ISSN 2278-3091
Volume 9, No.5, September - October 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse64952020.pdf
https://doi.org/10.30534/ijatcse/2020/64952020

Design and Development of Smart Waste Management System: A Mobile App for Connecting and Monitoring Dustbin Using IoT

Na Jong Shen[1], Azham Hussain[2], Yuhanis Yusof[3]
[1]School of Computing, Universiti Utara Malaysia, Kedah, Malaysia
[2]School of Computing, Universiti Utara Malaysia, Kedah, Malaysia, azham.h@uum.edu.my
[3]School of Computing, Universiti Utara Malaysia, Kedah, Malaysia

ABSTRACT
The Smart Waste Management System is a very innovative system which will contribute to the path towards Smart City. In our city, we usually observe that the trash bins put at open spots are always over-burden. It forms unsanitary conditions to the city and it is not optimize to solve the problem by currently existing waste management in Malaysia. Also, the traditional way of manually monitoring the wastes in dustbins is a complicated process and excessive more human effort with expenses. To avoid all such situations, a project called Smart Waste Management System is implemented. This system is developed to perform the connectivity of mobile application with Internet of Things (IoT) based dustbins. These dustbins are developed using IoT. IoT is the system of physical devices implanted with software, sensors and network connectivity which empowers these items to gather and trade information. The status of dustbins will be determined using ultrasonic sensor and collected data send through network to the database. The mobile application is used to monitor dustbins and perform route direction to the dustbins. The methodology which applies in developing this project is Adaptive Software Development (ASD). The benefits of this scheme are to reduce used of human resources and efforts together with the enhancement of Smart City. The prototype of this project is evaluated by some users before published to ensure the system can be enhanced in future works.

Key words: Smart City, Smart Waste Management, mobile application, IoT, ultrasonic sensor.

1. INTRODUCTION

In the era globalization today, the smart city has become the trend and aim to be achieved by almost every country. To become a smart city, smart waste management is playing an important role in it.

Smart waste management is the upgrade or optimization of traditional waste management with information technology. Waste management is the movements and actions that needed to direct waste from its beginning to last disposal. In simplest terms, it can be defined as the collection, transportation, and disposal of garbage, and other waste products. In this Smart Waste Management System, Internet of Things (IoT) was used for implementing the project. IoT is a recent technique which allow the interconnection of object with network. The plan of new idea in IT domain is maintaining things internet of mutual.
IoT enables to interconnect endless of gadgets via web and it makes a rich circumstance by partner the contraptions with web and outcome them with ability to exchange as well as collect data. IoT depicts the universe of gadgets that are associated for allocating data to one another. These articles have exceptional characters. We can associate every items and robotize them using this innovation. In IoT there are essentially three operational bodies that are answerable for the whole correspondence [Sensors, Controller, correspondence Medium]. IoT can be characterized as the organization of articles with the assistance of installed sensors. These sensors gather data regarding their environmental factors and send the data to the dependable through remote organization. We have capacity to work numerous effects from one deice through the web of things. The IoT makes an upheaval in the field of mechanization [1] [2].

Besides, the system includes Android mobile application that allow user to get the output. The reason to develop mobile application within this project is because the mobile communication technologies are diffusing around the planet faster than any other communication technology to date. Nowadays, almost every people have their own smartphone, the size of smartphone is relatively smaller and lighter compare to computer or laptop. In addition, the performance of smartphone is getting better for now. Therefore, it is suitable to develop a mobile application for Smart Waste Management System.

2. BACKGROUND

2.1 Problem Statement

There was a recent survey has shown that no matter how well educated people are, when it comes to throwing out a wrapper of the food packet or any waste material, people do not bother where to throw it and solid waste became a big challenge [3] for the people. So, in order to curb these problems, dustbins have been provided in various localities

of the city. With the rising populace, growing urbanization, and alter in the lifestyle, waste management has become a confront not only for developing countries, but also for the developed ones [4]. By 2050, more than 84% population in the developed countries and more than 64% in the mounting ones will be in urban places [5].

Nowadays, we can see the traditional waste management system already cannot handle well to the waste. One of the problems that found is inefficient trash collection. For example, some dustbins are overfilled while others are underfilled by the trash collection time.

