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Research Article

IoT (Internet of Things) Based Clog Detection System

Vanessa A. Estrera[1] | Fe B. Yara[2]

[1-2*] University of Mindanao, Professional Schools, Davao City, Philippines
*[1]vanestrera@gmail.com
[2]fe_yara@umindanao.edu.ph

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A B S T R A C T

Clogs had posed significant challenges, resulting in flooding of culverts with wastewater. Presently, market solutions for detecting clogs are either scarce or expensive, making them inaccessible to many. In response to this, the researcher had conducted a study to develop an alternative, more affordable device. The study proposes a clog detection system to monitor clogs through an increase in water level. The system runs in a reactive architecture with an ultrasonic sensor as the main data entry point that measures the water level from the drainage. IoT is utilized for real-time clog detection, using the following major components: Ultrasonic sensor, ESP32 microcontroller, GSM module and cloud for web server. Additional features are the map, graph, timestamp, and risk level category. The study implements a threshold to minimize false alarms caused by a sudden increase in water level, and a 5-meter base value. The risk level categories are no clog at 4 meters up, slightly clogged at 3.5-3.99 meters, moderately clogged at 3-3.49 meters, and highly clogged at 2.5-2.99 meters and above. Furthermore, the sensor cannot detect objects underwater and cannot predict the occurrence of a clog. The IoT-based clog detection serves as an early warning tool for potential flooding due to clogs, enabling prompt action to mitigate risks.

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

INTRODUCTION

1.1 Project Context

To keep the city clean, it's essential to monitor the sewage system. When monitoring is inconsistent, drains can become clogged. These blockages are a leading cause of sewer flooding and pollution. [1] Monitoring and maintaining drainage systems is vital for environmental and public safety, especially in large, densely populated cities. Regular checks are necessary to ensure the drainage system works properly and keeps the city tidy.[2] The Internet of Things (IoT) and Data Science offer tremendous potential for gathering and analyzing data on environmental and physical factors, along with their impacts.[3] With this, the study aims at creating a low cost but reliable system to use for detecting clogs without the need for manual checking and inspection at every drainage.

Leveraging IOT and networked devices to provide data through ultrasonic sensors, data analysis presented in graphs and real-time monitoring on the drainage. Researchers that utilized IOT has proved the possibility and great potential of using devices to improve remote monitoring over drainages. For instance, the development of IOT Based Sewer Clogging Prediction System for Smart City has utilized wireless sensors and integrated Geographic Information System to easily manage and visualize data. [4] Additionally, Anti-clogging Sewerage System Using IOT conducted similarly where they also use mostly same devices to detect clogs effectively. [5]

This study is conducted because of the experienced problem of clogging most especially during a rainfall where chances of flooding are high in the city. The overflows are evident in the center of the cities affecting business establishments and various infrastructures. In further research conducted, the City of Panabo also falls under a Type IV climate which means there is a distributed rainfall throughout the year. Furthermore, Panabo City is a typhoon-free city but still experiences flooding due to clogged drainage canals, which leads to water buildup and flooding. The figure below shows the average monthly rainfall in Panabo City.[6]

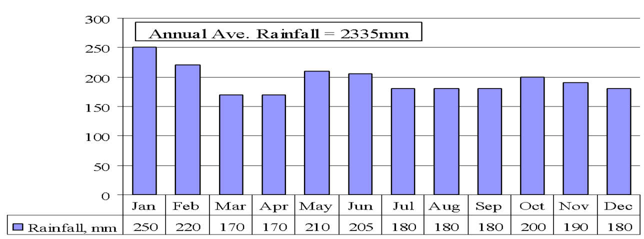


Figure 1. Mean Monthly Rainfall in Panabo City

Figure 1 illustrates the findings from a study conducted by the City of Panabo. It highlights how clogs form and the patterns that may contribute to the buildup. This research underscores the significant impact of water on the overall study. This inspired the creation of a solution for clogged

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

drainages, which is to be of help effectively and efficiently, minimizing health-related issues, damage to property, and the use of technological advancements for risk mitigation.

1.2 Purpose and Description

The study's primary purpose is to provide a solution to clogged drainages using IoT devices. This study aims to address problems in Sustainable Cities and Communities, making human settlements safe, resilient, and sustainable. The IoT (Internet of Things) Based Clog Detection System helps local government units (LGUs) by pinpointing the exact locations of clogged drainages, providing real-time clogged monitoring through water level increase. This makes it much easier for them to organize cleanup drives and remove obstructions, ensuring smooth water flow. With this system, there's no need to spend long hours physically checking each drainage for clogs, saving valuable time and effort.

