

INTELLIGENT EARLY FLOOD ALERT SYSTEM FOR ENHANCED FLOOD PREDICTION IN ALICAOCAL BRIDGE, CAUAYAN CITY, ISABELA

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Abstract— Flooding poses a significant risk to public safety, transportation, and infrastructure, particularly in vulnerable communities. In Cauayan City, the Alicaocao Bridge is a critical passageway frequently affected by rising water levels during heavy rains, resulting in traffic congestion, accidents, and limited access to timely information. Addressing this challenge is essential to improving disaster preparedness and response. Traditional methods often lack immediate communication and fail to integrate multiple channels for information dissemination and safety control. To bridge this gap, this study aimed to develop an Intelligent Early Flood Alert System for the Alicaocao Bridge. The researchers employed a quantitative, descriptive-developmental research approach to design and evaluate a prototype that integrates real-time water level monitoring, SMS notifications, LED visual indicators, and a one-way traffic control mechanism. These components were combined to enhance the accuracy, efficiency, and accessibility of flood alerts. Findings from user feedback revealed that the system is effective, reliable, and user-friendly, with respondents strongly agreeing that it improved flood monitoring through timely updates, clear alerts, and organized traffic management. The system received a grand mean of 3.64, indicating strong approval in design, functionality, and potential real-world application. The results suggest that the proposed system can significantly enhance flood response and community resilience, especially in areas that depend heavily on vulnerable infrastructures like the Alicaocao Bridge. By providing timely, reliable, and accessible alerts, the system empowers residents and motorists to make informed decisions, thereby improving safety and reducing disruptions during flooding events.

Keywords— *early flood alert system, LED monitoring, SMS alert*

I. INTRODUCTION

Flooding was one of the most critical natural disasters worldwide, causing loss of life, damage to infrastructure, and economic setbacks. According to a study by the United Nations Office for Disaster Risk Reduction, early warning systems can reduce the loss of life by up to 90% if communities receive timely information about incoming floods.

In the Philippines, where flooding was a significant threat due to its geography and climate, the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) developed flood alert systems like Project NOAH to provide early warnings for floods caused by heavy rainfall and storm surges, which had improved flood response in various regions. Flood alert systems were vital for addressing flood impacts, real-time data, and community resilience. Despite

technological advances, integrations need to be improved. Flood communication creativity was needed to address these gaps.

The Alicaocao Bridge faced significant challenges, especially during the rainy season and typhoons, as it tended to flood quickly due to its current state and surrounding environment. This hampered traffic flow and posed safety risks to residents. Heavy rainfall during the late quarter of 2024 caused the bridge to overflow multiple times, disrupting transportation and daily activities. A series of floods, triggered by Typhoons Nika, Ofel, and Pepito, further exacerbated the situation, primarily impacting barangays like Alicaocao and the low-lying areas of Turayong, Carabatan Chica, Carabatan Grande, Carabatan Punta, and Alicaocao, particularly those in the forest region. The residents always rely on social media, especially on the Facebook page, for updates on its status. These persistent issues underlined the urgent need to address the bridge's vulnerabilities to ensure safety and accessibility, even during extreme weather conditions.

The researchers proposed the study, "Intelligent Early Flood Alert System for Enhanced Flood Prediction in Alicaocao Bridge, Cauayan City, Isabela," as an innovative solution for efficiently monitoring and forecasting flood occurrences. To keep the community informed and safe during flood crises, this prototype used an LED indicator and SMS notification for bridge status updates and a one-way traffic system to improve vehicle flow and reduce the risk of accidents and congestion on the bridge.

II. METHODS

RESEARCH DESIGN

The researchers used a descriptive-developmental approach under the quantitative method, creating a prototype comparing two distinct but comparable longitudinal investigations and repeated observations of the same objects. The descriptive research method gathered information through surveying and data collection. It involves recording, tallying, and presenting the system process and composition. At the same time, the developmental method emphasized building and refining the system.

POPULATION OF THE STUDY

The respondents of the study are the Barangay Officials of the following Barangays: Barangay Turayong, Barangay Alicaocao, Barangay Carabatan Chika, Barangay Carabatan Grande, and Barangay Carabatan Punta, together with the Cauayan City Disaster Risk Reduction and Management Office (CCDRRMO). The researchers came up with twenty-seven (43) respondents.

Respondents of the Study

Table 1. Respondents of the Study

Barangays	No. of Respondents
Turayong	8
Alicaocao	8
Carabatan Chika	8
Carabatan Punta	8
Carabatan Grande	8
CCDRRMO	3
Total	43

RESEARCH INSTRUMENT

The researchers used a survey questionnaire for the instrumentation to identify the current issues with the manual flood and traffic flow monitoring and to evaluate the prototype's functionality. Pilot testing was conducted in Barangay Turayong, Cauayan City, Isabela, to determine the reliability of the questionnaire. The researchers used Cronbach's alpha for validation.

Pre-Survey Questionnaires. The researchers used it to identify the problems and the current situation of Alicaocao Bridge.

