*Original Research Article*

# SPAMAST Smart Garbage Bin Monitoring System Using Wireless Sensor Network

**Abstract: The main objectives of the project was to develop a monitoring system that displays the real-time level of the garbage inside the garbage bins using the ultrasonic sensor, a module the notifies the admin when it reached the maximum level of the garbage's inside the garbage bin that automatically opens using servomotor and laser sensor after detecting the objects nearer and automatically notify the users of the garbage level when the garbage bin is already full, and to capture the level of effectiveness in terms of functionality, reliability, usability, efficiency, maintainability and portability. The research locale of the project was the SPAMAST-DIGOS Campus. The system development method used by the project-developers was the modified-waterfall approach. The project team used Visual Studio 2012 as front-end and Text File as the back end of the system. Asp.Net was used for designing the user's interface. Using these applications, the project team created a Desktop Application that displays the level of the garbage inside the garbage bins which could be graphed. The result of the test taken from students, faculties, staffs and IT expert was 4.75 as the overall weighted mean which means excellent.**

**Keywords: Garbage Bin, Sensor, Monitoring, Software Development**



## INTRODUCTION

The project smart garbage bin monitoring system is a monitoring system which is designed to properly monitor the garbage's inside the bins. This system assures the cleaning of dustbins soon when the garbage level reaches its maximum. If the dustbin is not cleaned in a specific time, then the record is sent to the higher authority who can take appropriate action to the concerned contractor(Malak, Bhoyar, Atkar, & Aryan, 2017; Rosentrater, 2013).

A wireless sensor network was used to transmit and receive data for the project known as nRF24L01 or the transceiver. It is a combination of transmitter and receiver. This receives data and the data collected by it was transmitted to the concerned system to produce an output.

At present, the institution of Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST) Digos Campus, uses open garbage bins where students and even staffs can easily throw anything on it. The utilities will throw the garbage most commonly when it is overfull since they cannot fully monitor on it because of their other works to do. Because of that, it results to mess, pollution and even insects such as mosquitoes which can bring diseases to everyone in the surroundings. With these, the researchers were motivated to find a technological solution that fitted to the specific problems encountered by the institution. The researchers now developed a project which gave an efficient way to the administration of the institution in maintaining the cleanliness and in avoiding mess and diseases. With this, it reduced their time in monitoring the garbage since the utility was informed when the garbage to throw. This was a big help to the administration since the project was made to monitor the garbage's inside the garbage bins.

The project entitled "SPAMAST Smart Garbage Bins Monitoring System Using Wireless Sensor Network" was developed to automate and to easily monitor the garbage bins of the SPAMAST Digos-Campus. The garbage bin automatically opened with the use of servomotor after detecting the hand of the user with the use of laser sensors. The project used a wireless sensor network known as a transceiver to receive data from the garbage bins and transmit data to the Windows Form monitoring system. The data was gathered from the ultrasonic sensor. The monitoring system showed the level of the garbage bins and sent SMS notification if the garbage bins were already full.

## OBJECTIVES

The general objective of this study is to develop a project smart garbage bin monitoring system using wireless sensor network.

Specifically, it aims the following:

1. To develop a monitoring system that will display the real-time level of the garbage inside the garbage bins using ultrasonic sensors.
2. To develop a module that will send an SMS notification to the admin when it reaches the maximum level of the garbage's inside the garbage bin using transceiver via the webpage.
3. To develop a garbage bin that will automatically open using servomotor and laser sensors after

detecting the hand of the user and will automatically not open when the garbage bin is already full.

4. To capture the level of effectiveness of the SPAMAST Smart Garbage Bin Monitoring System using Wireless Sensor Network in terms of;
   4.1. Functionality
   4.2. Reliability
   4.3. Usability
   4.4. Efficiency
   4.5. Maintainability
   4.6. Portability

## REVIEW OF LITERATURE

The following are some related studies and review of literature from books, journals, articles from the internet that leads to the formulation of the problems stated in this study which includes the positive and negative characteristics or directions of this innovative research.

### Garbage Collection System Using IoT- A Review

A big challenge in the urban cities is solid waste management not only in India but for most of the countries in the world. The project gives us one of the most efficient ways to keep our environment clean and green (Solanki, & Nayyar, 2019). Ultrasonic sensors and Global System for Mobile Communication (GSM) are the latest trends and are one of the best combinations to be used in the project. Hence, a combination of both of these technologies is used in the project. The paper shows the smart garbage management system using GPS, ultrasonic sensor, microcontroller and GSM module. This system assures the cleaning of dustbins soon when the garbage level reaches its maximum. If the dustbin is not cleaned in a specific time, then the record is sent to the higher authority who can take appropriate action against the concerned contractor. This system also helps to monitor the fake reports and hence can reduce the corruption in the overall management system and keeps the environment clean. It reduces the total number of trips of garbage collection vehicle and hence, reduces the overall expenditure associated with the garbage collection. It ultimately helps to keep cleanliness in society. Therefore, the smart garbage management system makes the garbage collection more efficient (Malak, Bhoyar, Atkar, & Aryan, 2017).

### Dust Bin Monitoring System

In the present scenario, we only have conventional garbage disposal by periodic overflowing checks by local authorities, leading to garbage bins. All types of wastes are also seen to be dumped together. In this project, we aim at an automatic garbage level detecting system informing the concerned authorities timely and also classification among the wastes aiding efficient waste management. Whenever the garbage is full information can be sent to the concerned authority to clean the bin (Mahajan, et al., 2014). Here we use low maintenance recent communication development like GSM. GSM is used in the project as a communication backbone for the whole system for various reasons like low cost, easy to implement and less signal deterioration. Suppose this project is being implemented in a city and the different garbage bins placed at different locations within a city send messages indicating the garbage levels in the respective bins to a local Corporation office and at the same time to the head office as well.

