

# Fire and Motion Early Warning Device: Its Design and Development

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**Abstract:** Cases of theft and robbery of computers, CCTV equipment, and LCD projector have become more frequent in schools. In addition, fire hazards are great threat to educational institutions where expensive learning materials are kept. Such incidents could be lessened and avoided if schools are equipped with appropriate security systems capable of monitoring and informing people about the coming possible danger. Thus, the development of Fire and Motion Early Warning Device (FMEWD) is timely and relevant. FMEWD consists of a website and interconnected devices and sensors intended to provide an efficient and effective warning system for preventing incidents relating to fire, smoke, and intrusion within an office. Upon detection, the system automatically sends an email and SMS to registered users. This study used the Agile Development Model which allows features to be delivered quickly and more frequently with higher levels of predictability. Evidently, the integration of different technologies conceptualized by the researcher addresses the pressing security concerns faced by educational institutions like NEUST.

**Index Terms:** Alarm System, Arduino, Fire Sensor, Monitoring System, Motion Sensor, and Warning System

## 1. Introduction

The advancement in technology has been exceptionally fast in the 20th and 21st centuries. Technology nowadays is an important aspect of human lives. Parker (2015) stated that technology is constantly improving its applications and the way people communicate with the rest of the world.

For others, it is almost hard to believe what the technology has achieved.” [1]

Emerging technologies have already influenced how people live and work. They keep on changing how people approach, plan, and integrate security operations. Technology is critical to enhancing security. Without cameras, detectors and alarms, businessmen could not identify threats and respond immediately and appropriately to any situation that calls for urgent action and solution. It was in 2015 when two public schools in Metro Manila, Philippines were hit by fire. Buildings, including books, chairs, and other equipment that were damaged and approximately amounting to Php 300, 000.00. [3] Holy Angels Academy, located in Talavera, Nueva Ecija, Philippines, also suffered from a fire incident where four classrooms were burned [4].

No one knows when harmful incident will take place. What happened to these two public schools is totally devastating and surely incurred so much damage not only in the school facilities but also endangered the lives of many, particularly students, staff, and faculty. Such incidents could be lessened and avoided if schools were equipped with appropriate security systems capable of monitoring and informing people about the coming possible danger. Nguyen HuyBinh (2020) said in his paper that “...social psychologists and educators to create effective systems for identifying and evaluating relevance, search, optimization, analytics, management and monitoring.” [5]

Cases of robbery in public schools might also happen to universities. Aside from fire hazards, theft and robbery impose a great threat to educational institutions where expensive learning materials are kept. Most warning systems include fire detection components but the importance of motion sensors in warning systems cannot be denied.

Existing warning systems include either motion or fire detection feature. L. Bhavani Annapurna, K. Mounika, K. Chakradhara Chary, and Roohi Afroz (2015) worked on a Smart Security System using Arduino and Wireless Communication which focused on digital lock and vibration sensor for theft detection and the RF wireless communication technology to send signals for the indication of theft. The system is only limited to motion or unauthorized intrusion. [6] Another paper by Md Saifudaullah Bin Bahrudin, Rosni Abu Kassim, and Norlida

Buniyamin (2013) proposed a real time monitoring fire alarm system that detects the presence of smoke in the air due to fire and captures images via a camera installed inside a room when a fire occurs. [7] However, the system does not include motion detection feature and can therefore be improved. The major research objective is to combine and improve existing solutions to produce better security monitoring systems. Combining motion and fire detection and the addition of a notification feature can evidently addresses the pressing security concerns faced by educational institutions like NEUST.

In recent years, security system has become increasingly important to maintain safety and security in schools. Because of aforementioned cases concerned people realize the strong need to install warning systems to improve monitoring and security. With all these observable facts, the researcher is motivated to develop a Fire and Motion Early Warning Device (FMEWD). The researchers had decided to conduct the study in the NEUST General Tinio - Graduate School Unit for its accessibility. It will be beneficial to the school as well, since it has a large collection of learning materials and equipment, which makes it prone to high risk of robbery. In addition, some of the offices and rooms in the Graduate School Unit are made of light and combustible materials that can be more prone to fire.

With the proposed system, users will be able to receive notifications anywhere and anytime in their mobile phones in case any triggering event is detected and therefore can be acted upon accordingly. This means users may not suffer any loss as large as one may have incurred if the system is not in place. It can also keep users warned within seconds if there is fire or smoke within the place. This proposed surveillance system will provide peace of mind among users by monitoring homes, offices, and properties from most types of bad elements and situations and it provides convenience in acting as a hub for various automated technology.

