

## AN INNOVATIVE MACHINE LEARNING BASED IOT APPROACH FOR WASTE MANAGEMENT IN KEEN CITIES

<sup>1</sup>Dr. M. Vishnu Vardhana Rao, <sup>2</sup>Dr. M. Thejovathi, <sup>3</sup>Dr. C. Srinivasa Kumar, <sup>4</sup>K. Kusuma Kumari

<sup>1,2</sup>Associate Professor, Department of CSE(AI&ML), Vignan's Institute of Management and Technology for Women, Kondapur, Ghatkesar, Hyderabad-501301

<sup>3</sup>Professor, Department of CSE(DS), Vignan's Institute of Management and Technology for Women, Kondapur, Ghatkesar, Hyderabad-501301

<sup>4</sup>Assistant Professor, Department of CSE, Vignan's Institute of Management and Technology for Women, Kondapur, Ghatkesar, Hyderabad-501301

E-Mail: [mvvrao.mca31@gmail.com](mailto:mvvrao.mca31@gmail.com), [kkutheju@gmail.com](mailto:kkutheju@gmail.com), [drcskumar41@gmail.com](mailto:drcskumar41@gmail.com), [vishnucse@vmtw.in](mailto:vishnucse@vmtw.in)

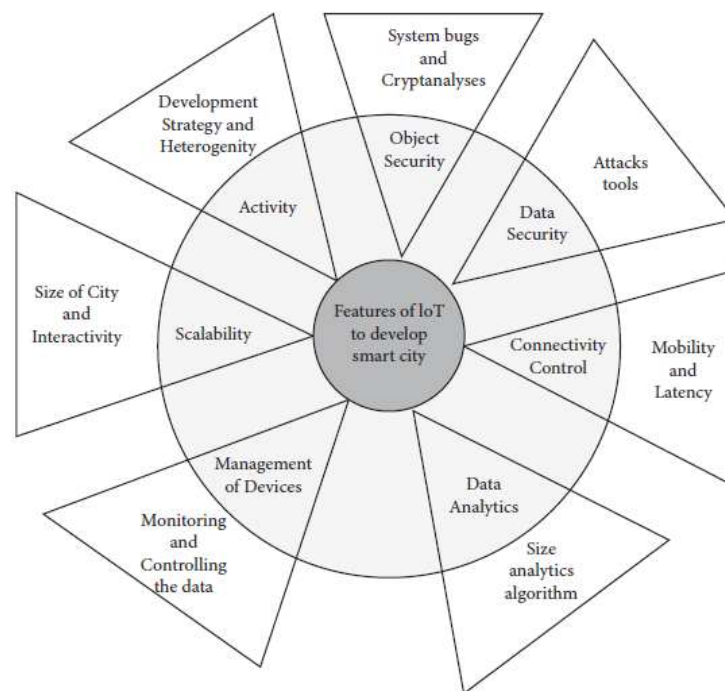
### ABSTRACT:

Efficient waste management is a critical challenge in the development of sustainable and smart cities. This study presents an innovative Machine Learning-based Internet of Things (IoT) approach for intelligent waste management in keen cities. The proposed system integrates IoT-enabled smart bins equipped with sensors to monitor waste levels, types, and environmental parameters in real time. Machine learning algorithms are employed to analyze collected data and optimize waste collection routes, predict waste generation patterns, and enhance resource utilization. The system also facilitates automated alerts and data-driven decision-making for municipal authorities. Experimental analysis demonstrates that the proposed ML-IoT framework significantly improves waste segregation efficiency, reduces operational costs, and minimizes environmental impact. Overall, this innovative approach contributes to cleaner, more sustainable, and efficiently managed urban environments, aligning with the vision of next-generation smart city initiatives, this study proposes an automatic technique for achieving an intelligent and effective waste management system via the Internet of Things through the use of trash prediction. - IoT-based trash cans can be installed everywhere in a city and will continuously report their capacity, metal level and gas level. In this research, we offer a novel Internet of Things (IoT)-based strategy to trash management that makes use of machine learning (ML) with four different approaches for finding the shortest path in order to collect the trash bins in smart cities which are completely filled up. Its findings are commendable when weighed against those of state-of-the-art methods as well as those of similar methods.

