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Surigao River Flood Watch and Warning App System

Arvin E. Mag-usara
Master in Industrial Education, Surigao State College of Technology, Surigao City, Philippines
Bachelor of Electronics in Engineering Technology, Surigao State College of Technology, Surigao City, Philippines

Abstract— *The Surigao River is the longest river in the Province of Surigao which majority of the rice crops and corn plantations were beside this river. In heavy rains and typhoons, most of these areas are directly affected. Existing flood monitoring relies on the water level. Still, it lacks data interpretation of whether the level is alarming. This project developed a flood monitoring and warning system using ultrasonic sensors. This research aims to keep track of the river's water levels and send real-time data and updates on the current situation. When a water level rises to a critical level, it sends out SMS alerts to people and uploads data to the web using NodeMCUESP8266. It is viewable through an app installed on mobile phones. Photovoltaic panels are used to power the system. Investigations and interviews were used to collect the data needed to assess system functionality. The descriptive rating of 4.0 signifies high functionality and 3.6 for easy access to the developed system. The total mean of 3.87, which translates to a very high descriptive rating, indicates that the mobile app's interface fulfills its purpose well. The project's cost is only 11700.00 Php, which is significantly less expensive than similar products in the market and proves to be accurate based on the simulation done in the field.*

Keywords— *Flood monitoring: GSM: NodeMCU ESP8266: Ultrasonic: Wireless.*

I. Introduction

The goal of the flood monitoring and warning system is to reduce the danger of loss of life and economic growth. Analysis, data gathering, monitoring, and warning are all supported by this system. A wireless sensor network is used to deliver raw, processed, and evaluated data from the microprocessor, which generates a flood monitor on the mobile application and sends an SMS alarm. [1]. Flood monitoring and warning system require three fundamental factors that need to look into: data collection through gaging, data processing, hardware and software to be used, and the dispersion of flood warning information throughout the community [2].

Overflowing of Surigao River affected many barangays, which includes: Barangay Bonifacio Purok 2 and 7 affected 31 houses; all Purok of Barangay Luna along Surigao River; Barangay San Juan in which 50 homes were affected; San Roque in which 24 houses were affected due to floodwaters reaching 200 meters from the banks, and in Barangay Washington particularly in Kaskag riverside in which the flood height ranges from 2.0 to 3.2 meters [3].

The flood monitoring and warning system will inform the subscribed residents through SMS that a flood might occur. The alert message of the system is available through a mobile app developed by the researchers. With the system installed, there will be no reason for people and authorities to have not prepared during heavy rainfalls.

App-based flood monitoring and warning system are relevant and vital for the safety and welfare of the community. It is encouraging to do a project related to disaster mitigation that can save uncountable properties and lives. It is also an immense contribution to the local and national government of the country for helping communities during disasters.

II. Related Literature

Flooding is a hazard that perennially occurs in five urban barangays, 12 coastal barangays, rural districts southeast and northwest of the metropolitan area, and ten barangays along Surigao River. The volume and magnitude of rainfall, current morphology, and obstruction of Surigao River, along with its tributaries Kinabutan and Tumanday, are the primary reasons for flooding. Flood occurs to an average of one to three per year with a higher frequency of as many as five events with level ranges from 0.5 meters along urban streets to 3 meters along river plains [3].

The accuracy feedback of ultrasonic sensors achieves real-time flood monitoring. Creating an effective flood monitoring system that includes dependable water level monitoring, early flood warning, real-time flood monitoring, and correct data is necessary. The ultrasonic sensor works properly in detecting water level changes. The use of multiple sensors (ultrasonic sensor) can improve the system's accuracy, especially when the river is in a moving-surface condition. The equipment will precisely measure and determine the river's floodwater level in real-time. With Arduino, the researcher was able to make the program on interfacing the devices like Global System for Mobile Communication (GSM) module to web-monitoring and allow editing the program on any changes to make [4][5][6][9].

Flood-prone areas in the Philippines require flood monitoring. Specific technologies like water sensors, web monitoring, and SMS notification will benefit the locals because of the enhanced decision-making due to timely flood warnings and information. Several local surveys were carried out to monitor the floods. In Davao, water level monitoring of the river uses UTP wires and activate siren when the water level is critical but is suffers low response time [7]. Natividad and Mendez (2017) conducted research in Isabela, Philippines, by establishing a real-time flood monitoring and early warning system which uses ultrasound sensors and alerts the community by SMS [8].

