Supervised Learning and IoT-based Smart Waste Management System

Perera E.J.O.
Faculty of Computing
Sri Lanka Institute of Information Technology, Malabe, Sri Lanka

Thilakarathne H.M.P.M.
Faculty of Computing
Sri Lanka Institute of Information Technology
Malabe, Sri Lanka

Thennakoon T.M.C.M.
Faculty of Computing
Sri Lanka Institute of Information Technology
Malabe, Sri Lanka

Amarasinghe Y.R.
Faculty of Computing
Sri Lanka Institute of Information Technology
Malabe, Sri Lanka

Jeewaka Perera
Faculty of Computing
Sri Lanka Institute of Information Technology
Malabe, Sri Lanka

Amali Gunasinghe
Faculty of Computing
Sri Lanka Institute of Information Technology
Malabe, Sri Lanka

ABSTRACT
With the rapid development of countries and the population increase, most countries have fully industrialized and urbanized which has predominantly caused the global waste problem. Poor waste management contributes to environmental pollution, and climate change and directly affects many ecosystems and species. Consequently, this has become a significant global issue which has led people to seek ways to deal with this problem and increasingly concerned about waste management although they still could not have minimized its impact. For solid waste disposal, major problems affect are unscientific and poor technical treatments, improper collection of waste, and ethical problems. To address the above problem areas this research has been conducted to find a solution to produce a smart waste bin to capture the filled level of bins based on the Internet of Things (IoT) with Ultrasonic sensors and an automatic locking system, connected to a waste sorting system using image processing by using a camera, Generated the shortest route for a waste bin that has reached the maximum waste level percentage using machine learning algorithms and visualized in a mobile application interface through a map. Finally, by using a machine learning-related Decision tree algorithm, a time series prediction is carried out on predicting the next waste pickup dates for each waste bin and generated a waste pick-up schedule in the mobile application. The novelty of this researched system is that we can efficiently achieve many solutions for waste mismanagement problems in one platform.

Keywords
Waste Management, Internet of things, machine Learning, Waste Sorting, Time Series prediction

1. INTRODUCTION
With the technological development of the world, almost all fields are improving according to human needs. But Waste management is a field that often uses low technology. Our primary goal in this study is to use information technology to address issues that arise in waste management. In the research, our team mainly addresses the issues of improper waste collecting, waste transportation issues, and resource maintenance issues. As a result, our team has created a supervised learning-based waste management system to handle all aspects of waste management. In our opinion, given the nation's economic crisis, it is crucial to lead a minimal lifestyle by minimizing the wastage of physical resources and human resources. As the main technical streams, our team used IoT and machine learning. IoT is a technology that could change lives in a favorable way. IoT enables communication between low-power gadgets and online interactions. IoT-based operations have been implemented by numerous applications all around the world to provide cutting-edge services for smart cities. [1]For IoT bases, trash management machine learning offers efficient solutions including regression, classification, clustering, and correlation rules perception. We have used IoT for Implementing a sensor to capture the filled level of waste and to implement a locking system for the bin. Also, to sort out the waste into perishable and nonperishable garbage via image processing. [2] Our team generates the closest route to only pick up filled trash cans as part of the machine learning components of the project and uses historical data to predict future trash can collection dates. [3]

2. LITERATURE REVIEW
A. Garbage sorting function
The first garbage disposal device was invented by John W. Hammes of Racine, Wisconsin. He was an architect. So, beginning around 1916, [4]he started tinkering in his basement and came up with an initial design. He was obviously a brilliant tinkerer, but not brilliant enough to come up with the idea of helping his wife clean. Her loss, however, was our gain. After coming up with his initial unit, Hammes rented a machine shop and started developing prototypes. He finally hit on a fully working disposal in 1927 and filed for a U.S. patent on May 22, 1933. Segregation of waste materials has been identified as a major stumbling block in the recycling of consumer waste in other studies. Sorting is a multi-stage process that transports waste materials to the proper disposal facility. Sorting begins with the separation of recyclable and non-recyclable waste. Recycling rates have increased by 30% at sites where waste materials are separated prior to collection. Using a segregated waste collection system, these can be easily transported to a centralized collection station. Encourage consumers to recycle waste materials and use sorted trash bins to help with the first stage of waste separation will go a long way toward removing this

