THE EFFECTIVENESS OF SEGREGATION RECYCLABLE MATERIALS BY AUTOMATED MOTORIZED BIN

S. Norhafiza[1], K. Masiri[1], A. Nor Faezah[1], A.L. Nurul Nadiah[2] and A. K. Aslila[1]

[1] Centre of Diploma Studies,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja,
Batu Pahat Johor.

[2]Faculty of Civil & Environmental Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja,
Batu Pahat, Johor

Corresponding Author's Email: [1]hafiza@uthm.edu.my

ABSTRACT: Recycling bins that have been introduced in the 3R campaign (Reduce, Reuse, and Recycle) are not optimally used by Malaysians. The research is an initiative to sort recyclable materials. The proposed research is an invention of automated isolation recycling bin where the bin equipped with several electronics components such as sensors and motors. The purpose of the sensors and motors are to enable the isolation process so it can be completed automatically with the aid Arduino Uno program. The installation of three types of sensors which are inductive sensor, capacitive sensor and infrared sensor will detect the type of recyclable materials that are inserted into the bin. Circular plate and pusher will be driven by DC motor to three compartments which are the bins for metal, paper and plastic. However, the materials will be discarded when the pusher plate is triggered by DC motor. The process of analyzing the effectiveness of this invention can be accomplished by recording the time taken for the product to separate the recyclable materials.

1.0   INTRODUCTION

The growing population in Malaysia has contributed towards higher production of domestic solid waste. The rate of generation of domestic solid waste per capita produced by the urban and rural citizens have increased to 1.5 kilogram and 0.8 kilogram respectively resulting in a total of 18,000 tons of waste generated every day [1] with 70-80% of the waste composition are recyclable [2-4]. As a result, the landfills started to fill up faster hence reducing the number of available landfills for waste management.

Generally, these solid wastes can categories up to 20 different types which is food waste, paper (mixed), cardboard, plastics (rigid, film and foam), textile, wood waste, metals (ferrous or non-ferrous), diapers, newsprint, high grade and fine paper, fruit waste, green waste, batteries, construction waste and glass [5]. It is about 60% wastes are recyclable items [6]. However, all of this composition wastes normally dumped together without any attempt for recovering or recycling.

Nowadays, the local communities have higher awareness of the importance of recycling solid waste compared to the general public [7]. Educating the public about the importance of recycling can increase the recycling rate [6, 8]. The recycling facilities provided by the Local Authority (PBT) have managed to improve the awareness of some local communities. While the rest have shown lack of interest proved by the missing recycle bins [9]. However, at current state of 5% recycling rate, a lot more awareness programs are required to achieve the 22% target by 2020 [2].

Recycling is a hassle for most people. For them, it is easier to put all the trashes into a bag and toss it into the general thrash bin instead of separating them into the categories for the recycling bins. Besides that, the current recycle bin is consisting of three different barrels such as paper, glass and plastic/aluminum consumed a huge space in public places.

This research was conducted to design, develop, test and analyze the effectiveness of the proposed recycling bin with respect to time

required to separate recyclable materials. This invention provides a practical solution to reduce daily inconveniences faced by consumers during recycling activity whereby it helps to sort the recyclable materials automatically through the use of different sensors mounted at the recycle bin's opening. The proposed automated isolation recycling bin utilizes AC supply from the mains for simplicity and less maintenance work. Through its convenient operation, it is thus expected to attract more people to recycle.

1.1 Literature Review

Reuse, recycle and recovery of valuable components of waste stream were given more attention in municipal solid waste management system (MSWMS) in both developed and developing countries [10]. Society typically treats trashes as unwanted materials which were dumped without knowing the correct method to manage them sustainably.

Creative entrepreneurs should take advantage of recycling as a profitable activity. This situation can be seen through a survey studied the recycling activity of the urban poor in Jakarta, Indonesia in the context of sustainable solid waste management [10]. The recycling business may generate monthly profits between Rp 99,960,000,000 (RM33 million) to Rp 200,940,000,000 (RM66 million) for the residents of Jakarta.