With the presented techniques of gathering and removal it is near unfeasible to direct such quantity of waste in the future as approximately 30% of waste end up on the roads and public places due to unproductive disposing and assembling techniques [6]. Besides, the problem of unoptimized truck routes during inefficient trash collection also causes excessive fuel usage and environmental pollution. Routes utilized by drivers are generally left to their discretion and this is completed except the operating cost reduction and environmental maintenance.

This state directs to elevated compilation and transport costs and also to environmental pollution [7]. According to this, the high operating expenses will also be a problem. So, I am developing the Smart Waste Management System which can fulfil the requirement and solve the problem.

2.2 Project Significance

This project will improve the wellbeing of workers and reduce operating expenses during process trash collection. Besides, this project is improving the trash collection process efficiency

2.3 Objective

This section describes the objectives of this project. There are several objectives that needs to be achieved in this project such as following:
a. To identify the requirements for Smart Waste Management System
b. To develop the prototype of Smart Waste Management System.
c. To evaluate the usability of Smart Waste Management System

2.4 Project Scope

The development of Smart Waste Management System is focused on several aspects which are Android mobile application, IoT, and user.

The mobile application is developed using Android Studio, which can only run on Android devices. To complete the prototype of this project, an IoT based dustbin was built by combining the sensor, controller and normal dustbin. Smart Waste Management System is mainly focus on trash collection workers as user.

3. METHODOLOGY OF THE STUDY

The methodology that chosen to apply in developing Smart Waste Management System is Adaptive Software Development. This methodology is executed in three-phase cycles. The phases of the cycles are Speculate, Collaborate and Learn.

The phases are named in a manner to highlight the function of change in the procedure. “Speculation” is used instead of “Planning”. Similarly, “Collaborate” focuses the importance of teamwork as the meaning of developing high-change systems. “Learn” stresses the require to recognize and respond to faults, and the reality that necessities may well change throughout the progress.

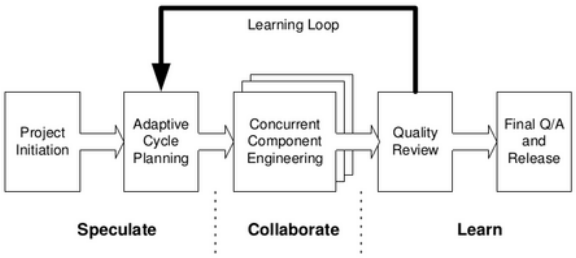

Figure 1: Shows the Adaptive Software Development Methodology

3.1. Speculate

The first phase is Speculate which includes “Project Initiation” and “Adaptive Cycle Planning” which means to understand and plan the project. Project initiation is determining the faced-problems and comes out with a project proposal which contains topic and solutions that can overcome the problems. After the topic is defined, it will proceed with adaptive cycle planning. In this step, developer will prepare the requirement specification together with guidance of supervisor. The functional and non-functional requirements will be created at this stage

3.2. Collaborate

Collaborate is the second phase. “Concurrent Component Engineering” will be carried on which means the modelling will be done in this phase. In other words, developer will start to develop and build the low fidelity prototype and high fidelity prototype.

3.3. Learn

The last phase is Learn. This phase includes the steps “Quality Review” together with “Final Q/A and Release”. In quality review, developer will implement the functionalities of system and testing evaluation. Developer will utilize the source code and prototype if the result is not satisfied. Then, the step final Q/A and release will proceed. Every user is allowed to comment and give feedback to the system based on their user experience. Developer will keep utilize the system after release of the system.

4. DESIGN AND DEVELOPMENT OF SMART WASTE MANAGEMENT SYSTEM

In this section, it describes the design and development of the Smart Waste Management System and initiates the requirement specification document that establishes entire system needs that will control the improvementnt and implements of Smart Waste Management System. It gives the purpose and the scope of the system and the definition of terms particular to the system.To develop the requirements for Smart Waste Management System, several research and discussions has been conducted with the program coordinator of School of Computing (SOC) in UUM. All the basic requirements are been combined with aim to develop the desired system. The functional requirements and non-functional requirements were listed down in Table 1 and Table 2 below together with their priority Mandatory (M), Desirable (D), and Optional (O).