stumbling block. In 2012, cities world over, generated 1.3 billion tons of solid waste per year, amounting to a footprint of 1.2 kilograms per person, per day needless to state that with rapid population growth and urbanization, the municipal waste generation is expected to increase to 2.2 billion tons (MT) by 2025. Inadvertently, with the current trends continuing, it is likely to rise from 3.5 MTs to 6 MTs per day with, each Person generating around 0.64 kg waste per day in Sri Lanka with an estimated 4.8 billion MT of waste collected per annum in the country [5]. Establishing the waste model is the first step in identifying it. Since knowing the waste model gives you access to more information about it, the type of garbage is plastic, food, iron, or glass are a few examples of supplementary data. In order to find out that information, a user must be able to identify the garbage disposal and what the disposal methods are. There are numerous technologies that can identify different waste makes and models and provide details about them. But in Sri Lanka, there isn't a system that can identify garbage types and direct the waste to the respective dustbin. When a person goes to dispose of the garbage that he has in the environment, some people release the garbage into the environment with or without understanding. Thus, they dispose of the garbage without even thinking about the environmental damage. In these unpredictable conditions and busy lifestyles, how timely is it to create a smart system to dispose of garbage in a manner that is convenient for humans using technology? It has been considered very important to develop a system that can recommend the right dustbin to dispose of identified garbage without making mistakes with or without individual knowledge. This system is trained to dispose of garbage with minimal environmental damage. The waste to be disposed of is shown to the camera installed in front of this smart dustbin, and the waste is properly managed. We can introduce this as a more effective and technical solution to waste disposal.

B. Implementation of the IoT-based smart waste bin

At present, several types of research related to smart waste management have been introduced by some researchers. We can see, Researchers have tried to build proper smart waste management by using several components. In that component, researchers are mainly focused on smart waste bins. Many of the research conducted include the,

- Monitoring system to identify the filling percentage of garbage
- Alert system

According to the existing research papers[Research A [6] Research B - [7], Research C - [8]and resources, most of the researchers are introduced smart waste bins with a monitoring system and alert system. Research A [6] has concerned about the filling level monitoring and alert system. The authors used sensors to detect the percentage of waste and they assign an alert system to send an SMS When the garbage fill out over the maximum level through the telecom network. In research B [5], they have also proposed IOT-based technologies for implementing the monitoring system alert system in the smart waste bin. When we consider research C [6], it seems, Researchers have connected sensors to identify the status of the waste level as in previous research. They did not use alert systems, but the admin and garbage collectors can check the status of the garbage bin through the mobile app.

Table 1 Gaps Identified with similar research

Research Name	Filling level monitoring system	Alert System	Percentage displaying system	Automatically locking system	Ability to check the waste status real time.
Research A	✓	✓	×	×	×
Research B	✓	✓	×	×	×
Research C	✓	×	×	×	✓
SmartBin	✓	✓	✓	✓	✓

Then considering the SmartBin with this table, we plan to fix the sensors to identify the filling level of garbage, an alert system for sending a message to authorized parties when the garbage system is filled as like another mentioned research. As a novelty, we hope to use the digital display outside the garbage bin to represent the garbage level in real-time. And garbage bin will be locked when the garbage comes over the maximum level then admins, residents, and other parties who use the smart bin have the ability to check the waste percentage in the waste bin through the website or mobile app.