Yumang et al. found that the system employs an Arduino Uno, a GSM shield, sensors, and is powered by a solar panel with a generator. It also has an early warning LED device that sends out SMS notifications in real-time. [10]. Another study by A. Supani et al. uses artificial intelligence fuzzy logic algorithms to predict floods using precipitation and water level input variables. The system employs the Wifi Wemos module D1 R2, which is based on the ESP8266-12 module.4. The graph of the data can be viewed in the Blynk application using the Blynk server [11].

Researchers developed a mobile application as a flood monitoring and warning platform based on the above-stated studies. The proposed project uses Arduino Mega 2560, ultrasonic sensor, GSM module, ESP8266 wifi module, and powered by a solar panel. SMS notification alone as a flood warning can be interrupted by unpleasant weather conditions, so the project integrates a mobile application to monitor the water level. It also displays an alert when the flood will most likely happen.

III. THEORETICAL FRAMEWORK

The ultrasonic sensor will emit the signal from the trigger pin and receive the pulse to the echo pin. Trigger and echo pin sends a digital reading to the microcontroller module for processing. The river's water level is detected by an ultrasonic sensor. After the pulse is transmitted, the microcontroller obtains data from the sensor and transforms it into time durations using the formula:

$$time = \frac{distance}{speed}$$

where; the speed of ultrasonic sensor = speed of soundwave = 340 ms

When the time difference is known, the obstacle's distance from the sensor can be computed using the following formula:

$$speed = \frac{distance}{time}$$

$$distance = speed \ x \ time$$

Because sound travels the same distance twice, it can be measured in as [12][13]:

$$distance = 340 \ x \ \frac{time}{2}$$

The transmitted ultrasonic signal has a specific radiation angle, and the form of the propagation was determined by the sensor's beam patterns, and the beam angle may be written as:

$$\theta_c = sin^{-1}\frac{0.61\lambda}{r}$$

Where λ is the wavelength of the ultrasonic signal, and r is the radius of the transmitter [14].

The researcher used an equation developed by Panda et al. to make up for heat and moisture effects on the air's speed of sound to enhance the reading certainty by the equation:

$$C_s = (331.296 + [0.606 \ x \ \theta])x(1 + [RH \ x \ 9.604 \ x \ 10^{-6} \ x \ 10^{0.032x(\theta - 0.004x\theta^2}])$$

Where C_s Is the speed of sound in the air after compensation θ is the air's temperature, and RH is the air's relative humidity [15].

The ultrasonic sensor uses sonar to determine distances. This sensor is utilized to detect floods as the river's water level rises in this investigation.

IV. MATERIALS AND METHODS

As shown in Figure 1, the researchers used the Rapid Application Development Model for the system, adaptable in every stage. This process emphasizes the rapid prototyping and testing cycle, making it possible for the researchers to perform multiple iterations and updates to the system without restarting the development from scratch.

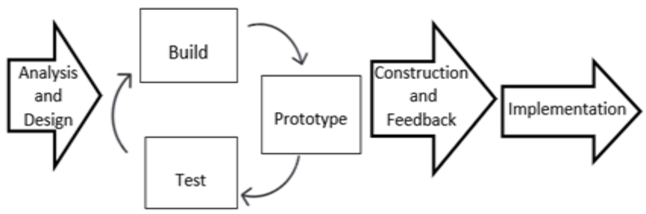

Figure 1. RAD Model of the System

The hardware of the flood monitoring and warning system is shown in Figure 2. The ultrasonic sensor is connected to the Arduino Mega, powered by a 12V, 5W solar panel. The data acquired from the sensor will be processed by the Arduino connected to the GSM module, which sends out a warning SMS to the user if the data reaches a certain water level. NodeMCU ESP8266 is used to transfer the data to the web.

Ultrasonic sensor, GSM module, and NodeMCU are programmed to the Arduino IDE platform. It includes installing the libraries needed in Arduino and inserting network credentials which is the mobile data of the GSM module. It will be the independent connection of NodeMCU to update the real-time database and fetch data of the mobile application.

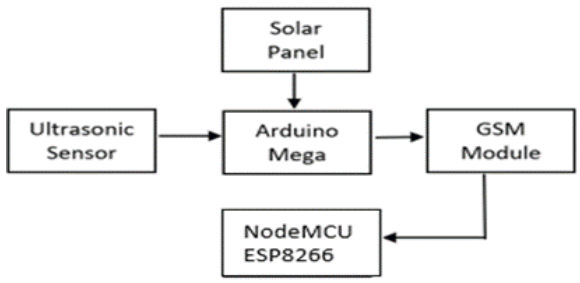

Figure 2. The Hardware of the System

As shown in figure 3, The development of the mobile app, which is connected to the system's hardware to display the data gathered from the hardware to the mobile app. The Graphic User Interface (GUI) of the mobile application is made with the MIT APP Inventor. The task involves initializing global distance to get the data through the firebase database and insert map pictures to the app's interface and the specific function of the buttons.

