Vol 2 No 1 (2020) *e*-ISSN: 2682-8383

Journal of Engineering Technology and Applied Physics

I-Bin: Weight Based IoT Smart Recycling Scheduler for Guarded Neighbourhood

Dinesh Ramasamy*, Siva Priya Thiagarajah and Shamini Pillay
Faculty of Engineering, Multimedia University, Persiaran Multimedia, 63100 *Cyberjaya, Selangor, Malaysia*
*dineshramasamy92@gmail.com
https://doi.org/10.33093/jetap.2020.2.1.1

Abstract - **Overpopulation and lack of awareness are the main causes of poor waste management. While existing research in waste management employs current technology such as the Internet of Things, it lacks emphasis on residential centric type of waste management system. This project designs a weight based scheduling system for a guarded neighbourhood using Arduino Uno, load cells and plastic bins which are then incorporated with WiFi to send waste weight information in real time to cloud for monitoring. Design verification tests such as the linearity test and non- repeatability test showed less than 1 percent standard deviation error. A Proof of Concept test was conducted to test the system's performance at a guarded residential area. Analysis of test showed that an average of 0.0966 kg of recyclable waste was collected per house. Based on the results also, it is predicted that approximately 483 kg of waste can be effectively collected from 10 residential areas using the I-Bin system. Residents tend to dispose waste after office hours and scheduling more waste collection frequency after office hours will lead to increased revenue for the recycling company.**

Keywords—Neighbourhood centric waste management, IoT based waste collection, Single bar load cell

I. Introduction

Waste management is one of the major environmental problems. Waste management is an activity where the waste is monitored from being generated until its final disposal. This includes the collection of waste, transportation, treatment, and disposal [1]. In 2002, a study revealed that Peninsular Malaysia generated about 6.2 million tonnes per year and between 0.5 to 0.8 kg per day and has increased to 1.7 kg in big cities. At this rate, it can lead to generation of up to 31000 tonnes per day by 2020 [2]. Approximately 75% of collected waste is dumped at landfills, 20% are composed while only 5% are recycled [3]. The rapidly increasing human population translates directly to increased production of waste such as organic waste, hazardous waste, liquid waste, and solid waste. Solid waste is waste such as paper, plastic, tin, glass, and metals. These waste are generally found in household and industrial locations. Waste management is no longer the sole responsibility of local authorities, and with current waste generation speeds, waste separation at the source plays a crucial role in waste management, recycling and waste disposal [4,5].

Recycling in Malaysia encounters some major challenges which are the rapidly increasing solid waste amount, waste management cost, lack of database on solid waste management and recycling, lack of awareness on the 3Rs (Reduce, Reuse and recycle), lack of policies to promote 3R's culture and limited information and network among the stakeholders [6,7].

While there is heightened awareness through social media and schools on the importance of recycling solid waste, better waste management techniques need to be implemented in residential neighbourhoods. The local government councils provide free garbage bins for each house but these bins do not separate waste for effective waste management and the subsequent recycling management. Recycling bins positioned in neighbourhood centres are mismanaged as the waste is not collected the moment the bins become full, but instead are collected at scheduled times, leading to bin overload and a general lack of motivation for residents to recycle. There is an immediate and concerned need for waste management that can provide a solution locally and globally [8].

II. Related Works and I-Bin System Approach

IoT is a user friendly technology as expected to reach 30 billion devices/users by the year 2020 to connect humans and machines [9, 10]. IoT has many uses including medical, health, finance, education and retail [11]. IoT can also be used to solve problems in agriculture, smart home and appliances control [12-14]. IoT is based on cloud technology, and enables the access to data easily and at any time [15,16]. IoT, when combined with data mining can be used in predictive analysis to solve or enhance existing problems or businesses [17]. More recently, IoT and data mining have been studied for application in waste management.