The system will have one user account which will be utilized by the administrator who is assigned by the head of office. The administrator can navigate through the systems web, use features such as adding or relocating sensors, generating reports and graphs of actual and historical events of data. The system serves as an early warning device for residents, the information of water level measurement and category is sent through an SMS.

The Urban areas often get clogged due to accumulated wastewater leading to events such as a rapid increase of water in the drainage. Furthermore, this issue intensifies during heavy rainfall, with intensities ranging from 5 mm/hr to 90 mm/hr and durations from 7.5 minutes to 180 minutes. The climate, dominated by the Intertropical Convergence Zone, increases the likelihood of drainage overflow during these periods.[7]

1.3 Objectives

1.3.1 General Objective

This project aims to develop an IoT (Internet of Things) based early warning device to detect clogs in drainages through water movements.

1.2.2 Specific Objective

Specifically, the study aims to:
1.2.2.1 Integrate IoT (Internet of Things) for real-time clog detection.
1.2.2.2 To use Ultrasonic Sensor as a device that will measure the water level from the drainage.
1.2.2.3 To provide SMS notifications using the GSM Module for information dissemination.
1.2.2.4 To provide a server that presents real-time water movement.
1.2.2.5 To provide clog details regarding location, timestamp and risk level category.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

METHODS

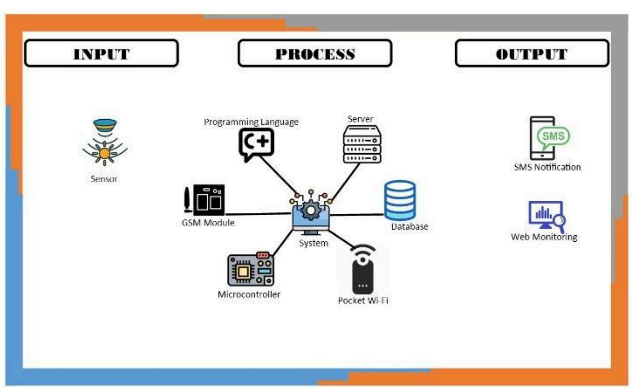
This chapter outlines the steps involved in creating the system. It details the requirements needed for the system to complete development and functionality. The chapter also explains the hardware and software devices used for users easy understanding. Additionally, it provides clear procedures and explanations on how to control and manage the system entirely. The Agile method is used to develop the system.

Figure 2. Agile Model Diagram

This figure illustrates the phases of the Agile Model in software development. To be able to realize the system, the phases were followed and carefully applied.

TECHNICAL BACKGROUND

Developing an IoT (Internet of Things) application for clog detection offers a modern approach to immediate information dissemination and alerts. Implementing such clog detection and warning systems can greatly assist in managing water overflow, ensuring timely drainage maintenance, preventing clog build-up and flooding, and, most importantly, saving lives. This section outlines the requirements identified by the researcher for the project's development. It also discusses the software tools used, the process flow, and the system infrastructure.



[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

Figure 3. Conceptual Framework

The IoT (Internet of Things) Based Clog Detection System is designed to provide an early warning system for detecting clogs during rapid increases in water levels within drainage systems. The primary function of this system is to detect and locate clogs using an ultrasonic sensor that monitors water level movements. The data collected by the sensor is recorded and transmitted to a microcontroller, which is programmed to continuously read and process this information for ongoing water and clog monitoring. The recorded data is stored in a PhpMyAdmin database for thorough analysis. Additionally, the system employs web-based monitoring to classify the degree of water measurement, which serves as an indicator of potential clogs. This processed data becomes now a useful information and is then disseminated to mobile devices, ensuring that users receive timely alerts, especially during rapid water level increase. By implementing this system, it can significantly improve the management of drainage systems, prevent clog build-up and flooding, and ultimately protect lives and property.

Input

Ultrasonic sensors work by sending out high-frequency sound waves. These sound waves travel through the air until they hit an object and bounce back to the sensor. The sensor then measures the distance of water and forwards received data to the microcontroller to process. The water is measured in meters.

Process

This section provides the necessary tools used to process the system. For system development C+ Programming language is the developer's preference. For the database implementation such as but not limited to retrieval and storing of data, PhpMyAdmin is utilized. For the Microcontroller and GSM Module in simple terms, the microcontroller acts as the decision-maker, processing sensor data and determining when to send alerts. The GSM module then takes care of sending these alerts to your mobile phone, keeping you informed about any issues in the drainage system. The pocket Wi-Fi will serve as a tool to stay connected to the internet and transmission of data to cloud for graphical representation and interpretation. The pocket Wi-Fi will enable continuous internet connectivity and facilitate data transmission to the cloud for graphical representation and interpretation.