It is an automatic dust bin monitoring system in order to detect the full condition of the garbage bins. This provides the authorized users timely updates of the status of the garbage bins and thus eliminates the need for periodic manual checks and overflowing garbage bins. This project also provides an additional feature to add new message receivers or alter the existing authorized users. It also aims at the classification of different waste and thus promoting waste management (Thomas, et al., 2016).

### Garbage Monitoring and Management using Sensors, RF- ID and GSM

The project can monitor the level of garbage and can send information regarding it to the control room. In this entire system, metal sensor, IR sensor, RF ID and TAG and ultrasonic sensor are going to play a crucial role. The sensors include a pair of diodes: IR diode which emits Infra-red radiations which fall on the garbage and get reflected back to the circuit and are detected by the photodiode. When the number of such pairs of diodes is fixed on the walls of the dustbin, the various levels of garbage in the dustbin are detected. The Ultrasonic sensors work on the principle of emission and detection of ultrasonic sound waves (greater than 20KHz) and thus detects the level of garbage. The RF ID TAG and READER work on the principle of electromagnetic induction and used for object detection purpose. The RF module is a communicating device which communicates between two locations on matching the frequencies. GSM is a Global System for Mobile which can send and emit the messages to and from various parts of the world. So, by completing this project and by making use of it, it is possible to solve the problem of improper collection of garbage by municipal staffs and it will work in favours of good health of society. The help of this system we will be able to keep a track on almost all the government service vehicles to ensure that they carry out their services faithfully. These will help in the proper functioning of the service sectors of the government that will contribute for a healthy environment to the citizens of the nation (Pandey, Bal, Bharti, & Sharma, 2015).

### Intelligent Monitoring System for Garbage Waste Bins Using Arduino

In the present day, many times we see that garbage bins or dustbins placed at public places are overflowing due to the increase in solid waste every day. It creates unhygienic conditions for all people and creates bad smell around the surroundings this leads in spreading some diseases and human illness, to avoid such situation we are designing "Intelligent Monitoring System for Garbage Waste bins". In this proposed system there are multiple dust bins are located throughout the city, these dust bins are provided with low cost embedded devices. Global system for mobile communication is the latest tread used nowadays can be used for our project. Sensors are placed above the dust bin. It will detect whether the garbage is at the low, middle or highest level. The main control unit consists of Arduino - it will receive the output signal of the sensor, process it and according to that, it will send the message to the office user. Along with the detection of the depth of garbage simultaneously it will detect the presence of flame or smoke. The work consists of an experimental approach towards waste management and finding an alternative to conventional materials in flexible pavements. As the resulting project can able to monitor the level of garbage in the dust bins placed at public places, according to that we can collect garbage of particular which will avoid overflow conditions and helps to reduce pollution as well as different hazards of health. The system will reduce the wastage of fuel by reducing the number of trips of the garbage collection vehicle. Hence an intelligent garbage monitoring system will make the garbage collection more efficient(Tapase, Mohite, Kadam, & Deshmukh, 2016).

### IOT Based Garbage Management System

Everything in this study is being based on the internet. Evolution of cloud computing and IOT is increasing rapidly. Here the communication takes between machine to man. All the devices that have been used in our day to day life are interconnected with IOT. The IOT allows an object to sense and control remotely. By implementing our project in a real-time scenario, we can reduce the unhygienic condition among the smart cities and many areas. The module will give information to the concerned person through the webpage. The webpage can be seen by all the officials. If the wastes are not properly cleaned and remove, there may be a possibility for diseases to spread. This may cause severe health hazards to humans. With our system, we can clean the environment and give our contribution to the society for Clean India concept. By intimating the notification of waste filled in the garbage, we can reduce the number of trips of the garbage collecting vehicle(Vinothkumar, Sivaranjani, Sugunadevi, & Vijayakumar, 2017).

## REVIEW OF RELATED STUDIES

### IoT Based Smart Garbage and Waste Collection Bin

Internet and its applications have become an integral part of today's human lifestyle. It has become an essential tool in every aspect. Due to the tremendous demand and necessity, researchers went beyond connecting just computers into the web. These researches led to the birth of a sensational gizmo, Internet of Things (IoT). Communication over the internet has grown from user-user interaction to device – device interactions these days. The IoT concepts were proposed years back but still, it's in the initial stage of commercial deployment. Home automation industry and transportation industries are seeing rapid growth with IoT. Yet not many articles have been published in this field of study. This paper aims to structure a state of the art review on IoT. The technology, history and applications have been discussed briefly along with various statistics. All the equipment we use in our day to day life can be controlled and monitored using the IoT. A majority of the process is done with the help of sensors in IoT. Sensors are deployed everywhere and these sensors convert raw physical data into digital signals and transmit them to its control centre. The system assures the cleaning of dustbins soon when the garbage level reaches its maximum. If the dustbin is not cleaned in a specific time, then the record is sent to the higher authority who can take appropriate action against the concerned contractor. This system also helps to monitor the fake reports and hence can reduce corruption in the overall management system. This reduces the total number of trips of garbage collection vehicle and hence reduces the overall expenditure associated with the garbage collection. It ultimately helps to keep cleanliness in society. Therefore, the smart garbage management system makes the garbage collection more efficient. Such systems are vulnerable to plundering of components in the system in different ways which need to be worked on(Navghane, Killedar, & Rohokale, 2016).