The work in [18] uses ultrasonic sensors to measure the distance of the sensor and waste. The image is then processed together with data from the ultrasonic sensor to calculate the container's content volume. The work in [19] uses volumetric sensors to measure the capacity of the waste and the data is exchanged to other levels of the system based on real time. In [20], waste bins are tagged with Radio-Frequency Identification (RFID) so the antenna of the collection vehicle can identify which bin to collect. The information describing the waste is stored in RFID tags, and this tag can be read from any location within 5 meters from the reader antenna. In [21], the authors suggest a smart pickup system in which each bin transmits the volume and location to nearby truck drivers. As the bins become full, the drivers nearest to the bins are assigned to pick up the waste. The authors in [22] discuss that change in recycling habits might highly impact the ecological and sustainability of a city. The use of a recycling app on a smartphone may be the solution to increase recycling awareness and behaviour as people tend to use smartphone in their daily life. Authors in [23] suggest deploying waste bins on each side of the floor with bins which are moved on a conveyor belt [23]. The lid of these bins will close automatically when the ultrasonic sensor detects the bin has reached an 80 percent capacity to avoid spillage. The authors in [24] deploy an app that allows users to post items for recycling that might be of interest to other users. The app allows the interested parties to communicate and meet to collect the waste for reuse.

Although extensively researched, there are some limitations in past works. Each of these papers had proposed different techniques to improve on the recycling methods. Most of the techniques developed are used in public areas. There is still need of better techniques to improvise the recycling efficiency in residential areas. The system that will be developed for this project is called I-Bin. It is impossible to overcome all the limitations of the selected past works as improving one limitation might conflict with another limitation.

The research work done in this paper proposes a smart recycling scheduler system that focuses on optimising the recycling waste collection time. The system triggers an alarm to the recycling centres when the bin's weight threshold is met. The system is based on a weight based recycling scheduler system using Arduino, a load cell and an analogue to digital amplifier. The system is incorporated with Internet of Things (IoT) for real time waste weight monitoring in order to schedule for more effective waste pickup.

WiFi is now mostly available in residential areas and thus can be used for stable connection to the recycling centres [25]. The ThingSpeak IoT platform allows real time monitoring and alarm trigger which allow fast arrangement for unscheduled collection. The load based sensor triggers the alarm only when the threshold is met, thus reducing unwanted collection trips when the bins are not full, or increasing collection trips during peak disposal times to encourage more recycling by residents.

The proposed I-Bin system uses a single board computer which is Arduino Uno. The simple design provides fast processing and low cost maintenance, which are crucial factors in sustainable engineering practices.

III. Problem Statement

The proposed system addresses two problems that are fundamental in ensuring an effective waste management system.

The first problem is the challenges of optimising collection of recycled waste collection. Timely waste collection provides a sustainable practice in terms of cost and fuel saving. The collection is only done when the threshold value is met. It is unnecessary but routine clearing of unfilled recycle waste bins can be avoided.

The second problem is concerned with the psychological behaviours of urban dwellers. In most urban areas, recycling companies are situated nearby residential areas. However, urban dwellers do not have the time to physically go to the centres to dispose recyclable items, in spite of their moral obligations to do so. Given traffic and time constraints, urban dwellers choose the easy way out of the problem and end up mixing recyclable and non-recyclable waste together and throwing the waste at their respective garbage bins outside their houses for collection. Some individuals who do find the time to go the recycling bins in their residential areas become demotivated when they see the bins full and are unable to throw the recyclable waste. This will demotivate them to make the next trip to the recycling bin area.

IV. System Implementation and Design Factors

A. I-Bin Hardware

The I-Bin system contains two bins, one for paper and another for plastic. The testing location is a guarded residential area in Puchong, Malaysia. The bins are placed in a commonplace in the neighbourhood for ease of access by the residents.

Straight bar load cells that can measure up to 5 kg are connected to the 24-bit analogue-to-digital HX711 amplifier. The load cells have four strain gauges that are hooked up in Wheatstone bridge design. The output voltage of the load cell is measured to check the weight. The HX711 will convert the analog signals received from the load cell to digital signal and amplify them before sending the signals to Arduino to process the weight.

WiFi integration is done through the use of ESP8266 module connection. The data to ThingSpeak application is written using the write Application Program Interface (API) key that allows the system to write or read data from ThingSpeak [26].

The load cell is mounted on a stable base to provide an equilibrium level. The equilibrium level is crucial to ensure weight accuracy of the load. Apart from the equilibrium, there are a few other factors that can affect the systems weighing accuracy, namely, the nonlinearity, hysteresis, environmental forces and temperatures.