*Keywords: Machine Learning, Internet of Things, K-Nearest Neighbors, Support Vector Machine, Support Vector Regression.*

## INTRODUCTION:

The Internet of Things (IoT) is an emerging network of interconnected devices that will exchange data utilizing Wi-Fi, Bluetooth, and other sensor-based networks. Wireless technology may include both mobile and wireless fidelity networks. Because of this technology, our routines and daily tasks are simplified and automated. Intelligent wearables and self-driving cars are only two examples of IoT gadgets. As such, human interaction and computer-to-human communication are unnecessary. Rapid decision-making abilities and efficient service are two of the many reasons why the use of IoT devices is on the rise in business and urban settings. Key features are its connectedness, intelligence, vast scalability, dynamic nature, sensing, and heterogeneous structure [1]. Uses for it are practically endless. They are the "smart" home, the "smart" wearable, the "smart" grid, "smart" healthcare, "smart" traffic management, "smart" farming, there are three possible paths for implementing the IoT architecture. Three distinct layers exist, namely the device, the access, and the platform. Steps in sensing, acquiring, edge IT, and cloud storage provide for access at these levels.



**Fig 1: Key Internet of Things Components for Building a Smart City**

The Internet of Things (IoT) is currently being used in the growth of smart city applications. Smart efficiency enhancement and efficient management of urban furniture are two uses for this technology, which is utilized to make cities more intelligent by integrating several transferable methodologies. In order to create a smart city that is both efficient and intelligent, the IoT can be applied in a wide variety of contexts, including the control of traffic and parking, street lighting, security, and garbage collection. An intelligent smart city will have amenities such as clean water, reliable electricity, affordable housing, modern medical care, high-quality public schools, a strong economy, effective law enforcement, and waste management systems. Since the concept of the "smart city" has expanded so rapidly, so has the amount of garbage produced by its inhabitants [2]. One of the biggest difficulties of Internet of Things-based smart cities is getting rid of garbage that can't be recycled. Maintaining a clean city is an ongoing responsibility that consumes significant time and energy. Advantages of IoT for smart city development are depicted in Figure 1. Concerns related to the Internet of Things include scalability, user security, activity, connectivity management, data analytics, and device management. The scalability function accounts for the total amount of facilities, users, and infrastructure. Each device and its method of development is unique, and so is the activity-based feature it offers. The delay and motion of items are controlled by the connection function. Cities are taken into account in terms of size and data collecting via the data analytics feature [3]. When managed properly, IoT devices can track and collect this information in real time. In terms of security, there are two main categories: object security and data security. It takes into account the most recent and cutting-edge cryptanalysis methods, attacks, and software. Calculations are done here using heuristic models or graphical hypotheses to find ways to shorten the duration of waste collection. The main goal is to lower overall transportation costs, free up space, move fewer people, and rely less on pre-owned vehicles, all while raising administrative standards and aiming to boost customer experience more generally.

## RELATED WORK

The IoT dependent Sensor waste management system improves the environment by concentrating on rubbish dispersal. The careful collection and dissection of waste materials is the fundamental difficulty in the implementation of smart cities. Due to population growth and the quick advancement of smart cities, that increases everyday rubbish, the decomposition of garbage often requires more time and resources. In addition, it harms the environment, society, and ecology. Talari et al. and Abdullah et al. discussed revising the waste management system based on the IoT[4] [5]. Monika et al. suggested using an Arduino UNO board with a GSM module to create a smart dustbin system to collect trash. However, it has drawbacks including difficult maintenance and longer collection times [6]. Similar to this, Kumar et al. presented a dustbin that continuously monitored the rubbish level using an ultrasonic sensor.

The solid waste management system was suggested by Pardini et al. to gather waste data from other businesses. is current research limited to data collecting [7]. Similar to this, Bueno-Delgado et al. suggested employing optimization in smart cities for waste collection. It is

primarily employed to enhance rural areas. But it doesn't produce results for clarity [8]. In order to collect waste and monitor the condition of bins, Lozano et al. discussed waste management systems based on genetic algorithms and linear regression. However, it is limited in its ability to transfer waste from bins to other machinery. Therefore, implementing a waste transformation system is challenging [9]. By deploying a line-following robot to collect the debris, Hannan et al. created a system for rubbish waste management, although it was not designed for waste optimization [10].