Post-Survey Questionnaires. This was used by the researchers to evaluate the functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, maintainability, and flexibility of the prototype.

DATA GATHERING PROCEDURE

Likert Scale

Table 2. Likert Scale

Scale	Range	Interpretation
4	3.26 – 4.00	Strongly Agree
3	2.51 – 3.25	Agree
2	1.76 – 2.50	Disagree
1	1.00 - 1.75	Strongly Disagree

THE RESEARCHERS FIRST SECURED A LETTER OF PERMISSION FROM THE SCHOOL DIRECTOR TO CONDUCT THE STUDY. THEY THEN EXPLAINED THE PURPOSE AND OBJECTIVES OF THE SURVEY TO THE RESIDENTS OF THE FOLLOWING BARANGAYS: **TURAYONG, ALICAOCALAO, CARABATAN CHICA, CARABATAN GRANDE, AND CARABATAN PUNTA**, AS WELL AS TO REPRESENTATIVES FROM THE **CAUAYAN CITY DISASTER RISK REDUCTION AND MANAGEMENT OFFICE (CCDRRMO)**. DATA WAS GATHERED USING A STRUCTURED SURVEY QUESTIONNAIRE TO COLLECT RELEVANT INFORMATION FOR THE STUDY. AFTER THE DATA COLLECTION PHASE, THE RESEARCHERS CAREFULLY TALLIED THE RESPONSES AND CONDUCTED A THOROUGH ANALYSIS TO INTERPRET THE RESULTS.

DATA ANALYSIS

To analyze and interpret the data, the researchers followed the statistical procedure:

Weighted Average/Mean. This was used to determine the answers to the questionnaire and to test the functional suitability, performance efficiency, compatibility, interaction capability, reliability, security maintainability, and flexibility.

$$X = F/N$$

Where:

X= mean

F= sum of the total rating of the product

N= total number of ratings

ETHICAL CONSIDERATIONS

The researchers ensured that all respondents' identities and personal information remained strictly confidential and were used solely for this study. Informed consent was obtained from all participants, with their privacy and autonomy fully respected throughout the research process. The researchers also acknowledged and appreciated the time and effort contributed by the respondents. All data were handled with the utmost care and responsibility to uphold trust, transparency, and ethical integrity.

Research ethics comprise a set of guiding principles that help scientists conduct their studies responsibly and respectfully. These principles safeguard the rights and well-being of individuals involved in research and promote fairness in pursuing knowledge. While research aims to enhance understanding, develop treatments, and improve lives, it must also address two fundamental questions: *what* to study and *how* to study it ethically.

PROJECT DEVELOPMENT

The system project was developed utilizing the Agile methodology, which is characterized by iterative cycles and a

focus on continuous feedback mechanisms. The methodology encompasses stages such as planning, design, development, testing, deployment, and review and maintenance.

Requirement Specification



Figure 1. Agile Methodology

Planning. The researchers identified the core functionalities, such as monitoring flood risk, sending alerts, and optional traffic management.

Design. In this phase, the researchers outlined how the sensor was connected to the processing unit and how data was displayed or acted upon. Prototypes of the interface and visual outputs (e.g., LED indicator and traffic lights) were created to ensure user-friendly interaction.

Development. During this phase, the system was constructed with an emphasis on progressively implementing features. This involved setting up the LED signage to display flood status alerts, connecting and integrating the water level monitoring system, and creating a real-time processing unit to evaluate data. A traffic light system was also included to provide a complete flood and traffic management solution to control traffic flow on the one-way bridge.

Testing. The system's accuracy, reliability, and responsiveness were evaluated under various conditions. These included modeling water levels, confirming that the warnings were sent to residents and the LED indicator, and ensuring the traffic signal system functioned as planned at the appropriate times. Ongoing feedback was gathered and utilized throughout the testing process to enhance and optimize the system.

Deployment. Once testing is complete, the prototype is installed at the Alicaocao Bridge. The researchers ensure the system is operational during the rainy season and monitor its performance in real-world conditions.

Review and Maintenance. Feedback is gathered from users, such as local authorities and residents, to identify potential improvements. Any detected issues are addressed, and new features may be added.

REQUIREMENT SPECIFICATION

OPERATIONAL FEASIBILITY

FISHBONE DIAGRAM

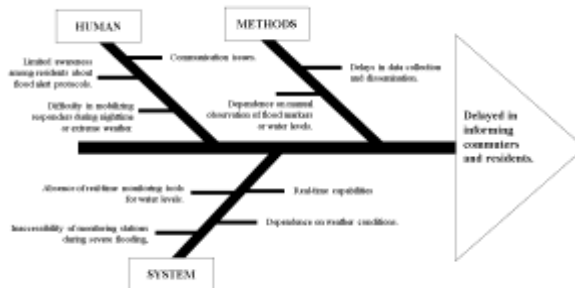


Figure 2. Fishbone Diagram

The Fishbone Diagram shows the current problem of having manual flood and traffic monitoring. This shows all the possible problems that could be fixed to improve the system.