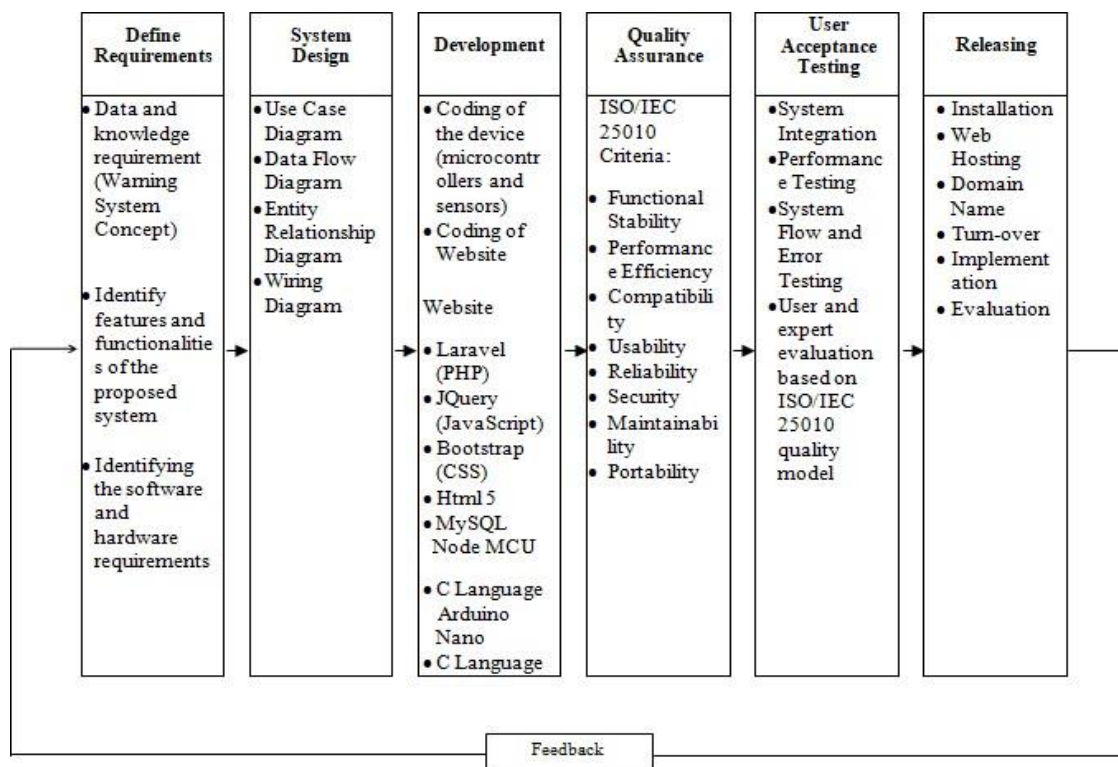


Fig.1. Research Paradigm

The conceptual framework of the study is divided into different stages and each stage has a requirement. These stages are from Agile Development Model. Agile has six (6) phases and it will be used to design, develop, and test the quality of the system. Defining requirements is the most important and fundamental stage in Agile Model. The set requirement is then used to plan the basic project approach and to conduct product feasibility study in the economical, operational, and technical areas. The System Design stage involves the identification of modules, interfaces, and components to be included in the system to satisfy the specified requirements.

The development stage shows that the system comprises a website and a device. It also shows the programming languages involve in the process. Quality Assurance stage examines the quality of the system based on the requirements by adhering to several standards that will also be used in the testing stage. This stage involves identifying and assessing potential risks associated with the project and catching any problems that may have been introduced before moving to the next. User Acceptance Testing is where the system will be evaluated by IT Experts and End users based on the criteria indicated in the ISO/IEC 25010. Releasing the system includes installation of the device and hosting of the website for proper turn over.

