International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Predictive Analysis based Efficient Routing of Smart Garbage Bins for Effective Waste Management

Mabel Johnson, Dhanalakshmi R

Abstract:*The crux of an effective waste management system is a well-organized routing algorithm that aids to collect the garbage from the bins efficiently and thereby eliminate the overflow of the garbage bins. To automate the garbage collection, the bins use a smart integrated sensing system. Three sensors (ultrasonic, load and gas sensors) are equipped in the proposed garbage bin to sense the level, weight and Carbon-di-oxide (CO_2) concentration of the garbage in the bin. A dedicated webpage is assigned to monitor the collected garbage bin sensor data continuously. If the bin reaches the maximum waste level or weight or CO_2 level (threshold) it will be marked as "Ready to be picked up". Scheduling the route(s) and allocating pickup vehicle(s) to collect the filled bins is a significant concern for the efficiency of any waste management system. This scheduling problem boils down to a capacitated arc routing problem (CARP).Considering multiple trips for the available vehicles, capacity of the vehicle, capacity of the bins to be collected, etc., as factors a heuristic algorithm for an efficient routing is proposed in this paper. The primary aimof the proposed heuristic routing algorithm is to reduce the total usage cost of vehicles by minimizing total traversed distance. Predictive analysis algorithms will aid the pickup trucks to be used to the fullest capacity even though there are only few bins to collect so that better efficiency is achieved. In this paper, simple linear regression and multiple linear regression algorithms are applied to suggest the bins (that will be filled in near future) to be added to the route that will help achieve maximum usage of truck capacity. The waste management web application allows the admin to add these bins to the route and authorize the same for the drivers.*

Keywords : Smart bin, Heuristicrouting, Predictive Analysis, Linear Regression, Waste Management

I. INTRODUCTION

A study by United Nations predicts [1] that by 2050 about 70% of the global population (which is about six billion people) will be residing in urban or sub-urban communities. This prediction requires the urban and sub-urban districts to scale up on infrastructure, economy, healthcare and environmental hygiene to sustain its new and growing population [2].

Manuscript published on 30 September 2019
* Correspondence Author
Mabel Johnson*, Department of Computer Science and Engineering,KCG College of Technology, Chennai 600097, India.
Dhanalakshmi R, Department of Computer Science and Engineering, KCG College of Technology, Chennai 600097, India
Corresponding Author, Email: mabelj.finney@gmail.com

An option for scaling up on the above parameters could be to use Internet of Things (IoT) and their applications to convert urban and sub-urban cities into smart cities.

Smart city solutions offer advanced sensing, exchange of data and control systems for better administration of infrastructure, healthcare, waste management and environment. Continuous growth in population has led to degradation of garbage management due to the difficulty in maintaining the cleanliness of public areas [3,4]. An ideal approach for waste management would include planning of garbage collection, pickup route management, and recycling of garbage that will aid to improve the health and sanitary conditions of the city and reduce the operational cost of garbage management. The above stated approach can be included in the set of technologies widely known as "Smart waste management system" and it is imperative that this is implemented for the cities of the next generation.

This paper proposes a system consisting of an intelligent sensor-based garbage bin to monitor the level, weight and gases in it. The authority can remotely monitor the garbage bin continuously and will be notified once the bin is ready for pickup. Now, the need for effective garbage pickup planning requires generating a shortest route for the bins that are ready for pickup. The problem statement of generation of routes for pickup vehicles are widely categorized as vehicle Routing Problem (VRP). The garbage pickup routing will fall into the Capacitated Arc Routing Problem (CARP) [5]. To solve this routing problem this paper proposes a heuristic routing algorithm. To add better efficiency to the system, the pickup truck using the route generated by the heuristic algorithm must be used to its fullest capacity. Predictive analysis done by linear regression algorithms help to achieve the maximum capacity usage of the pickup trucks. Linear Regression based predictive analysis combined with heuristic algorithm makes the waste management collection system effective and efficient.

II. LITERATURE SURVEY

Debajyoti Mishra, Gautham Das, Triankur Chakraborty, Debaprasad Das has proposed "An IoT-based waste management system monitored by cloud" [6] which detects and notifies whenever the garbage in the bin exceeds the calibrated threshold (garbage level and concentration of bio-gas) of the garbage bin. The datagathered from the bin using sensors is uploaded to a server where it is saved, analysed andreported. This datais used to identify the binsthat have reached the threshold and ready for pickup.