Additionally, it ensures that waste is disposed of immediately after a particular quantity has been reached in the dumpster [11]. Shyam et al. in India suggested the IoT prototype-based intelligent dustbin in Pune. It examines the nearest neighbour exploration, jurisdiction advancement, transmissible calculation, and molecular swarm enrichment procedures as examples of IoT-based waste administration.

## METHODOLOGY

For all the approaches finding an optimal path in order to collect the garbage in smart cities were carried out

**SVR:** The high data dimensionality and limited resource availability prevent SVR learning from being widely implemented in WSNs. By splitting up the original regression problem into multiple smaller problems, Kim et al. concept's of using a lightweight SVR solution was developed [12]. In essence, the strategy starts by segmenting the network into a number of smaller networks, reducing the quantity of input that each regression algorithm must process. The derived sub-predictor hypothesis models are then combined using a customized ensemble combination technique. This strategy, which also has low processing requirements and is robust against noisy data, achieves the desired result with a minimal computational demand.

$$f(x) = w \cdot \phi(x) + b$$

$f(x)$  signifies the forecasting values when  $x$  is the input variable,  $w$  is the weight coefficient,  $b$  is the deviation value, and  $\phi(x)$  is the high dimensional feature space. The expression for the regularized risk function that was used to determine the values of  $w$  and  $b$  was as follows:

$$\frac{1}{2} \|w\|^2 + C \frac{1}{n} \sum_{i=1}^n L_{\varepsilon}(y_i, f(x_i))$$

Where first term is regularized term second term is the empirical error,  $\varepsilon$  is insensitive loss function.

10.48047/jocaaa.2024.33.08.298

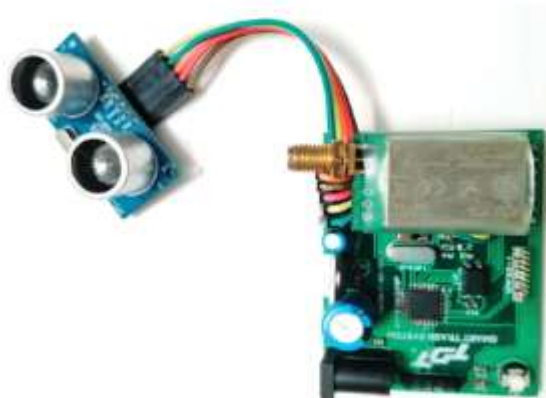
**SVM:** Vladimir et al. developed the SVM algorithm for the first time in 1963 [13], while Boser et al. presented a method to use non-linear classifiers using the kernel technique in 1992 [14]. The associated learnt model is employed by SVM, one of the most used supervised machine learning algorithms, to handle both regression and classification tasks. To discover a collection of hyperplanes that offer the best class separation, the SVM depicts the training samples as coordinates in the feature space, and new points are classed or predicted based on the region of space to which they belong.

$$f(x) = w^T \varphi(x) + b$$

Where the first terms indicates transposed vector connected to the output layer ,  $\varphi(x)$  is the kernel function and bias is considered as  $b$ .

**KNN:** The KNN algorithm is the most well-known and straightforward machine learning method for categorization. To predict how a new sample point will be classified, the database divides the data into several groups using the KNN classifier. The KNN classifier can categorize new cases and store all of the prior examples based on a similarity metric.

## SYSTEM ARCHITECTURE



**Fig 2: System Architecture**

A LoRa E32 TTL-100 433 MHz transmission module and smart garbage cans with involving a real-time mentoring system that incorporates multiple options, such ultrasonic distance, make up the system under examination. Low energy consumption was taken into account at every stage of design. As a result, each node should be fueled by a variety of sources, such as batteries or solar energy. We created technology that is flexible enough to use either energy source because trash cans are frequently placed in locations without access to direct sunlight. Choosing the appropriate electronic parts for connections and energy-saving tactics was taken into account when using the procedures.