## 2. Methodology Research Design

The study used developmental research method. According to Ibrahim, as cited by Luciano, et al. (2020), developmental research involves situations in which the product development process is analyzed and described and the final product is evaluated. [8] Further, Luciano (2020) also stated that this methodology places an emphasis on customer interaction, feedback and adjustments rather than documentation and prediction alone. [9]

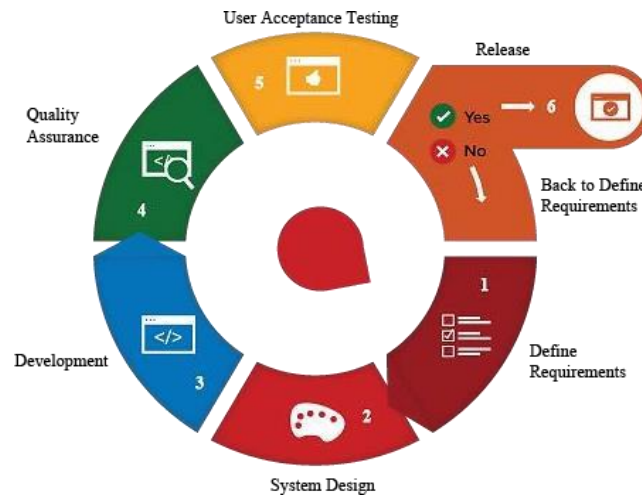


Fig. 2. Agile Development Model

The development of the FMEWD is based on the Agile Development Model. Agile SDLC model is a combination of iterative and incremental process models with focus on process adaptability and customer satisfaction by rapid delivery of working software product. Figure 2 shows the research paradigm of the study. This development model allowed the researchers to deliver and change features quickly and more frequently with higher levels of predictability.

## 3. Results and Discussions Design Phase

The system design was established based on the set requirements. The following illustrations were created as results of the analysis:

For this study, the external entity is the admin. The FMEWD allows the admin to login, view events, recipients, and reports.

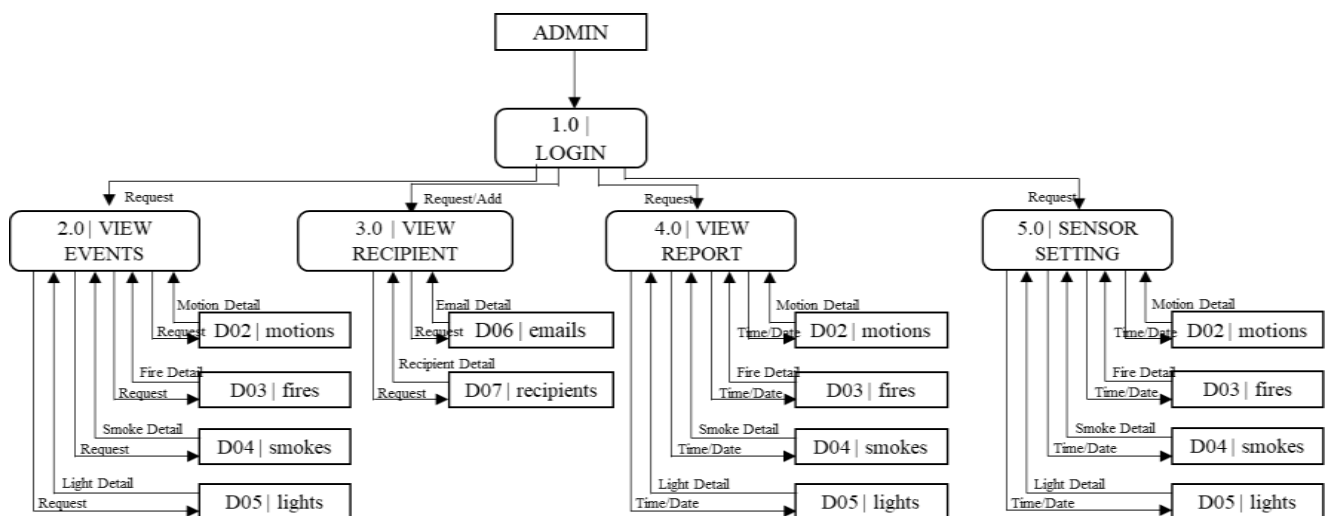


Fig.3. DFD Level 1 Admin

The figure above illustrates a more detailed breakdown of the different processes FMEWD performs. The system allows admin to view event of detection of smoke, fire, motion, and light sensing.

Admin can also view and add recipients of SMS and email notifications. Reports of detection can be generated on a daily and weekly basis. Reports can be sorted according to events detected. Moreover, admin has the option to adjust the level of detection for each sensor.