This process helps to reduce the operational cost. ErfanBabaeTirkolae, Iraj Madhavi, Mir Mehdi SeyedEsfahanioffers solutions on the effectivepreparation and identification of routes for vehicles for periodic CARP in their paper “A robust periodic capacitated arc routing problem for urban waste collection considering drivers and crew’s working time” [5]. This is one of the mainconcernsof the waste collection process of any urban management system. The model proposed in this paper aids to reduce the operational cost of the vehicles over a scheduling period. The solution is given bya hybrid simulated annealing algorithm (SA) and has proved that the outcome of this algorithm is acceptable in comparison with the exact solution method.

Aksan Surya Wijaya, ZahirZainudin and Muhamad Nishwarcontributed their idea to “Design a Smart Waste Bin for Smart Waste Management” [7] whichpurposesto generate dynamic routes for the process of garbage collection based on the real-time datafrom the garbage bins’ predefined threshold value. The route generation (travelling salesman problem) for the garbage collection process is solved by using a Genetic Algorithm. GSM/GPRS is used to transmit the data gathered by the ultrasonic sensor positionedat the upper part of the bin. This data is saved in the databaseand the genetic algorithm uses this data to generate the optimized pickup route.

M.G. Hoang, T. Fujiwara, S.T. Pham Phu, K.T. Nguyen Thiperformed a study on “Predicting waste generation using Bayesian model averaging” [8] and gathered data using waste sampling and a survey. To identify the most influential criteria (factors)contributing to the waste generation Bayesian model average method was used. Multivariate linear regression analysis was used to evaluate the impacts of the identified factors on household waste production. The outcome of this study was to identify the following factors that had high impact on waste generation: location of the household, size of each household, location of the house(community), and economic status of each family. This research also confirms that choosing the significant variables will result in a much more refined prediction.

Cristina Ghinea, Elena Niculina Dragoi, Elena-Diana Comaniț, Marius Gavrilescu, TeofilCampean, Silvia Curteanu, Maria Gavrilescu proposed a system on “Forecasting municipal solid waste generation using prognostic tools and regression analysis” [9] that forecasts waste generation using predictive and prognosis models based on various factors that can affect waste trends. Population, age of the population, city life longevity, entirecommunity solid wastewere considered to be the mostcontributingfactors to predict the amount of garbagegenerated. Waste prediction based on the above mentioned 4 inputs, an ANN algorithm combined with multiple linear regression using 10 neurons in the hidden layer produced 6 outputs (plastic,paper, glass, metal, organic wasteand other waste). The outcome of the research proved that ANN based prediction algorithm provide more accurate results when social and economic factors are considered.

III. SYSTEM DESCRIPTION

The garbage bin is made to be smart by integrating three different sensors to measure the level, heaviness of waste, and the concentration of CO_2in it. This smart garbage bin contributes to the waste management system to become cannier as it helps to alert the authority when appropriate action needs to be taken. As ultrasonic sensor provides longer range and durability than IR sensors (IR sensors get affected by sunlight, color of object and hardness of object) it is used to measure the garbage level. The heaviness of the garbage in the bin is measured using a load sensor and the intensity of the alcohol in the air (i.e. the concentration of a CO_2) is measured using a gas sensor. The data gathered from the above mentioned three sensors are uploaded to a server using GSM technology (internet) where it is saved and managed [10].A dedicated webpage is provided to monitor the collected garbage bin sensor data continuously. Once the bin reaches the maximum level or weight or CO_2 level it is marked as “Ready to be picked up” and an alert is sent to the authority. A heuristic algorithm is used to generate effective dynamic routes for the garbage pickup trucks to collect the bins that are ready to pick up. The web application helps to manage the vehicles available for pickup.

The key feature of this methodology is not only to make decisions based on the day-to-day garbage level/weight status but also use the same data predicts the future bin status based on other influencing features. If the bins that are ready are too few, then to efficiently use the pickup truck capacity this vital feature is used to perform predictive analysis using Linear Regression methods and hence add the bins (that will be filled in near future) to the route. Driver will use a mobile app to update the pickup status of the bin and also have a provision to update if any bins needed manual service.

a. System Architecture - Overview

The smart waste management system proposed in this paper contains the following four modules:

1. Garbage bin equipped with sensors (hardware)
2. Communication between the garbage bin and server
3. Web Application for Garbage Management (Routing and Prediction)
4. Mobile application for Drivers

The figure (Fig 1)below details the architecture for the smart waste management system:

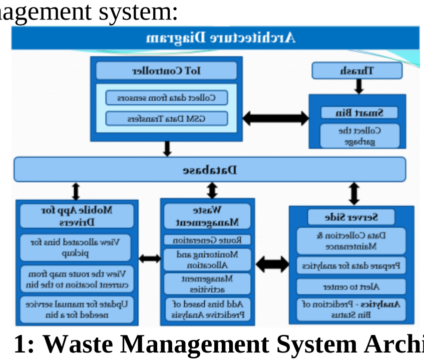

***Figure* 1: Waste Management System Architecture**

b. Smart Bin with Sensors (Hardware)

i. *Microcontroller*

Arduino.cc developed an open-source microcontroller board based on the ATmega328P microcontroller called the Arduino UNO (similar to Arduino Nano and Leonardo).The board is commonly used and has 6 Analog pins and 14 Digital pins. Type B USB cable can be used along with Arduino IDE (Integrated Development Environment) to program the Arduino UNO.Arduino UNO can be powered by an external battery or USB cable.

ii. *Ultrasonic Sensors*

The height or level of the thrash in the bin is found by determining the distance from the highestpoint of waste bin to the uppermost level of the waste usingultrasonic waves. The ultrasonic sensorHC-SR04 has a range of 2.0 to 400 cm with 3.0 mm accuracy [7] and is suitable for any practical garbagebin.The level measured by the sensor is sent to the Arduino UNO. The overflow condition of the binis calculated based on fixed value that is predetermined as the threshold value[11]. The height of the garbage bin and the placement of the ultrasonic sensor in the bin are factors to decide this threshold value. The predetermined threshold value is programmed to indicate the overflow condition.

iii. *Gas sensor (MQ-3)*

Hydrogen sulfide (H2S), ammonia (NH3), carbon monoxide, Methane(CH4) and carbon dioxide(CO2) are the gases typically produced in garbage bins. Odorless gaseslike methaneand carbon monoxide are very difficult to detect whereas gases like ammonia and hydrogen sulfide produce pungent smell can be detected easily. This system uses MQ3 sensorto sense the alcohol level (sensor's conductivity increases when the gas concentration increases) in the environment. High alcohol level indicates that thecarbon dioxide content is highand is a good indication for gas pollution.The alcohol level measured by the sensor is sent to the Arduino UNO.

iv. *Weight Sensors (Load cell, ADC-HX711)*

This weight sensor used in this system is like the load sensors used in electronic scale, price computing scale, electronic platform scale, parcel post scale, etc., The maximum capacity will be 50 kg. The threshold for weight is set to be 20kg.
The prototype of the bin constructed using these sensors is shown the figure (Fig 2) below.

c. Bin-Server Communication

All input UART data (from the sensors - weight, level and CO_2 level)is converted into GPRS based online data and the IoT board featured with SIM900 GPRS modem is used to upload the data to the server. This data is stored in the server for further processing and continuous monitoring. The IoT Board is programmed to send its data in a special format so that the server identifies the bin data.

*Message Format: *message / Data # - (Start with * and End with #).*

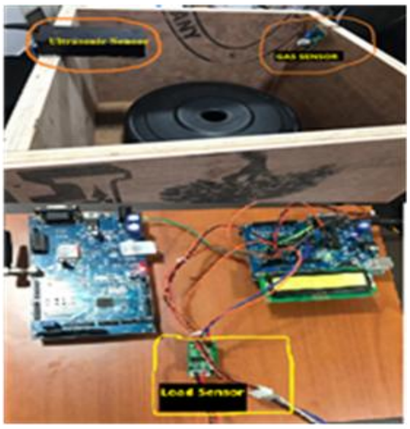

Figure 2Garbage Bin equipped

This process flowchartfor bin to servercommunication using IoT Board is explained in the flowchart shown in Fig 3.

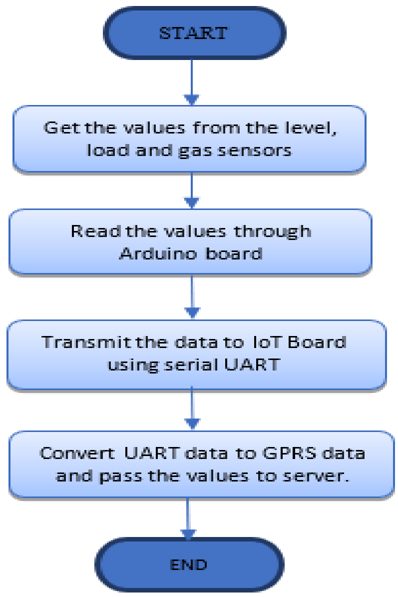

Figure 3. Flowchart

The webpage shown in following figure (Fig 4) is used for continuous monitoring of bin data

Figure 4 Webpage to continuously monitor the garbage bin status

d. Routing Model Development

This section explains how to plan the collection of bins that are ready for pickup. A good waste management system generating dynamic routing combined with the IoT capabilities to provide solutions that outperform existing models [12]. The aim here is to determine the optimum number of vehicles and optimum number of trips requiredso that theoperational cost ofvehicles is reduced. The amount of garbage a vehicle can hold (capacity) is an important factor that decides the maximum possible trips the numberof required vehicles needed to collect all the bins marked as "Ready to be picked up".

i. *Problem Assumptions*

The heuristic algorithm proposed in the below sectionaims to minimize the operational costwhile generate the routeto collect all the "Ready to be picked up" bins (demand). The algorithm assumesthe following constraints to generate the efficient route.