Nonlinearity measures the load cell's weighing fault over the total operating range. It indicates the load cell calibration curve from zero load until the load cell's maximum rated capacity. A system is defined as linear when the output is linear to the input. Hysteresis is the change between the load cell's outputs when the corresponding sum of the load is applied to the load. Error sensor calibration is done by increasing the weight from zero to maximum, and decreasing the weight from maximum to zero.

Non-repeatability test is done by measuring the variance in output when the same weight is applied to the load cell repetitively. Higher variances indicate a higher non reliability in the weight reading. Due to the continued pressure applied by the disposed waste on the load cell (while it waits to be collected by the collection truck), the creep effect will affect the reliability of the system over time. To reduce the creep effect, the system must be placed in an optimum operational temperature to reduce the creep effect on the load cell’s sensitivity.

Environmental forces that can affect the load cell based weighing system are wind, vibrations and shock loading. Shock loading happens when high load items are dropped into the bins from a high altitude. User education is crucial to ensure the vibrations do not affect the accuracy of the weighing.

The load cell can expand under very high temperatures and this will affect the calibration factor, ultimately affecting the system accuracy. Given that Malaysia has a constant weather temperature and humidity, no test is conducted to control the temperatures for this system.

B. I-Bin Software

The Arduino board is programmed using Arduino IDE and connected to the load cell, HX711, and WIFI module. Once the hardware has been integrated with the software, a 50 g load is applied to the load cell. The accuracy of the weight is then compared to the weight obtained from a digital weighing scale. If the values are different, a calibration factor coding is performed on the load cell until the matching weight is obtained from the I-Bin system.

Data is programmed to be updated to the cloud every 30 minutes. The weight displayed on the cloud is the cumulative weight of the 2 I-Bin system bins.

C. I-Bin System Architecture

Figure 1 shows the I-Bin system architecture. Two bins will be placed outside the recycling centre’s management office. Residents can dispose of the recycle items at the bin at any time.

During the Proof of Concept, the system threshold for weight is set at 4 kg. Once the weight is met, the LED light on the bin will be on to indicate the weight is met or the bin has reached its maximum capacity. Residents will not be able to dispose items into the bin once the LED is on. When the expected weight is met, the recycle company will alert their dispatch to collect the items that have been disposed of in the I-Bin.

D. Advantage of I-Bin System

Costing is an important factor that drives all businesses. The costs that a recycling company incurs also include the logistics cost for collection of the recycled items, which include the wages for the truck driver and fuel cost. Conventional systems require the driver to make scheduled pickups to waste bins that may have not reached their capacity. In another extreme, an overloaded bin may have to wait for a few days before the next pickup, hampering the motivation of residents who might be thinking of recycling.

Demotivated residents may end up not wanting to recycle their waste, because each time the go to the centre, the bins are full, and they are unable to place the recyclable waste. I-Bin overcomes this challenge because pickups are scheduled each time the bins reach the threshold. In spite of increased pickup cost, the recycling companies can expect increased revenue because the quantity of recycled items per week increases dramatically.