Functional Diagram

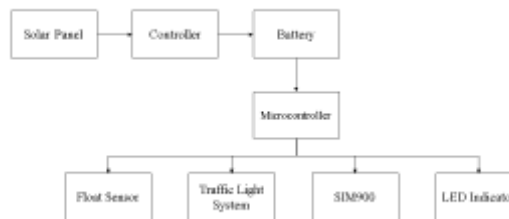


Figure 3. Functional Diagram

The functional block diagram demonstrates the functions and interrelationships of the system. The prototype is powered by a solar panel with a solar panel controller and a battery to store energy. The Arduino Uno microcontroller manages the float sensor, as well as the traffic light system for vehicle management, the SIM900 for disseminating message alerts, and the LED indicator, which receives messages to alert motorists before going to the Alicaocao Bridge.

Economic Feasibility

Estimated Cost of Materials for Prototype Construction

Table 4.1 Estimated Cost of Materials for Prototype Construction

Electronic Components	No. of item	Amount per item (₱)	Total Amount(₱)
Arduino Uno	2	284	284
SIM900	2	568	568
SIMCARD (Globe Plan)	2	174	174
Relay Module 10A (2channel)	2	348	348
AC/DC 5v 5A	2	500	500

DC Switch	2	1,000	1,000
Inverter	2	104	104
Battery Pack 18650 (15AH)	2	208	208
Solar Panel 50w	2	230	230
Solar Controller and Cable	1	460	460
Float Sensor	1	25	25
Enclosure box	1	50	50
Jumper Wires	1	350	350
LED Lights	6	700	700
Real Time Clock	1	650	650
Sub-total (Materials)			₱ 9,897

The costs of the materials needed to construct the prototype system were listed in Table 4.1, which was optimized to reach a target total of nearly ₱11,000.

Additional Costs for Prototype Construction

Table 4.2 Additional Costs for Prototype Construction

Additional Cost	Estimated Amount (₱)
Labor (Welder)	5,000
Transportation	500
Hidden Costs	1,000
Subtotal (Additional Costs)	₱ 6,500

The additional hidden costs that were incurred during the prototype's construction were shown in Table 4.2. These costs included labor wages, transportation fees, and minor miscellaneous expenses required for installation and assembly.

Grand Total for Prototype Construction

Table 4.3. Grand Total for Prototype Construction

Cost of Developing: Intelligent Early Flood Alert System for Enhanced Flood Prediction in Alicaocao Bridge, Cauayan City, Isabela.	
Electronic Parts	₱ 9,897
Other Expenses	₱ 6,500
Total Expenses	₱ 16,397

The overall cost of creating the optimized tilapia farming prototype system is displayed in Table 4.3.

Determination of Cash Flow

The following were among the prototype's estimated yearly benefits:

1. Damage Prevention Savings (due to early warning alerts):+₱30,000 annually
2. Reduced Government Response Costs: +₱20,000 annually

3. Increased Community Safety and Productivity:+₱10,000 annually
4. The estimated total profit per year is ₱60,000.

Estimated Yearly Expenses:

1. Maintenance, Repairs, and Component Replacement: P5,000
2. Communication Costs (SIM load, updates): P1,000

Total Yearly Expenses: P6,000

Net Annual Cash Flow = P60,000 – P6,000 = P54,000

Assessment of Financial Viability Return on Investment (ROI)

$$ROI = \frac{\text{Net Annual Cash Flow}}{\text{Total Investment Cost}} \times 100$$

$$ROI = \frac{P54,000}{P16,397} \times 100 = 329.33\%$$

The prototype was financially profitable, as evidenced by the project's ROI of roughly 329.33%.

Break-Even Point (BEP)

$$\text{Break – Even Period} = \frac{\text{Total Investment}}{\text{Net Annual Cash Flow}}$$

$$\text{Break – Even Period} = \frac{P16,397}{P54,000} = 0.36 \text{ years}$$

$$= 3.6 \text{ months}$$

It was anticipated that the system would recover its entire cost in about 3.6 months of operation.

The early warning prototype costs ₱30,000 to develop. It provides annual benefits worth ₱90,000—₱60,000 from damage prevention, ₱20,000 in reduced government response costs, and ₱10,000 from improved community safety. Yearly expenses total ₱6,000, resulting in a net annual gain of ₱84,000.

With a 280% return on investment and a break-even point of just 4.3 months, the prototype proves highly cost-effective. It offers a low-cost, high-impact solution for local governments and disaster-prone communities.