#### A. Wiring Diagram

Figure 4 shows the wiring diagram connection implemented in the hardware component of the FMEWD. Arduino Mega acts as the brain of the device. GSM modules are responsible for sending and receiving SMS notification. ESP32 Camera, which includes internet connectivity functions, is responsible for securing proof images and processes that requires internet connection. PIR motion sensor is for motion sensing. MQ2 gas sensor and temperature sensor are intended for fire detection. On the other hand, the LDR sensor is used in the automated lighting function. The buzzer produces sound every time there is detection in any of the sensors.

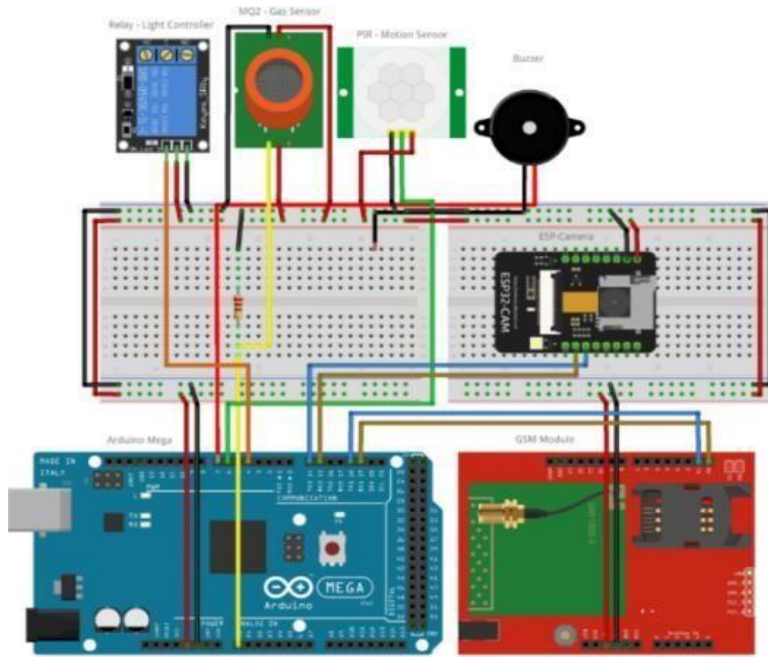


Fig.4. Wiring Diagram

#### B. Use Case Diagram

In the use-case diagram, interactions between the admin and the system were defined. Figure 5 presents the use – case diagram for FMEWD.

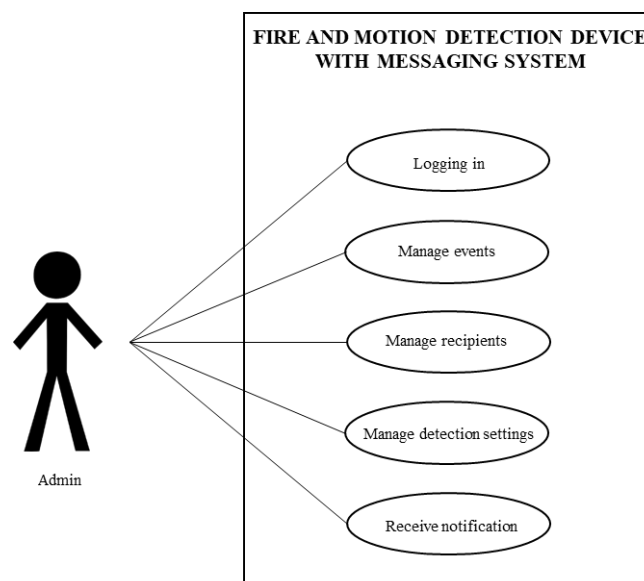


Fig. 5. Use – Case Diagram

The use – case diagram represents the interaction of the administrator with the system. The diagram shows that the administrator can log in, manage events, recipients, detection settings and receive notification as well.

### C. Coding Environment

The layout and functions of the FMEWD website were developed using Laravel 5.2 Framework for PHP. It is a web application framework with expressive, elegant syntax. Laravel provides ease on common tasks used in the majority of web projects, such as authentication, routing, sessions, and caching.