C. Shortest path-generating function

Waste management is an important aspect not only for keeping a city's environmental well-being but also its residents' hygiene and health. Developed countries now have the resources and equipment necessary to maintain these favorable conditions, such as up-to-date and real-time waste generation and collection statistics, well-experienced. personnel resources, and trucks equipped with advanced technologies, such as geographic information systems. However, according to a survey. conducted by our team, environmental challenges arising from garbage management continue to exist. As a result, our. The team came up with the idea of leveraging smart technology to address the challenges. The goal of this component is to alleviate Sri Lanka's. garbage collection difficulties. Many scholars have presented methods for solid waste collection and management in the past.

María-Victoria Bueno-Delgado and three other members proposed a system for Optimal Path Planning. for Selective Waste Collection in Smart Cities for Spain where the compilation of plastic waste is critical. The system is primarily concerned with reducing environmental and socioeconomic impacts by reducing CO2 emissions and acoustic harm. The desired solid waste management system must be low-cost to operate and environmentally sustainable. The prosed system used Net2Plan, an open-source planning .application for modelling and designing communication networks, is used to run the algorithm. Net2Plan makes it easier to feed city layout data into the algorithm .by automatically importing it from GIS databases using the Net2Plan-GIS library, which may also contain smart bin placements. A Geographical Information System (GIS) database provides the city plan, which. includes information on roads and the position of containers in streets. The system can detect solid waste bins and collect solid trash effectively using the technologies described above. But the map is not updated on real n the proposed system and. only the filled bins are shown. [9]

Tariq Ali,Muhammad Irfan with another two-member proposed IoT Based Smart Waste Bin Monitoring and Municipal Solid Waste Management System for Smart Cities. It primarily entails employing a. sophisticated IoT sensor prototype to capture the garbage level in the bins and transmitting the data. to a server via Internet services. The suggested system is able of effectively collecting garbage, since an alarm is sent to the truck driver. But the route will be generated according to the. distance in the MySQL database. Shortest path will not be generated between the bins and also the maps will not be updated. on real time. [10]

Maher Arebey, M.A. Hannan and two-other members proposed a system to. monitor and manage solid waste in an effective way. This system has been developed for Malaysia by considering the Waste collecting and transportation sections too. The system's primary goal is to. increase efficiency, which includes lowering expenses per kilometer and per hour to transport garbage once it has been collected from various sites. According to the review of the research the garbage collecting productivity mainly depends on some facts such as service level, route related facts and collection methodology and climate changes. So, the system has excellently addressed all the challenges by using RFID, GIS, GSM as main. technologies. The system can recognize the serial numbers and positions of solid waste bins using the technologies. described above, allowing it to collect solid trash effectively. The proposed solid waste management system is a web-based system that allows users to monitor and receive information about vehicles and garbage bins via a dashboard. For communication between the tracking device and the server, as well as vehicle location tracking, GSM and GIS are used, and the system consists of RFID system. The system, on the other hand, is primarily focused on collecting solid waste from consumers. The level of user participation in rubbish collecting is minimal. [11]

D. Next waste pickup dates prediction

An analysis of literature and reports related to waste management in developing countries showed that few articles supplied quantitative information. Yet most of the research on waste management systems does not include all solutions and mechanisms to address each area in waste management but only for a few elements. In the domain area of time series prediction and pre-scheduling implementations on waste management systems, there are some related works of previous research. All that previous research has only done an analysis on waste generation for a period and predict trends on how the waste generation would be in the near future. Also, their scope was only for a particular waste material type and as the final output a time plan or a schedule-based product has not implemented along with smart waste management systems specially in Sri Lanka. As the contribution to the existing knowledge in predicting and prescheduling systems in waste management, this component in our proposed waste management system has new features such as analyze the waste generation of each smart waste bin for a period, predict the trends of waste generation and train a time series model to predict next waste pick up dates and generate a schedule for the next week waste collection. Also, stakeholders will be able to view real time updating schedules through a mobile application as well. If the pre-scheduling system for the next waste pick-up dates component is specifically taken into discussion, some related work has also been done previously. As in the [12] research has been done to predict the waste generation under uncertainty in smart cities through Deep Neuroevolutionary. There, they have used the Recurrent Neural Networks (RNN) approach for predicting uncertain data on waste generation in the USA. Some other waste management models found in the literature include ANN and Multiple Linear Regression (MLR) [13]. One of those studies has used comparative modeling and ANN to a prediction of waste generation rates of the hospitality industry in North Cyprus. [14]In weekly waste generation of a city in Iran is researched with Neural Networks (NN). In that they have only done an analysis and mainly focused on different seasons for the predictions. As the main point, most of these waste management ystems related predictions have missed the element of predicting waste generation for pre-scheduling the time series of filled bins collection. Therefore, this research component proposed by this research is mainly focusing on filling that gap of the state-of-the-art in this research domain. As the final solution of this research, our team focused on achieving a highly accurate prediction using Auto Regressive Integrated Moving Average (ARIMA) model and connect to a prescheduling system to fill up the space and develop the path for future work as well.