Table 1: List of functional requirements of Smart Waste Management

Requirement ID	Requirement Description	Priority
WMS_01	**Register**	
WMS_01_01	User able to register an account with email, password and confirm password.	M
WMS_01_02	The system shall display error message if the compulsory field is not completed.	M
WMS_02	**Login**	
WMS_02_01	User able to login into the system with email and password.	M
WMS_02_02	The system shall display error message if the compulsory field is not completed.	M
WMS_02_03	The system shall display error message if the user enters wrong information.	M
WMS_02_04	User able to save their username and password in login page.	O
WMS_03	**Display Map Views**	
WMS_03_01	User able to see the map views.	M
WMS_03_02	The system require user to enable GPS.	M
WMS_03_03	User able to see their current location.	M
WMS_03_04	User able to see the dustbins' location.	M
WMS_03_05	User able to see the dustbin's status.	M
WMS_03_06	The system shall refresh the dustbins' status every 1 hour.	D
WMS_03_07	User able to zoom in and out the map views.	D
WMS_03_08	The system allows user gets the route direction from user's current location to dustbin's location.	D
WMS_04	**Logout**	
WMS_04_01	User able to logout the system.	M
WMS_05	**Detect Dustbins' Volume**	
WMS_05_01	The sensor shall detect the distance of dustbin and calculate in term of volume.	M
WMS_05_02	The system able to update the dustbins' status to real-time database.	M

Table 2: List of non-functional requirements of Smart Waste Management System

Requirement ID	Requirement Description	Priority
WMS_06	**Operational**	
WMS_06_01	The system can be accessed via internet.	M
WMS_06_02	The system can be used in any android devices.	M
WMS_07	**Performance**	
WMS_07_01	The system can be accessed within 24 hours per day and 365 days per year.	M
WMS_08	**Security**	
WMS_08_01	The system can be only accessed by registered email and password.	M

The use case diagram in Figure 2 below shows the behavior of the Smart Waste Management System.

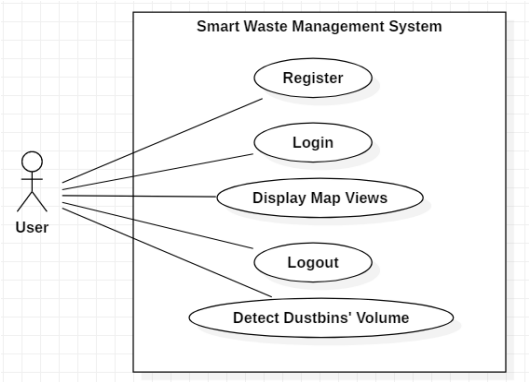

Figure 2: Use case diagram of Smart Waste Management System

The Figure 3, 4, 5, 6, and 7 below show the sequenced operations that performed in every functions clearly.