### IoT Based Smart Garbage Detection System

Internet of Things is nothing but the applications performing with the help of internet access. It's an advanced domain of technology in which all your data is stored on the cloud with real-time quick access to data as well as its data mining. While the data is stored on the cloud and people having internet access, will provide great access to people on the same application from anywhere in and around the world. Such advancement also equips sensors and routers for gathering and sending data across the internet. Such a domain can be used in all sorts of Pervasive Computing, and Business Intelligence applications. This paper introduces you to the use of IoT on one such area, that is, Garbage Detection in smart ways

using IoT and see how this can also be a major part of developing a city into a smart city. The basic project idea is to design a smart waste detection system which would automatically notify the officials about the current status of various garbage bins in the city, would have real-time monitoring capabilities, which would be remotely controlled using IoT techniques. This implementation of Smart Garbage Collection System using IoT assures the cleaning of dustbins soon when the garbage level reaches its maximum. If the dustbin is not cleaned in a specific time, then the record is sent to the higher authority who can take appropriate action against the concerned official. This system also helps to monitor the fake reports and hence can reduce corruption in the overall management system. This reduces the total number of trips of garbage collection vehicle and hence reduces the overall expenditure associated with the garbage collection. The very important aspect of our project is the web portal that is designed in such a way that operators and citizens both will find it user-friendly to monitor the garbage information of various places (as discussed above). Hence, all in all, an Iot Concept based software project with electronic devices used, is the one that will be a great service to the world and make it a better place to live in, to some extent(Dev, Jasrotia, Nadaf, & Shah, 2016).

**IoT-Based Smart Garbage System for efficient food Waste Management**

The Internet of Things (IoT) is a concept in which surrounding objects are connected through wired and wireless networks without user intervention (Nayyar et al., 2018; Puri et al., 2017). In the field of IoT, the objects communicate and exchange information to provide advanced intelligent services for users. Owing to the recent advances in mobile devices equipped with various sensors and communication modules, together with communication network technologies such as Wi-Fi and LTE, the IoT has gained considerable academic interests. This paper proposes an IoT-based smart garbage system (SGS) composed of a number of smart garbage bins (SGBs), routers, and servers. Each SGB, which plays a role in collecting food waste, is battery operated for mobility and, considering the convenience to residents, performs various techniques through wireless communication. The server collects and analyzes the status of all SGBs and resident information collected through RFID readers. The router is used for server load distribution. The proposed system had been operated as a pilot project in Gangnam district, which is one of the local districts in Seoul, the capital of Republic of Korea, according to the food waste reduction policy of the Korean government. Through the proposed system, not only food waste is reduced but also residents and the government save costs. To solve this problem, the photovoltaic power generation is being considered. Moreover, high-intensity plastic materials are also being considered for durability against external impact and corrosion from humidity(Hong, et al., 2014).

**Smart Dustbin-An Efficient Garbage Monitoring System**

This project IOT Garbage Monitoring system is a very innovative system which will help to keep the cities clean. This system monitors the garbage bins and informs about the level of garbage collected in the garbage bins via a web page. For this, the system uses ultrasonic sensors placed over the bins to detect the garbage level and compare it with the garbage bins depth. The system makes use of Arduino family microcontroller, LCD screen, Wi-Fi modem for sending data and a buzzer. The system is powered by a 12V transformer. The LCD screen is used to display the status of the level of garbage collected in the bins. This project will help to eradicate or minimize the garbage disposal problem. The Internet of Things (IoT) is a recent communication paradigm that envisions near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users, becoming an integral part of the Internet. Whereas a web page is built to show the status to the user monitoring it. The web page gives a graphical view of the garbage bins and highlights the garbage collected in colour in order to show the level of garbage collected. The LCD screen shows the status of the garbage level. The system puts on the buzzer when the level of garbage collected crosses the set limit. Thus this system helps to keep the city clean by informing about the garbage levels of the bins by providing a graphical image of the bins via a web page. The technologies which are used in the proposed system are good enough to ensure the practical and perfect for solid garbage collection process monitoring and management for the green environment (Monika, Rao, Prapulla, & Shobha, 2016).

**Waste Bin Monitoring System UsingIntegrated Technologies**

A big Challenge in urban cities is Solid waste management. Not only in India but for most of the countries in the world. The project gives us one of the most efficient ways to keep our environment clean and green. ZigBee and Global System for Mobile Communication (GSM) are the latest trends and are one of the best combinations to be used in the project. Hence, a combination of both of these technologies is used in the project. To give a brief description of the project, the sensors are placed in the common garbage bins placed at the public places. When the garbage reaches the level of the sensor, then that indication will be given to ARM 7 Controller. The controller will give an indication to the driver of the garbage

collection truck as to which garbage bin is completely filled and needs urgent attention. ARM 7 will give an indication by sending SMS using GSM technology. The sensor is placed in the garbage bin at a max level, if that level is crossed by the garbage in the bin, then the sensor will sense that and will communicate to ARM 7 controller through Zig Bee technology. When the garbage box 1 becomes full, the ultrasonic sensor attached to its lid will detect the level and send a command through ZigBee. The ZigBee receiver will always receive the command and show the condition of garbage box on Liquid Crystal Display and on the computer. The Message would be that the garbage bin 1 in a particular area is filled completely, please collect it". At the same time, the same message will be sent to a driver's mobile that particular garbage bin is completely full through Short Message Service. The same thing will happen when the garbage box 2 becomes full; the ultrasonic sensor will detect the level and send a command through ZigBee. The receiver attached to Zig bee will receive that command and will display that on Liquid Crystal Display (LCD) and computer that garbage bin 2 in another area is filled completely, please collect it. At the same time, the same message will be sent to a driver's mobile to collect the garbage bins through Short Message Service. By Instance even if both the garbage bin is full at the same time, they also both messages will be displayed on liquid Crystal Display and computer of base station one by one. Also, the Short Message Service will be sent to the driver's mobile one by one(Mahajan & Chitode, 2014).