- Every vehiclehas aunique starting point.
- Every vehicle is assumed to be the same location for the starting and ending point.
- All the garbage bins are assumed to have the same capacity (homogenous).

- The vehiclescapacity to hold the garbage is programmable (i.e)heterogenous.
- The route generated begins from the starting point and endsat thesame point.
- Multiple trips can be allocated for all vehicles.
- The shortest path between any two given points (determines the operational cost)is calculated using the existing Google APIKey -Dijkstra algorithm(Distance Matrix lat long algorithm).

ii. *Mathematical Implementation*

To represent the operational cost mathematically, the required variables, parameters and sets need to be defined. The objective of the heuristic algorithm is to generate a pickup route that will minimize the operationalcost.

All the pickup points (bin locations) are considered as the nodes in the graph network. The edges (distance between them) connecting the nodes will decide the operational cost. The required sets, parameters and variables and the mathematical representation of the required minimal operational cost is defined below [13]:

Sets[13]

V: Set of the nodes in the graph network

K: Set of the vehicles

E: Set of all the edges defined in the network

T: Set of trips

Parameters[13]

d_{ij}: Traversing distance of the edge (i,j) ∈ E

cv_k: Usage cost of kth vehicle

W_k: Capacity of kth vehicle in each trip

Decision variables[13]

x_{ijk}^{t} : 1 if edge (i,j) ∈ E is traversed by t^{th} trip of vehicle k in trip t, otherwise 0.

u_{kt}: 1 if vehicle k is used in trip t, otherwise 0.

$$MinCost = \sum_{(i,j)\in E}\sum_{k\in K}\sum_{t\in T} x_{ijk}^{t}\, d_{ij} + \sum_{k\in K, t\in T} cv_k\, u_{kt}$$

(1)…[13]

iii. *The Heuristic algorithm*

The heuristic algorithm follows the below mentioned step by step procedure to generate the efficient route(s) for the vehicle(s) to collect all the bins that are ready to be picked up.

Step 1:Save the locations of all the bins that are ready to be collected in a pool (Binsready to be picked up).

Step 2:The number of required trips is calculated based on the bin's capacity. If the bins marked as "Ready to be picked up" have capacity 'c'and a truck has capacity 'C', then the truck can load waste fromC / c bins (maximum bins that can be picked up by the truck).

Step 3: The web application will allow the admin to choose the vehicle(s) for allocation of trips. Based on the allocation we will now have the total number of routes/trips to be generated (A same vehicle can be allocated for multiple trips).

Step 4: Thetripto be allocated to the vehicle will be chosen by the admin for route generation

Step 5: Based on the distance from the starting point of the vehicle the bins that need to be picked are sorted (shortest distance first). This sorting ensures that the operational Cost is kept as low as possible (minCost)

Step 6: The bin with the shortest route is chosen and added to the route. The vehicle's starting point is now updated to the selected bin's location. The bin added to route is removed from the pool of available bin locations to be picked up.

Step 7: Steps 5,6are repeated until there are no more bins or the vehicle capacity (W_k) is reached.

Step 8: If the vehicle capacity (W_k) is reachedand there are more bins in the pool to be picked up, then the next route (the next vehicle selected by the admin or a new trip to the already selected vehicle) for the next trip will be generated by repeating steps 4,5,6,7

Step 9: If no more bins are there to be added to any route then display the route generated for the vehicle for the admin to approve

The following figure (Fig 5) shows the route generated based on heuristic algorithm.

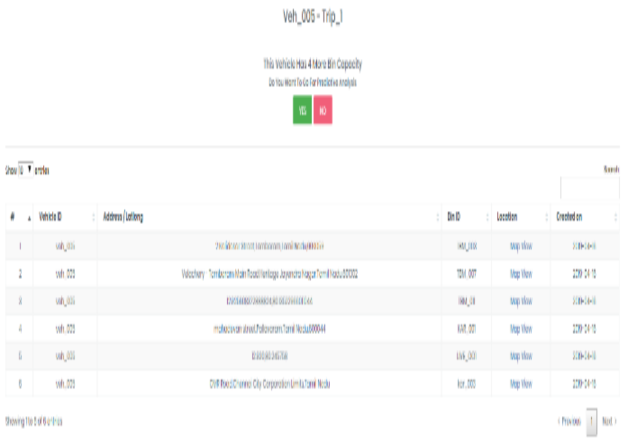

Figure 5Output of the heuristic algorithm (Route Generation)

e. *Predictive Analysis*

Predictive Analytics is a branch of advanced data analytics that involves the use of various techniques such as machine learning, statistical algorithms and other data mining techniques to forecast future events based on historical data.For maximum efficient usage of the vehicle used for pickup, predictive analysis is to predict the bins that will be filled in near future so that they can be picked earlier to maximize the truck capacity usage.

