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E-Recycle Bin: An IoT Based Model for Solid Waste Management

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ABSTRACT

This study focused on developing a Smart Bin Prototype by integrating Internet of Things(IoT) Technology in a Barangay Based Material Recovery Facilities (BBMRF) that is capable of printing a receipts based on the equivalent value of recyclable waste deposited in the bin which is called the e-Recycle Bin. The generated data from the e-Recycle Bin prototype is send in the clouds used by the web application to generate analytical report for monitoring purposes. This research used descriptive method and Rapid Application Development (RAD) methodology in developing the e-Recycle Bin prototype. This study explored the used IoT components namely, Rapsberry pi, Arduino Mega, SIM800 GSM Module, Straight Bar Load Sensor, Ultrasonic Sensor, IR Proximity Sensor, 2x4 LCD Monitor, and thermal printer. The IT experts evaluated the project and at overall weighted mean of 4.91 and a qualitative description of Very High Extent of compliance with ISO 25010:2015 Software Quality Requirements. This study sought the implementation of the developed system in the City of Ilagan to help mitigate solid waste problems and encourage waste recycling among the city residents.

Key words : Arduino, CENRO, Internet of Things (IoT), ISO, Raspberry-Pi, Smart Bin, Solid Waste Management (SWM).

1. INTRODUCTION

Reducing waste is among of the primary concern that arises in every growing city. As economic development and population growth continue to increase in the city, the amount of waste generated in the place also increases. In the paper of [1], [2], and [3] the waste in world cities is projected to increase by up to 70 percent from 2.1 billion tons to 3.4 billion tons by the year 2050. These alarming rate calls for a collective action from the government, public, and private sectors to find a smarter and sustainable solution to manage solid waste. As a response to this impending crisis, the Philippine government enacted and passed Republic Act (RA) 9003[4], an act that provides an Ecological Solid Waste Management Program that mandates publics officials from the national to the barangay level to perform their duty to solve waste problem in the country. The RA 9003 empowers the Local Government Unit(LGU) to directly develop sustainable actions for solid waste management within its jurisdiction. The call of the National to Government to adopt a systematic ecological solid waste management program that to ensures the protection of public health and environment was rejoined by many cities in the country.

The City of Ilagan is one of the fastest growing cities in Region 2 and it has embarked its commitment towards solid waste management. The City aimed to be the first sustainable and livable city in the region by the year 2030. In its anticipation to the impending generation of waste in its city, it has conducted a Waste Analysis Characterization Study (WACS) to formulate a 10 year Solid Waste Development Plan and imposes program like "No Segregation, No Collection Policy", and setup a Barangay-Based Material Recovery Facility (BBMRF) in its 91 barangays that serve as a separation waste facility to encourage waste recycling and lessen the generated wastes that reaches the land fill.

As an advocate for sustainable and livable city, the researchers conducted this study relating to Solid Waste Management with the integration of Internet of Things (IoT) to help the City of Ilagan implement a smarter solution in managing solid waste.

The purpose of this study is to use IoT technology as a smarter approach to manage solid waste. IoT sensor is embedded in a Barangay Base Material Recovery Facility to developed Smart Bin Prototype that is capable of printing a receipts point's base on the amount of recyclable waste deposited in the bin. The Smart bin can also generate and send data to clouds that will be later used to monitor the status of the bin and generate analytical reports for authorities like the threshold level of the bin, the receipts points generated, number of interaction of citizen to the bin, the locations the bin, and the fastest route map to the bin. The developed Smart Bin Prototyped is called the e-Recycle Bin.

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HC-SR04	
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 Table 1: Studies Conducted Related to IoT Based Model Solution in Managing Solid Waste

Table 1 shows the related studies conducted in relation to IoT based Model solution which help the authors established a solid foundation and understanding of the study.