Data and Process Modeling

System Flowchart

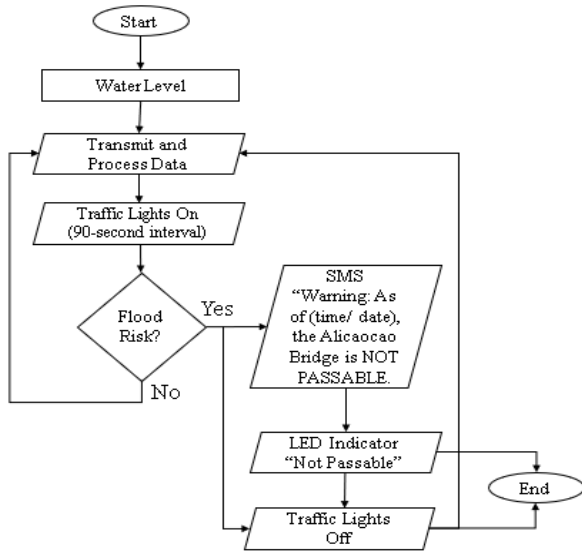


Figure 4. System Flowchart

The flowchart illustrates the operational process of the flood alert system. It starts by collecting data from the float sensor and transmitting it to the microcontroller for analysis. If flood risk is detected, the system activates alert messages and the LED indicator, and the one-way traffic light automatically turns off. Notifications are sent to local authorities to ensure appropriate emergency response. If no flood risk is detected, the system loops back to processing data.

Use Case Diagram

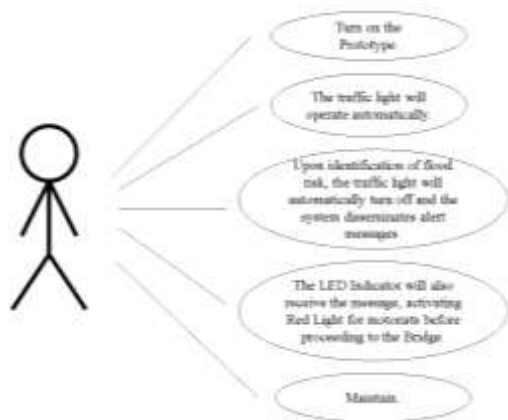


Figure 5. Use Case Diagram

The use case diagram shows the key interactions between the user and the flood alert system, focusing on the operational workflow and optional functionalities to enhance safety and traffic management during critical periods.

III. SCHEMATIC DIAGRAM

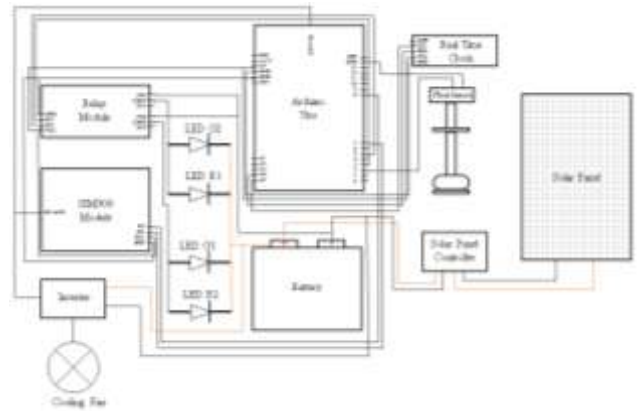


Figure 6.1. Flood Monitoring and Traffic Light Schematic Diagram

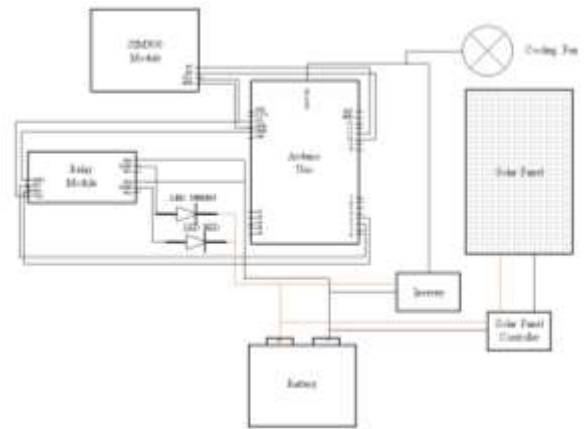


Figure 6.2. LED Indicator Schematic Diagram

TECHNICALITY OF THE PROJECT

The prototype utilizes a float sensor to detect rising flood levels and trigger alerts. When floodwater reaches a sensor, the SIM900A module automatically sends an SMS notification to residents, informing them that the bridge is not passable. An SMS alert is sent once a sensor is triggered, and the LED indicator signage updates its status. The green light remains on by default, indicating that the bridge is passable. However, when a message is received, the signage switches to a red light, indicating that the bridge is not passable for all vehicles. The traffic light system runs with a set of 90-second intervals. One direction is given a green light for 90 seconds, while the opposite side waits with a red light. After that, the lights switch, giving the other side a turn to pass. In the event of flooding, the traffic light is automatically disabled, preventing vehicles from passing on either side to ensure public safety.

The Security of the Project

The prototype is designed with restricted access to ensure its security and proper functionality. Only authorized personnel

are permitted to access, operate, or modify the system. Unauthorized handling or tampering with the prototype is strictly prohibited to prevent system malfunctions or security breaches.

