



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.

1.1 Related Studies

Authors	Title	Nature of the System Developed	Contribution, Similarities, Difference with this Study
O. Rybnytska, F. Burstein, A. V. Rybin., A. Zaslavsky.[5]	Decision support for optimizing waste management	This study developed a decision support system for sustainable garbage collection route planning and optimization .	The study increased the effectiveness of municipal waste management intended to aid a dispatcher in providing the optimal route problem for garbage collection based on the capacity and type of the trucks. It focused more on the use of technology to improve the efficiency on garbage collection,
K. Deka, K. Goswami, A Sagarika [6]	IoT-Based Monitoring and Smart Planning of Urban Solid Waste Management	This study developed a system that monitors and manages waste collection in real time.	The system provided insights on how IoT can determine the status of waste generated in the city. It focused on smart system that includes

			on-site handling, storage, and transfer process using cost-efficient and quality system.
Gattim N.K., Krishna M.G., Nadh B.R., Madhu N., Reddy C.L. [7]	IoT-Based Green Environment for Smart Cities.	The study developed smart waste container that could indicate the level of waste to the concerned authorities.	The developed system provided inputs on how IoT based system can detect and avoid overflowing of garbage in the bin by immediately notifying garbage truck collector.
D. Misra, G. Das, T. Chakraborty, & D. Das [8]	An IoT-based waste management system monitored by cloud	The study developed a smart waste bin that uses ultrasonic sensor and gas sensor to automatically sense hazardous gases and monitor the max limit of waste in the bin. It uses cloud and mobile apps linked in the bin for authorities to virtually monitor the status of the bin.	The system provided benchmarking opportunities for the researchers on how to create an efficient waste collection processes which save money, power, and time
K. Pardini, J. J. P. C.	Smart Waste	This paper proposes an	The proposed

Rodrigues, S. A. Hassan, N. Kumar and V. Furtado.[9]	Bin: A New Approach for Waste Management in Large Urban Centers.	integrated system combining identification through ultrasonic sensors and load cell sensors, location by Global Positioning System (GPS), and communication through Global System of Mobile Communications (GSM) / General Packet Radio Service (GPRS).	study provided inputs to the researchers on how to develop a smart waste bin. Bins could be easily integrated with the municipal collection service and assists in efficient collection scheduling promoting optimized routes.
P. Haribabu, S. R. Kassa, J. Nagaraju, R. Karthik, N. Shirisha and M. Anila.[10]	Implementation of an smart waste management system using IoT.	This study developed a mobile application associated with a Smart Trash Bin interfaced with a GSM modem and equipped with Ultrasonic sensor (HC-SR04).	The study provided insights on how to replace traditional bin in the city and manage waste efficiently as it avoids unnecessary lumping of waste on roadside which becomes a breeding grounds for mosquitoes and insects.
C. J. Baby, H. Singh, A. Srivastava, R. Dhawan and P. [11]	Smart bin: An intelligent waste alert and prediction system	These papers developed a smart bin and collects and analyze waste information	The proposed system provided inputs on how to save both money

	using machine learning approach .	using machine language concepts to predict the amount of waste generated in the future	and time spent by the authorities in manually tracking all the dust bins. The study provided insight how to provide a map route that can be used by collector to lessen travel time and cost.
D. W. Shiju[12]	Canny Junk System based on IOT	This study uses ultrasonic sensor. Arduino UNO was used to check the level of waste filled in the dust bin and sends alert to the common web server once if waste is filled. Once a particular level is sensed, information SMS message is sent requesting clean-up. Sensor such as Radio Frequency Identification (RFID) and sensor networks optimize the	The study provided inputs how e-Recycle Bin can be set up.

		waste management .	
Mahajan S. A., Kokane A., Shewale A., Shinde M., Ingale S. [13]	Smart Waste Management System using IoT	The study presented an IoT model for real-time monitoring the garbage level of respective garbage bins and to detect the level when threshold value is reached using combination of Sensors and Raspberry pi.	It provided inputs on how to use GSM module as a communication device to transmit data that is design and embedded in the developed system
U. Ravale, A. Khade, N. Patel and S. Chaurse [14]	Smart Trash: An Efficient Way for Monitoring Solid Waste Management	The study designed a Smart dustbin that can transmit alert SMS messages to the municipal garbage collector regarding the volume of the waste in a bin whether it is full or half full.	The paper help the researcher to used SMS as a notification alert system efficiently collection of recyclable waste in the bin.
T. S. Vasagade, S. S. Tamboli and A. D. Shinde[15]	Dynamic solid waste collection and management system based on sensors, elevator and GSM	This paper developed a Smart Solid Waste Collection embedding IR sensor, GSM, Alarming system, Mechanical Shaft and	The study provides optimum solution for the major issues of managing solid waste properly in terms of collecting and

		Elevator Assembly; the develop system not only monitors waste level in the dustbin and alerts authorities but also senses waste that overflow outside the bin and immediately notifies users whether wastes deposited in the bin are properly placed or not.	cleaning waste. This paper provided input a smarter solution to manage solid waste.
A. Jain and R. Bagherwal [16]	The design and implementation of a smart solid waste monitoring and collection system based on Internet of Things	The study developed an IoT based smart waste management system monitoring the status of the dust bin located in different places if it's semi-full, empty or completely full by embedding RL Renesas microcontroller and sensor such as ultrasonic sensor, force sensor, PIR sensor, GPRS, GPS.	The system provides an efficient collection of garbage providing collector with real time location and status of the bin. This provides inputs of the needed sensor to build the prototype.
P. S. N. Reddy, R. N. Naik, A. A.	Wireless dust bin monitoring	The study developed a system that	The system provided insight on

