# Literature Review

1. **Paper: Data Analytics Platform for the Optimization of waste Management Procedures** by **Thanasis Vafeiadis** et al **2019**

It talks about the key characteristics required in the development of Industry 4.0. This work presents a data analytics platform for the optimization of waste management procedures using IOT sensors on Industrial premises, big data availability and advance data analytical tools for waste management companies to smarten and optimize their processes and solutions. The study focuses on monitoring solid waste collection and transportation processes for disposal based on sensors. Using sensor-based bins makes garbage collection more efficient by monitoring the dust bin level. The Smart-M3 platform achieves real-time monitoring of bin fullness through sensors, providing incoming data to decision-support algorithms. The main platform features include monitoring bin fill levels based on IoT sensors, analysis of bin fill levels, forecasting the tonnage of waste transported by a waste management company, calculating the optimal pair of routes and tonnage, price forecasting for various waste types and materials, and statistical analysis and visualization for better data exploration and understanding. The core technologies of these devices include ultrasonic sensors for fill level measurement, long-range communication provided by LoRa, and MQTT protocol for data transmission. The solution provides services for different types of bins located on industrial plants through platform interface monitoring.

2. **Paper: An Intelligent Waste Management Application Using IoT and a Genetic Algorithm-Fuzzy Inference System** by **Sumaiya Thaseen Ikram** et al **2023**

The paper presents an intelligent waste management model for smart cities using a hybrid model of genetic algorithm (GA) and fuzzy inference engine. The system can read, collect, and process information intelligently using a fuzzy inference engine that decides dynamically how to manage waste collection. The key motive of this model is to enhance its correctness and robustness, primarily by reducing errors that arise due to working conditions. The primary issue with traditional genetic algorithms is the possibility of essential gene loss during execution, which may lead to efficiency or accuracy loss. This problem is overcome by integrating fuzzy logic with a genetic algorithm to identify crucial genes while preserving FIS interpretability. The proposed model uses cost-effective, small-size sensors and ensures reproducibility. Experiments using the Proteus simulator yielded satisfactory results, achieving overall accuracy, precision, and recall of 95.44%, 96.68%, and 93.96% in the proposed model. Also, recyclable items were classified, and accuracy was determined, which resulted in waste minimalization. The cost of manual interpretation is minimized in the intelligent smart waste management system compared to the traditional approach. However, this model has its own drawbacks on the part of implementation in terms of design and optimization at the technical level. By appropriately deploying this model, it helps identify and recycle waste, segregate carcinogenic waste, and destroy it, contributing to building a hygienic green environment and improving the circular economy of the nation.

3. **Paper: Smart Waste Collection Monitoring and Alert System using IoT** by **Zainal Hisham Che Soh** et al **2019**

The paper offers an efficient way to monitor waste material at the selected site of the garbage collection area. The proposed work is to monitor garbage bin level, once the bin is nearly filled an SMS notification is sent to the Garbage collection department for immediate waste collection, making waste collection more effective and systematic. This system is implemented using an ultrasonic sensor connected to Arduino UNO to monitor the bin level, the data will be sent through Arduino Ethernet Shield to Ubidots IoT cloud. The Ubidots stores the collected waste bin level data and display a real-time visualization in an online dashboard. The Ubidots Event manager invokes a notification alert when the bin is nearly full. In this proposed system the garbage overflow can be avoided and managed efficiently. But this system depends on the garbage collection facility provided in the area. Thus, a better facility must be provided to make waste collection more efficient.

4. **Paper: Smart Waste Management and Classification Systems Using Cutting Edge Approach by Sehrish Munawar Cheema, Abdul Hannan, and Ivan Miguel Pires 2022**

In this paper the authors propose a real time smart waste management and classification mechanism using Internet of Things (IoT), deep learning, and cutting-edge techniques for storing and analysing the data over cloud to classify and segregate waste in a dump area. They have also proposed a waste grid segmentation mechanism, which basically identifies the pile at the waste yard into grid like segments. A camera captures the image of the dump and sends it to an edge node to create a waste grid. This grid cell image acts as a test image for training the deep learning model. Based on the prediction results obtained the waste are classified as bio- degradable and non-bio degradable. Non bio degradable waste is further classified as metal, plastic, glass, and trash. Wholly, this is one of the approaches that allows efficient and accurate waste managements.