Output

In the systems output section, SMS is used for information dissemination, while web monitoring will provide real-time updates on water levels and clog details.

3.2 System Requirements

The researcher describes and identifies the system requirements for IOT (Internet of Things) Based Clog Detection System. This part describes the application's various software and hardware

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

requirements to function correctly. Indeed, compatibility is considered for the functionality of the system. It serves as a manual to understand the behavior of the devices and their entire description.

1. Functionality:

The following are functional requirements of the system:

a) Verification that the sensor can accurately measure and record water levels.
b) Distance difference between actual (using measuring tape) and sensor.
c) Ensuring that the sensor and microcontroller are integrated correctly and function as intended.
d) This shall be achieved through sensor actual reading and web platform display.
e) Confirm that the sensor and cloud database specified requirements for accuracy and precision in water level detection are met.
f) This shall be achieved through data reading consistency for several times of deployment.

2. Energy Efficiency:

a) Check if the devices operate efficiently in terms of power consumption.
b) This is achieved by testing the battery and solar panel to assess the sustainability of the battery and utilize the solar panel for long-term operation.
c) Assess the suitability of the chosen power source and its longevity for prolonged use.
d) This is achieved through long-term deployment.

3. Documentation:

The documentation is achieved through evaluation of completeness and clarity of documents provided for cloud database, including proper assembly of devices, careful instructions, user manuals and technical specifications.

Table 1. List of systems attributes

User Class and Characteristics	The software is designed for detecting clogs that cause possible drainage overflows. The system has only one user account which is the administrator.
Network Connectivity Independent	IOT Based Clog Detection System is not dependent on network connection. It is a stand-alone application that can be utilized without any communication on a network.
Clog Detection through water level.	IOT Based Clog Detection System has a feature that detects clog through analyzing water data movement in using ultrasonic sensors.
Operating Environment	Desktop Platform Core i3 processor Windows OS 4GB RAM 500 GB HDD

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

Design and Implementation Constraints	It cannot detect objects underwater.
User Documentation	This presents the documentation of the system to fully maximize it and utilize it efficiently and effectively.
User's Manual	The user's manual is the ultimate guide on how to use the system. The step-by-step process in the manual will greatly help the user in terms of the basic and advanced utilization of the system.
External Interface Requirements	
Software Interface	Arduino IDE XAMPP PhpMyAdmin Full Stack Php
Hardware Interface	Arduino device GSM module interface Battery Sensors Solar Panel 12V Lead Acid Battery ESP 32 Microcontroller
Server Requirements	Desktop or Laptop Core i3 processor or higher At least 500 GB HDD At least 4GB RAM
Other Non-Functional Requirements	
Safety Requirements	A sturdy full concrete base is created so that all the devices can withstand a windy environment. The devices are enclosed in a case so that they are protected.
Security	The system is only accessible through its server. It mainly has only 1 user which is the admin. The admin has the full privilege and accessibility to all data and information in the system. For the security and confidentiality that the system may not cause chaos due to wrong information disseminated, the system uses encryption method before it can be accessed.

Table 2. Software Quality Attributes

Availability	The IOT (Internet of Things) Based Clog Detection System is not available online for everyone. It can only be accessed by the admin in charge. The residents may only receive notification but cannot interact with the system.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

Flexibility	The system can add sensors, provide/set location and name for a possible larger scope to cope. It is created in a way that can easily be modified, changed and improved for future researchers.
Usability	The IOT (Internet of Things) Based Clog Detection System is designed with high usability for users. The interface structure provides an approach that can easily be utilized and understood.
Reliability	The system had undergone several tests such as but not limited to volume testing – targeting acceptance of large data sets and feature testing – targeting execution of each function at least once to ensure that the output meets its standard and produce accurate results.

3.3 System Design

The user interface comprises of two modules. The location module and the sensor module. The location module is composed of 'index page', 'create page' and 'edit page'. The index page serves as the main page for the system where all activities are presented. The creation page is for the purpose of creating or setting up another location and information of the Barangay personnel to be texted whenever the system is to send a message. The edit page is where the user can edit information which is limited only to changing the information of the residents and contact number. The sensor module is composed of 'index page', create page' and 'edit pages where all are connected to the sensor module. This module focuses on creating entries for new sensors accompanied by location where the sensor is installed.