Kumar and S. N. Kishor[17]	ng and alert system using Arduino	provides alert to local authorities responsible of collecting waste if the garbage bin is not cleared from any waste in specific period of time. It uses an Ultrasonic sensor to measure level of waste in the dust bin, an Arduino microcontroller is used to manage sending of information VIA Bluetooth to the server which processes information and sends SMS alert to authorities via GSM module sensor.	how to monitor the threshold level of the developed prototype.
S. Kanta, S. Jash and H. N. Saha[18]	Internet of Things based garbage monitoring system	This paper used IoT technology sensor such as wireless sensor network to provide an efficient garbage collection system by sending information to the municipal	The projects help save time, reduce cost, human effort and are more efficient compared to the previous manual collection of waste. The wireless communica

		waste collector about the level of waste in the bin.	tion concept in this paper provide input how to transmit data efficiently in the cloud using SMS.
N. Muyunda and M. Ibrahim[19]	Arduino-based smart garbage monitoring system: Analysis requirement and implementation	This paper presented a solution that allows the city authorities to manage resources in the collection of garbage and provide a platform that will allow an efficient garbage collection system.	The system provides a solution to a cost efficient waste management system. The study provided insight how to collaboratively involve LGU, residents, and waste entrepreneurs in a cost efficient handling of waste using IoT platform
T. P. Fei, S. Kasim, R. Hassan, M. N. Ismail, M. Z. M. Salikon, H. Ruslai, and M. S. Arshad[20]	SWM: Smart waste management for green environment	The paper developed a smart waste management system that tracks the status of level of trash bins equipped with ultrasonic sensors and GPS for a greener environment design with Bootstrap platform.	The developed system helps trash collection routine become more efficient and help contribute to a greener environment The concepts of the paper established

		The system provides an effective way to detect trash bin that require an immediate collection by incorporating sensor in the bin.	a strong foundation to the researcher in using smart sensor to manage solid waste
A. Mohan, S. Johar and S. Mini [21]	A Waste Collection Mechanism based on IoT.	This paper presented IoT based smart waste collection system that provides information to a certain municipality on which wastes are collected on time. The method is supported using Ultrasonic sensor, weight sensor, and MQ gas sensor that is attached to a microcontroller. It read thresholds values of the bin and sends alert to the municipality server.	This system reduces the human intervention in waste management and monitoring. This paper provided insights on how to Manage solid waste without too much human intervention.
S. Idwan S, J. A. Zubairi and I. Mahmood [22]	Smart Solutions for Smart Cities: Using Wireless Sensor Network for Smart Dumpste	This paper developed a system that finds optimized path and resources optimization for solid waste	The simulation conducted of the set of dumpsters served by a single truck shows that the total length of

	r Management	collection in a smart city environment . Using a Smart dumpster with a HC-SR04 sensor is modeled agent.	the trip is reduced substantially if the fill level is known in advance. The study provided inputs of optimizing travel route to the bin.
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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.

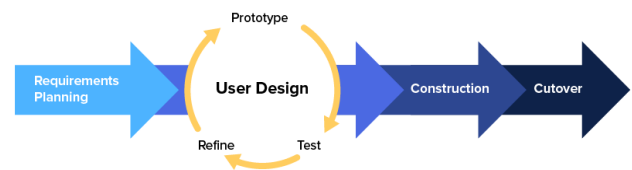


Figure 1: Rapid Application Development

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

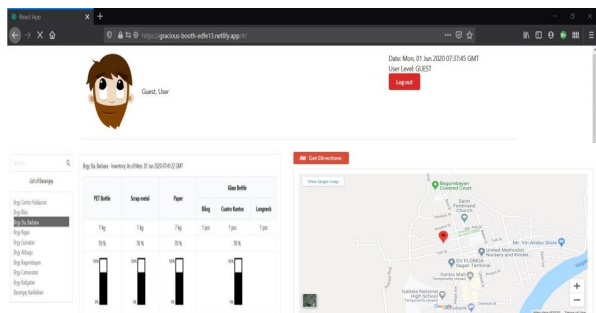


Figure 3: Web Application

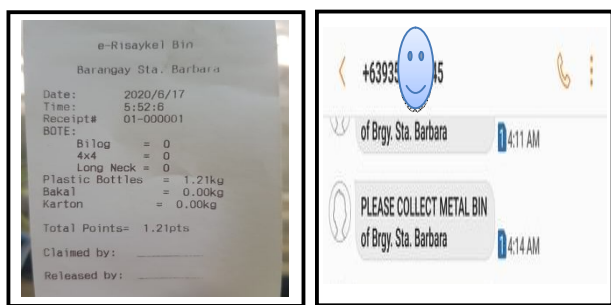


Figure 4: Receipts and SMS Notification

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

Category	Resident		IT Experts		Overall	
	Weighted Mean	Description	Weighted Mean	Description	Weighted Mean	Description
Functionality	5.00	VHE	4.90	VHE	4.95	VHE
Performance	5.00	VHE	4.83	VHE	4.92	VHE
Compatibility	5.00	VHE	4.90	VHE	4.95	VHE
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
Maintainability	5.00	VHE	4.77	VHE	4.89	VHE
Portability	5.00	VHE	4.68	VHE	4.84	VHE
Overall mean	5.00	VHE	4.81	VHE	4.91	VHE

Table 2. Summary of the System Compliance to ISO 25010:2015 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.

ACKNOWLEDGEMENT

The author is very much grateful to Graduate School of St. Paul University Philippines, Commission on Higher Education (CHED) for the Scholarship Grant given to the author, CENRO personnel City Of Ilagan especially to CENRO OIC Arvin Perez and to all the member of Isabela State University System and most especially to my ISU Ilagan Campus.

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