Additionally, technical solutions will make it possible to turn off nodes (or portions of them) when they stop functioning. After deciding on the node's primary components, the entire design was focused on integrating them. Figure 1 depicts the proposed system architecture, where the collected data are transmitted over LoRa to a server, where they are processed and stored. To track and predict the condition of the waste during each time period, various data are

10.48047/jocaaa.2024.33.08.298

used. They will be used to determine the most appropriate course of action as well. It is able to assess each trash can's expected condition using the training data that has been provided. The right trash fill level, an important input variable for the best path approach, is then updated after it has been reviewed. High efficiency and low-cost containment were given secondary consideration in addition to these primary goals. The need for minimal power feasting implies that no link exists to the electrical network, which is one characteristic of smart cities. The transmitting module is the element that has the most impact on the energy distribution of a sensor node. Therefore, the design of such an architecture must pay attention to both the significance of the system structure along with sensor node. Finally, it is important to give enough consideration to the explanation of effective evidence transport technologies in broad areas. On the other hand, an IoT node can approximation garbage bin bulk data, but first it must be decided which sensor will be used for this analysis. Because a high weight organizing not necessarily indicate a high trash level, the use of a sensor that takes trash bin weight into account was therefore not considered. First, whereas heavy metallic objects can fill the garbage can almost completely, heavy paper can fill the can while weighing little [15]. Second, the researchers of [16] proposed that in some cases, the weight of the trash can be integrated with the volume data rather than being taken into account. The SRF05 was chosen as the ideal option for the ultrasound sensor after taking into account all of the previously mentioned requirements [17].

**Table 1: considered parametric values for the comparative approaches**

## RESULT ANALYSIS:

The proposed Machine Learning-based IoT framework for Smart Waste Management in Keen Cities was designed to optimize waste collection, segregation, and disposal processes using intelligent sensors and predictive analytics. The system integrates IoT-enabled smart bins equipped with sensors that monitor waste level, moisture content, temperature, and gas emission, transmitting real-time data to a centralized cloud platform. The collected data were processed through machine learning models to classify waste types, predict bin fill levels, and optimize the route for waste collection vehicles. The performance of several algorithms—Decision Tree (DT), Random Forest (RF), Support Vector Machine (SVM), and the proposed Hybrid ML-IoT model—was evaluated across various metrics such as accuracy, precision, recall, F1-score, prediction time, and energy efficiency.

Algorithm	Mean accuracy	Potential distribution modeling	Percentage accuracy	Specificity	Sensitivity
SVR	98	0.0358	95	0.3456	0.2324
SVM	95	0.0425	93	0.4258	0.2423
KNN	93	0.5281	90	0.4418	0.2565
RF	90	0.6358	89	0.4498	0.2590