2. METHODOLOGY

The study used descriptive and system development methods. The descriptive approach is used in the in-depth analysis of the situation, condition, role, and processes involve in Solid Waste Management in the City of Ilagan. The researcher used this paper [23] as a guide to develop the system. The Rapid Application Development (RAD) methodology has been chosen as the processes involve in the RAD model provides a holistic approach in building the project in the shorter time possible focusing on prototype development. Figure 1 depicts the RAD model adopted in this study.

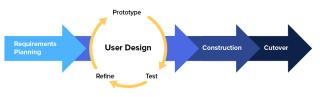


Figure 1: Rapid Application Development

In this study the researcher gathered requirements, facts and information from CENRO personnel, barangay officials and residents to established unknown and observed policies and problems regarding Solid Waste Management in the City of Ilagan this is to provide the researcher an overview of the processes and deliverable needed in the study.

The design structure and construction of the bin is initiated and is patterned to the existing Barangay Base Material Recovery Facilities (BBMRF) deployed in the barangay's of City of Ilagan. After the construction the necessary IoT sensors and hardware components is embedded to build the e-Recycle Bin prototype. The Prototype is interface with a Web Application accessible to intended users and to generate analytical report needed for monitoring purposes. The developed system was provided for review and participated by the IT experts and participants from Barangay Sta Barbara, City of Ilagan to assess the ability of the developed system. The study underwent ethics review at St. Paul University Philippines.

3. RESULTS AND DISCUSSIONS

3.1 E-Recycle Bin Prototype Developed for Solid Waste Management

The e-Recycle Bin Prototype was developed embedded with IoT sensors and hardware component interface with a Web Application that can generate analytical report for monitoring purposes. The e-Recycle Bin can also generates receipts points for recyclable waste deposited in the bin and provides a SMS notification alert for recyclable waste collector if the bin is full.



Figure 2: e-Recycle Bin

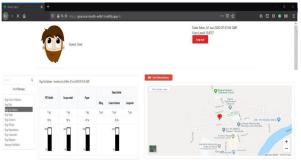


Figure 3: Web Application



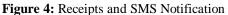


Figure 2, 3, and 4 shows the screenshots of the developed system.

3.2 The Extent of Compliance to ISO 25010:2015 Software Quality Standard

The developed system overall result in evaluating its framework using ISO 25010:2015 Software Quality Standards is Very High Extent as evaluated by the residents and IT Experts. The developed system was assessed and evaluated base on the functionality, performance, compatibility, usability, reliability, security, maintainability and portability. Table 2 illustrates the weighted means of the assessment.

VHE -	- Very	High	Extent
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Category	Resid	lent	IT Ex	perts	Overall	
	Weighted	Descrip	Weighted	Descrip	Weighted	Descrip
	Mean	tion	Mean	tion	Mean	tion
Functionalit	5.00	VHE	4.90	VHE	4.95	VHE
У						
Performance	5.00	VHE	4.83	VHE	4.92	VHE
Compatibilit	5.00	VHE	4.90	VHE	4.95	VHE
У						
Usability	5.00	VHE	4.85	VHE	4.93	VHE
Reliability	5.00	VHE	4.80	VHE	4.90	VHE
Security	5.00	VHE	4.78	VHE	4.89	VHE
Maintainabi	5.00	VHE	4.77	VHE	4.89	VHE
lity						
Portability	5.00	VHE	4.68	VHE	4.84	VHE
Overall	5.00	VHE	4.81	VHE	4.91	VHE
mean						

Table 2. Summary of the System Compliance to ISO25010:2015 Software Quality Standard

All the resident-participants assessed the developed system gave the 5 as the highest score in all 8 areas of ISO standards. This implies that user of the developed system were satisfied with the features and value of the developed system. The IT experts-participants had a 4.91 overall weighted mean as assessed as a very high extent compliance with the ISO standards.

4. CONCLUSION AND FUTRE WORK

The developed systems met the ISO 25010:2015 software quality standards and could be enhanced by integrating features like dust and water resistant enclosure for IoT components, object identification and recognition features, beep card as a permanent storage of points earned, and developed mobile application to interface with the e-Recycle Bin Prototype.

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