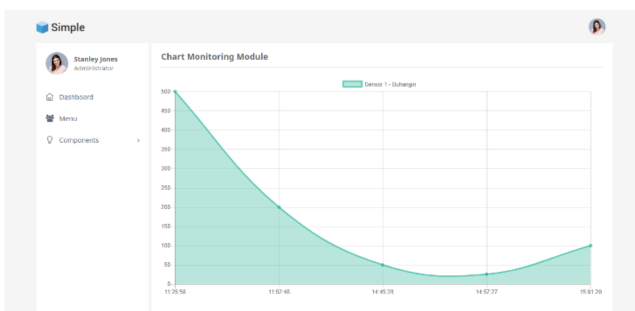


Figure 4. Chart

The IoT-Based Clog Detection System includes a chart monitoring feature that displays real-time water activity recorded by the sensors. This initial design of the system allows users to view dynamic charts that illustrate water levels and flow rates. Additionally, users can select specific dates to display historical data on the charts, providing a comprehensive view of water activity over time. The figures also reflect detailed information about water levels, ensuring users have a clear and accurate understanding of the system's performance.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

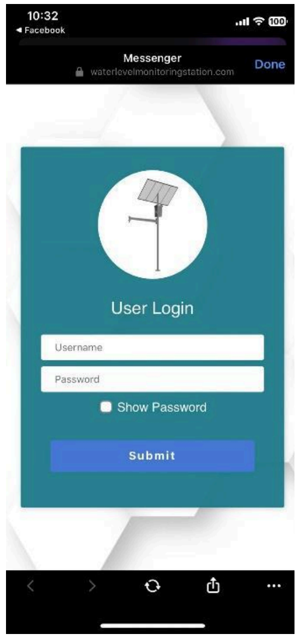


Figure 5. System portal

The figure illustrates the portal or entry point, where users and administrators must enter the username and password provided by the developer to gain secure access to the system. Once logged in, they can utilize the full range of features and functionalities included in the system. The system does not have a mobile app but it can be viewed through mobile. An integral component of the IoT system is the development of its web interface, where user interactions take place. The system is designed to be viewed through mobile but can only be fully accessible through the web. The design is also made web-responsive, ensuring seamless access across various devices.

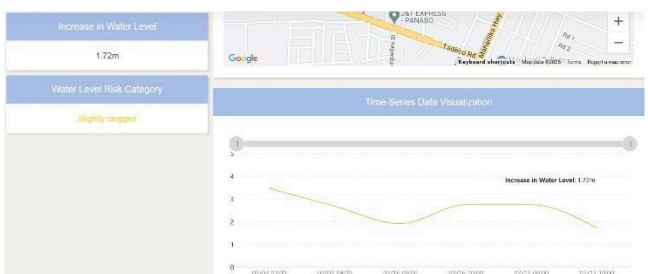


Figure 6. DClog Web-Based View

This figure shows the web server of the IoT-Based Clog Monitoring System, providing a comprehensive view of the system. It displays real-time water movement, represented through dynamic charts. The water level activity is depicted with corresponding timestamps, reflecting actual data alongside a description of the water level's risk category. This feature enables quick

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

assessment of necessary actions for the affected area. Additionally, a map is integrated to visually identify the clog-affected locations by tagging sensors deployed in the field.

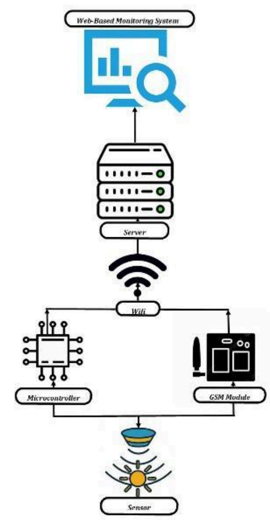


Figure 7. Block Diagram

Figure 7 shows the visual presentation of how devices are utilized and how the object relates to each other. This figure will help us to understand the overall flow of the system and how it works towards achieving an IoT-based clog detection system.

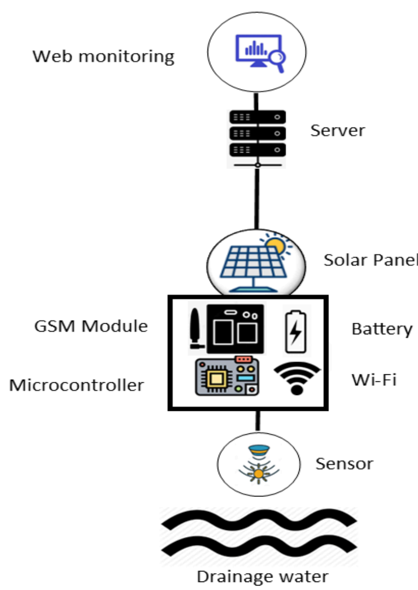


Figure 8. Sample Set-Up Diagram

The IOT (Internet of Things) Based Clog Detection System has one water level sensor which objective is to determine clogs using movement in water levels. The measurement gathered is forwarded to the following devices: the microcontroller processes the information received

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

through the sensor. The GSM module transmits the data processed to Wi-Fi. The Wi-Fi will send the data to the server for analysis on the category of water level and risk assessment. The battery will support the devices inside the enclosure in functioning and having power. The solar panel is installed to ensure uninterrupted water monitoring for the continuous life of devices. The server presents timely monitoring of water level, the location and its risk level. The server also provides means through SMS notification for information dissemination.