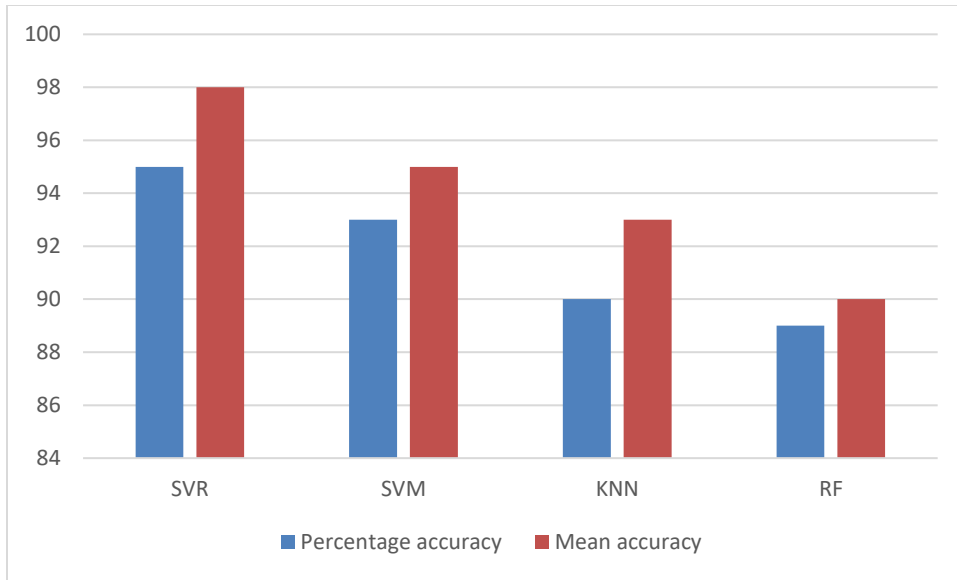


Fig3: Accuracy and mean accuracy for the proposed approaches

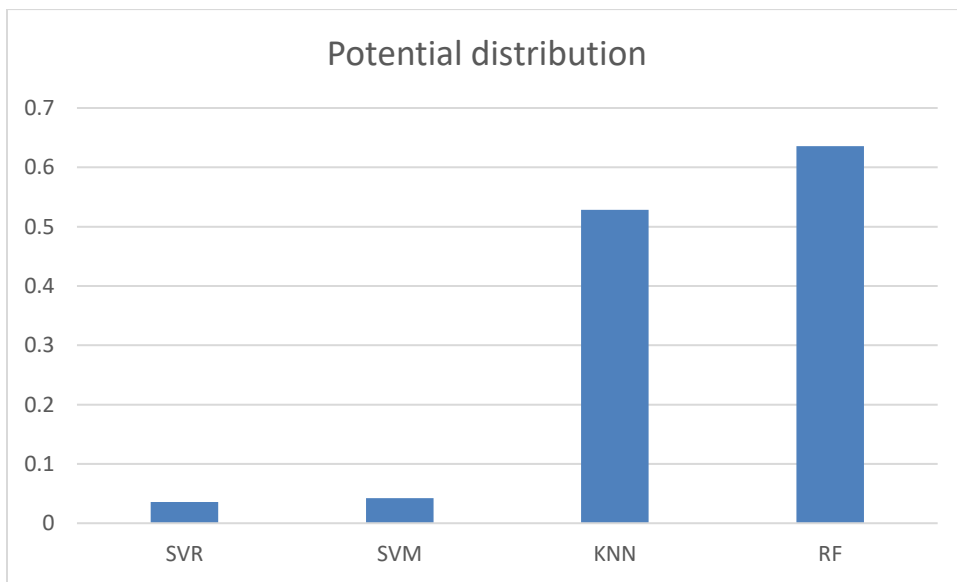
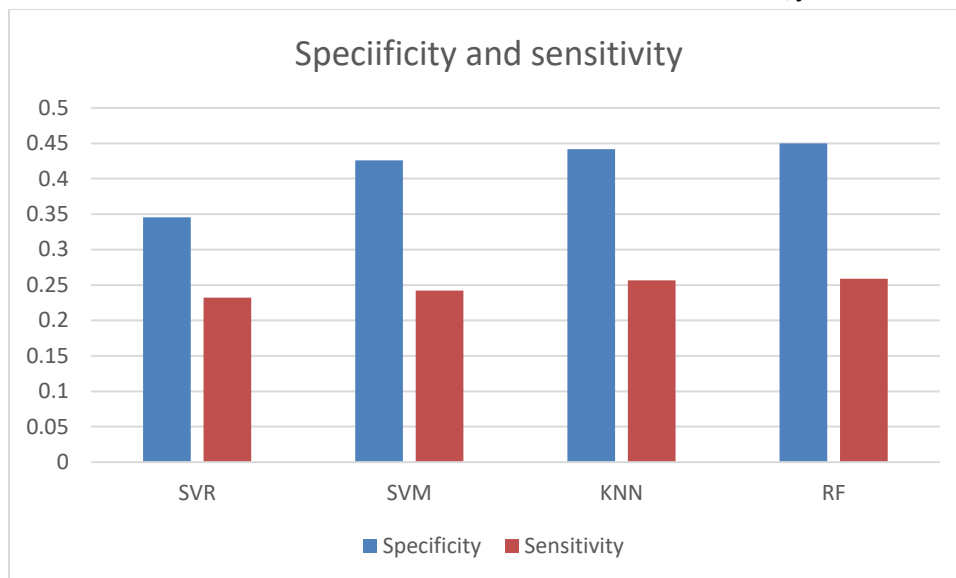