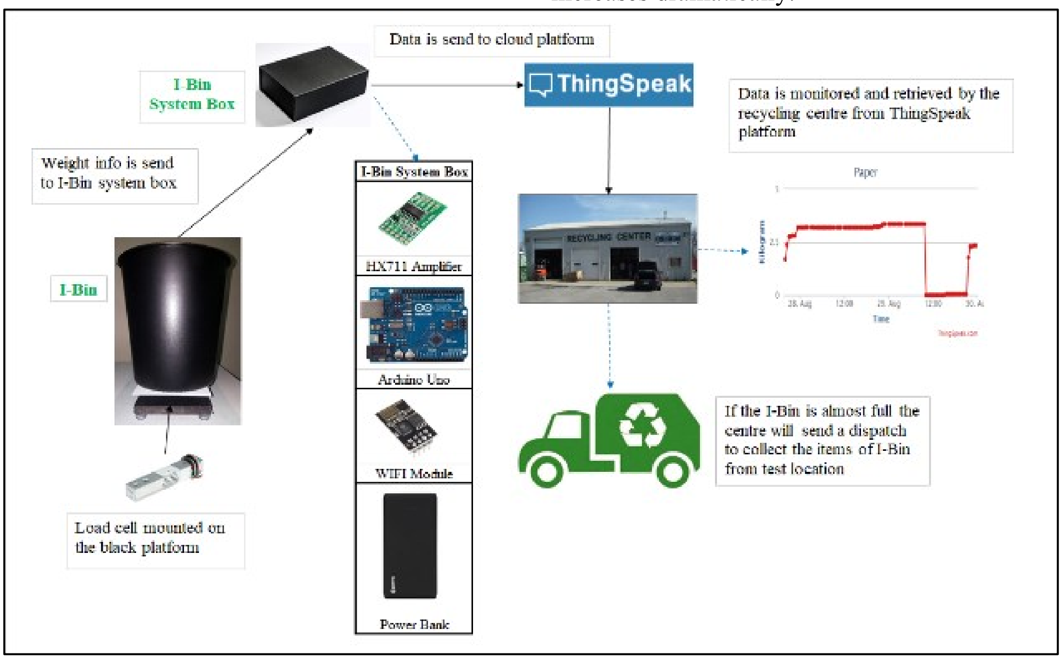

Fig. 1. I-Bin System Architecture.

I-Bin also assists in waste separation, as it can allow different materials to be thrown in different bins. This provides much convenience for the business as it does not have to employ extra manpower to segregate the rubbish according to their types.

V. Design Test and Proof of Concept

A. I-Bin Design Verification Results

The non-repeatability test was conducted to verify that when the same amount of load was applied to the load cell repetitively it has to produce the same output. Figure 2 shows the results of the non-repeatability test that was conducted for Bin 1 (paper) and Bin 2 (plastic). The test proved that the same output is produced when the load of 500 g was applied to both bins. The creep effect was tested during this non-repeatability test and the results were as expected as there were no changes in the reading or the output of both load cells when a load was applied on the load cell for 24 hours continuously. Linearity test was also conducted and the results show that the system is linear. The results of the linearity test are shown in Fig. 3.

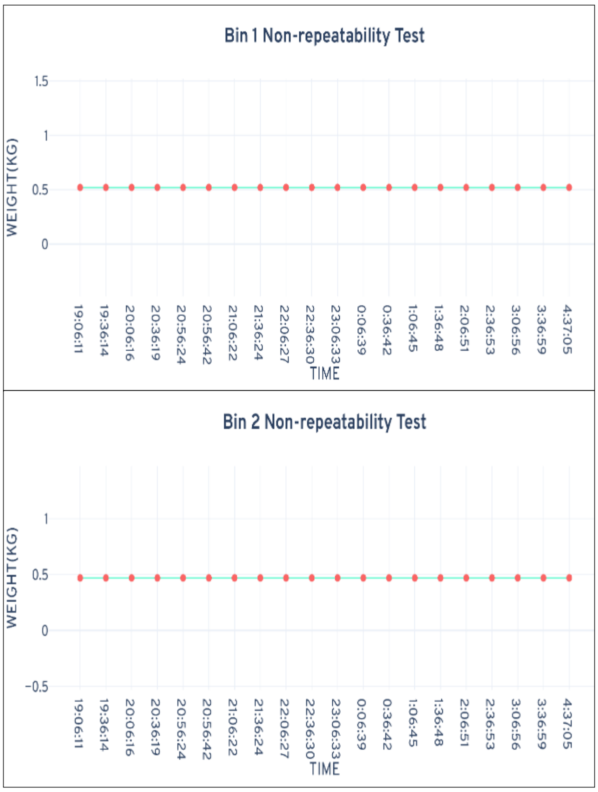

Fig. 2. Results of the non-repeatability test for 500g load.

The Proof of Concept (PoC) for the I-Bin system was deployed for testing at the Bandar Puteri 8 residential area. The test duration was for seven days. Social media was used to advertise the PoC test and residents were urged to dispose their recycled waste at the recycling centre. Figure 4 and Figure 5 show the data collected for both bins for Day 1 and Day 4 of the PoC respectively. These days were selected as they showed some significant fluctuations to the weights in the bins.