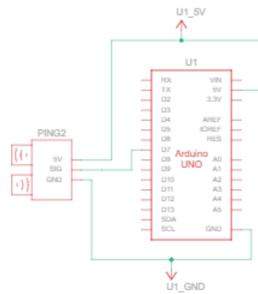


Figure 9. Schematic Diagram

Figure 9 illustrates the system's schematic diagram, showing the utilization of various devices. Clog detection is triggered when the sensor data reaches a threshold, reducing false alarms caused by sudden water level increases. The clogging categories are defined as follows: no clog at 4 meters and above, slightly clogged at 3.5-3.99 meters, moderately clogged at 3-3.49 meters and highly clogged at 2.5-2.99 meters. Both the ultrasonic sensor and the GSM module are powered by the 5V pin on the ESP32, like plugging them into a small power outlet on the microcontroller.

For Trigger and Echo Pins:

Trig Pin: The pin is connected to GPIO 5 on the ESP32, this pin tells the ultrasonic sensor to send out a sound wave.

Echo Pin: The pin is connected to GPIO 18 on the ESP32, this pin listens to the sound wave to bounce back, helping the ESP32 measure distance.

For GSM Communication

TX Pin: Sends data from the GSM module to the ESP32 (connected to GPIO 16).

RX Pin: Receives data from ESP32 (connected to GPIO 17).

This setup allows the ESP32 to measure distances with the ultrasonic sensor and send the data via the GSM module, like sending a text message with the measurements.

3.4 System Development

This section presents the tools used in the development of the study. In the development phase of the system, the researcher gathered information and data from skilled and knowledgeable individuals as well as those who have experienced the tackled issue. The information collected leads to the formulation of how the system was developed. The researcher conducted further research by himself to fully understand how software and hardware is used. The extent where the software and hardware requirements are implemented for effective use. During the development period, the researcher conducted tests to ensure the functionality of the system in its every vital

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

component. The recommendations and suggestions given by the city engineering office were considered to produce the best output that solves the problem of overflowing drainage effectively. In the succeeding weeks, tools to use were identified and consultation on documents created was prioritized. There were revisions encountered during consultations which also beneficial during the development. It took a month to finish the setup of hardware devices from planning, selecting and choosing down to enclosure for electronics safety. And another (6) months for software development.

Table 3. Real-time Clog Detection

Activity	Expected Outcome	Result
Measurement of water level at 4 meters and above.	Message: Increase in Water level 4 meters Risk level Category: No clogged	Passed
Measurement of water level at 3.5-3.99 meters	Message: Increase in Water level: 3.5 meters Risk level Category: Slightly clogged	Passed
Measurement of water level at 3-3.49 meters	Message: Increase in Water level: 3 meters Risk level Category: Moderately clogged	Passed
Measurement of water level at 2.5-2.99	Message: Increase in Water level: 2.5 meters Risk level Category: Highly clogged	Passed

The following were also steps that add to the development of the system:

3.4.1 Interview

For the realization of the system's reliability, flexibility and functionality the researcher conducted an appointment for interview in the City Engineering's Office to further gather data, blueprint and structure of the drainage, additional knowledge, clarifications and vital questions that will help to fully understand the problem which is critical for the system development.

3.4.2 Integration

The integration comes after systems development. It is where the system is deployed and integrated into the organization to further test its functionality and determine other important matters to consider. The system has undergone several tests to ensure its utmost efficiency. It is by going through integration that the developer was able to find out if it's properly working and if the features are present and effective.

3.4.3 Software Requirement Specification

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

This phase is where the researcher gathered significant information for system development. The researcher has made appointments with the city engineering department for all the information that is needed in the system and identifies the software that would be best to use.

3.4.4 Application Design and Software Design

The system design is highly considered. It was thoroughly analyzed, planned and assessed before actual coding begins. The application and software design were carried out after systems development revisions are done every day after reviewing design to see what would best fit.

3.4.5 Ultrasonic Sensors

The ultrasonic sensor device is used to read data of water level in the drainage through using sound waves to measure the distance. The waters movement is recorded and monitored that may potentially cause clog in the drainage system.

3.4.6 IoT (Internet of Things)

The IoT (Internet of Things) is used to connect all devices together for real-time monitoring of drainage's water level and detecting blockage through an increase in water level.