3. METHODOLOGY

The system software works as follows; Firstly, the Tidy Town: Smart bin program controls the waste sorting algorithm. Then there is a Raspberry Pi, which is a central repository for waste data and to capture filing level information of each dustbin. In the next component, the web application for stakeholders where the monitoring the status of smart bins and generating the shortest path according to the filled dustbin. As the final component, a schedule is shown in the mobile application for general stakeholders to retrieve the future collection dates of waste bins based on waste generation history data.

The Raspberry Pi 4 Model B and web cam are used as a hardware part and the Ultrasonic, DHT11, Terminal Blocks,40 pin Female headers are used as a sensor. USB mini cable,3 Pin JST cable,4 Pin JST cable, Circuit Wires, Dot Bord Were used for the connection between hardware components and sensors image processing platform is embedded in the waste bins by implementing a system to sort the waste. The waste sorting component is implemented as follows; Show waste material to the camera, Capture camera snapshot, Input the image to the trained model, then the trained model sort the material, and starts the motor corresponding to the matched material, after sorting is done, the motor is moved to its original position. IP Camera-based rubbish detection analyzes the image and chooses the appropriate trash bin to place the trash in. We'll use the Tensor Flow library to properly capture and classify the images. Open CV is a popular library for understanding images and videos. It now has over 2500 optimized algorithms, and over 18 million people have downloaded it. It works with a variety of languages, including C, C++, Python, and Java. Tenso Flow has a lot of different Library. TENSORFLOW is used to carry out object detection and classification. Object detection and segregation of waste is performed by Al based framework with pre-trained object detection model Convolutional Neural Network (CNN). This model is trained with images of the waste of several types, and it generates frozen interference graph. This study of a smart waste sorting system with the image-supervisor learning-based application is involved two compositions, the classification model construction and the waste classification model integrated with the IoT part designing the sorting machine. To build a classification model, the collected image datasets from both the standard (Kaggle) and the local database would be used to train the machine learning model in order to be able to identify garbage

types. The model was implemented using the Python and Google collab notebook, YOLO darknet, and TensorFlow, which can provide automated advice to authors. The experiments were designed to evaluate the classification model, which results in efficient results with an accuracy of 98.81 percent. Ultrasonic sensor technology has been used to detect the filling levels of garbage. When the waste reaches the maximum level of the bin, it automatically locks and sends an alert Message in the mobile app. The digital screen in the garbage bin displays the percentage level of the garbage. The Ultrasonic sensors (Sensor HCSR04) installed in the containers provide Realtime information on the fill level. This information helps determine when and which bin to prioritize in the waste bin collection. IoT Hardware's based waste bin component is implemented as follows; First, utilizing ultrasonic level sensors with integrated LED indicators, then the controller receives feedback on the dustbin level. Next, the level sensors are used to continuously capture the bin levels to the Raspberry Pi. To transfer the level data over the internet, a Wi-Fi module is additionally interfaced with the raspberry pi The Level sensor panels are designed to attach quickly to any trash can. This makes it simple to screw the system over any dustbin for quick installation. Collected data is sent via IoT platform, which then stores the bin-level data in a database. This signal can be used to inform relevant stakeholders that it's time to empty the trash cans. Likewise, the system automates garbage segregation and level monitoring. The ultrasonic sensor is used to estimate the level of waste while the GSM module is used for sending SMS. [15] [16]

