang	Sek. Keb. Pantai Senok
PPK KADA Bachok	Sek. Keb. Seneng
Rumah Pak Yeh	Sek. Keb. Sri Kemuning Beoh
Sek. Keb. Tangok	Sek. Men. Keb. Long Yunus
Sek. Men. Agama Tangok	Sek. Keb. Bakong
Sek. Men. Arab B/ Kubor Besar	Sek. Men. Jelawat
Sek. Men. Keb. Dato	Sek. Men. Sri Gunong

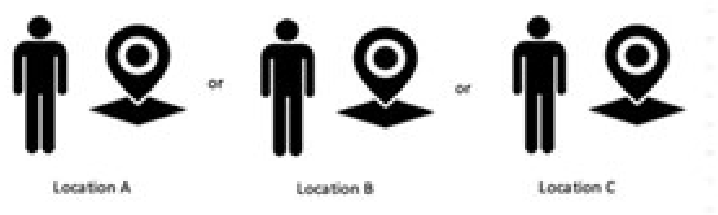


Figure 4. Experiment 2 setup

For this experiment, three different locations have been implemented. For each current location, the appropriate evacuation center is different due to its distance from the current location (illustrated in Figure 4). Also, the appropriate evacuation center is different for each scenario. For this experiment, three different locations have been implemented and the result is in Table 3. This experiment has been conducted using the evacuation centers' input from the portal website of the evacuation centers in Kelantan. The evacuation centers represented by the sensors are listed in Table 3, along with the maximum value.

Table 3. The maximum value.

	Sensor 1	**Sensor 2**	**Sensor 3**
Evacuation Center	Masjid Mahligai	SMK Jelawat 2	SMK Sri Gunung
Maximum Value	700	600	270

Three different locations have been set and tested with 4 different scenarios in Table 4 to determine the appropriate evacuation center for each scenario of the different locations. The outcome of this phase is the analysis of the application's performance using Android phones in navigating users to the appropriate evacuation center (Table 2).

Table 4. The four tested scenarios.

Scenario	**Condition 1**	**Condition 2**	**Condition 3**
1	No	No	No
2	Exceed	No	No
3	No	Exceed	No
4	No	No	Exceed

Table 5 shows the result of the calculation of the distance between different current locations and the evacuation center.

Table 5. Distance between the current location to the evacuation center

Coordinated (User)		**Distance (Meter)**		
Latitude (degree)	Longitude (degree)	Center 1	Center 2	Center 3
6.0056	102.3596	6832.2515	1163.4694	1666.7039
5.9983	102.3541	6110.1953	2081.5396	686.8096
5.9423	102.3012	5553.3394	10582.6914	7906.6411

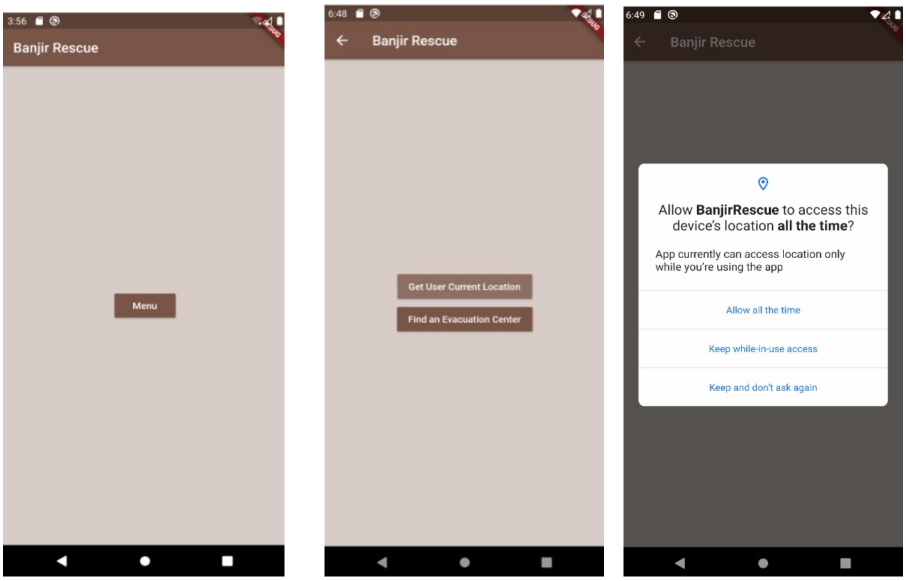
After the system determines the water level and the distance, the system will determine the appropriate evacuation center for each location with different scenarios. Table 6 shows the result of this experiment.