The increment of non-biodegradable products in global market has led to the increment of non-disposal waste. Based on the research findings obtained by the Department of Municipal Solid Waste Management, the composition of non-recyclable materials in food waste were 43% compared to 53% of recyclable materials which translates to higher demand for recycling activity. The existing recycling bin is large in size. Therefore, major operators like the shopping centers were reluctant to provide the bins due to space constraint. Figure 1 shows the existing recycling bin.

Figure 1: Existing Recycle Bin

1.2 Previous Project

The proposed recycle bin was developed to perform automatic isolation of recyclable materials via implementation of one recycle bin only. Previously, several projects related to recycling bin improvement have been developed such as Smart Recycle Bin proposed by students from University of Michigan, USA [11], Smart Recycling Bin with LCD [12] and also Smart and Reward Bin that operated using solar power [13]. Renewable energy such as solar energy has been applied as the power supply on these researches.

An interactive WeRecycle Bin such in [14] was able to attract users which contribute to higher recycling rate. Recycle bins equipped with internet of things (IoT) was developed to monitor the amount of wastes at each location and to identify the most optimized location for the recycle bins and to optimize wastes collection management [15-16]. Similarly, [17] has also utilized integrated web based system to enable points-based reward program for active users through RFID identification. RFID tags were also implemented in [18] to sort wastes automatically.

Larger scale recycling process can be achieved through a more structured waste monitoring and management system [19] which used the RFID, GPRS and GPS and working in real time while a state of the art recycling system via implementation of advanced control system and various sensors [20].

2.0   M E T H O D O L O G Y

A product has been designed and developed as an alternative to increase the efficiency of the existing recycling bin which is produced in three colours namely brown, blue and orange. The efficiency of the product is measured via the time taken to sort the recyclable materials in three different categories; metal, plastic and paper. The development process were divided into three main stages, product design stage, hardware development stage and final stage to test and analyze the effectiveness of the final product.

2.1   Product Design

A typical barrel type trash bin as shown in Figure 2 was selected as the frame for the proposed recycle bin. This trash bin design is very user friendly as the user are not required to lift the bin's lid. It also required a less space compared to the existing recycling bin.

Figure 2: Trash bin

Modifications of the trash bin are shown in Figure 3 and 4. The bin's main body was divided into 3 compartments for the 3 types of recycling wastes; paper, plastic and metal while internal part of the lid contains electronic components, a circular plate with a hole and a pusher plate to push the trash into its respective compartment. The main control box is attached on the side of the lid.
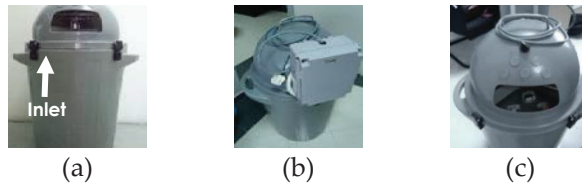

| (a) | (b) | (c) |

Figure 3: External view of modified trash bin, (a) Front view,
(b) Rear view and (c) Top view
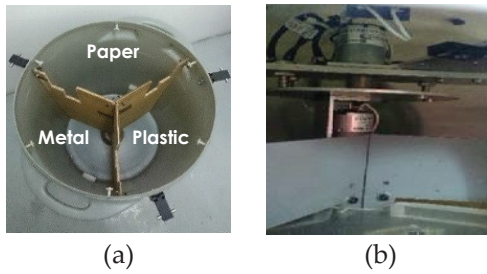
(a)   (b)