Waste management is a field that often uses law technology. But machine learning and IoT concepts have the power to accelerate the waste management field by improving its effectiveness. In the supposed system authors have planned to implement waste bins in some exact locations which consist of sensors that can detect the filling level of the waste bins. Those waste bins are provided with a unique bin ID. By that, it will be easy to track the waste bin which is filled. The authors have planned to update those filled bins in a google map structure in an android application. Google map is a technology provided by Google for web-based mapping and it can be used to create personalized maps in software applications. The map will be loaded using a free API key. A special login has been created Authors have created a special login that can be accessed only by authorized truck drivers, and we have given a color code for the filled waste bins to make the identification easier. Through this feature, the truck drivers can reach the filled waste bin by skipping the unfilled waste bins. As another special feature in the component authors has generated the nearest path for the filled waste bins. The nearest route will be generated in the mobile application by sorting the filled waste bins. vehicle routing problem for Metaheuristic (VRPM) machine learning algorithm has been used and by using that concept android application provides the shortest possible path that visits every filled waste bin, by collecting a set of the distance between the bins. Here map API has been used to display the generated route.

Since there is no proper communication between residents and waste management units in cities and a lack of awareness about how and when to dispose of waste and collect them are key causes of waste mismanagement. Also, without having a proper schedule for waste collection rides, productivity and the efficiency of waste pickup drivers are being dropped. Therefore, a few of the main research questions of the authors were How to implement a single prescheduling system with the use of ML algorithms, How to select the most dependable algorithm for a time series forecast can provide How can a model be trained to increase the accuracy level of prediction. Many statistical models like exponential smoothing and generalized regression can be used to describe a time series forecast. In this study, to predict the next waste pick-up date by using past data of waste bin filling level percentages, Auto Regressive Integrated Moving Average model (ARIMA) is used. Since predicting future waste bin filling levels along with dates is a stationary time series, ARIMA a typical linear model can be a good match. This model is proposed by Box and Jenkins [17] by taking past values and predicting errors. ARIMA model is the combination of the Auto-Regressive (AR) and Moving Average (MA) models. ARIMA models cover both aspects of AR and MA. Since the ARIMA model predicts future values based on previous data values and errors, the ARIMA model has better performance than AR and MA models alone. As explained in [18], an ARIMA(p,q) process of order p and q, where p is the order of the AR part and q is the order of the MA part with autocorrelation and moving average coefficient respectively.

Since this implemented system is including functional series of unobserved shocks (In the MA part) along with its own behavior ARIMA model is appropriate to use. As the framework to connect the backend process which is the forecasting model and the frontend component as in the mobile application, Flask framework is used as the API. Moreover, a manually created dataset of 2000+ waste bin capacity level data is used to train the time series forecasting model to find patterns in the data to predict the future. This prediction solely depends on the waste capacity levels along with days. Therefore, a time series forecasting model like ARIMA is accepted by authors as a perfect way other than regression models. In the frontend interfaces of the mobile application, a calendar view is displayed with future weekdays of predicted waste pick-up dates for bins that will reach the maximum waste capacity level on that day so that waste management teams can be prepared for waste collection properly.

4. DISCUSSION

A. The smart bin can be able to show the waste capacity on the digital screen. The waste capacity is measured by the ultrasonic sensor. Then waste reached the maximum level (80% of the waste bin) waste bin will be locked automatically. Servo motors and cables are used to implement that locking system. When considering the overall system this hardware component as in a smart waste bin can be manufactured affordably in a particular metropolitan area cost-effectively.