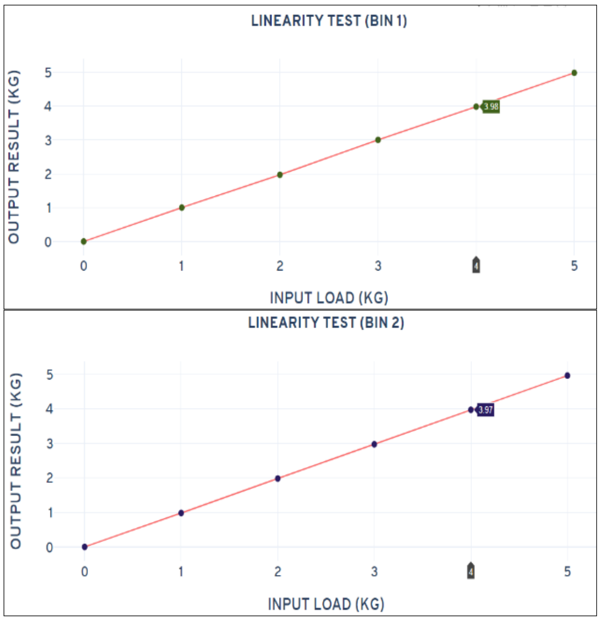

Fig. 3. Results of the linearity test for 500g load.

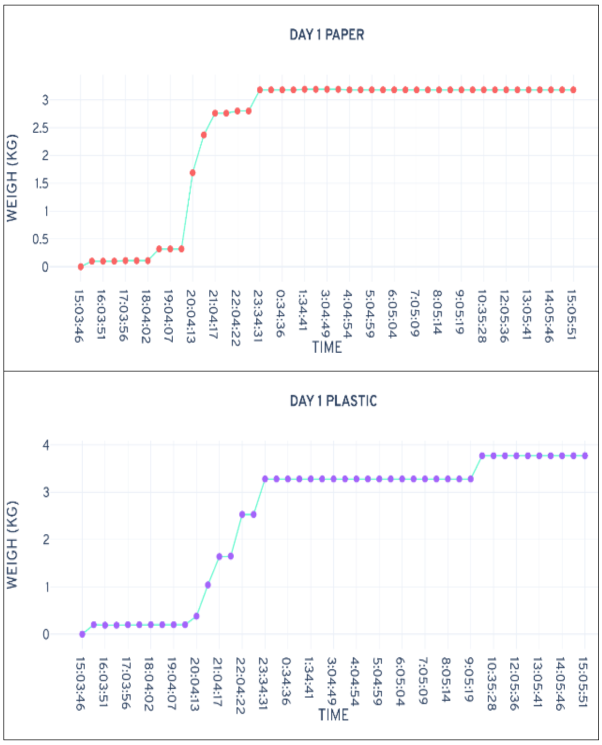

Fig. 4. Data monitored on IoT platform for Day 1 of PoC.

VI. OUTPUT ANALYSIS

A. Analysis Recyclable Waste Weight Collected

Data obtained from the PoC was analysed to conclude the behavioural of the residents on recycling and predict a possible outcome if I-Bin systems were deployed in other residential areas.

Figure 6 shows the total weight of waste collected from the PoC. The total weight accumulated for papers and plastics are 24.39 kg and 23.91 kg respectively. Figure 6 also shows that the highest collection for paper and plastic were on Saturday. On that Saturday, the collection was done twice as the plastic bin met its threshold twice on the same day. This could be due to the fact that residents tend to have more time to clear their unwanted plastic and paper items for recycling on weekends.

B. Waste Disposable Behavioural Analysis

From a daily graph analysis (not shown in this paper due to space constraint), it was clear that most of the residents tend to dispose the recycle items after working hours, specifically after 8 pm. compared to morning or early evening.

A total weight of 48.3 kg of waste was collected during the PoC. There are 500 houses in the PoC tested residential area; hence, this averages to 0.0966 kg of recycled items per house per week. The low average value per house could be due to the habit of residents who still prefer to wait for the recycle truck to come to their doorstep, or the fact that no reward was given to use of the I-Bin system as it was in a testing phase.

C. Predicted Waste Collection

Based on figures provided by the local recycling centre, an estimated 10 tonnes of recyclable items is collected by the lorries in a week. If 48.3 kg of waste can be accumulated from an inactive neighbourhood, it is predicted that the I-Bin system deployed in multiple residential areas can provide a high yield for the recycling companies. The I-Bin system can be deployed with proper user education and a fair reward system in place.