3.4.7 ESP 32 Microcontroller

The study uses microcontroller to process data from the sensor making sure activities function smoothly.

3.4.8 GSM Module Interface

The study uses GSM module to send immediate alert notifications, especially during emergency times of rapid increase in water level.

3.4.9 C++

The system is developed using C++ programming language to be able to create a monitoring interface in the server and write calculations for water status classification.

3.4.10 PhpMyAdmin

The PhpMyAdmin is used to be able to store and retrieve water level data, water level data category, sensor information and sensor location.

3.4.11 WampServer

The study utilizes WampServer for web development, providing an opportunity to test web applications locally without requiring an internet connection or a live web server. This approach is highly valued as it enables the researcher to test the system before it goes live, minimizing any risk of impacting the actual website.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

3.4.12 Solar Panel

The hardware devices consume energy with that, the solar panel helps support the devices through gathering energy from the sun converting it to electrical power supply to power-up the devices inside the case.

3.4.13 Connecting Wires

The wires are used to connect the devices in the study, enabling each device to perform its intended function.

3.4.14 12V Lead Acid Battery

The study uses 12V Lead Acid Battery is used to provide power to the devices. This choice is due to its popularity as a rechargeable battery that is compatible with solar panels, effectively storing energy generated by them. It serves as a reliable backup power source when solar panels are unable to produce electricity, particularly during nighttime or inclement weather.

3.4.15 Pocket (Wi-Fi)

The IoT Based Clog Monitoring System is using pocket Wi-Fi to be able to send the data gathered to the server and cloud. This way, real-time activity will be projected on the web and monitored.

3.4.16 Metal Stand

To ensure the deployed devices can endure strong winds in the field and remain out of reach of water, a metal stand is used to elevate the devices installed in the drainage, preventing them from being submerged.

3.4.17 Metal Frame for Electronic Enclosure

The metal frame is used to protect the electronic devices installed in the drainage from all outside factors that may destroy them.

3.4.18 Full Stack Php

To develop the system's web application, Full Stack PHP is utilized for both the front-end and back-end. This choice is favored because it excels in building dynamic websites and offers a vast array of framework libraries, making development more efficient.

3.5 System Testing

This section presents the testing conducted for the study to ensure all components are functional.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

Table 4. Component Testing

Sensor Testing	The researcher tested ultrasonic sensors to detect water level. The test run is excellent as it reads objects while connected to Arduino micro controller.
GSM Module Testing	The researcher tested the GSM module through checking first the COM port which it is connected to. After being established, a sim card is inserted into the GSM for alert notifications.
Arduino Microcontroller Testing	The researcher tested the Arduino Uno board through connecting it to the computer and configuring used ports.
Distance Testing	The researcher tested several distances for an accurate result of water level monitoring.
Scenario Simulation	The researcher conducted a simulation of the system where home testing was conducted through testing the distance from the window to the stairs.
SMS Notification Testing	The researcher conducted an SMS notification testing by sending a sample text to the number encoded in the program.
User Scenario Testing	The researcher conducted a series of tests to find out if the system and devices work properly and produce desired results. The system test proved that IOT Based Detection System works properly with detecting clogs having water level as basis.
E. Testing for the electronic housing of the controller using a weatherproof electronic box where devices and battery are enclosed.	
Waterproof Testing	To achieve waterproof testing, the housing was exposed to rainy conditions to ensure that no water could penetrate the devices, thereby protecting its internal components. By confirming its waterproof nature, we guarantee durability and reliability under rainy weather conditions.
Material Durability Testing	To achieve this test, the electronic housing material was exposed to environmental factors such as UV exposure, temperature fluctuations, and impact resistance. The materials were thoroughly tested during the deployment and testing period, where it was exposed to sunny and rainy days.
Internal Component Fitting	For internal component fitting, all parts are considered, like the controller, sensors, GSM module, and battery, it was tested to fit inside the electronic housing before securely attaching it one by one.
Mounting and Installation Test	For Mounting and Installation Testing, proper placement is considered through ensuring that the housing can be mounted on different surfaces without compromising its weatherproof seal. Even when installing the bolts for a more secure device position.
UV Resistance Test	For UV Resistance Test, the device was directly exposed to sunlight. The material was checked to see if there are signs of degradation or damage due to heat.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