B. In the shortest path generation component java has been used for displaying the filled and non-filled waste bins on the app and a python API has been implemented to generate the shortest path. A vehicle routing problem for the Metaheuristic algorithm is used and that API has been integrated into the android app. As the output of the developed system users can view the nearest possible path only for the filled waste bins. This leads the users to an efficient and effective waste transportation procedure. Some screenshots of the interfaces are shown in the below figures.

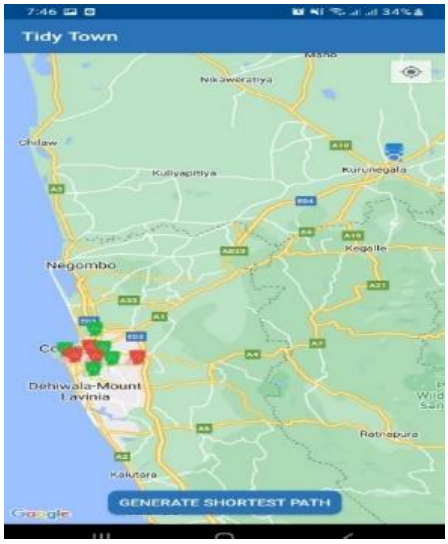


Fig1..Displaying the filled the filled waste bin

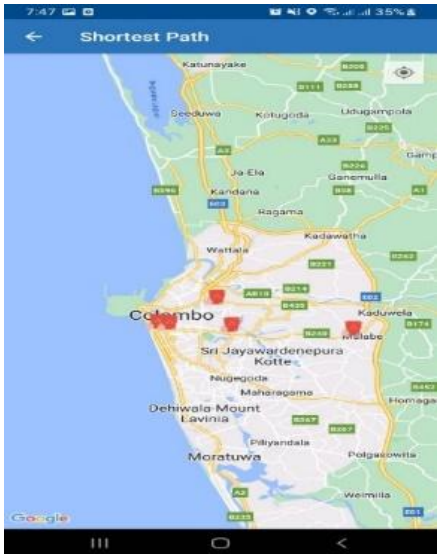
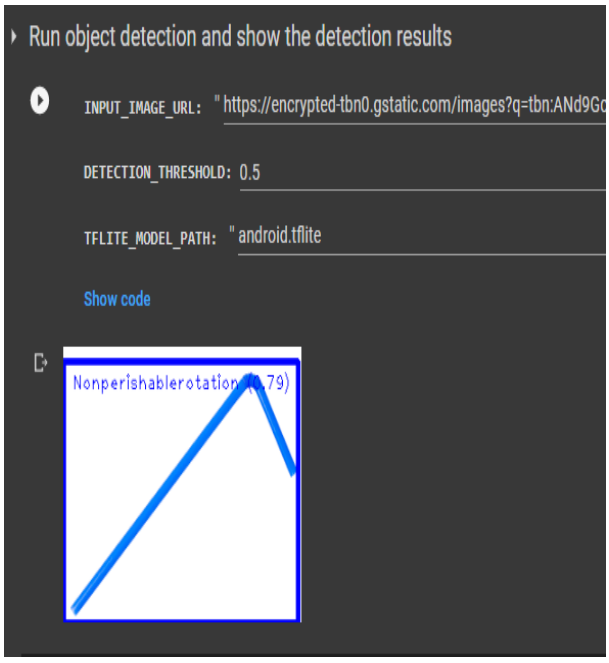