## MATERIALS AND METHODS

The following strategies used in this study is based on the framework and procedures that innovative research design standards. Innovative research is a systematic study and research using the standard as well as innovative approaches (Radhakrishnan, 2014) which include the development approach of the study. The development approach that this study used is modified waterfall model which involves validation or verification between the phases, so any deviations can be corrected immediately, providing the customer satisfaction that is best to use and mostly preferred by almost developer (Zeil, 2014).

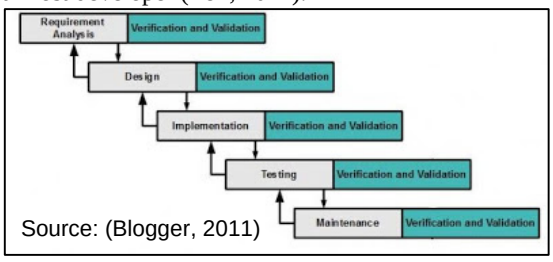


**Figure 1: Modified Waterfall Model**

The requirement analysis phase of the study that establishes the components for building the system, including the hardware requirements, software tools, and other necessary components that is being described and discussed in Table 1 and Table 2. Table 1 shows the technologies used in achieving the specific and to support the project needs in terms of hardware.

**Table 1: Hardware Specification**

| Device Name | Picture | Description | Specification |
|---|---|---|---|
| Arduino UNO |  | The microcontroller that assigns all electronic devices use. | Arduino Uno R3 |
| GSM Module |  | A device that is used to send SMS notification if the garbage bin is full. | SIM900 SIMCOM GPRS/GSM Shield |
| Laser sensors |  | A sensor that is used to detect an object to assign the motor when to open the garbage bin. | KY-008 Laser Detector |
| nRF24L01 |  | A device used for wireless sensor network for transmitting and receiving the data. | RF NRF24L01 Module |
| Ultrasonic sensor |  | A device used for detecting the level of the garbage waste. | Ultrasonic Sensor (HC-SR04) |
| Servomotor |  | A motor that is used to pull the garbage bin to open. | TowerPro MG995 Continuous Rotation Servo 360° |

Table 2 shows the technologies used in achieving the specific and to support the project needs in terms of software.

**Table 2: Software Specification**

| Software | Minimum Requirement | Recommended | Logo |
|---|---|---|---|
| Operating System | Windows XP | Windows OS 7/8/10 (32bit/64bit) | |
| Programming Language | Visual Studio 2012 Arduino Compiler | Asp.net c# Arduino UNO compiler | |
| Database | MySQL Administrator | MySQL Administrator 1.9 | |
| Multimedia | Photoshop | Photoshop CC 2016 | |

Table 3is the budgetary requirement of the hardware used in the development of the system specifically the price of the technologies used in achieving the specific and to support the project needs.

**Table 3: Hardware Budgetary Requirements**

| Hardware | Quantity | Price | Amount |
|---|---|---|---|
| Arduino UNO | 1 | 800.00 | 800.00 |
| nRF24L01 | 2 | 250.00 | 500.00 |
| Laser sensor | 6 | 55.00 | 330.00 |
| Ultrasonic sensor | 2 | 320.00 | 640.00 |
| GSM module | 1 | 1,300.00 | 1,300.00 |
| Servo motor | 2 | 639.00 | 1,278.00 |
| Garbage bins | 2 | 490.00 | 980.00 |

| | | | |
|---|---|---|---|
| UTP wire | 2 | 11.00 | 22.00 |
| Super Glue | 1 | 80.00 | 80.00 |
| Plywood | 1 | 450.00 | 450.00 |
| **TOTAL** | | | **Php 6,380.00** |

The theoretical framework of the study is part of the designing phase of the approach which establishes the expectations for software functionality and identifies which system requirements the software effects. As theory mentioned that the garbage bins is an independent variable in this project, the process of this project is to detect the hand of the user by using the sensors. The ultrasonic sensors are assigned to detect the hand of the users to automatically open the garbage bins. It is also assigned to detect the level of the garbage inside in the garbage bins. After that, the data will be passed into the Windows Form monitoring system to see the level of the garbage. If the garbage bin is full, it will send an SMS notification using the GSM module.

Figure 2 is the conceptual framework of the study which involves the IPO Model that a process is viewed as a series of boxes (processing elements) connected by inputs and output. Information or material objects flow through a series of task or activities based on a set of rules or description points. Flow charts and process diagrams are often used to represent the process. What goes in is the input; what causes the change is the process; what comes out is the output (Alcantara, et al., 2014).

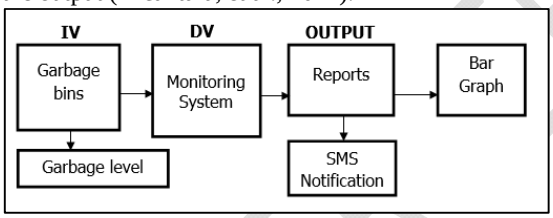


**Figure 2: Conceptual Framework of the Proposed System**

An ultrasonic sensor is a device that can measure the distance to an object by using sound waves. Through these sensors, it will assign the motor when the garbage bins automatically open. The sensors also detect the level of the garbage and pass it to the windows form monitoring system. The garbage added to the garbage bin will be sent to the monitoring system and the level of the garbage bin will change.GSM module is a device that responsible in sending an SMS notification to the administrator if the garbage bins are full and the administrator will send to the utility about the garbage level that ready to dispose of. A router is a device that joins multiple computer networks together via either wired or wireless connections. The laser sensor is a device that will be used in detecting an object that passes through it. This will be used to assign the servo motor when to open. The transmitter is a device that will be used to transmit data to the receiver. The receiver is a device that will be used to receive data from the transmitter.