Connectivity Test	For Connectivity Testing, the LTE module used must successfully establish and maintain a connection with the network. The signal strength and stability were also considered a factor for smooth data fetching. A speed test was conducted to check internet speed.
Data Transmission Test	In data transmission tests, the data being transmitted using Arduino console is observed to verify if the database reflects the same.
Security Testing	For security, data transmission is encrypted to keep it away from unauthorized access.
Error Handling Test	To test error handling, the devices are intentionally disconnected from the internet and then reconnected to verify if they will continuously send data to the server.
Performance and Throughput Test	To evaluate the performance of LTE-based connectivity, the speed and efficiency of data transfer are measured. A speed test is conducted at the station where the device is deployed.
Latency Test	The objective of the latency test is to measure data transfer latency, ensuring that data reaches the server promptly and is transmitted in a timely manner. To achieve this, the transfer times from the sensor to SMS, database, and web have been recorded.
Reliability Test	To test the system's reliability, it was operated continuously for an extended period, monitored for any signs of performance degradation.
Scalability Test	For the scalability test, an increased data load was applied to determine whether the system can handle a large volume of data without encountering significant issues.
Integration with Database	To verify the integration between the controller and the database server, ensuring that the data is accurately stored. A comparison of the data from the sensor and with the data stored in the database are made to confirm consistency.
Database Retrieval Test	For database retrieval test, its aim is to ensure the system can accurately retrieve water level data from the database for specified time intervals (daily, weekly, monthly, yearly, and custom ranges). For this, the consistency of data is compared from database and web visualization based on the time series.
Data Consistency Test	For data consistency tests, the database data and format are checked to ensure that the retrieved data matches what is stored. This process includes comparing data for any discrepancies or missing information.
Visualization Accuracy Test	For this test, a need for evaluation on the accuracy of data visualization is done by comparing it to the raw data. It is a way to confirm that the visual representation accurately reflects the water level values stored in the database. A comparison between database data and actual water level number sequence from database to web is conducted.
Time Series Report Generation Test	To test, the system generated a sample report for daily, weekly, monthly and yearly. It will also provide insights into water level trends over time.

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

Custom Range Test	To test, the system has been set to provide reports through selecting a specific date.
Graphical Representation Test	For graphical representation, a graph is provided to be able to project and visualize data allowing to convey data trends and patterns.
Responsive Design Test	For the responsive design test, the system was tested in a web and mobile view.
Cross-Browser Compatibility Test	The system is tested across various browsers to ensure optimal performance and compatibility.
Error Handling Validation	For error handling validation, the system will provide prompt/clear messages and guidance when a user inputs invalid date range and other issues.
Calibration Test	During a calibration test, the water level is measured both manually and using a water level sensor to compare the accuracy of the two methods. The test focuses on the distance between the water surface and the sensor. Initially, the water level is measured manually by recording the distance from the water surface to a fixed reference point. Then, the same distance is measured using the water level sensor. By comparing these measurements, the accuracy and reliability of the water level sensor can be evaluated. The goal is to determine how closely the sensor's readings match the manual measurements.
Accuracy Test	To be able to conduct accuracy test, the sensor was placed in a controlled condition with varying water levels. The goal is to record measurements at different levels and compare them to the expected values. Accuracy tests would go through each water level category if the data collected is accurate.
Precision Test	To be able to conduct precision tests the water level is measured multiple times under similar conditions, to prove that the measurement gathered by the device is consistent with the varying water levels.
LTE Connection Test	The device uses an LTE connection, and during testing, it recorded a bandwidth of 93 Mbps.
Metal Stand Testing	The IoT device is deployed in a selected area. During this testing phase, environmental factors such as strong winds were considered. Durability plays an important role, which is why the base of the device is made entirely of metal and concrete to ensure it does not easily fall off its base.
Manual measurement test on the drainage	The IOT device was installed in the selected drainage area, before collecting data through ultrasonic sensor, the height of the sensor from the base of the drainage were manually measured using a steel tape to check for discrepancies.
Ultrasonic mesurement test on the drainage	The IoT device is used to detect water levels. In this testing phase, the ultrasonic sensor is positioned to measure the water level in the drainage system. This phase involves the actual testing of the ultrasonic sensor's accuracy and functionality.
Enclosure devices test.	The IoT devices utilized are placed inside a metal closure for additional protection and attached firmly to the standee through tightening bolts. The

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

	devices were already tested before deploying them to the site and then tested again to gather actual water level data from the drainage.
SMS Alert Notification Test	The Drainage Clog System uses SMS notification to track clogs in the drainages. The picture depicts measurements sent by the GSM including the water level increase in the drainage and its corresponding risk level category.
Data Transmittion Test	The IoT devices utilize LTE to transmit data to the server. In the picture, you can see the URL that corresponds to the measured bandwidth. This URL provides a direct link to the data, showcasing the efficiency and reliability of the LTE connection in ensuring seamless data transmission.
Map Testing	A map was successfully integrated into the system to pin sensor's location to easily identify and response to clog situations experienced by a barangay.
Time Stamp Test	To be able to provide details of the clog, the timestamp is a vital factor in knowing the timeline of events and preventing overflowing to happen. To test, simulation was made through generating reports and matching it to the actual time the test was conducted.
Risk Level Category Test	A threshold is set to identify the degree of clog. The risk level test established the following categories: no clog at 4 meters and above, slightly clogged at 3.5-3.99 meters, moderately clogged at 3-3.49 meters and highly clogged at 2.5-2.99 meters. Each level was tested and successfully met the criteria set for each category.