Garbage bin level and weight predictions are done using the following two methods:

- Simple Linear Regression
- Multiple Linear Regression

In both methods, response(dependent) variable is predicted froma given set of predictor(independent) variables. Using theseset of variables, a function mapping inputs to outputs isgenerated. This process continues until the model achieves adesired level of accuracy on the training data. The predictions based of simple linear regression and multiple linear regression will be displayed for the authority to choose the best from them.

i. *Assumptions and basic Calculations:*

- Population (no of people) that will be using a binis a known data.
- In real time the algorithm will use the data collected 4 times a day at 06:00hrs,12:00hrs,18:00hrs, 23:59hrs for 10 days.

Retrieval Number: B2600078219/2019©BEIESP
DOI:10.35940/ijrte.B2600.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

- For demo purpose, a randomized matrix method is used to generate the required 10-day data.
- If there are multiple bins predicted for bin the shortest distanced bins from the last pickup point will be chosen.
- The difference in the weight at each time is calculated as the Δweight/Δlevel and the average Δweight (avgΔweight)/ average Δlevel (avgΔlevel) for a 6-hour window is then calculated based on the 10-day data.
- Predicted bins will be sorted in the ascending order based on of how quick the bins will be filled.

ii. *Variables used:*

1. RV :Response Variable (dependent variable)– The predicted value of the bin weight or level.
2. C : Constant – The current value of the bin. This variable denotes the dependent variable RV's valuewhenthe predictor variables (PV,PV1,PV2) are equal to 0;
3. Coef:Coefficient – weightage of the time window taken for consideration. If the value is 1 then the predictor is not correlated. Else it is (1/no.of time windows taken)
4. PV/PV1: Predictor Variable – Independent variable indicating the average increase in the weight/level of the bin under prediction in the considered time window in hours (6,12,18,24 and so on..) (avgΔweight or avgΔlevel)
5. Coef1:Coefficient1 - weightage of the predictor (weight or level) taken for consideration. The results displayed below consider Coef2=50% hence 0.50
6. Coef2:Coefficient2 – weightage of the predictor (population) taken for consideration. The results displayed below consider Coef2=50% hence 0.50
7. PV2 :Predictor2 – per person contribution to the increase in the weight/level of the bin under prediction

iii. Calculation:

- Step 1: This calculated value of PV is added to the current weight and level of the bin respectively to calculate the value of response variable.
- Step 2: If RV is greater than the corresponding threshold value then the bin will be marked for pickup.
- Step 3: If no bins are predicted for pickup then calculation window will be increased to 12 hours, 18 hours,24 hours and so on.
- Step 4: Such predicted bins are sorted in the ascending order of how quick the bins will be filled. Required number of bins is added to the already generated route

iv. *Simple Linear Regression:*

Thesimple linear regression model is explained in Equation (2).

$$RV = C + Coef *(PV) + Coef *(PV) + Coef *(PV) + \ldots \quad (2)$$

The PV value calculated with first time window(Coef=1) is applied to all the bins that needs to be predicted. If required number of bins are predicted to be full then we display the result. Else the PV value calculated with next time window(Coef=0.5) is applied to all the bins will also be added. This process will continue until all the required number of predictions is achieved. The result based on simple linear regression is calculated as shown in the following figure (Fig 6)

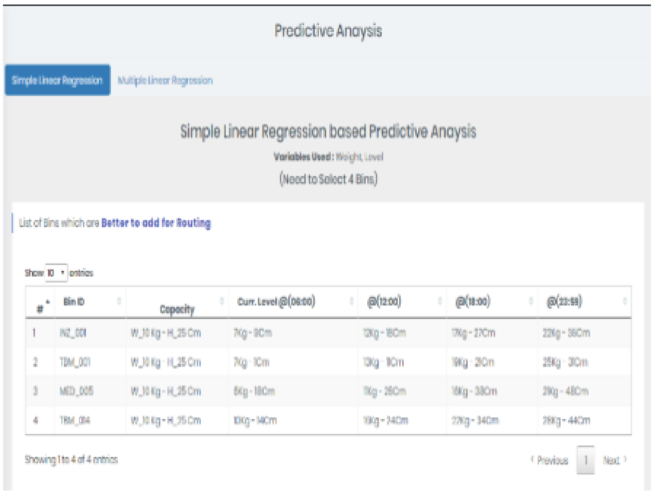

Figure 6. Output of Simple Linear Regression Predictive Analysis

v. *Multiple Linear Regression:*

Apart from the average weight increase (independent variable PV1) in a time window, population is another factor (independent variable PV2) that will be considered based on researches done by many scholars [14].