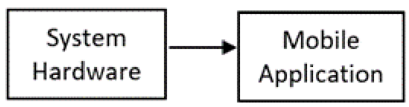

Figure 3. Mobile Application

A. *Operationability of the System*

The system's operationality was determined by the period to send SMS warnings, the period of change in real-time data, and the mobile app SMS warning functionality.

To get the period of SMS warnings, the researchers triggered the ultrasonic sensor to its critical level. They got the time difference between ten users after receiving the text message through a stopwatch.

To get the period of change in real-time data, the researchers call the time difference through a stopwatch when data changes in the mobile app display.

To assess the system's functionality in terms of mobile app and warning SMS, the researchers surveyed ten participants answering the survey questionnaire regarding the system's functionality.

B. Project Design

The distance between the sensor and the water was measured using an ultrasonic sensor. HC-SR04 sends out a soundwave to the water's surface, and it will bounce back and receive as an echo by the sensor's transducer. Ultrasonic is used to measure the water level of the river.

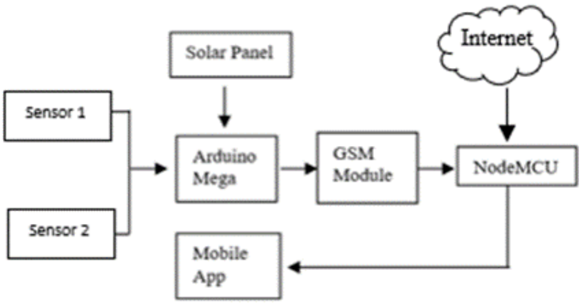

Figure 4. Project Design

The gathered data from the sensor will be processed by the microprocessor of the system, the Arduino Mega powered by a solar panel. The system sends an SMS warning when the water is in critical range through the GSM module. NodeMCU ESP8266 is used to transfer the data to the web. As for mobile app users, there will be advice shown in the interface as the flood would likely happen in that distance range.

C. Project Development

Project Development shows the whole process of conducting the study from the beginning until the end.

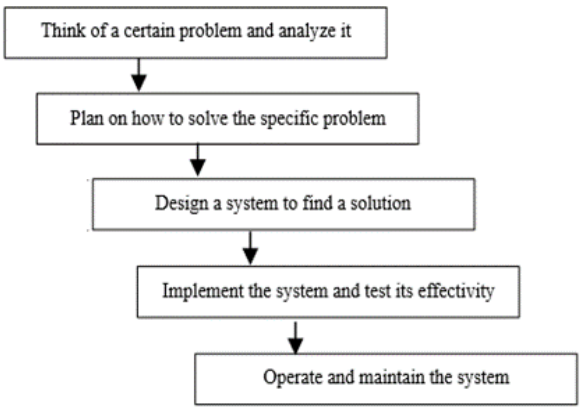

Figure 5. Project Development

The researcher must identify a specific problem in the community that needs to be solved. The second stage involves planning on how to solve the problem at hand, followed by the design of the system by applying engineering technology to create a solution. Next is to implement the system and test the effectiveness and functionality. Lastly, keep the system operated and maintained to serve people in the community.

D. Project Implementation

The Surigao River Flood Monitoring and Warning System was implemented and tested its functionality. Furthermore, the quality and performance of the proposed project are also determined.

The implementation of the proposed project undergoes three phases for efficient and optimal operation. The first phase includes the hardware and software setup, project orientation, and personnel training.

The second phase is the trial run of the project's system and its full functional implementation. The last phase is maintenance, which involves the enhancements and adjustments of the users' program. This phase also involves adding new features expansions or the project's program system to another function as requested by the user.

A 12 V supply powers the proposed project, and the program codes are loaded in the Arduino, such as the distance of water from the sensor and warning messages sent by the GSM module. The ultrasonic sensor is positioned perpendicular to the river's water level to avoid inaccurate distance readings between the sensor and the water. If the water level increases to a critical level and the sensor detects it, it will instantly send out a notice to individuals that a flood is imminent, and so on. The water level and alerts can be viewed through a mobile application developed by the researcher.