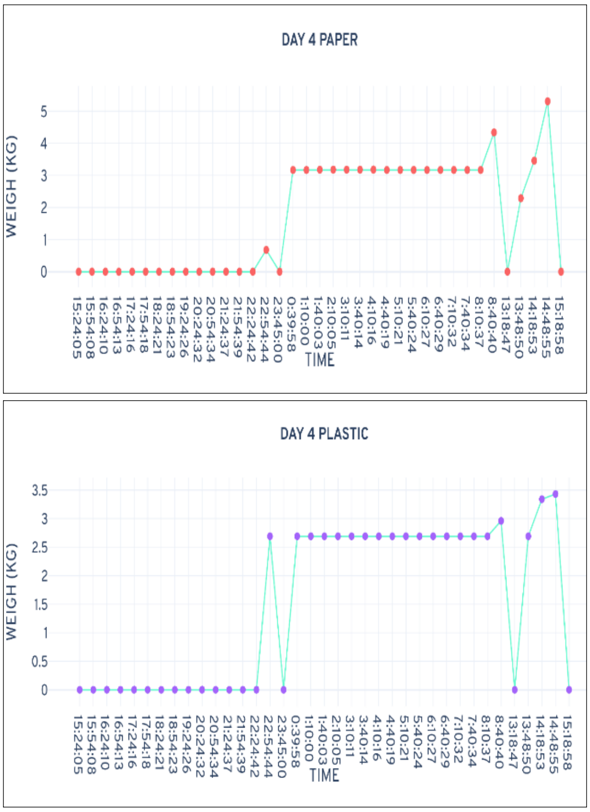

Fig. 5. Data monitored on IoT platform for Day 4 of PoC.

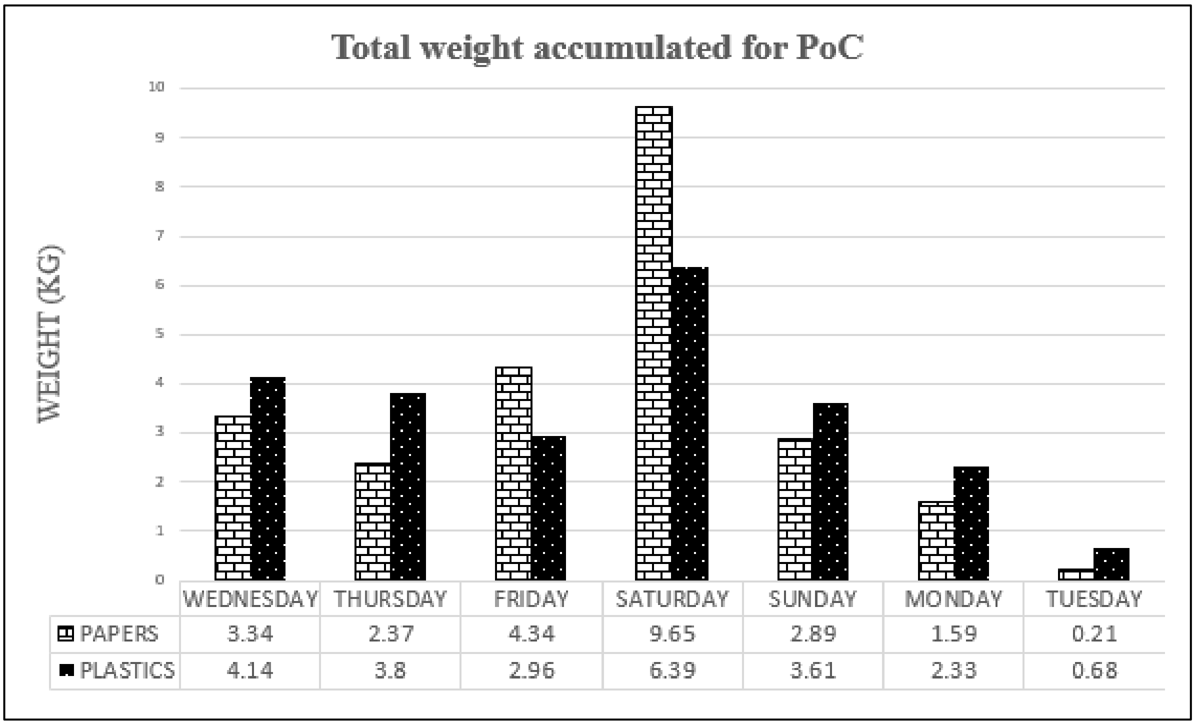

Fig. 6. Total weight of waste collected from the PoC.