RESULTS AND DISCUSSION

The IoT-Based Clog Detection System's web interface, supplemented by test results based on the provided datasets showcases its functionality in real-world scenarios and its mobile device interpretations. The system gathers water level data from sensors in the drainage and forwards this information to a database for storage and retrieval, before sending it to the server.

The system displays real-time water movement through dynamic charts, updated at adjustable time intervals. Significant increases in water levels due to continuous drainage blockage are represented as large movements in the chart. A base value of meters is implemented. The current water level data is deducted from the base value of 5 meters to get the increase in water level. The water levels are classified into four categories:
(1)no clog at 4 meters and above;
(2) slightly clogged at 3.5-3.99 meters;
(3) moderately clogged at 3-3.49 meters;
(4) and highly clogged at 2.5-2.99 meters.
When the water level exceeds the parameters for highly clogged category, the system issues a "critical" alert. To prevent false alarms caused by sudden but harmless changes in water level (e.g., a stone dropping into the drainage), a threshold mechanism has been implemented.

[1]Corresponding Author: Vanessa A. Estrera
*Corresponding Email: vanestrera@gmail.com

On mobile devices, the user can view these results in real time, including the water level's category and corresponding risk description. The map feature enables users to visually identify affected areas by marking sensor locations in the field, helping them assess the situation and decide on appropriate actions swiftly and efficiently. Furthermore, the alert message received through the dissemination of information will include the clog level and its corresponding category status, as follows: No clog, slightly clogged, moderately clogged and Highly clogged. This categorization ensures clear and concise communication of the drainage status.

The IOT (Internet of Things) Based Detection System is mainly expected to detect clogs through water levels. However, in the process as the development of the system progresses, the researcher found that to effectively analyze clog's location, multiple sensors should be used for a wider scope. During the installation and testing of devices, the ultrasonic sensor can measure water level but is limited to the capabilities of having just water level as basis for the clog detection. Because of this constraint, the researcher now considered objects as vital aspects in detecting clogs. Also, GSM module interface and Arduino Uno are the researcher's best choice because of its compatibility and much less expensive than other devices. The C++ Programming Language is also the language used to code the program because it is much easier to interact with the data in the long run. It is decided for easier utilization that the researcher shifted from PHP Laravel to C++ and Full Stack.

CONCLUSION AND RECOMMENDATIONS

In conclusion, The IoT-based Drainage Clog Monitoring System has shown great potential in managing drainage systems. By utilizing advanced technologies such as LTE for data transmission, ultrasonic sensors for water level detection, and robust hardware components, the system ensures real-time monitoring and swift action to prevent clogs and overflows. This study successfully developed and integrated an IoT-based early warning device to detect clogs in drainages via water movements. The system provided a web interface for real-time monitoring of water movements, clog details, timestamps, and risk level categories. Additionally, SMS notifications efficiently alerted people about the risk of overflowing drainages, enabling quick responses so that those responsible for drainage maintenance could clean them before overflows occurred. The work was made efficient, saving lives and property was made possible through the development of IoT Based Clog Monitoring System.

To make the system even better, it's recommended to use LTE for reliable and fast communication between the IoT devices and the server. This ensures real-time monitoring and a swift response to any issues. Lithium-ion batteries are a good choice because they have a high energy density and long lifespan, meaning the devices can run for longer without needing frequent maintenance. Using a modem with an open line that can work with any ISP will help maintain a consistent connection, no matter the signal strength in the area.

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

Adding more sensors in different locations will help cover a wider area and improve the system's ability to detect clogs in various spots. It's also important to securely install the devices in a cage to prevent theft and vandalism, ensuring the system stays intact and operational. Conducting thorough assessments of the deployment area to understand its risk level will help in placing the sensors and other hardware in the best spots for maximum efficiency.

Integrating cameras into the system for visual monitoring will provide real-time visual data, making it easier to assess and respond quickly to any issues. By following these recommendations, the IoT-based Drainage Clog Monitoring System can become more efficient, reliable, and secure, ultimately leading to better management of urban drainage systems and preventing clogs and overflows.

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[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com

[1]Corresponding Author: Vanessa A. Estrera
[*]Corresponding Email: vanestrera@gmail.com