Figure 4: Internal view of modified trash bin, (a) main body and (b) lid

2.2 Hardware Development

Selection of electronic components and programming occurred in this stage. The electronic components installed inside the lid consist of 2 DC motors and 4 sensors as shown in Figure 5.
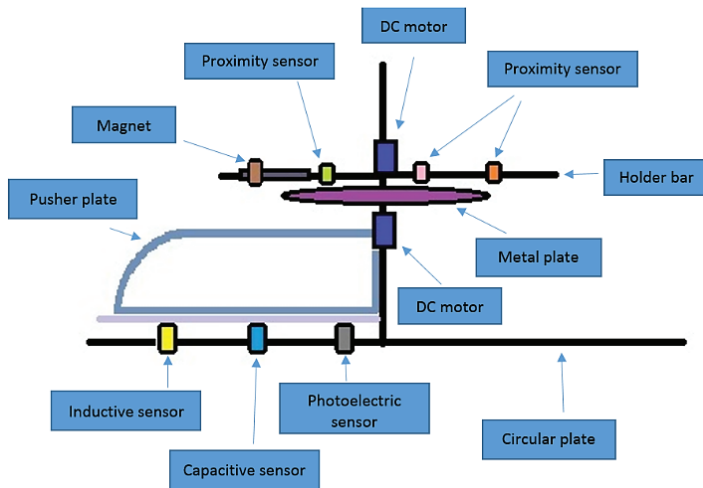

Figure 5: Electronic components arrangement

Top DC motor will rotate the circular plate while the bottom DC motor rotates the pusher plate. The sensors implemented in this project are depicted in Table 1.

Table 1: Sensor type and functions

No.	Sensor type	Function
1	Capacitive Sensor	Detect metal
2	Inductive Sensor	Detect plastic
3	Photoelectric Sensor	Detect paper
4	Proximity sensor	Detect motor position

The main control box contained Arduino Uno controller, motor driver and an AC to DC converter. Arduino Uno controller played an important role to receive and compute data from the sensors. The controller has been programmed to activate the DC motors accordingly. AC supply sourced from the mains is converted to DC to operate all the electronic components.

2.3   Test and analysis

The testing process involves operation/function test and response time test. The operation/function test was conducted to validate the recycle bin's operation as per designer's specification while the latter test was done to analyse the effectiveness of the recycle bin in terms of time taken to isolate each material.

The response time test was carried out three times for each type of material in order to get the average reading of the time response of the bin. Time is taken once the circular plate starts moving as well as the pusher. The reaction circular plate resembles the time required for Motor 1 to response due to the presence of recyclable materials. The time taken for pusher plate to react resembles the time response for Motor 2. Total time is taken starting the recyclable materials are inserted until they reach the bin's compartment. Based on the results acquired thus, the average time was calculated.

3.0   RESULTS AND DISCUSSION

The results from both tests were documented as below.

3.1   Operation/Function test

Isolation of recyclable materials occurs through four stages as shown in Figure 6. The operation was started by inserting the recyclable materials one by one through the bin's inlet. The material was placed right on top of the sensors which were located on the circular plate. When one of the sensors detects the type of the recyclable material, the top motor will start to rotate the circular plate to align the hole with its respective waste compartment. Once aligned, the bottom motor will then rotate the pusher plate towards the same position and the recyclable material will fall into its compartment through the hole.

Overall, the recycle bin has completed the isolation process for each material successfully according to its category.
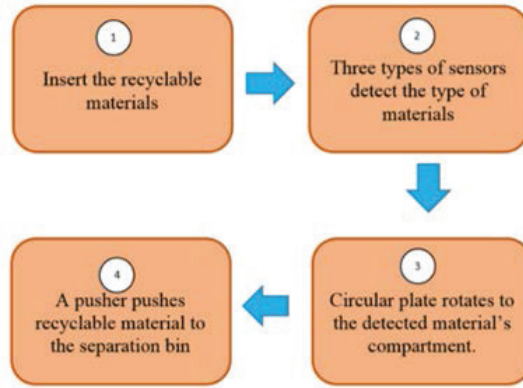

Figure 6: Electronic components arrangement

3.2 Time response test

Tables 2-4 show the results acquired from the tests where M1 and M2 are the time response for motors 1 and 2, respectively while Table 5 shows the calculated average time response.