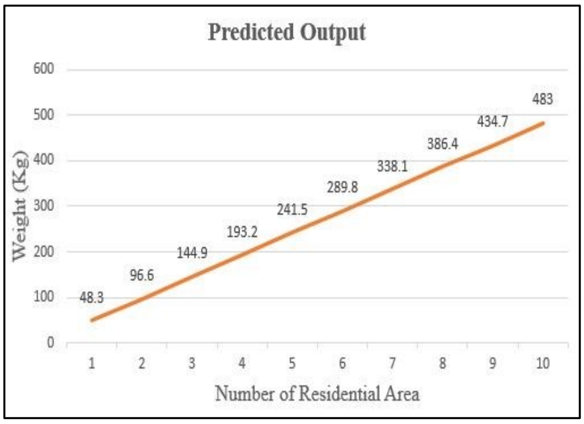

Fig. 7. Predicted waste yield for 10 residential areas.

Figure 7 shows a simple linear prediction model for the yield of waste collected if the I-Bin system is deployed in 10 residential areas similar to the tested residential area. Figure 7 shows that almost half a tonne weight of recycling item from the 10 residential areas can be collected, with reduced costs of logistics.

VII. CONCLUSION

The work developed a weight based smart recycling system using a single board computer. Arduino Uno R3, plastic bins, and load cells were used to design the hardware which was incorporated with a WiFi module to send the data to the IoT platform which serves as the cloud storage. To prove the concept, a seven day trial run was conducted at a residential area in Puchong, Malaysia. The output of the test was used to predict the waste yield if the I-Bin system was deployed in other similar residential areas. Results showed that an average of 0.0966 kg of recyclable waste was collected per house. It is predicted that 483 kg of waste can be effectively collected from 10 residential areas using the I-Bin system. The collection of the bin was done almost immediately once the bins met their threshold value. This increases the efficiency of collection, saves time and more importantly it reduces the operating costs for recycling companies.

REFERENCES

[1] 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.

[2] Y. Moh, "Solid Waste Management Transformation and Future Challenges of Source Separation and Recycling Practice in Malaysia," *Resources, Conservation and Recycling*, vol. 116, pp. 1-14., 2017.

[3 A. Johari, S. I. Ahmed, H. Hashim, H. Alkali and M. Ramli, "Economic and Environmental Benefits of Landfill Gas from Municipal Solid Waste in Malaysia." *Renewable and Sustainable Energy Reviews*, vol. 16, no. 5, pp. 2907-2912, 2012.

[4] A. Periathamby, F. S. Hamid and K. Khidzir, "Evolution of Solid Waste Management in Malaysia: Impacts and Implications of the Solid Waste Bill," *Journal of Material Cycles and Waste Management*, vol. 11, no. 2, pp. 96-103, 2009.

[5] S. Ting, S. T. Tan, C. T. Lee, H. Hashim, W. S. Ho and J. S. Lim, "Optimal Process Network for Municipal Solid Waste Management in Iskandar Malaysia," *Journal of Cleaner Production*, vol. 71, pp. 48-58, 2014.

[6] S. Nagapan, I. A. Rahman and A. Asmi, "Construction Waste Management: Malaysian Perspective," *In International Conference on Civil and Environmental Engineering Sustainability (IConCEES)*, Malaysia, vol. 2, pp. 299-309, 2012.

[7] K. G. Tiew, N. E. A. Basri, H. Deng, K. Watanabe, S. M. Zain and S. Wang, "Comparative Study on Recycling Behaviours Between Regular Recyclers and Non-regular Recyclers in Malaysia," *Journal of Environmental Management*, vol. 237, pp. 255-263, 2019.

[8] I. Botetzagias, A. F. Dima and C. Malesios, "Extending The Theory of Planned Behavior in The Context of Recycling: The Role of Moral Norms and Demographic Predictors," *Resources, Conservation and Recycling*, vol. 95, pp. 58-67, 2015.

[9] N. L. Andrei, V. Tanasiev, G. Sava and A. Badea, "IoT for Smart Residential Buildings," *2018 IEEE Int. Conf. Environ. Electr. Eng. and 2018 IEEE Ind. Commer. Power Syst. Eur. (EEEIC / I&CPS Eur.*, pp. 1–4, 2018.