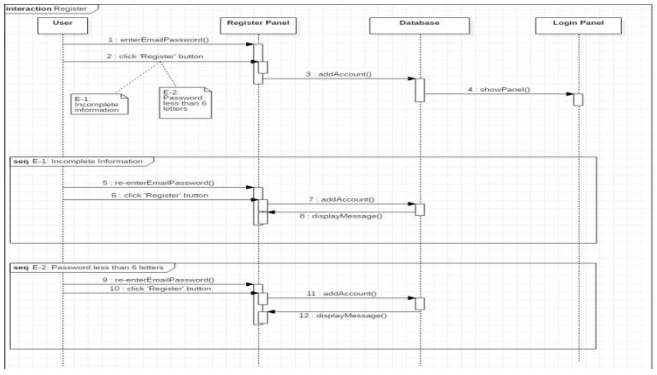

Figure 3: The sequence diagram of Register

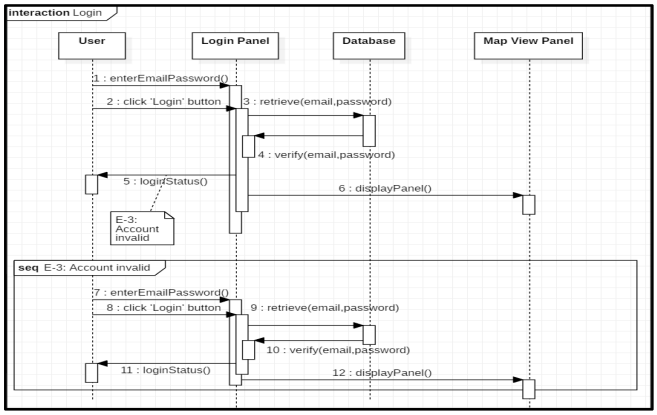

Figure 4: The sequence diagram of Login

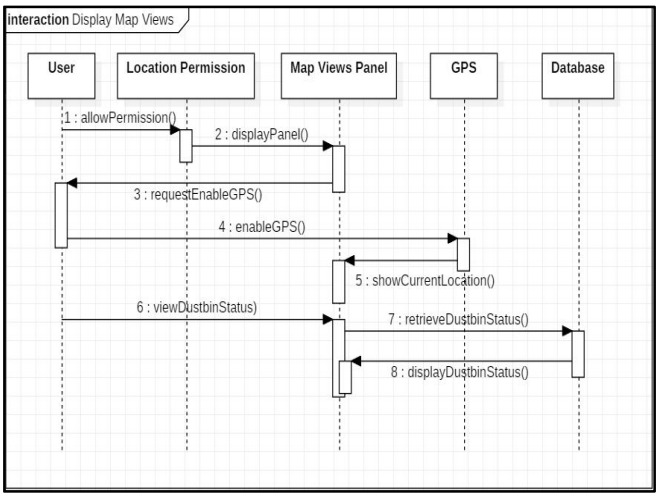

Figure 5: The sequence diagram of Display Map Views

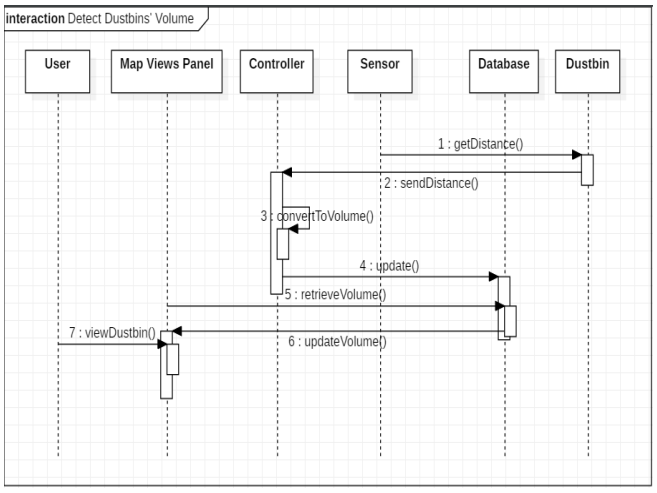

Figure 6: The sequence diagram of Detect Dustbins' Volume

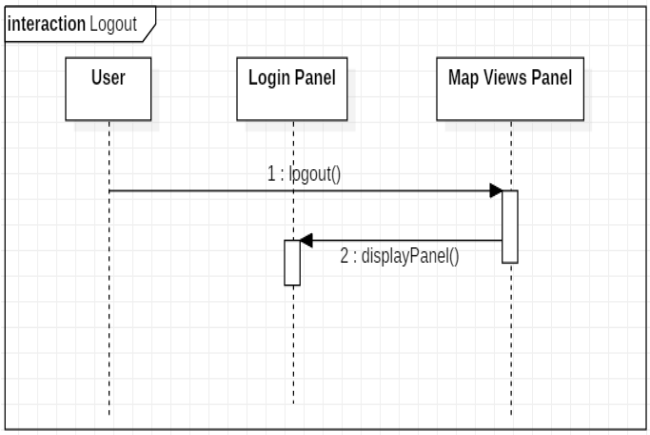

Figure 7: The sequence diagram of Logout

The structural components of the Smart Waste Management System are represented in a class diagram shown in Figure 8 below. It shows the operations and interactions between that performed between every classes.