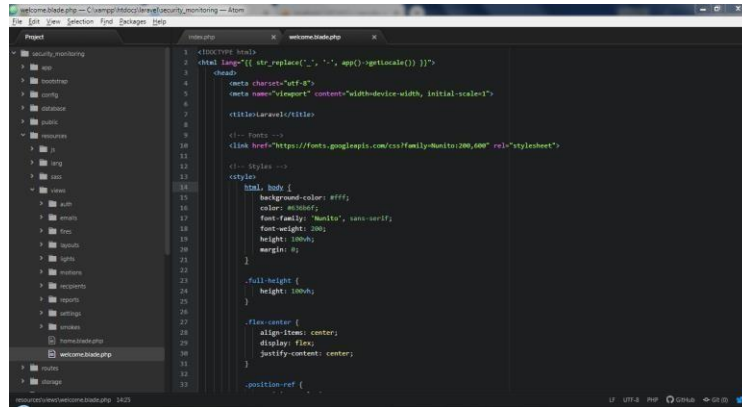


Fig. 6. Laravel Coding Environment

On the other hand, the device was coded using Arduino. This is where the different sensors were set and connected. Arduino is an open-source electronic prototyping platform enabling users to create interactive electronic projects.

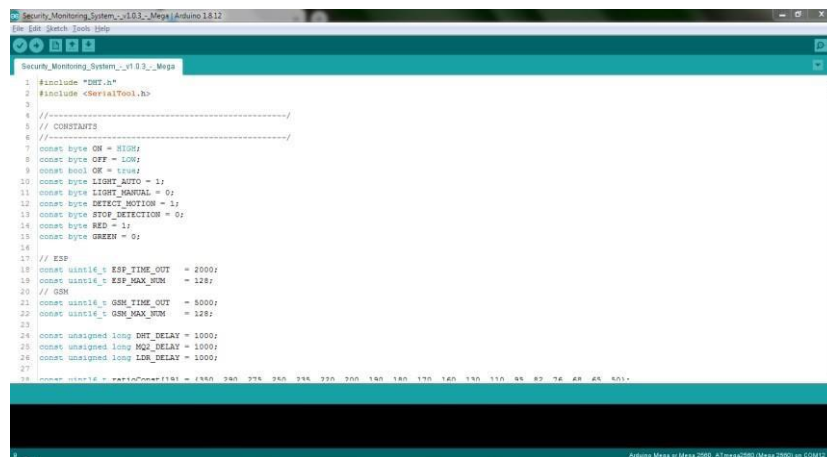


Fig.7. Arduino Coding Environment

### D. Development Phase

In this stage, the researchers finalized the design and built the system. Software and hardware specifications were determined in the development of the system. The development phase began including the coding, assembling, application improvement, testing and debugging of the system.

The development of the proposed system was divided into two phases, the website development and the device assembly. The website serves as the record keeper of the device. Through the website, users can change the device's setting, view all records of detection, generate reports, and register contacts where notifications will be sent. The device, made up of microcontrollers and sensors, monitors an office by continuously checking for presence of fire and unauthorized intrusion.

In creating the website of the proposed system, the researchers used the following technologies in the development process:

**Laravel 5.2 Framework for PHP.** It is an open-source structure that follows MVC (Model – View – Controller) model ensuring clarity between logic and presentation. This architecture helps in enhancing the performance, allows better documentation, and has several useful built – in features.

**MySQL.** It is one of the relational database management systems being used for developing web – based software applications, hence, used in the design of the proposed system.



**Bootstrap.** It is a web designing framework that uses HTML, CSS and JavaScript for developing responsive and mobile-first websites.

**JavaScript.** This makes interactivity possible in web application. JavaScript is utilized for user requests and it provides a richer user experience to the system.

**HTML5.** This is used in designing the web interface used in the developed system.

The device setup was done using the C programming language and the following sensors and microcontrollers were assembled in the physical device:

**Arduino Nano.** The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. [10]



Fig. 8. Arduino Nano

**DHT 22 Temperature Sensor.** The DHT22 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). [11]



Fig. 9. DHT 22 Temperature Sensor

**ESP32 Camera.** The ESP32 is a low-cost system-on-chip (SoC) series created by Espressif Systems. It is an improvement on the popular ESP8266 that is widely used in IoT projects. The ESP32 has both Wi-Fi and bluetooth capabilities, which make it an all-rounded chip for the development of IoT projects and embedded systems in general. [12]



Fig.10. ESP32 Camera

**Light Dependent Resistor.** A photo-resistor or light dependent resistor is a component that is sensitive to light. When light falls upon it then the resistance changes. Values of the resistance of the LDR may change over many orders of magnitude the value of the resistance falling as the level of light increases. [13]



Fig. 11. Light Dependent Resistor

**Piezo Buzzer.** Piezo buzzers are simple devices that can generate basic beeps and tones. They work by using a piezo crystal, a special material that changes shape when voltage is applied to it.