Trigger Voltage: Low-level or High-level (depends on module)
Interface: IN1, IN2 (control pins)

HARDWARE SPECIFICATIONS

Table 5. Hardware Specifications

Hardware	Specification
Float Sensor	Operating Voltage: 3V Contact Type: Normally Open (NO) or Normally Closed (NC) Material: Plastic or Stainless Steel Switching Capacity: 10W - 50W Operating Temperature: -10°C to 80°C Mounting Type: Vertical or Horizontal Waterproof: Yes
Arduino Uno Microcontroller	Microcontroller: ATmega328P Operating Voltage: 5V Input Voltage (recommended): 7-12V Digital I/O Pins: 14 (6 PWM) Analog Input Pins: 6 Flash Memory: 32 KB SRAM: 2 KB Clock Speed: 16 MHz Communication: UART, I2C, SPI USB Port: USB-B (for programming & power)
Power Supply (Solar Panel)	Power Output: 50W Voltage Output: 12V (with regulator for 5V output) Material: Polycrystalline or Monocrystalline Silicon
SIM900 GSM Module	Operating Voltage: 3V Frequency Bands: 850/900/1800/1900 MHz (Quad-band) Communication: UART (Serial) Power Consumption: Up to 2A (during transmission) SMS & Call Support GPRS Data Support External Antenna Required
LEDs	Operating Voltage: 12V - 24V (varies by model) Power Consumption: ~5W - 15W per light LED Colors: Red, and Green
5V 2 Channel Relay Module	Operating Voltage: 5V DC Relay Channels: 2 Max Switching Voltage: 250V AC / 30V DC Max Switching Current: 10A

STRUCTURE OF THE PROJECT

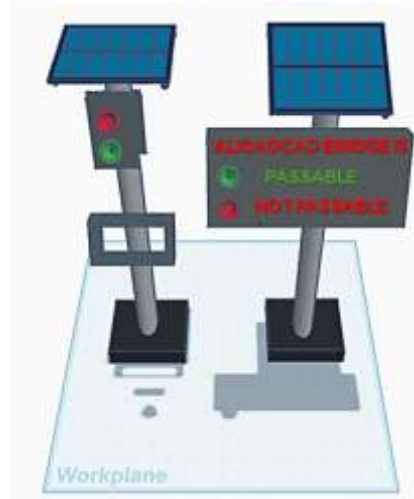


Figure 7. Structure of the Project

III. RESULTS AND DISCUSSION

PROJECT EVALUATION

The researchers evaluated the prototype and its function to ensure it is working appropriately. The researchers also identified the problems and objectives of the study.

PRE-SURVEY QUESTIONNAIRE RESULT

Mean Distribution of Pre-Survey Questionnaire Result

Table 6. Mean Distribution of Pre-Survey Questionnaire Result

Statement	Weighted Descriptive Mean	Equivalence
1. The actual flood monitoring at Alicaocao Bridge is inefficient.	3	Agree
2. The actual flood monitoring often causes delays in informing the residents about safe crossing conditions.	3	Agree
3. Relying on the current flood monitoring is inefficient for commuters.	3.09	Agree
4. Real-Time update during rainy seasons at Alicaocao Bridge is needed.	3.38	Agree
5. There is no traffic monitoring system at Alicaocao Bridge.	3	Agree
6. Accurate warnings and organized traffic management system to improve	3.5	Agree

safety at Alicaocao Bridge is needed.		
7. Having inaccurate information at Alicaocao Bridge causes residents and commuters' confusion.	3.59	Agree
8. Accurate warnings would help raise awareness of flood risks for everyone.	3.69	Agree
9. Inappropriate flood monitoring affect commuters' safety.	3.69	Agree
10. An Intelligent Early Flood Alert System at Alicaocao Bridge is essential for enhancing safety and preparedness in the community	3.69	Agree
Average Weighted Mean	3.36	Strongly Agree

Table 6 shows the mean distribution of the pre-survey questionnaire results. As shown in Table 6, the item with the highest mean of 3.69 belongs to the item. "Accurate warnings would help raise awareness of flood risks for everyone.", "Inappropriate flood monitoring affects commuters' safety.", "Inappropriate flood monitoring affects commuters' safety.", and "An Intelligent Early Flood Alert System at Alicaocao Bridge is essential for enhancing safety and preparedness in the community." Followed by the item "Having inaccurate information at Alicaocao Bridge causes residents and commuters' confusion." with a mean of 3.59, "Accurate warnings and organized traffic management system to improve safety at Alicaocao Bridge is needed." with a mean of 3.5, followed by the item "Real-Time update during rainy seasons at Alicaocao Bridge is needed.", with the mean of 3.38, "Relying on the current flood monitoring is inefficient for commuters." With a mean of 3.09, and the last item "The actual flood monitoring at Alicaocao Bridge is inefficient.", "The actual flood monitoring often causes delays in informing the residents about safe crossing conditions.", "There is no traffic monitoring system at Alicaocao Bridge." with a mean of 3. This signifies that the system has an average weighted mean of 3.36 with a verbal interpretation of "Strongly Agree." This is supported by Zhang et al. (2021), who highlighted the importance of real-time flood early warning systems in minimizing risks and enhancing community preparedness. Their research indicates that when integrated with communication systems, intelligent flood monitoring technologies significantly reduce response times and improve public safety during flood events.