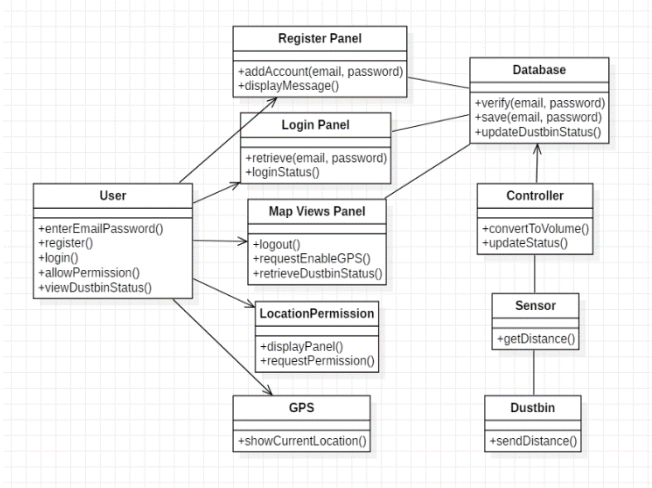

Figure 8: The class diagram of Smart Waste Management System

5. THE SMART WASTE MANAGEMENT SYSTEM PROTOTYPE DEVELOPMENT

The prototype of Smart Waste Management System was developed. The prototype is consisting the Android mobile application and IoT based dustbin. It means the requirements that interpreted in the prior subsection. Android Studio was utilized as the major incorporated development environment (IDE) device to develop the mobile application. Raspberry Pi was used as a processor to the dustbin's prototype which connects to ultrasonic sensor to detect the volume of the dustbin. The IDE tool that been used in programming the Raspberry Pi is Thonny IDE. Furthermore, the Firebase expansion platform was utilized to ease vital operations like user verification, and real-time file for storing the updated data from Raspberry Pi. Figure 9 below shows the step of using Android mobile application and Figure 10 shows the prototype of IoT based dustbin.

Figure 9: The interface of Android Application Smart Waste Management System

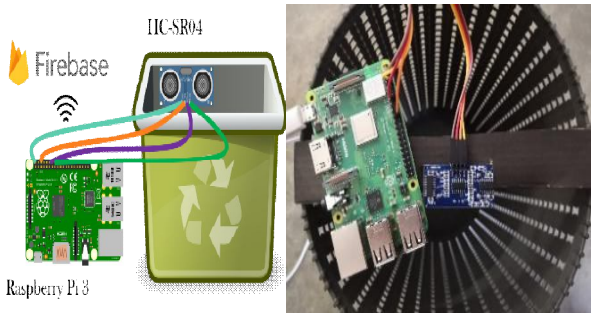

Figure 10: The prototype of IoT based dustbin

6. EVALUATION OF SMART WASTE MANAGEMENT SYSTEM

6.1. The Evaluation Setting

A survey was conducted with recruiting 5 respondents consisting of 3 male and 2 female participants for this study. Their age group all are between 21 to 25 years old. The instrument that used for the evaluation is questionnaire in form of Google Form.

The participants were receiving a google form link form developer through WhatsApp application. Participants were asked to download and install the Smart Waste Management Android mobile installation file through the link inside google form. The participants can fill in the Google Form after browsing the app.

6.2. The Respondents' Demographic Information

The results of respondent's demographic information show that 60% are male and 40% are female. All of the respondents' age group is between 21 to 25 years old. All of the respondents know about IoT. However, there are only 60% of respondents have ever use mobile app which can connect or interact to sensors, but 40% of respondents did no. Besides, there is only 20% of the respondents have ever heard about Smart Waste Management System before.

6.3. The Usability of Smart Waste Management System

An analysis was carried out on the participants' responses in Section B of the questionnaire. The part measures the respondents' view towards Smart Waste Management System.

The usefulness and ease of use of Smart Waste Management System are been analyzed through several questions. Moreover, the satisfaction of user and security level of Smart Waste Management System also are determined by asking few questions through the questionnaire. The scale that been used to measure for every section is 1 to 5 which are Strong Disagree, Disagree, Neutral, Agree, and Strongly Agree. All of the questions and data are shown in Table 3, Table 4, Table 5, and Table 6 below

Table 3: Usefulness of Smart Waste Management System

Questions:	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Smart Waste Management System enhances my effectiveness on monitoring dustbins' status.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System increases my productivity.	0 (0%)	0 (0%)	0 (0%)	3 (60%)	2 (40%)
Smart Waste Management System gives me greater control over my work.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System enables me to accomplish tasks more quickly.	0 (0%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)
Smart Waste Management System saves my time when I use it.	0 (0%)	0 (0%)	0 (0%)	2 (40%)	3 (60%)
Smart	0 (0%)	0 (0%)	0 (0%)	2	3 (60%)