The system architecture of the study which determines the software framework of a system to meet the specified requirements. The design defines the major components and the interaction of those components, but the design does not define the structure of each component. Figure 3 shows the architecture of the system that determines the external interfaces and tools to use in the project.

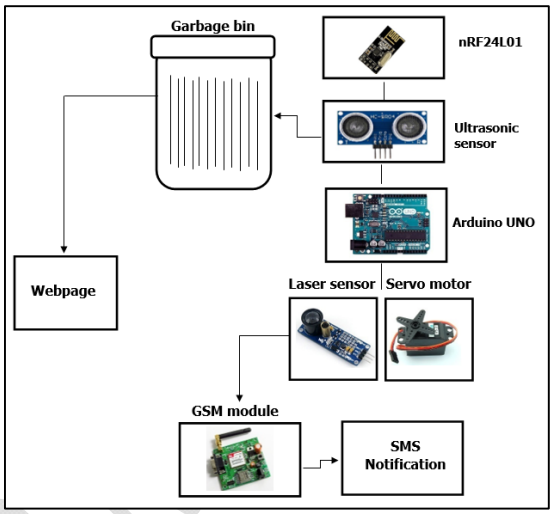


**Figure 3: System Architecture of the System**

The testing phase of the system which determines whether the software meets the specified requirements and finds any errors present in the code. The study used white box testing known as structural testing or code-based testing, is a methodology which ensures and validates a software application's mechanisms, internal framework, and objects and components. Specifically, this method of testing not only verifies a code as per the design specifications but also uncovers an application's vulnerabilities. White box testing is also known as a transparent box, glass box, and clear box testing as it clearly visualizes the software's internal mechanisms for a software engineering team (Rangala, 2015). Figure 4 shows the white box testing techniques which check the code and run with preselected input values to validate the preselected output values. If a mismatch is found, it implies that the software application is marred by a bug. This process also involves writing software code stubs and drivers.

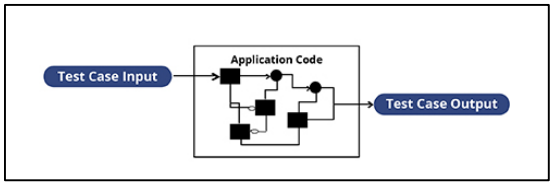


**Figure 4: White Box Testing Techniques**

The system also being tested with respondents using ISO Software Quality Model 9126 questionnaire which described the quality of the

software implemented. ISO 9126 software quality characteristics are defined which are used to evaluate the quality of a software product. These characteristics shall assure a complete evaluation, but in most projects, these characteristics need to be weighted to each other. This evaluation procedure is quite complex and it differs from project to project and maybe also over time due to changing requirements (Ludwig, 2016).

The questionnaire mainly the software characteristics in accordance with ISO 9126 are Functionality, Reliability, Efficiency, Usability, Maintainability and Portability. Figure 5 is the graphical representation of these main characteristics and the sub-characteristics is show nearby.

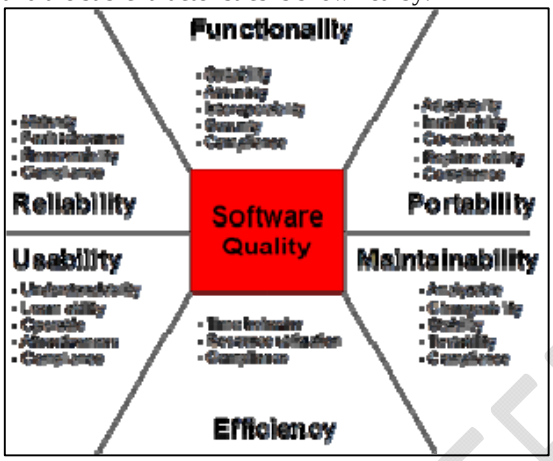


**Figure 5: Characteristics of Quality Software (ISO 9126)**

The statistical method used in the study to get the results are frequency and mean. Frequency is the rate of a repetitive event (Lombardi, 2002) and mean calculates a set of data adding-up (sum) all of the data values(x) and then divide the result by the number of values (n).

## RESULTS AND DISCUSSIONS

The chapter presents the result and discussion of the methods of the project entitled SPAMAST Smart Garbage Bin Monitoring System Using Wireless Sensor Network based on the objectives. The project was made in order to give the institution Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST) Digos Campus an avenue in emitting the overfilling of garbages inside the bins that can cause pollution and mosquito diseases on the people around in the future. Objectives were answered and defined specifically.

Dataflow Diagrams, Schematic Diagram, the physical appearance of the project, screenshots of the interfaces of the system of the project and tables that derived from the questionnaires that were given to the respondents were also presented as evidence to the output of the project. During the testing, there were thirty (30) respondents: Twenty-three (23) students, five (5) faculties/staffs, one (1) Utility Personnel and one (1) IT expert.

**Development of the Monitoring System**

According to research that the real-time level of the dustbins assures the cleaning of dustbins soon when the garbage level reaches its maximum (Malak, Bhoyar, Atkar, & Aryan, 2017). Also, the Dust Bin Monitoring System of one research stated that the monitoring system provides the authorized users timely updates of the status of the garbage bins and thus eliminates the need of periodic manual checks and overflowing garbage bins can able to monitor the level of garbage in the dust bins (Thomas, et al., 2016). In addition, according to one study that collecting garbage of particular resulted to avoid overflow conditions and helps to reduce pollution as well as different hazards of health (Tapase, Mohite, Kadam, & Deshmukh, 2016). Therefore, the system developed showed the real-time level of the garbage bin helped a lot in minimizing the pollution due to overflowing. Many places suffered from pollution because of it. In order to avoid such a mess, the researchers found a way and that was to create the project. The monitoring system was in a Windows Form. It has a back-end of TextFile and a front-end of Visual Studio 2012. The monitoring system has its own database for the users.