Table 2: Time response for Test 1

Materials	Test 1		
	M1	M2	Total time, s
Metal	0.7	0.2	2.1
Plastic	0.9	0.2	2.3
Paper	0.5	0.2	1.9

Table 3: Time response for Test 2

Materials	Test2		
	M1	M2	Total time, s
Metal	0.6	0.2	2.0
Plastic	0.8	0.2	2.2
Paper	0.5	0.2	1.9

Table 4: Time response for Test 3

Materials	Test 3		
	M1	M2	Total time, s
Metal	0.7	0.2	2.1
Plastic	0.8	0.2	2.2
Paper	0.7	0.2	2.1

Table 5: Average time response

Materials	Average			
	Test1	Test 2	Test 3	Total time, s
Metal	2.1	2.0	2.1	2.1
Plastic	2.3	2.2	2.2	2.2
Paper	1.9	1.9	2.1	1.9

Based on the data obtained from time response of Test 1, Test 2 and Test 3 thus, the time taken for motor 1 to response with the presence of metal are 0.7s, 0.6s and 0.7s, respectively. Moreover, the times taken for motor 1 to response with the presence of paper are 0.5s, 0.5s and 0.7s, respectively. It can be noticed that, the differences of time response between these two materials are close. However, it also observed that, the times taken for motor 1 to response to the presence of paper are slightly higher. The times recorded are 0.9s, 0.8s and 0.8s, respectively.

The differences are influenced by the physical condition and colour of the recyclable materials whereby the metals and papers also can be seen as opaque materials while most of the plastic materials were transparent.

Detection of transparent material takes longer time compared to opaque material. This is because the sensor used depends on the concept of cutting the beam of light emitted by a photoelectric sensor to sensor distance or proximity. Opaque material will cut the beam of light and receive an immediate response of the motor action. However, the transparent material requires more time to cut the beam of light as the light emitted from the photoelectric sensor which successfully penetrates the material.

Regardless of considering the time response, the product assists in sorting materials without depending on human reasoning and evaluation.

4.0 CONCLUSION

The biggest environmental challenge facing the automated isolation recycling bin is the implementation of 3R strategy. Waste processing and recycling have been the world wide key technologies during the

last two decades. In promoting the performance and efficiency of automated isolation recycling bin in the developed countries therefore, the main concern of municipalities is the sound management of recyclables [8].

In this paper, the application of robotic and Arduino Uno technologies in the development of recycling bin especially for an advanced recycling were discussed. Arduino Uno technology is emerging very rapidly in development of recycling bin industry and it will penetrate faster in the near future.

ACKNOWLEDGMENTS

REFERENCES

[1]   S. Azrina. (2015). *Pengurusan Sisa Pepejal di Malaysia dan Masalahnya* [Online]. Available: http://www.ikim.gov.my/index.php/ms/artikel/7193-pengurusan-sisa-pepejal-di-malaysia-dan-masalahnya.

[2]   Y.C. Moh and A.M. Latifah, "Overview of household solid waste recycling policy status and challenges in Malaysia," *Journal Resources, Conservation and Recycling*, vol. 82, pp. 50–61, 2014.

[3]   Y. Sumaiani, C.C. Onn, M.A. Mohd Din and W.Z. Wan Jaafar, "Environmental planning strategies for optimum solid waste landfill siting," *Sains Malaysiana*, vol. 38, no. 4, pp. 457–462, 2009.

[4]   T.B. Yousuf and M. Rahman, "Monitoring quantity and characteristics of municipal solid waste in Dhaka city," *Environment Monitoring Assessment*, vol. 135, no. 1-3, pp. 3–11, 2007.