Figure 6 shows the Surigao River location in Surigao City, where the sensor configuration and testing were done. It also showed some of the nearby barangays that are flood-prone located near the river.

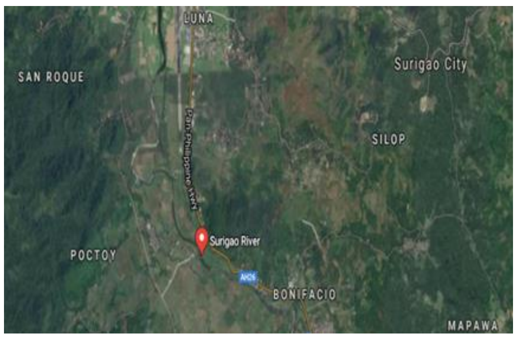

Figure 6. Location Map

E. Project Evaluation

The project developed was evaluated as to usability and operability based on the design and purpose.

TABLE I. Participants of the Study

Participants	f(n=10)	% of involvement
Residents	10	100%
Total	10	

This study uses purposive sampling. The residents were chosen purposively to answer the survey instrument as to the reliability and functionality of the mobile app. The researchers enlisted the help of ten persons to evaluate the study.

The researcher will use a survey and interview questionnaire for the qualitative data and assess the effectiveness and functionality of the project. The researcher will use the tally and rating sheets to collect qualitative data and write down all the observations made to the project.

1. Survey Questionnaire
2. Tally and Rating sheets

F. Data Collection Procedure

Figure 7 shows the systematic flow of the data collection. It involves surveying the location, installing the project in the area, and starting the experiment. Then, formulate a question that will assess the system. Next, implement the trials and observe. Record the data gathered from each test conducted. Record and tabulate all the collected data, and the researcher must use it to assess the project.

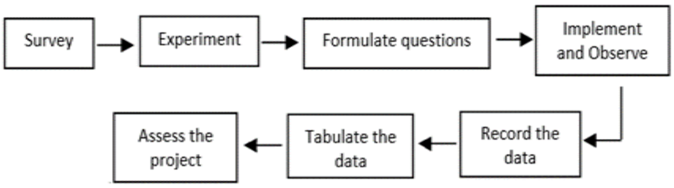

Figure 7. Data Collection Procedure

G. Statistical Tool

Computing the mean shall be used as a statistical tool in our project. This tool will get the average period for sending a warning through SMS notification to the participant after the Arduino receives a signal that the water is at a critical level and the average period the monitor displays if there's a change in water level.

V. Results and Discussions

A. Hardware Design of the System

Figure 8 shows the system installed at the riverside of Surigao River at Barangay Luna. There are two sensors used in the design placed 20 meters apart.


Figure 8. The System Installed Alongside the Surigao River

Figure 9 shows the pictorial diagram of the system in which the wiring connection of the components is established.

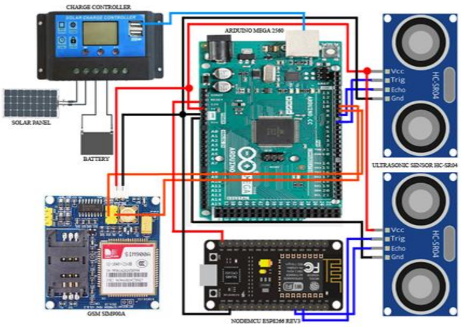
Figure 9. Pictorial Diagram

Figure 10 shows the connection of components of the project. On the upper part is the solar panel connected to a battery and charge controller to avoid over-charging and protect from over-voltage. On the inside of the casing are Arduino Mega, NodeMCU ESP8266, and GSM module.

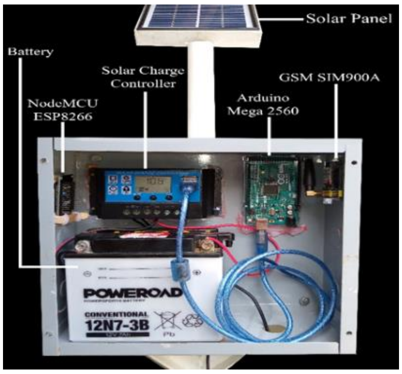

Figure 10. Project Prototype

B. Mobile Application of the System

The implemented project also developed an android based app for remote monitoring.