This monitoring is shown in details in Figure 6, that provides the data flow diagram of the entire functions of the capability of the system in terms of monitoring.

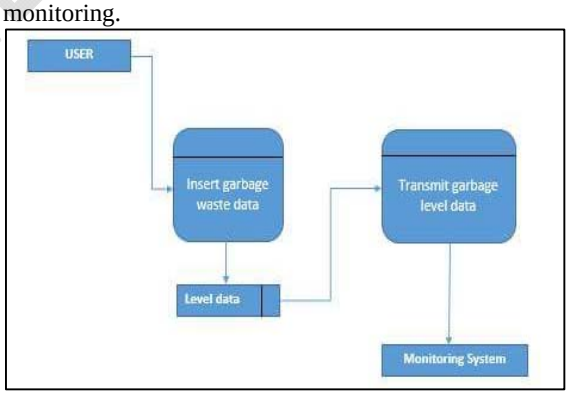


**Figure 6: Monitoring Data Flow Diagram**

In line with the data flow diagram of the monitoring system, Figure 7 also showed the sample output as the graphical user interface of the system developed.

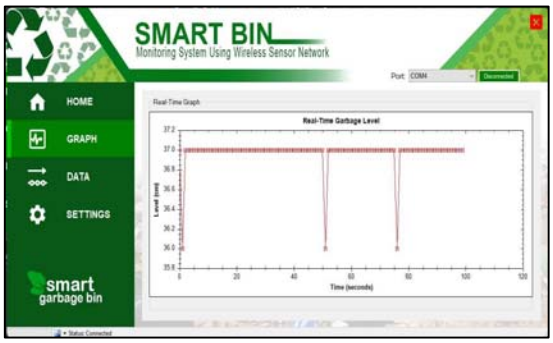


**Figure 7: Monitoring Graphical User Interface**

**Development of Module of SMS Notification**

According to experts developed same as this study provides that the latest trends and are one of the best combinations to be used in the project because when the garbage reaches the level of the sensor, then that indication will be given to Micro-controller(Malak, Bhoyar, Atkar, & Aryan, 2017). Then it is supported that whenever the garbage is full information can be send to the concerned authority to clean the bin where GSM is used in the project as a communication backbone for the whole system for various reasons like low cost, easy to implement and less signal deterioration(Thomas, et al., 2016). Also, in study IOT Based Garbage Management System, the module is given information to the concerned person through the webpage that can be seen by all the officials(Vinothkumar, Sivaranjani, Sugunadevi, & Vijayakumar, 2017). Lastly, in IoT Based Smart Garbage Detection System, it aims at advanced management of the whole garbage collection system(Dev, Jasrotia, Nadaf, & Shah, 2016). Therefore, as the result, the module that sends an SMS notification to the admin or concerned personnel was with the use of Global Message Mobile (GSM) and Arduino microcontroller which serves as the brain of the system that processed the programs. An ultrasonic sensor was placed inside the bin in which when the garbage's reaches its maximum level, the SMS notification followed which was sent to the admin or concerned personnel, and the transceiver which sends and receives data from the garbage bin's records.

Figure 8 is the data flow diagram of the GSM Module that produces SMS notification to the administrators or to the benefactors.

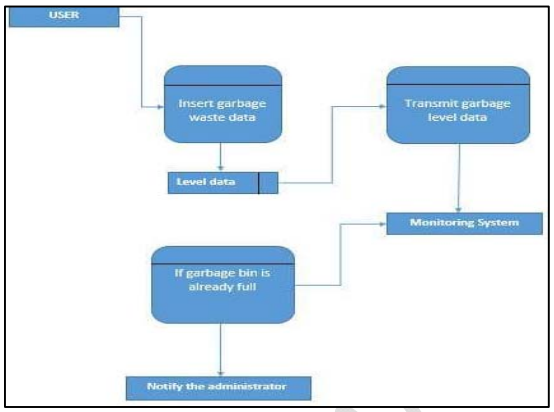


**Figure 8: SMS Notification Data Flow Diagram**

**Development a Garbage Bin**

According to one research entitled Waste Bin Monitoring System Using Integrated Technologies, the opening of the dustbin will automatically open with the use of a servomotor and a hand motion detector (Mahajan & Chitode, 2014). The result of the study illustrates that the developed smart garbage bin was with the use of a servomotor which pulled the bin after detecting the hand of the user. In detecting the hand of the user, the researchers preferred to use the laser sensor because of its low cost as suggested by the experts. With these, the data was processed again by the Arduino microcontroller which commands the sensors and motor to do the tasks.