Post-Survey Questionnaire Result

Mean Distribution of the Design in Terms of Functional Suitability

Table 7.1 Mean Distribution of the Design in Terms of Functional Suitability

Statement	Weighted Mean	Descriptive Equivalence
1. The prototype correctly detects and	3.69	Agree

identifies flood impassable water level based on sensor readings.		
2. The LED signage accurately displays the bridge's passability status.	3.73	Agree
3. The prototype successfully sends SMS alerts when impassable water level is reached.	3.76	Agree
4. The traffic light system properly signals passable and non-passable conditions.	3.78	Agree
5. The prototype functions as intended without frequent malfunctions.	3.76	Agree
Average Weighted Mean	3.74	Strongly Agree

Table 7.1 shows the mean distribution of the design in terms of functional suitability. As shown in Table 7, the item with the highest mean of 3.78 belongs to the item "The prototype correctly detects and identifies impassable flood water level based on sensor readings." . Followed by the items "The prototype successfully sends SMS alerts when an impassable water level is reached" and "The prototype functions as intended without frequent malfunctions," with a mean of 3.76, and "The LED signage accurately displays the bridge's passability status," with a mean of 3.73. And the last item, "The prototype correctly detects and identifies flood impassable water level based on sensor readings," with a mean of 3.69. This signifies that the system has an average weighted mean of 3.74, with a verbal interpretation of "Strongly Agree." In correlation to the study of **Hassan and Al-Azzawi (2021)**, which emphasized the importance of integrating real-time sensor systems with alert mechanisms for early warning applications, improving public safety and disaster response through timely information dissemination.

Mean Distribution of the Design in Terms of Performance Efficiency

Table 7.2 Mean Distribution of the Design in Terms of Performance Efficiency

Statement	Weighted Mean	Descriptive Equivalence
1. The flood level detection process operates without noticeable delays.	3.73	Agree
2. The SMS alert system delivers messages promptly after detecting flood risks.	3.61	Agree
3. The LED signage updates its display immediately when the water level changes.	3.54	Agree
4. The traffic light system responds immediately to bridge passability status changes.	3.5	Agree

5. The system operates efficiently without excessive power consumption.	3.64	Agree
Average Weighted Mean	3.6	Strongly Agree

Table 7.2 shows the mean distribution of the design in terms of performance efficiency. As shown in Table 7.2, the item with the highest mean of 3.73 belongs to the item “The flood level detection process operates without noticeable delays,” followed by the items “The system operates efficiently without excessive power consumption,” with a mean of 3.64; “The SMS alert system delivers messages promptly after detecting flood risks,” with a mean of 3.61; “The LED signage updates its display immediately when the water level changes,” with a mean of 3.54; and the last item, “The traffic light system responds immediately to bridge passability status changes,” with a mean of 3.5. This signifies that the system has an average weighted mean of 3.6, with a verbal interpretation of “Strongly Agree.” Raza et al. (2021) emphasized that real-time flood detection systems integrated with automated alert mechanisms significantly enhance community preparedness and infrastructure responsiveness in disaster-prone areas.

MEAN DISTRIBUTION OF THE DESIGN IN TERMS OF COMPATIBILITY

TABLE 7.3 MEAN DISTRIBUTION OF THE DESIGN IN TERMS OF COMPATIBILITY

Statement	Weighted Mean	Descriptive Equivalence
1. The prototype integrates well with different mobile networks for SMS notifications.	3.69	Agree
2. The hardware components (Arduino, SIM900, sensors) work together seamlessly.	3.66	Agree
3. The prototype can be powered using various sources, including solar panels and batteries.	3.71	Agree
4. The prototype is adaptable for use in different bridge or flood-prone locations.	3.64	Agree
5. The SMS alerts are compatible with different mobile phone brands and carriers	3.66	Agree
Average Weighted Mean	3.67	Strongly Agree

Table 7.3 shows the mean distribution of the design in terms of compatibility. As shown in Table 7.3, the item with the highest mean of 3.71 belongs to the item “The prototype can be powered using various sources, including solar panels and batteries.” Followed by the item “The prototype integrates well

with different mobile networks for SMS notifications,” with a mean of 3.69, “The hardware components (Arduino, SIM900, sensors) work together seamlessly. “The SMS alerts are compatible with different mobile phone brands and carriers,” with a mean of 3.66, and the last one, “The prototype is adaptable for use in different bridge or flood-prone locations,” with a mean of 3.64. Habib et al. (2021) emphasized that the successful integration of IoT-based flood monitoring systems depends heavily on the system’s ability to function in variable conditions and communicate through widely accessible platforms such as SMS.