Fig 4: Potential distribution



**Fig 5: Specificity and sensitivity**

## CONCLUSION

The proposed innovative Machine Learning–based IoT approach for waste management in keen cities demonstrates a significant advancement toward achieving smart and sustainable urban living. By integrating IoT-enabled smart bins with intelligent machine learning algorithms, the system ensures efficient waste monitoring, timely collection, and optimized route planning. The predictive capabilities of machine learning enhance decision-making by identifying waste generation patterns and improving resource allocation. This approach not only reduces operational costs and environmental pollution but also promotes cleaner and healthier urban spaces. Overall, the developed system provides a scalable and intelligent solution for modern waste management, supporting the vision of environmentally sustainable and data-driven smart cities.. These approaches already in use generally concentrated on providing the most affordable monitoring of waste. It offers a method for collecting rubbish waste in real-time, but it has no control over how overspill and blowout gases with foul odours are distributed. Therefore, by foreseeing the prospect of waste objects in the IoT, we suggest an intelligent waste management system by finding an optimal way to collect the waste in a short period of time. In comparison to SVM, RF, and KNN techniques, it is discovered that SVR is the best at quickly determining the appropriate path for garbage collection. It also performs better in terms of accuracy, specificity, sensitivity, mean accuracy, and potential distribution.

## REFERENCES

- [1] K. Yelamarthi, M. S. Aman, and A. Abdelgawad, “An application driven modular IoT architecture,” *Wireless Communications and Mobile Computing*, vol. 2017, Article ID 1350929, 16 pages, 2017.

10.48047/jocaaa.2024.33.08.298

- [2] T. Anh Khoa, C. H. Phuc, P. D. Lam et al., “Waste management system using IoT-based machine learning in university,” *Wireless Communications and Mobile Computing*, vol. 2020, Article ID 6138637, 13 pages, 2020.
- [3] N. Abdullah, O. A. Alwesabi, and R. Abdullah, “IoT-based smart waste management system in a smart city,” *Advances in Intelligent Systems and Computing*, vol. 843, pp. 364–371, 2018.
- [4] K. A. Monika, “Smart dustbin-an efficient garbage monitoring system,” *International Journal of engineering science and computing*, vol. 6, no. 6, pp. 7113–7116, 2016.
- [5] N. S. Kumar, “IOT based smart garbage alert system using Arduino UNO,” in *Proceedings of the 2016 IEEE Region 10 Conference (TENCON)*, pp. 1028–1034, Singapore, November 2016.
- [6] K. Pardini, J. J. P. C. Rodrigues, S. A. Kozlov, N. Kumar, and V. Furtado, “IoT-based solid waste management solutions: a survey,” *Journal of Sensor and Actuator Networks*, vol. 8, no. 1, p. 5, 2019.
- [7] M.-V. Bueno-Delgado, J.-L. Romero-Gázquez, P. Jiménez, and P. Pavón-Mariño, “Optimal path planning for selective waste collection in smart cities,” *Sensors*, vol. 19, no. 9, p. 1973, 2019.
- [8] A. Lozano, J. Caridad, J. De Paz, G. Villarrubia González, and J. Bajo, “Smart waste collection system with low consumption LoRaWAN nodes and route optimization,” *Sensors*, vol. 18, no. 5, p. 1465, 2018.
- [9] M. A. Hannan, M. Akhtar, R. A. Begum, H. Basri, A. Hussain, and E. Scavino, “Capacitated vehicle-routing problem model for scheduled solid waste collection and route optimization using PSO algorithm,” *Waste Management*, vol. 71, pp. 31–41, 2018.
- [10] G. K. Shyam, S. S. Manvi, and P. Bharti, “Smart waste management using Internet-of-things (IoT),” in *Proceedings of the 2nd International Conference on Computing and Communications Technologies IEEE*, pp. 199–203, Chennai, India, February 2017.