[10] F. Abate, M. Carratù, C. Liguori and V. Paciello, "A Low Cost Smart Power Meter for IoT," *Measurement*, vol. 136, pp. 59–66, 2019.

[11] J. Santos, J. J. Rodrigues, B. M. Silva, J. Casal, K. Saleem and V. Denisov, "An IoT-based Mobile Gateway for Intelligent Personal Assistants on Mobile Health Environments," *Journal of Network and Computer Applications*, vol. 71, pp. 194-204, 2016.

[12] A. P. Kale and S. P. Sonavane, "IoT based Smart Farming: Feature Subset Selection for Optimized High-dimensional Data Using Improved GA based Approach for ELM," *Computers and Electronics in Agriculture,* vol. 161, pp. 225-232, 2019.

[13] M. S. Munir, I. S. Bajwa and S. M. Cheema, "An intelligent and Secure Smart Watering System Using Fuzzy Logic and Blockchain," *Computers & Electrical Engineering*, vol. 77, pp. 109-119, 2019.

[14] P. Kumar and U. C. Pati, "IoT based Monitoring and Control of Appliances for Smart Home," *In 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, pp. 1145-1150, 2016.

[15] A. Botta, W. De Donato, V. Persico and A. Pescapé, "Integration of Cloud Computing and Internet of Things: A Survey," *Future Generation Computer Systems*, vol. 56, pp. 684-700, 2016.

[16] P. M. Kumar, S. Lokesh, R. Varatharajan, G. C. Babu and P. Parthasarathy, "Cloud and IoT based Disease Prediction and Diagnosis System for Healthcare Using Fuzzy Neural Classifier," *Future Generation Computer Systems*, vol. 86, pp. 527-534, 2018.

[17] T, Hastie, R. Tibshirani, J. Friedman and J. Franklin, "The Elements of Statistical Learning: Data Mining, Inference and Prediction," *The Mathematical Intelligencer*, vol. 27, no. 2, pp. 83-85, 2005.

[18] A. Rovetta, F. Xiumin, F. Vicentini, Z. Minghua, A. Giusti and H. Qichang, "Early Detection and Evaluation of Waste Through Sensorized Containers for A Collection Monitoring Application," *Waste Management*, vol. 29, no. 12, pp. 2939-2949, 2009.

[19] M. Faccio, A. Persona and G. Zanin, "Waste Collection Multi Objective Model with Real Time Traceability Data*," Waste Management*, vol. 31, no. 12, pp. 2391-2405, 2011.

[20] Y. Glouche and P. Couderc, "A Smart Waste Management with Self-Describing Objects," *In The Second International Conference on Smart Systems, Devices, and Technologies*, HAL Id : hal-00924270, 2014.

[21] J. M. Gutierrez, M. Jensen, M. Henius and T. Riaz, "Smart Waste Collection System based on Location Intelligence," *Procedia Computer Science*, vol. 61, pp. 120-127, 2015.

[22] D. Bonino, M. T. D. Alizo, C. Pastrone and M. Spirito, "WasteApp: Smarter waste recycling for smart citizens," *In 2016 International Multidisciplinary Conference on Computer and Energy Science (SpliTech)*, pp. 1-6, 2016.

[23] B. Bharadwaj, M. Kumudha and G. Chaithra, "Automation of Smart Waste Management Using IoT to Support "Swachh Bharat Abhiyan"-A Practical Approach," *In 2017 2nd International Conference on Computing and Communications Technologies (ICCCT)*, pp. 318-320, 2017.

[24] R. Yunanto, "Android-based Social Media System of Household Waste Recycling: Designing and User Acceptance Testing," *In IOP Conference Series: Materials Science and Engineering*, vol. 407, no. 1, pp. 012139, 2018.

[25] K. Lee, J. Lee, Y. Yi, I. Rhee and S. Chong, "Mobile Data Offloading: How Much Can Wi-Fi Deliver?" *IEEE/ACM Transactions on Networking (ToN)*, vol. 21, no. 2, pp. 536-550, 2013.

[26] M. A. G. Maureira and L. Teernstra, "ThingSpeak – an API and Web Service for the Internet of Things," *World Wide Web*, 2017.