Mean Distribution of the Design in Terms of Interaction Capability

Table 7.4 Mean Distribution of the Design in Terms of Interaction Capability

Statement	Weighted Mean	Descriptive Equivalence
1. The LED signage is clear and easy to understand for pedestrians and drivers.	3.73	Agree
2. The SMS notifications provide real time data and information.	3.64	Agree
3. The system provides visual and text-based warnings for better accessibility.	3.57	Agree
4. The prototype indicators, such as lights, are effective in alerting the public.	3.59	Agree
5. The prototype allows for easy troubleshooting and interaction when needed.	3.49	Agree
Average Weighted Mean	3.59	Strongly Agree

Table 7.4 shows the mean distribution of the design in terms of interaction capability. As shown in Table 7.3, the item with the highest mean of 3.73 belongs to the item “The LED signage is clear and easy to understand for pedestrians and drivers.” Followed by the item “The SMS notifications provide real-time data and information” with a mean of 3.64, “The prototype indicators, such as lights, are effective in alerting the public” with a mean of 3.59, “The system provides visual and text-based warnings for better accessibility” with a mean of 3.57, and the last item, “The prototype allows for easy troubleshooting and interaction when needed,” with a mean of 3.49. This signifies that the system has an average weighted mean of 3.59 with a verbal interpretation of “Strongly Agree.” This assisted in the study of Raza et al. (2021), who emphasized that effective real-time visual and textual alerts play a critical role in enhancing user interaction, accessibility, and safety in smart public systems. Their study highlighted that integrating multi-modal feedback mechanisms, such as LED signage and SMS updates, significantly improves system responsiveness and user engagement.

Mean Distribution of the Design in Terms of Reliability
Table 7.5 Mean Distribution of the Design in Terms of Reliability

Statement	Weighted Mean	Descriptive Equivalence
1. The LED signage is clear and easy to understand for pedestrians and drivers.	4.54	Strongly Agree
2. The SMS notifications provide real time data and information.	3.64	Agree
3. The system provides visual and text-based warnings for better accessibility.	3.54	Agree
4. The prototype indicators, such as lights, are effective in alerting the public.	3.57	Agree
5. The prototype allows for easy troubleshooting and interaction when needed.	3.61	Agree
Average Weighted Mean	3.78	Strongly Agree

Table 7.5 shows the mean distribution of the design in terms of interaction reliability. As shown in Table 7.5, the item with the highest mean of 4.54 belongs to the item “The LED signage is clear and easy to understand for pedestrians and drivers.” Followed by the item “The SMS notifications provide real-time data and information” with a mean of 3.64, “The prototype allows for easy troubleshooting and interaction when needed” with a mean of 3.61, “The prototype indicators, such as lights, are effective in alerting the public” with a mean of 3.57, and the last item, “The system provides visual and text-based warnings for better accessibility,” with a mean of 3.54. This signifies that the system has an average weighted mean of 3.78 with a verbal interpretation of “Strongly Agree.” This assisted in the study of Nguyen and Le (2021), which emphasized that real-time communication technologies and multimodal warning systems improve user responsiveness and engagement, particularly in urban smart systems.

Mean Distribution of the Design in Terms of Security
Table 7.6 Mean Distribution of the Design in Terms of Security

Statement	Weighted Mean	Descriptive Equivalence
1. The prototype prevents unauthorized access or tampering with its components using security lock.	3.61	Agree
2. The prototype considers environmental factors like weather and water exposure that may compromise hardware security.	3.61	Agree

3. The hardware setup is secured against potential vandalism or damage.	3.69	Agree
4. The prototype ensures that false or misleading information is not displayed.	3.69	Agree
5. The flood monitoring data is protected from unauthorized modifications.	3.54	Agree
Average Weighted Mean	3.62	Strongly Agree

Table 7.6 shows the mean distribution of the design in terms of security. As shown in Table 7.5, the item with the highest mean of 3.69 belongs to the item “The hardware setup is secured against potential vandalism or damage.” “The prototype ensures that false or misleading information is not displayed,” followed by the item “The prototype prevents unauthorized access or tampering with its components using a security lock,” “The prototype considers environmental factors like weather and water exposure that may compromise hardware security,” with a mean of 3.61, and the last item, “The flood monitoring data is protected from unauthorized modifications,” with a mean of 3.62. This signifies that the system has an average weighted mean of 3.62 with a verbal interpretation of “Strongly Agree.” This assisted in the study of Kim and Lee (2021), which emphasized that secure hardware design and data integrity are fundamental in developing resilient monitoring systems in vulnerable environments, particularly in disaster-prone areas.

Mean Distribution of the Design in Terms of Maintainability

Table 7.7 Mean Distribution of the Design in Terms of Maintainability

Statement	Weighted Mean	Descriptive Equivalence
1. The prototype allows easy replacement of faulty components when needed.	3.5	Agree
2. The wiring and connections are accessible for repairs and upgrades.	3.47	Agree
3. The system design enables quick troubleshooting and diagnostics.	3.5	Agree
4. The code can be updated without major reinstallation.	3.42	Agree
5. The sensors and display units are easy to clean and maintain.	3.4	Agree
Average Weighted Mean	3.58	Strongly Agree

Table 7.7 shows the mean distribution of the design in terms of maintainability. As shown in Table 7.7, the item with the highest mean of 3.5 belongs to the item “The prototype allows easy replacement of faulty components when needed.” “The

system design enables quick troubleshooting and diagnostics,” followed by the item “The wiring and connections are accessible for repairs and upgrades” with a mean of 3.47, “The code can be updated without major reinstallation” with a mean of 3.42, and the last item, “The sensors and display units are easy to clean and maintain” with a mean of 3.4. This signifies that the system has an average weighted mean of 3.58, with a verbal interpretation of “Strongly Agree.” This assisted in the study of Alshammari and Mahfouz (2022), which emphasizes that the maintainability and modularity of embedded systems significantly enhance system performance and reduce downtime in field operations.