[5]   A. Kalanatarifard and G. S. Yang, "Identification of the municipal solid waste characteristics and potential of plastic recovery at Bakri landfill, Muar, Malaysia," *Journal Sustainable Development*, vol. 5, no. 7, pp. 11-17, 2012.

[6] M.O. Saeed, M.N. Hassan and M.A. Mujeebu, "Assessment of municipal solid waste generation and recyclable materials potential in Kuala Lumpur, Malaysia," *Waste Management*, vol. 29, no. 7, pp. 2209-2213, 2009.

[7] T.W. Seow, "Masalah pengurusan sisa pepejal di Daerah Batu Pahat, Johor," Ph.D. dissertation, Fakulti Sains Sosial dan Kemanusiaan, Universiti Kebangsaan Malaysia, Bangi, 2009.

[8] A.M. Nur Khaliesah, A.H. Sabrina and A.M. Latifah, "Community participation on solid waste segregation through recycling programmes in Putrajaya," *Procedia Environmental Sciences*, vol. 30, pp. 10-14, 2015.

[9] M.J. Masyitah, J. Nurjahanah and M. Juliana, "Kajian Pengurusan Sisa Pepejal dan Komposisi Bahan Kitar Semula di Seluruh Negeri Perlis," Research Reports, Institute of Research, Development and Commercialization, Universiti Teknologi MARA, Shah Alam, 2010.

[10] S. Abdoli, "RFID Application in Municipal Solid Waste Management System," *International Journal Environment Research*, vol. 3, no.3 pp. 447-454, 2009.

[11] C.M. Nicole. (2013). *Smart recycle bin wins record-breaking MHacks Hackathon* [Online]. Available: http://ns.umich.edu/new/multimedia/videos/21705-smart-recycle-bin-wins-record-breaking-mhacks-hackathon.

[12] C. Yi. (2012). *London's New Smart Recycling Bins Come with LCD Displays & Wi-Fi*. [Online]. Available: https://www.psfk.com/2012/02/london-wifi-recycle-bin.html.

[13] S.S.L. Michelle, "Trash Can Recycle and Reward Bin," Bachelor Degree Thesis, Fakulti Kejuteraan Elektrik & Elektronik, Kolej Universiti Teknologi Tun Hussein Onn, Batu Pahat, 2006.

[14] E. Mozo-Reyez, J.R. Jambeck, P. Reeves, and J. Kyle, "Will they recycle? Design and implementation of eco-feedback technology to promote on-the-go recycling in a university environment," *Journal of Resources, Conservation and Recycling*, vol. 114, pp. 72–79, 2016.

[15] K.V. Sruthi and K.N. Manjunath, "A Novel approach to design a Smart bin using through IoT," *International Journal of Advanced Networking & Applications, IJANA*, pp. 483-485, 2016.

[16]   V. Catania and D. Ventura, "An Approach for Monitoring and Smart Planning of Urban Solid Waste Management Using Smart-M3 Platform," in the Proceeding of 15th Conference Open Innovations Association, St. Petersburg, 2014 pp. 24-31.

[17]   A. W. Mohd Helmy, A.K. Aeslina, T. Mohd Razali and J. M. Hairul, "Smart Recycle Bin: A Conceptual Approach of Smart Waste Management with Integrated Web based System," in International Conference on IT Convergence and Security, Beijing, 2014, pp. 1-4.

[18]   Y. Glouche and P. Couderc, "A Smart Waste Management with Self-Describing objects," in 2nd International Conference on Smart Systems, Devices and Technologies, Rome, 2013, pp. 63-70.

[19]   A. Maher, M.A. Hannan, B. Hassan, R.A. Begum and A. Huda, "RFID and Integrated Technologies for Solid Waste Bin Monitoring System," in the Proceedings of the World Congress on Engineering, London, 2010, pp. 29-33.

[20]   S.P Gundupalli, S. Hait and A. Thakur, "A review on automated sorting of source-separated municipal solid waste for recycling," *Waste Management*, vol. 60, pp. 56-74, 2017.