Waste Management System meets my needs.				(40%)	
Smart Waste Management System does everything I would expect it to do.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System is useful in overall.	0 (0%)	0 (0%)	0 (0%)	3 (60%)	2 (40%)

Table 4: Ease of Use of Smart Waste Management System

Questions:	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Smart Waste Management System is easy to use.	0 (0%)	0 (0%)	1 (20%)	3 (60%)	1 (20%)
Smart Waste Management System is user friendly	0 (0%)	0 (0%)	0 (0%)	2 (40%)	3 (60%)
Smart Waste Management System is flexible.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System is easy to learn how to use it.	0 (0%)	0 (0%)	0 (0%)	3 (60%)	2 (40%)
I can use Smart Waste Management System without written instructions.	0 (0%)	0 (0%)	1 (20%)	3 (60%)	1 (20%)
I can easily remember how to use it	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
I don't notice any inconsistencies as I use Smart Waste Management System.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
I can recover from mistakes quickly and easily when using Smart Waste Management System.	0 (0%)	0 (0%)	0 (0%)	3 (60%)	2 (40%)
I can use Smart Waste Management System successfully every time.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)

Table 5: Satisfaction of Smart Waste Management System

Questions:	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I am satisfied with Smart Waste Management System.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System works the way I want it to work.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System is wonderful and pleasant to use.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)

Table 6: Security of Smart Waste Management System

Questions:	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Smart Waste Management System allows user to change their password at any time.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)
Smart Waste Management System only kept a single credential.	0 (0%)	0 (0%)	1 (20%)	3 (60%)	1 (20%)

Smart Waste Management System allows other users to use same email address and password.	0 (0%)	1 (20%)	0 (0%)	2 (40%)	2 (40%)
Smart Waste Management System authenticates users.	0 (0%)	0 (0%)	1 (20%)	3 (60%)	1 (20%)
Smart Waste Management System is secure and makes my work easier.	0 (0%)	0 (0%)	0 (0%)	4 (80%)	1 (20%)

7. CONCLUSION AND FUTURE WORKS

This paper described the design and development of android mobile app and IoT for monitoring the waste management system. The development of this system still can be improved widely. In future, we plan to expand the used of sensors in dustbins to improve the accuracy of detection and functionalities. The mobile application also can be developed for both Android and IOS user. Also, the user scope can expand to all residents in the cities and not only focus on trash collection workers. Furthermore, the machine learning technology can be added into the system to perform analysis of large volume of data.

ACKNOWLEDGEMENT

Authors wish to appreciate the support and assistance of Prof. Madya Dr. Yuhanis and Prof. Madya Dr. Azham bin Hussain towards the success of this research.

REFERENCES

[1] Monika Kashyap, Vidushi Sharma, Neeti Guptam, "Taking MQTT and NodeMcu to IOT: Communication in Internet of Things", *International*

[2] *Conference on Computational Intelligence and Data Science (ICCIDS 2018), Proceddia Computer Science 132* (2018) 1611-1618.

[3] Ajmal Khan, et.al, "IoT based smart waste bin to track dustbin and public complaint management system." *8th IEEE International conference Communication System and Network Technology* -2018, DOI-10.1109/CSNT.2018.8820272.

[4] Guerrero L.A., Maas.G, Hogland.W, "Solid waste management challenges for cities in developing counties," *Journal of Waste Management.*

[5] "Municipal solid waste: Is it garbage or gold?" *UNEP Global Environmental Alert Service (GEAS)*, October 2013.

[6] Caniato, Marco, Mentore Vaccari, Chettiyappan Visvanathan, and Christian Zurbrugg. "Using social network and stakeholder analysis to help evaluate infectious waste management: A step towards a holistic assessment." Waste Management, 34, no. 5, 938-951, 2014.

[7] Zurbrugg, Christian. "Urban solid waste management in low-income countries of Asia how to cope with the garbage crisis." *Presented for: Scientific Committee on Problems of the Environment (SCOPE) Urban Solid Waste Management Review Session, Durban, South Africa* (2002): 1-13.

[8] Sulemana, Alhassan, Emmanuel A. Donkor, Eric K. Forkuo, and Sampson Oduro-Kwarteng. "Optimal routing of solid waste collection trucks: A review of methods." *Journal of Engineering* 2018 (2018).