Mean Distribution of the Design in Terms of Flexibility

Table 7.8 Mean Distribution of the Design in Terms of Flexibility

Statement	Weighted Mean	Descriptive Equivalence
1. Authorized person can add or remove contact numbers from the registered list as needed.	3.59	Agree
2. The system can integrate new sensor technologies if needed.	3.61	Agree
3. The system can be modified to accommodate future improvements.	3.61	Agree
Average Weighted Mean	3.6	Strongly Agree

Table 7.8 shows the mean distribution of the design in terms of flexibility. As shown in Table 7.7, the item with the highest mean of 3.61 belongs to the item “The system can integrate new sensor technologies if needed.” “The system can be modified to accommodate future improvements.” Followed by the item “Authorized person can add or remove contact numbers from the registered list as needed” with a mean of 3.59. This signifies that the system has an average weighted mean of 3.6 with a verbal interpretation of “Strongly Agree.” This assisted in the study of Khan (2021), which emphasized that adaptive systems with modular designs are better positioned to incorporate emerging technologies and user-driven updates, thereby enhancing long-term usability and relevance.

Summary of Project Evaluation

The Intelligent Early Flood Alert System for enhanced Flood Prediction in Alicaocao Bridge, Cauayan City, Isabela, is a prototype composed of and utilizing various input and output electronic materials. Each component has its functions and program codes connected to control the prototype. It uses a microcontroller as a processing unit to control and process data. The survey was conducted on the Barangay officials of the following Barangays: Barangay Turayong, Alicaocao, Carabatan Chica, Carabatan Grande, and Carabatan Punta, and representatives from the Cauayan City Disaster Risk Reduction Management Office (CCDRMO) as the respondents. Each

respondent answered the question that helped the researchers further understand the dilemmas in flood issues in Alicaocao Bridge, Cauayan City, Isabela; the observation and involvement of the Barangay officials and CCDRRMO officials in monitoring the bridge; and how to encourage them to adapt to new technology. The researchers asked both Barangay and CCDRRMO officials if they wanted to implement the prototype to help with flood monitoring on the said bridge to improve monitoring and disseminate information to residents. The respondents strongly agreed with implementing the Intelligent Early Flood Alert System in Alicaocao Bridge. This prototype helps the residents to be updated in real-time about bridge status and helps Barangay Officials and CCDRRMO Officials access information more conveniently. After presenting the design and functions, a post-survey questionnaire was conducted to determine the prototype's usability, efficiency, reliability, and affordability.

Summary of Post-Survey Questionnaire Result

Table 8. Summary of Post-Survey Questionnaire Result

Evaluation Criteria	Weighted Mean	Descriptive Equivalence
Functional Suitability	3.74	Agree
Performance Efficiency	3.6	Agree
Compatibility	3.67	Agree
Interaction Capability	3.59	Agree
Reliability	3.78	Agree
Security	3.62	Agree
Maintainability	3.58	Agree
Flexibility	3.6	Agree
Grand Mean	3.64	Agree

Table 8 summarizes the mean distribution of the four aspects of the design. It can be interpreted from the grand mean of 3.64 that the respondents “Agree” to the Usability, Efficiency, Reliability, and Affordability of the Intelligent Early Flood Alert System for Enhanced Flood Prediction in Alicaocao Bridge, Cauayan City, Isabela. Almarashdeh (2021) highlights that ensuring software quality through continuous evaluation of characteristics such as functionality, maintainability, and security significantly contributes to overall system success and user satisfaction.

IV. CONCLUSION AND RECOMMENDATIONS

Based on the summary of findings, the study concludes that the primary challenge in manual bridge monitoring is the lack of real-time information, which limits timely decision-making and may compromise safety and efficiency. In response to this issue, the developed prototype demonstrates strong potential as a practical solution. It incorporates key features such as real-time updates on bridge status, a one-way traffic light system to regulate the flow of vehicles, and LED monitoring signage strategically placed in Villa Luna to ensure accessibility for residents without mobile devices. These features collectively address the identified gaps in the current monitoring system and highlight the prototype's capability to improve traffic

management and information dissemination within the community in a cost-effective manner.

In light of these findings, it is recommended that future designers and researchers further enhance the prototype to increase its functionality and reliability. Improvements may include integrating a siren for emergency alerts, incorporating sensors to accurately detect water levels, and conducting long-term testing to ensure the system's accuracy and durability over time. Additionally, modifications such as adjusting the height of the metal pipe may be considered to optimize performance under varying environmental conditions. These enhancements can further strengthen the effectiveness of the system and support its potential for wider application.

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