Table 6. Results of experiments

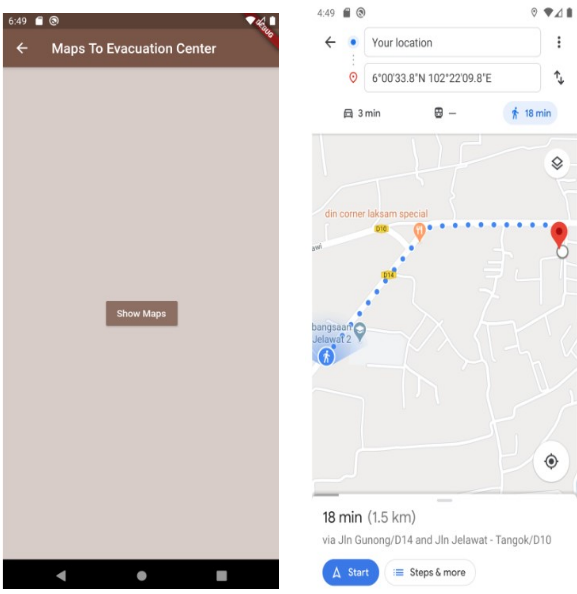
Coordinated (User)		**Scenarios (Water Level)**			**Appropriate Evacuation Center**
Latitude (degree)	Longitude (degree)	Sensor 1	Sensor 2	Sensor 3	
6.0056	102.3596	No	No	No	Center 2
		Exceed	No	No	Center 2
		No	Exceed	No	Center 3
		No	No	Exceed	Center 2
5.9983	102.3541	No	No	No	Center 3
		Exceed	No	No	Center 2
		No	Exceed	No	Center 3
		No	No	Exceed	Center 2
5.9423	102.3012	No	No	No	Center 1
		Exceed	No	No	Center 3
		No	Exceed	No	Center 1
		No	No	Exceed	Center 1

4.2 Final Output

Figure 5 displays the navigation screen that will appear on the user's screen. Users will be assisted to the location.



(a) (b) (c)



(d) (e)

Figure 5. The Banjir Rescue Navigation Screen

Step 1:(Figure 5a): As the user launches this application, the homepage contains the Menu button.

Step 2:(Figure 5b): Once the Menu button is clicked, the user will be navigated to the next page, which contains two options (Get User Current Location and Find an Evacuation Center).

- The top button, "Get User Current Location," is to receive the user's current location. This data is important to proceed to the next step of the system. However, the requested location will only receive the user's current location if they allow it.
- The user will then click on the bottom button "Find An Evacuation Center". Banjir Rescue will calculate the nearest evacuation center (i.e., the shortest distance). The user will be navigated to the page Maps to Evacuation Center.

Step 3: Referring to Figure 5d, if the user clicks on "Show Maps", the page will pop up installed navigation applications on the user's mobile phone. This means that they can choose any navigation application that they are comfortable with to navigate them to the appropriate evacuation center. In this test, there is only one application installed, which is Google Maps. The system will pass together the latitude and longitude of the appropriate evacuation center.

Step 4: Referring to Figure 5e, for this test, the user's current location is Zah Ayam Kampung store and the appropriate evacuation center is Sekolah Kebangsaan Jelawat 2. It only takes eighteen minutes for the user to reach the center.

5. Conclusion

Banjir Rescue is proposed to provide near real-time information to the victims about the appropriate evacuation center when the disaster takes place. Two experiments have been conducted to test the effectiveness of this system. The first experiment considered different Android real devices, and the second experiment considered different locations and affected areas. The experiment results show that the system can be run on all real devices detected, and the determination of an appropriate evacuation center is reliable. This suggests that the proposed solution can be applied to locals in the area that is frequently hit by floods such as Kelantan, to help them move to a safer place when the disaster takes place.

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Author Contribution

Author 1 wrote the research methodology and revised the entire paper.
Author 2 collected the data, conducted the statistical analysis, and interpreted the results.
Author 3 and 4 checked on the paper structure and content.

Conflict of Interest

The authors have no conflicts of interest to declare.

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