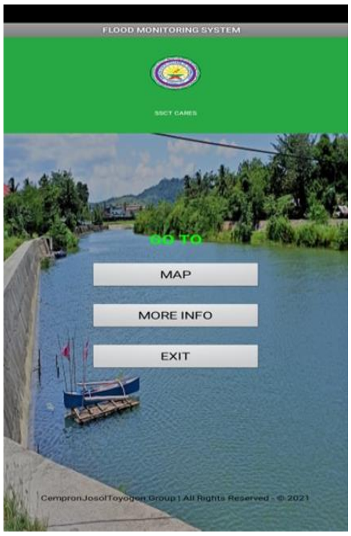

Figure 11. GUI of the App

Figure 12. Flood Monitoring App

Figures 11 and 12 shows screenshots of the mobile app in which there are options such as the map, more info, and exit for the users to click. The figure shows the screenshot of the map of the river wherein the user can click which map of the river to monitor.

Figure 13. Status of the River

Figure 13 shows the river status in the mobile app, in which it states the average distance detected by the two sensors labeled as left and right.

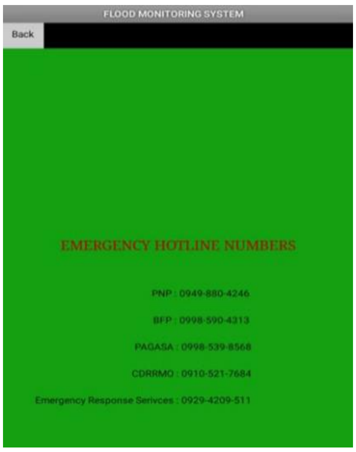

Figure 14. Emergency Hotlines

The figure above shows the screenshot of the emergency hotlines in Surigao City, which can be found on the designed mobile app.

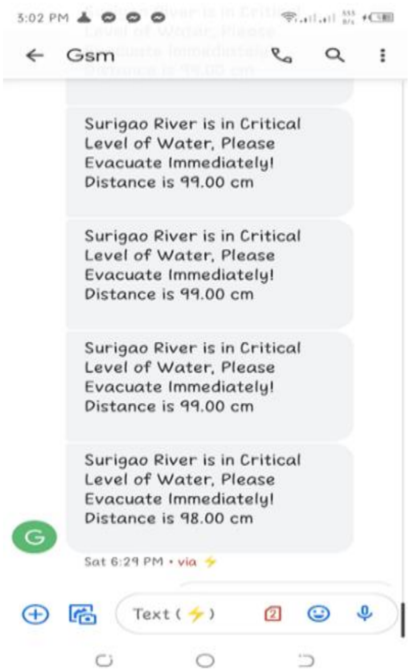

Figure 15. Warning SMS

The above figure shows the warning SMS sent by the system to an individual when it reaches the critical level, indicating the distance of the water level in centimeters.

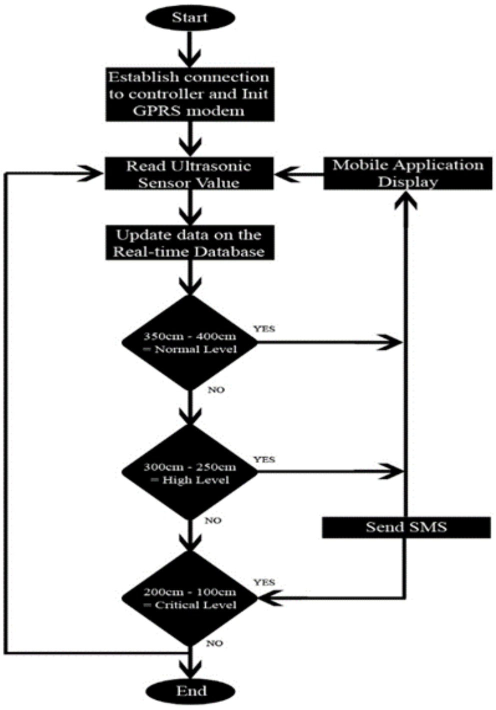

Figure 16. Flowchart of the System

The system's flowchart is shown in Figure 16. There is an established connection between the controller and the GPRS modem. The data gathered by the sensor will be uploaded to the system's database and displayed in the mobile application. If the data falls to the critical level, the system will send an SMS to the user.

C. Test Result of the System Operation

The developed system was evaluated based on operability and ease of use.

TABLE II. Period to Send Warning Message

Trial no.	Time (seconds)
1	8.51
2	7.46
3	4.68
4	7.30
5	7.73
6	3.78
7	7.95
8	7.61
9	7.95
10	7.51
Mean	7.05
Acceptable time gap	10

Table II shows that the time it takes to send a message to a user is shorter than the allowable time gap, implying that the text warning is sent out quickly to alert people if the river is approaching critical levels. Also, Table III shows the period of the change of real-time data on the app displays if there are changes in the distance of water level.