Fig2.Screen after sorting and non-filled waste bins



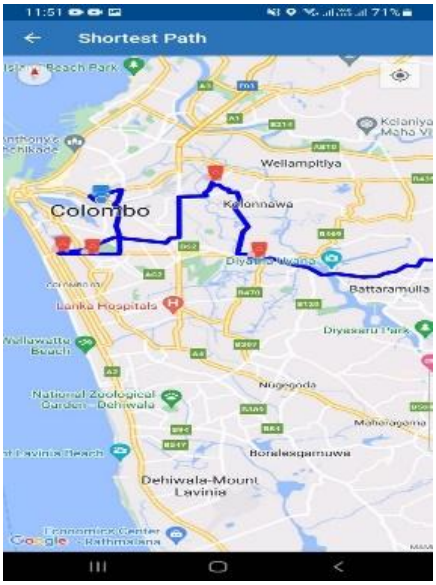


Fig3.Screen with the generated shortest path

C.To improve the awareness of waste management stakeholders on waste generation patterns and future waste collection dates of a particular residential area a proper solution is researched through this study. And the findings show that the ARIMA Machine learning model can be used to train a dataset of waste generation through past time series with an accuracy level of 85%. As the output of the prediction model, the waste bin's 80% capacity level reaching date is displayed in a calendar view on the mobile application by connecting through an API. So that the stakeholders can easily view the next waste pick-up dates of each type of waste bin and dispose of their waste accordingly. This type of prediction will guide us to improve waste management services more efficiently previously through related research to [19] [20], have only done an analysis and predictions on waste generation through a time period and mainly focused on different waste types for the

predictions. As the main point, most of these waste management systems-related predictions have missed the element of predicting waste generation for pre-scheduling the time series of filled bins collection. Therefore, this research component implemented is mainly focusing on filling that gap of the state-of-the-art of this research domain by integrating the predicted component with the mobile application.

D. These are the outcomes of this image-processing component. By using this trained model system will identify the garbage type and it will decide if the dustbin should open or not.

5. CONCLUSION

These days most countries are greatly suffering from threats occurred by waste mismanagement. Improper waste bin collection practices, waste transfer, and transport issues, poor scientific and technology involvement, lack of information concerning the waste collection schedule, poor infrastructure waste pickup resources, and many other reasons cause this grave problem to occur. [3] In this research, the main key findings were focused on the above-mentioned problem areas. As the final output, a real waste bin related to ultrasonic sensors and a servo motor using an Arduino board to capture the waste filling levels as percentages. Alerts and notifications of real-time data in waste bins are sent to the mobile application through a GSM module. Also, a digital screen in

the waste bin's front interface displays information related to waste-filled levels. As the outcome of the next component, the system can perform waste sorting according to the correct bin by using a Raspberry Pi model and an IP camera embedded to waste bins. Once the waste type is matched with the relevant waste bin, the bin is unlocked and automatically opens. As another outcome, a schedule for the next waste bin collection dates can be viewed in the mobile application as per the waste generation prediction. Moreover, this researched system provides the option to generate the shortest path/ nearest route to filled waste bins on relevant waste pick-up dates. Finally, through this study, an overall system that can be used to provide solutions for main waste disposal mismanagement problems in one platform is introduced. In this work, a combination of IoT and Machine learning algorithms are used and integrated into the whole system. Algorithms and IoT components are tested for reliability, efficiency, and application simplicity for users as per the authors' main intentions. This system can effectively supervise waste disposal, waste collection and transportation, and the awareness of users on a regular basis while saving time. With respect to the infrastructure in Sri Lanka, this study is proposed and carried out as a dynamically updating system to integrate different stakeholders in the waste management entity. In future work, authors propose to find out technology-based mechanisms for waste minimization along with waste management and to develop the current system with next step problem areas such as waste recycling, waste dumps monitoring, etc. Also, the use of Robotics related technologies to automate garbage collections by replacing the human effortfor waste collection would make the waste management system more reliable. [21] [1]

6. ACKNOWLEDGMENT

We would kindly like to thank our Supervisor and CoSupervisor and who has given us their precious time and advice throughout our research work. We would also thank our Seniors who provide insight, technical, and experiential knowledge that greatly assisted the research. Lastly, we would like to mention our heartful gratitude to our parents who have helped us to do this research perfectly.

7. REFERENCES

[1] S. K. A. K. S. N. D. M. G. N. B. P. K. Rijwan Khan, "Machine Learning and IoT-Based Waste Management Model," Hindawi, vol. 2021, p. 11, 2021.