$$RV = C + Coef\,1*(PV1) + Coef\,2*(PV2) \quad (3)$$

The multivariable linear regression model is explainedin Equation (3). PV2 value is calculated based on the average per person contribution to the waste generation. The PV1 value and the PV2 for first time window is applied to all the bins that needs to be predicted. The weightage of the predictor variables is factored through the Coef1, Coef2. If required number of bins are predicted to be full then we display the result. Else the process will continue to the next time window until all the required number of predictions is achieved. The result based on multiple linear regression is shown in the following figure (Fig 7).

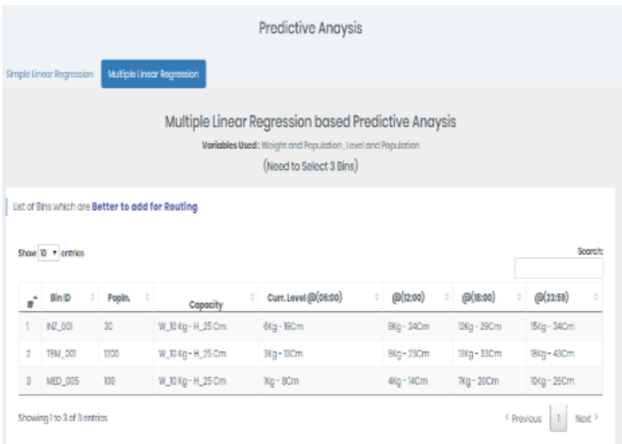

Figure 7. Multiple Linear Regression

The top predicted bins (simple and multiple linear regression results combined) will be added to the route to obtain maximum truck capacity usage. If many bins are predicted for the same time window, then the top and shortest distant bins from the last pickup point will be chosen.

f. Mobile Application for Drivers

Any system can provide better integration of internet in management via the use of Smartphones[15].

Retrieval Number: B2600078219/2019©BEIESP
DOI:10.35940/ijrte.B2600.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The mobile application developed for this project helps the drivers to perform their work efficiently by providing the following:

- Allows drivers to login and view their work allotment.
- Drivers can view the route and vehicle assignment for the day.
- Route to the bin navigation will be given using google maps.
- Drivers can update if any manual service is needed for the bin.

Following figure (Fig 8) shows the mobile app screenshots for map navigation and driver update for manual service need.

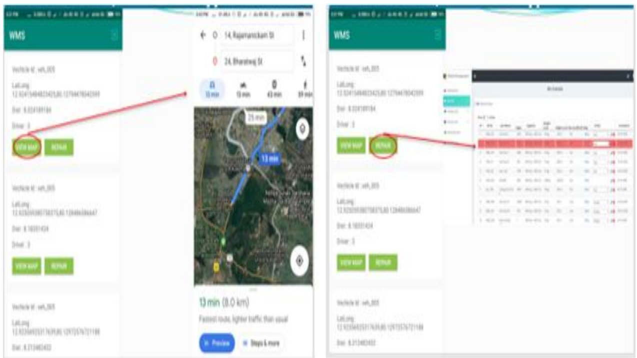

Figure 8 Mobile application screenshots

g. Result and Analysis

The first graph (Fig 9) shows the sensor information received from the garbage bin. The graph details the information collected ina day from 12AM to 8PM. It is clear from the graph that thebins are filled more at evening than noon. Hence the authority can quickly arrive at a decision that the picked has to be scheduled in the morning instead of evening or noon. Thisapproachaids to collect thebinswith minimal usage of staff/vehicle requirement and hence reducing the overall operational cost.