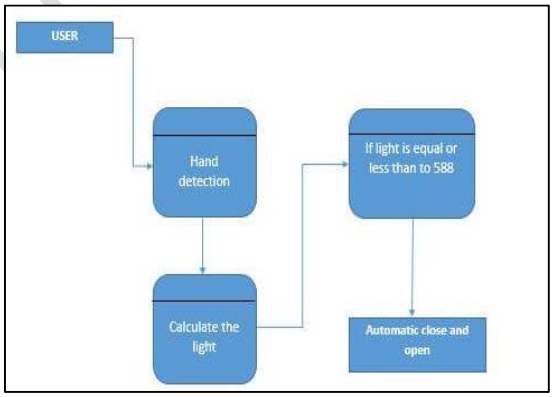


**Figure 9: SMARTBin Data Flow Diagram**

**Figure 10: Physical Appearance of the SMARTBin**

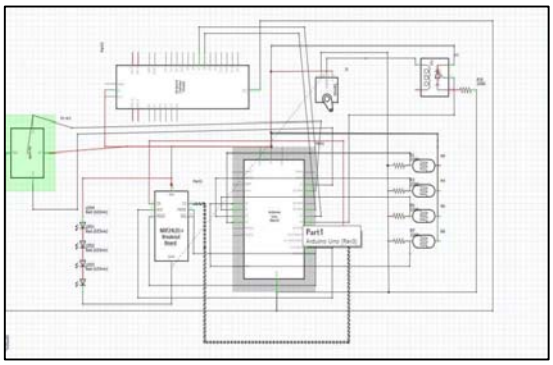

**Figure 11: Schematic Diagram of the SMARTBin**

Table 4 is the overall result of the test being undertaken by twenty-three (23) students, five (5) faculty or staff, one (1) utility personnel and one (1) expert that the SMARTBin is excellent in performance with 4.75 mean result. This is supported by the study that intimating the notification of waste filled in the garbage can reduce the number of trips of the garbage collecting vehicle (Vinothkumar, Sivaranjani, Sugunadevi, & Vijayakumar, 2017).

**Table 4: Effectiveness of the SMARTBin**

| Particulars | Mean | Verbal Description |
|---|---|---|
| Functionality | 4.60 | Excellent |
| Reliability | 4.60 | Excellent |
| Usability | 4.90 | Excellent |
| Efficiency | 4.60 | Excellent |
| Maintainability | 4.90 | Excellent |
| Portability | 4.90 | Excellent |
| **Over-all** | **4.75** | **Excellent** |

The evaluation of the functionality of project SPAMAST Smart Garbage Bin Monitoring System Using Wireless Sensor Network. According to the results, the monitoring systems displays the real-time level of the garbage inside the garbage bins with a weighted mean of 4.8, the module sends SMS notification to the admin when it reaches the maximum level of the garbage's inside the garbage bin with a weighted mean of 4.9 and that the garbage bin automatically opens when detecting the hand of the user with a weighted mean of 4.1. Overall, the rating of the functionality of the project has a consolidated mean of 4.6 which means "Excellent".

The evaluation of the reliability of the project. According to the results, most errors have been corrected over time with a weighted mean of 4.8, The project is capable of maintaining its performance despite the presence of errors when used with a weighted mean of 4.2 and that the project resumes working after failure with a weighted mean of 4.9. Overall, the rating of the reliability of the project has a consolidated mean of 4.6 which means “Excellent”.

The evaluation of the usability of the project. According to the results, the information generated by the project is easy to understand with a weighted mean of 4.9 and that the project performs tasks in a straightforward manner with a weighted mean of 4.9 again. Overall, the rating of the usability of the project has a consolidated mean of 4.9 which means "Excellent".

The evaluation of the efficiency of the project. According to the results, the project responds immediately when used with a weighted mean of 4.9 and that the project maximizes the utilization of available resources such as people, data and materials with a weighted mean of 4.3. Overall, the rating of the efficiency of the project has a consolidated mean of 4.6 which means "Excellent".

The evaluation of the maintainability of the project. According to the result, the project is easily tested with a weighed and a consolidated mean of 4.9 which means “Excellent”.

The evaluation of the portability of the project. According to the results, the project performs its functions even it is moved to another environment with a weighted mean of 5 and that the project can easily be installed with a weighted mean of 4.9. Overall, the rating of the portability of the project has a consolidated mean of 4.9 which means "Excellent".

## SUMMARY AND CONCLUSIONS

The project entitled SPAMAST Smart Garbage Bin Monitoring System Using Wireless Sensor Network was designed for Southern Philippines Agri-Business and Marine and Aquatic School of Technology, Digos Campus. The capstone project met all the objectives of the study where the monitoring system displayed the real-time level of the garbage inside the garbage bins, sent SMS notification to the admin or the concerned person when reaching the maximum level of the garbage’s inside the garbage bin, and automatically open after detecting the hand of the user and automatically close when the garbage bin is already full.

It was concluded that the SPAMAST Smart Garbage Bin Monitoring System Using Wireless Sensor Network for Southern Philippines Agri-Business and Marine and Aquatic School of Technology, Digos Campus, succeeded during the testing. Most of the thirty (30) respondents agreed that the project met all the objectives stated.

The functionality, reliability, usability, efficiency, maintainability and portability of the project were evaluated. The functionality of the project has a consolidated mean of 4.6 which means “Excellent”, the reliability of the project has a consolidated mean of 4.6 which means “Excellent”, The usability of the project has a consolidated mean of 4.9 which means

"Excellent", the efficiency of the project has a consolidated mean of 4.9 which means "Excellent", the maintainability of the project has a consolidated mean of 4.6 which means "Excellent", and the portability of the project has a consolidated mean of 4.9 which means "Excellent".

During the testing of the project, there were problems encountered such as no SMS notification sent to the admin or concerned utility due to lack of microcontroller that was used for coding but, the monitoring itself still notifies the admin or the concerned person whenever the garbage bin is already full and is ready for disposal which only appears at the monitor of the monitoring system; and the delayed of opening the garbage-opening when used due to shortage of power supply.