TABLE III. Period of the change of real-time data on the app display

Trial no.	Time (seconds)
1	1.00
2	0.84
3	0.41
4	0.44
5	0.40
6	0.41
7	0.59
8	0.69
9	0.97
10	0.87
Mean	0.66
Acceptable time gap	1

TABLE IV. Water Level Distance of the River

Time	Water level distance (cm)	Status
9:00 am	386	Low
10:00 am	357	Low
11:00 am	305	Normal
12:00 pm	256	Normal
1:00 pm	205	Normal
2:00 pm	211	Normal
3:00 pm	253	Normal
4:00 pm	282	Normal
5:00 pm	322	Normal
6:00 pm	354	Low
7:00 pm	371	Low
8:00 pm	386	Low
9:00 pm	397	Low

Table IV shows the water level status of the river from 9:00 am until 9:00 pm. It shows that from 9:00 to 10:00 am. The river is at a low level. From 11:00 am, the water level rises until 5:00 pm, indicating that the river is in high tide. From 6:00 pm until 9:00 pm, the water level status is at a low level.

TABLE V. The functionality of the mobile app

Functionality	Mean	Description
1. Displays the average distance of the two sensors	4.00	Very high
2. The app is easy to access	3.6	Very high
3. Displays the indicator of the distance of water level range	4.0	Very high
Overall mean	**3.87**	**Very high**

Table V illustrates the results of 10 assessors' evaluations of the mobile app's functioning. The first item had a mean of 4.00, which is equivalent to an excellent descriptive grade. The smartphone app shows the average distance between the two system sensors. The second item had a mean of 3.6, which corresponds to an excellent descriptive grade, indicating that the program is simple to use. The third item had a mean of 4.0 and a descriptive rating of very high, indicating that there is a distance indicator for the range of water level. The overall mean was 3.87, equivalent to an excellent descriptive grade, implying that the mobile app's UI performs well.

TABLE VI. The functionality of output in terms of SMS warning

Functionality	Mean	Description
1. Sends SMS immediately when reaches a critical level	3.8	Very high
2. SMS indicates flood warning and advice	3.9	Very high
3. SMS is readable and understandable	4.0	Very high
Overall mean	**3.9**	**Very high**

Tables VI indicate the results of 10 assessors' assessments of output correctness in terms of SMS warning. The first item received a mean of 3.80, equivalent to an excellent descriptive grade. It means that if the water level reaches its critical range, the system will promptly send an SMS warning. The second item had a mean of 3.9, which corresponds to an excellent descriptive rating, indicating that the SMS notification implies a flood warning and advises people to flee. The third item received a mean of 4.0, suggesting a robust descriptive grade, implying that everything on the SMS alert is clear. The overall standard was 3.9, equivalent to a very high descriptive grade, indicating that the system's SMS output is functional.

TABLE VII. Cost Analysis of the System

Components	Quantity	Amount	Total
Materials Cost			
5W, 12V Solar Panel	1	800.00	800.00
12V, 7Ah Battery	1	1200.00	1200.00
Arduino Mega2560	1	1615.00	1615.00
NodeMCU ESP8266	1	270.00	270.00
HC-SR04 Ultrasonic Sensor	6	83.00	498.00
Wires	100m	8.00	800.00
Total			5183.00
Labor Cost			
Labor		2000.00	2000.00
Total			2000.00
Factory Overheads			
Electricity		1500.00	1500.00
Boarding Rent		1000.00	1000.00
Total			2500.00

The cost of the product can be obtained through this formula:

$$cost = Cost\ of\ Materials + Cost\ of\ Labor + Cost\ of\ Factory\ Overheads$$

$$final\ product\ cost = cost + Desired\ profit\ (20\%)$$

$$cost = 5183 + 2000 + 2500 = 9683.00$$

$$final\ cost = 9683 + (9683\ x\ 20\%) = 11{,}619.60$$

If this project is commercialized, the product cost of it will be 11,700.00 Php.

VI. CONCLUSIONS

The project contributes towards the economy and community because it visualizes safety, preparedness, and minor casualty to the community as it warns people before flooding incidents happen.

The system uses real-time monitoring through a mobile application and a warning system through SMS to quickly disseminate the information. By this, the system is more flexible in serving the community by providing information.

The App-based flood monitoring and warning system detect the river's water level using an ultrasonic sensor, which works flawlessly. The system passed several tests depending on various parameters.

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