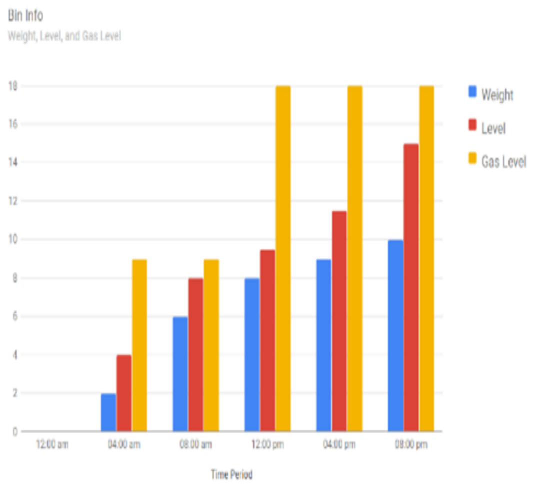

Figure 9 Garbage Bin Status

The second graph (Fig 9) shows the comparison in the total kilometerscovered by the garbage pickup vehicles using theusual CARP algorithm versus the heuristic algorithm. The data is based on the truck's kilometer usage over the same give period for the same set of garbage bins. The graph clearly shows that the heuristic algorithm effectively reduces the overall distance travelled and thereby reduce the operational cost.

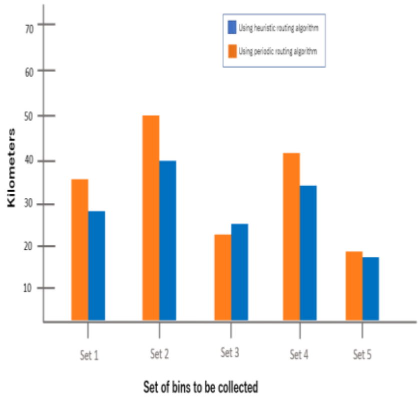

Figure 10. Operational Cost

The third graph (Fig 11) shows the prediction of weight and level raise for four 6-hour windows. The graph is generated based on the values prediction by simple linear regression algorithm.

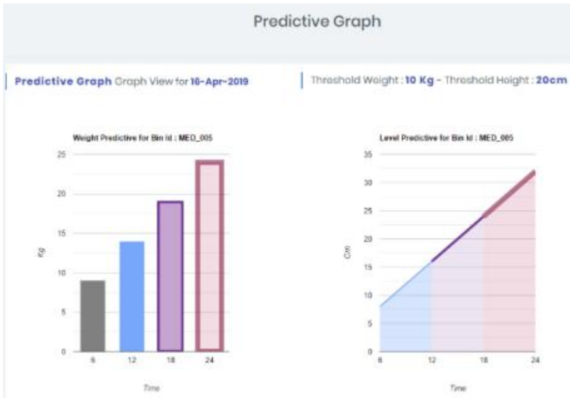

Figure 11 Level and weight predictions for bin MED_005 using simple linear regression

The fourth graph (Fig 12) shows the prediction of weight and level for all the bins that are added to the route to make the maximum usage of the truck capacity. The graph is generated based on the values prediction by simple multiple regression algorithm.

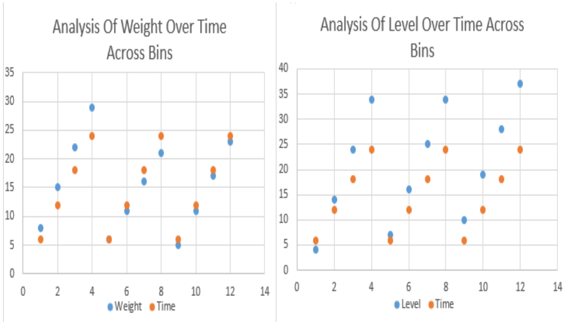

Figure 12 Level and weight predictions for all the selected bins for efficient routing using multiple linear regression

The fifth graph (Fig 13) shows the comparison of the efficiency achieved with respect to the total distance travelled by a vehicle over a week when predictive analysis is used and not used. It clearly shows that Predictive analysis helps minimizing the total distance travelled hence achieve cost effectiveness.

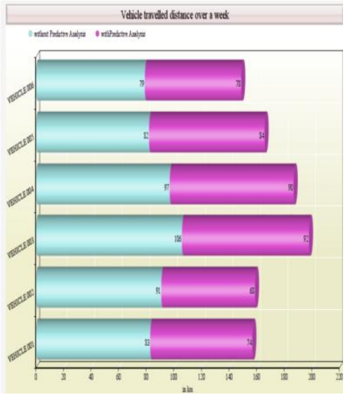

Figure 13 Vehicles total distance travelled with and without Predictive analysis

IV. CONCLUSION AND FUTURE WORK

An intelligentIoT based waste management system for an ultramodern smart city is proposed in the paper. The garbage bin integrated with sensors measures the level/weightof the garbage and presence of CO_2. This measured data is uploaded to a server for further analysis and reporting. This statisticsis used to generate aneffectivepick-upmethodthat effectively cuts money, manpower and time. The results and analysis section details on the economic efficiency attained using this system.The major hygiene issue of overflow of the garbage bins are addressed as the garbage bin's sensor data is continuously monitored and notification is sent for the authority to take appropriate action. Also, the mobile application enables the driver to update the pickup status and need for any manual service for a garbage bin. The heuristic algorithm combined with the linear regression based predictive analysis generates efficient routing for vehicles that reduce the total operational cost in planning and scheduling. The results given by both simple and linear regression algorithms will be combined to choose the best bins predicted to be filled soon. Hence the goaltosustain a hygienic and better sanitized city can be achieved.