Fig.12. Piezo Buzzer

**PIR Sensor.** PIR sensors allow the proposed device to sense motion, almost always used to detect whether a human has moved in or out of the sensors range. They are small, inexpensive, low- power, easy to use and do not wear out because they are commonly found in appliances and gadgets used in homes or businesses. They are often referred to as PIR, "Passive Infrared", "Pyroelectric", or "IR motion" sensors. [15]



Fig. 13. PIR Sensor

**SIM800L.** This SIM800L is a miniature cellular module which allows for GPRS transmission, sending and receiving SMS and making and receiving voice calls. Low cost and small footprint and quad band frequency support make this module perfect solution for any project that requires long range connectivity. [16]

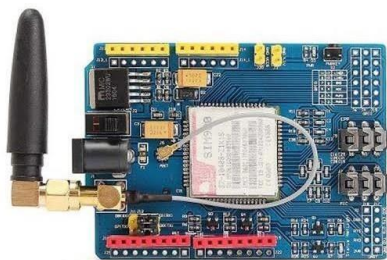


Fig.14. SIM800L

**MQ2 Gas/Smoke Sensor.** MQ2 is one of the commonly used gas sensors in MQ sensor series. It works on 5V DC and draws around 800mW. It can detect LPG, Smoke, Alcohol, Propane, Hydrogen, Methane and Carbon Monoxide concentrations anywhere from 200 to 10000ppm. [17]



Fig.15. MQ2 Gas/Smoke Sensor

### E. Quality Assurance Phase

The researchers conducted quality assurance to verify if all of the set requirements were met and incorporated in both website and device.

Each function of the device was tested in both indoor and outdoor settings. The light dependent resistor recognizes light input in both settings which causes the automated control of the connected bulb when light falls upon the sensor. The motion sensor was able to detect motion within its set range. Temperature and smoke sensors that were meant for fire detection also detected inputs from improvised sources. The researchers have to improvise smoke and heat inputs for testing purposes. The camera activated every time smoke, temperature, or motion is detected. Captured images were sent to the website and registered email address. Upon detection, a text message was also sent to the registered contact number. Rane (2020) has found out that "...system can be easily modified for different instances or for different applications by modifying the IoT based gesturing module only that may require less efforts." [18]

All records of detection were reflected in the website. There were four events where notifications were categorized. These are fire, smoke, motion and light. Time and date for each notification were recorded. An image was provided for each notification except for light events. The settings for sensors could be updated in the website. Contact details could also be added. Emails and SMS notifications were also received by the system user/s.

### F. User Acceptance Testing Phase

This stage assesses the hardware and software performance of the system. It was during this stage, when the system flow was checked and possible errors on the system were detected. The user acceptance testing was conducted with two (2) groups of respondents: End users consist of faculty of NEUST Graduate School and IT Professionals. The system was presented to the respondents.

They were also given an orientation on how to use the system. After they were made familiar with the system, they were allowed to test its functionalities as they evaluate the system using a questionnaire based on ISO/IEC 25010. IT professionals were asked to evaluate the system based on the eight ISO/IEC 25010 quality characteristics such as functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability and portability. On the other hand, end-users were asked to evaluate the system based on three selected qualities such as functional suitability, performance efficiency and usability. [19]

### G. Releasing Phase

After the system had been fully tested, feedback was obtained from the respondents. The developed FMEWD system was deployed in the NEUST Graduate School in November 2020. The website is hosted in a secure web-hosting server. A maintenance plan was also set to check and evaluate the functionality of the system over time.

## 4. Conclusions and Recommendations

The study focused on the development and assessment of FMEWD. The study started with the idea of providing an automated system to improve the monitoring and surveillance of an office with the application of microcontrollers, sensors, and the concept of IOT. The developed system has advanced security monitoring by combining fire and motion detection features and including both SMS and email notification. With FMEWD in place, users will be able to receive notifications anywhere and anytime in their mobile phones in case any triggering event is detected and therefore can be acted upon accordingly.

The following recommendations are given to improve the study.

1. Adding a battery or power source to the device that allows it to work even if power shuts down.
2. An option to see a live video feed or actual photo of the coverage area anytime so users can monitor the area with or without detection.
3. Creation of a mobile application which will make it easier to access the dashboard.
4. Use camera with night vision so the system will be able to capture clear images even in dark areas.
5. Use the light bulb as an indicator for every detection so people in the area who will not be notified by either SMS or email will also be alerted using light signals especially those with hearing impairment.

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