## IMPLICATIONS AND RECOMMENDATIONS

This capstone project provides great impact not only to the learning of the proponent but also to the body of knowledge in terms of software development and to environmental awareness. The result of these capstone project can contribute and provide information to different agencies that may apply to have advancement and improvement to various processes in terms of waste disposal. Particularly to the government agency that deals with waste management to lessen the issues on schedule collection and non-compliance to segregation for future use. Also, to the institution to provide awareness about the result of this study by means of presentation that there are ways to provide assistant to the development of the community. Lastly to the beneficiaries of the project that efforts and initiatives of the concerning agencies should be followed and appreciated.

It is recommended that the project must consider wet garbage in order to be flexible in terms of waste disposal and should have no delay in detecting the hand of the user. It also must send an SMS notification to the admin using two (2) arduino microcontrollers – one of the sensors and the other one for the SMS itself.

## REFERENCES


Alcantara, A. V., Angat, A. P., Angeles, R. I., Baro, E. D., Daniel, W. A., Jamolin, J. P., . . . Terana, L. G. (2014, March). LinkedIn Corporation. Retrieved from Assessment of the Study Skills of 1st Year and 2nd Year Computer Engineering Students of Polytechnic University of the Philippines Institute of Technology: https://www.slideshare.net/AngeAlcantara/a-thesis-asses

Blogger. (2011, October 25). Software Testing Storm. Retrieved from What is Modified Waterfall Model?: http://myowntestingspot.blogspot.com/2011/10/modified-waterfall-model.html

Dev, A., Jasrotia, M., Nadaf, M., & Shah, R. (2016). IoT Based Smart Garbage Detection System. www.irjet.net, 153–155.

Hong, I., Park, S., Lee, B., Lee, J., Jeong, D., & Park, S. (2014). IoT-Based Smart Garbage System for Efficient Food Waste Management. Retrieved September 2, 2017, from dx.doi.org: http://dx.doi.org/10.1155/2014/646953

Lombardi, M. A. (2002). Fundamentals of Time and Frequency. National Institute of Standards and Technology. Retrieved from https://tf.nist.gov/general/pdf/1498.pdf

Ludwig, R.-R. (2016, December 16). 5S Methodology and Software Development. Retrieved from Software Quality Characteristics in ISO 9126: https://rickrainerludwig.wordpress.com/2013/12/16/software-quality-charateristics-in-iso-9126/

Mahajan, K., &Chitode, P. J. (2014). Waste Bin Monitoring System Using Integrated Technologies. www.ijirset.com, 3(7), 14953–14957.

Malak, A., Bhoyar, P., Atkar, S., & Aryan, A. (2017). GARBAGE COLLECTION SYSTEM USING IOT - A REVIEW. www.ijrise.org, 6. Retrieved from www.ijrise.org|editor@ijrise.org

Monika, K. A., Rao, N., Prapulla, S. B., & Shobha, G. (2016). Smart Dustbin-An Efficient Garbage Monitoring System. Digital Object Identifier, 6(6), 7113–7116. Retrieved from https://doi.org/10.4010/2016.1694

Navghane, S. S., Killedar, M. S., &Rohokale, V. M. (2016). IoT Based Smart Garbage and Waste Collection Bin. www.ijarece.com, 5(5), 1576–1578.

Pandey, N., Bal, S., Bharti, G., & Sharma, A. (2015). Garbage Monitoring and Management using Sensors , RF- ID and GSM. www.ijiere.com, 2(3), 39-41.

Radhakrishnan, V. (2014). Innovative Research. http://www.psgias.ac.in/wp-content/uploads/2014/01/Innovative-Research.pdf.

Rangala, A. (2015, March 24). Invensis Global Outsourcing Services. Retrieved from What is White Box Software Testing: Advantages and Disadvantages: https://www.invensis.net/blog/it/white-box-software-testing-advantages-disadvantages/

Rosentrater, K. A. (2013). Literature Review for Seaweed Harvest Value Chain. AquaFish CRSP, Oregon State University. Retrieved June 12, 2017, from http://marineagronomy.org/node/474

Tapase, R. B., Mohite, A., Kadam, T., & Deshmukh, P. (2016). INTELLIGENT MONITORING SYSTEM FOR GARBAGE WASTE BINS USING ARDUINO. http://ijret.org, 2319–2321.

Thomas, A. M., Philip, A. R., Peter, T. E., R, E., N, P., & Working, I. I. (2016). Dust Bin Monitoring System. IJARCCE, 5(3), 1063–1065. Retrieved from https://doi.org/10.17148/IJARCCE.2016.53255

Vinothkumar, B., Sivaranjani, K., Sugunadevi, M., & Vijayakumar, V. (2017). IOT based Garbage Management System. www.ijsr.net, 6(3), 2015-2017.

Zeil, S. J. (2014, September 2). Software Development Process Models. Retrieved from Software Development Process Models: https://secweb.cs.odu.edu/~zeil/cs350/f14/Public/processModels/index.html

Solanki, A., & Nayyar, A. (2019). Green Internet of Things (G-IoT): ICT Technologies, Principles, Applications, Projects, and Challenges. In Handbook of Research on Big Data and the IoT (pp. 379-405). IGI Global.

Nayyar, A., Ba, C. H., Duc, N. P. C., & Binh, H. D. (2018, August). Smart-IoUT 1.0: A Smart Aquatic Monitoring Network Based on Internet of Underwater Things (IoUT). In International Conference on Industrial Networks and Intelligent Systems (pp. 191-207). Springer, Cham.

Puri, V., Nayyar, A., & Le, D. N. (2017). Handbook of Ardunio: Technical and Practice. Scholars Press.

Mahajan, K., & Chitode, J. S. (2014). Waste bin monitoring system using integrated technologies. *International Journal of Innovative Research in Science, Engineering and Technology*, *3*(7).