[2] S. chakraborty, "Smart Waste Management System," International Journal for Research in Applied Science and Engineering Technology, p. 3, 2017.

[3] C. H. P. P. D. L. L. M. B. N. N. M. T. N. T. H. P. N. V. D. N. T.-Y. H. N. N. D. N. M. D. Tran Anh Khoa, "Waste Management System Using IoTBased Machine Learning in University," Hindawi, vol. 2020, p. 13, 2020.

[4] P. Holley, "Racine Country Eye," 13 may 2019. [Online]. Available: https://racinecountyeye.com/john-w-hammes-and-the-garbagedisposal/.

[5] D. B.-T. P. Hoornweg, "Open Knowladge," 3 2012. [Online]. Available: https://openknowledge.worldbank.org/handle/10986/17388.

[6] M. W. N. Muhammad Javed Ramzan, "Smart Waste Collection System (BS Final Year Project Report)," ReaserchGate , p. 82, 2018.

[7] O. M. I. A. N. A. O. Adeniran Sunday Afolalu, "Development of Smart Waste Bin for Solid Waste Management," International Journal of Sustainable Development and Planning, vol. 16, p. 7, 2021.

[8] F. Samann, "The Design and Implementation of Smart Trash Bin," Academic Journal of Nawroz University, p. 9, 2017.

[9] J.-L. R.-G. P. J. P. P.-M. María-Victoria Bueno-Delgado, "Optimal Path Planning for Selective Waste Collection in Smart Cities," Sensors, p. 14, 2019.

[10] M. I. A. G. ,. A. S. A. Tariq Ali, "IoT-Based Smart Waste Bin Monitoring and Municipal Solid Waste Management System for Smart Cities," Arabian Journal for Science and Engineering, 2020.

[11] M. R. H. M.A.Hannan, "An automated solid waste bin level detection system using a gray level aura matrix," Science Direct, vol. 32, no. 12, pp. 2229-2238, 2012.

[12] J. T. J. F. E. A. Andrés Camero, "Waste generation prediction under uncertainty in smart cities through deep neuroevolution," redin, pp. 128-138, 2019.

[13] A. O. R. V. H. A. SolmazAzarmi, "Comparative Modelling and Artificial Neural Network Inspired Prediction of Waste Generation Rates of Hospitality Industry: The Case of North Cyprus," Reaserch Gate, p. 19, 2018.

[14] M. I.-G. J. A. L. J. J. A. J. M. P. I. J. D. Juana CarmenRodríguez López, "Prediction of container filling for the selective waste collection in Algeciras (Spain)," Science Direct , vol. 58, pp. 583-590, 2021.

[15] 1. S. K. A. K. S. N. D. M. G. N. B. P. K. Rijwan Khan, "Machine Learning and IoT-Based Waste Management Model," Hindawi, p. 11, 2021.

[16] P. V. Parkash Tambare, "IoT Based Waste Management for Smart City," International Journal of Innovative Research in Computer and Communication Engineering, vol. 4, no. 2, p. 9, 2016.

[17] G. M. J. G. C. R. G. M. L. George E. P. Box, "Time Series Analysis: Forecasting and Control," Wiley, p. 712, 2015.

[18] J. L. Weimin Li, "The financial time series forecasting based on proposed ARMA-GRNN mode," Research Gate , vol. 4, p. 6, 2005. [19] J. T. J. F. E. A. Andrés Camero, "Waste generation prediction under uncertainty in smart cities through deep neuroevolution," redin, pp. 128-138, 2019.

[19] J. T. J. F. E. A. Andrés Camero, "Waste generation prediction under uncertainty in smart cities through deep neuroevolution," Scielo, 2019.

[20] M. A. R. N. ,. M. H. K. P. MS. HARSHITHA CHANDRASHEKAR NAIK, "IOT BASED AUTOMATIC WASTE MANAGEMENT," MANGALURU