As a continuation to this research/study,segregation of waste which is another major concern of waste management can be done using special cameras to recognize the type of waste using image processing and classification (Machine learning) techniques. Automatic bin positioning based on based on various factors of an area could be done as a future work.Other algorithms for predictive analysis based on social and economic factors can be analyzed so that a better pickup schedule can be generated for areas where remote monitoring is required.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to all those who provided me the possibility to complete this project. A special gratitude to our project coordinator, Dr.R.Dhanalakshmi, Department of Computer Science and Engineering, K.C.G. College of Technology whose contribution in stimulating suggestions and encouragement, helped us coordinate our project especially in writing this paper.

Furthermore I would also like to acknowledge with much appreciation the crucial role of the Professor and Head, Department of Computer Science and Engineering, K.C.G. College of Technology Dr.M.Krishnamurthy, who gave the permission to use all required equipment and the necessary materials to complete the project. A special thanks and appreciation to the guidance given by other supervisors and the panels (in project presentation) that has helped to improve the outcome of the project.

REFERENCES

1. United Nations (https://www.un.org/en/development/desa/news /population/ world-urbanization-prospects-2014.html
2. McNutt, Kathleen. *Canadian Public Administration* 57.1, pp 49-70 (2014).
3. Islam, F, *Journal of Modern Science and Technology*. 4: pp192-209(2016).
4. Wilson, D., Rodic, L., Scheinberg, A., Velis, C., Alabaster, G, *Waste Management & Research*. 30: pp237-254 (2012).
5. ErfanBabaeeTirkolaee, Iraj Mahdavi, Mir Mehdi SeyyedEsfahani, *ElsevierWaste Management* 6: pp138-146 (2018) https://doi.org/10.1016/j.wasman.2018.03.015
6. ErfanBabaeeTirkolaee, Iraj Mahdavi, Mir Mehdi SeyyedEsfahani, *Journal of Material Cycles and Waste Management* Volume 20, Issue 3, pp 1574–1582 (2018)
7. Aksan Surya Wijaya ZahirZainuddin Muhammad Niswar , "Design a Smart Waste Bin for Smart Waste Management" *5th International Conference on Instrumentation, Control, and Automation (ICA)* Yogyakarta, Indonesia, (2017)
8. M.G. Hoang , T. Fujiwara, S.T. Pham Phu , K.T. Nguyen Thi, *Global Journal of Environmental Science and Management*, Volume 3(Issue 4): pp 385-402 (2017) DOI: 10.22034/gjesm.2017.03.04.005
9. Cristina Ghinea, Elena Niculina Dragoi, Elena-Diana Comanit, Marius Gavrilescu, Teofilampean, Silvia Curteanu c, Maria Gavrilescu, *Journal of Environmental Management. 182*: pp80-93 (2016) https://doi.org/10.1016/j.jenvman.2016.07.026
10. Parag Kedia, *IJRET: International Journal of Research in Engineering and Technology* Volume 5(2016) eISSN: 2319-1163 | pISSN: 2321-7308
11. D. K. J. G. A. G. V. A. Papalambrou, "A Versatile Scalable Smart WastebinSystem based on Resource-limited Embedded Devices,", *2015 IEEE 20th Conference on EmergingTechnologies & Factory Automation (ETFA)*, Luxemburg (2015).
12. Anagnostopoulos, T., Kolomvatsos, K., Anagnostopoulos, C., Zaslavsky, A. and Hadjiefthymiades, *Journal of Systems and Software*, Vol. 110, p. 178-192 (2015).https://doi.org/10.1016/j.jss.2015.08.049
13. Mabel Johnson, Dr.C.EmilinShyni, *International Journal of Applied Engineering Research (IJAER)* (2019), Volume 14 Number 5, pp: 80-89. https://www.ripublication.com/ijaerspl2019/ijaerv14n5spl_14.pdf
14. K.A. Kolekara, T. Hazrab, S.N. Chakrabartyc, Elsevier Journal, *Procedia Environmental Sciences.*Volume35: pp238-244 (2016) https://doi.org/10.1016/j.proenv.2016.07.087
15. S M Labib," Volunteer GIS (VGIS) Based Waste Management ", *IEEE Third international conference on Research in Computational Intelligence and Communication Networks* (2017).**DOI:** 10.1109/ICRCICN.2017.8234495