5. **Paper: Recycle.io: An IoT-Enabled Framework for Urban Waste Management by E. Al-Masri, I. Diabate, R. Jain, M. H. Lam, and S. Reddy Nathala 2018**

In this paper the authors have proposed an innovative approach to waste management using Internet of Things (IoT) technology. They have named this system as Recycle.io. This system is designed to monitor waste generation and collection in real-time, providing valuable insights to waste management companies about violations in waste disposal. This system is built on a serverless architecture and is integrated with Microsoft Azure IoT Hub for effective device management. One of the key features of this system is its ability to geographically track waste disposal violations, which can assist in enforcing stricter waste disposal regulations.

6. **Paper: Smart Waste Management Using Deep Learning with IoT by Jobin Joseph, Aswin R, Allen James, Alwin Johny, and Prince V Jose 2019**

In this paper the authors have proposed an autonomous solution that can independently identify, classify, and organize waste into specific bins (recyclable, organic, and harmful wastes). This system employs deep learning algorithms to categorize the waste, thereby facilitating its efficient use. When a user approaches the bin with waste, the system analyses it and identifies the type of waste. The bin then opens the specific compartment for that type of waste and collects it. The bin also checks the volume of waste. If the bin is full, it sends an alert to the authorities. The authorities then collect the waste. The collected waste is subsequently recycled and used as resources.

7. **Paper: Waste object detection and classification by Hrushikesh N. Kulkarni and Nandini Kannamangalam Sundara Raman 2019**

This paper uses the TrashNet dataset as its baseline dataset to perform waste detection techniques so that a decision can be made to classify the disposable items into recyclable and non-recyclable categories. Since the dataset used here contains only 400 images with 6 classes (namely cardboard, plastic, paper, metal and trash), the images are augmented by creating array of collages by cropping the images to overlap randomly and by placing the images in quadrants to generate multiple input images. With the generated TrashNet collage, a hybrid transfer learning model is implemented for classification considering various learning rates. This model is further refined through fine-tuning using Faster R-CNN on the Inception V2 network, allowing for the detection of object boundaries.

8. **Paper: Intelligent waste management system using deep learning with IoT by Md. Wahidur Rahman, Rahabul Islam** Et al **2022**

This paper presents a smart waste management system that combines IoT and deep learning for optimal garbage management. The proposed methodology is a combination of two key components: waste classification (digestible and indigestible waste) through convolutional neural networks and smart trash box architecture that uses multiple sensors for data collection and transmission, enabling real-time monitoring.

The process involves waste scanning, image capture, pre-processing, and image resizing. A microprocessor classifies the waste, and a servo motor places it into the corresponding trash box. Data is sent to an Android application for real-time monitoring. The system also incorporates a roller for waste transportation based on the processing unit's commands. This approach aims to improve waste management and recycling practices. The research finally reports a waste classification accuracy of 95.31% and a System Usability Scale (SUS) score of 86% from user satisfaction evaluations.

9. **Paper: Waste Management and Prediction of Air Pollutants Using IoT and Machine Learning Approach by Ayaz Hussain, Umar Draz, Tariq Ali** Et al **2020**

It presents an IoT-based smart bin that utilizes machine and deep learning models to manage waste disposal and forecast air pollutant concentrations. The system is connected to a Google Cloud Server (GCP) for real-time data analysis. The sensor data stored in Firebase are utilized by the GCP for predicting the status of the

bin with the help of a trained model and utilized a trained LSTM model for forecasting the levels of air pollutant and toxic gases present in a specific range of smart bin. The research involves a comprehensive analysis of machine learning classifiers using real-time garbage datasets to determine an effective model for classifying bin status as filled, half-filled, or unfilled. It provides real-time monitoring of garbage levels along with notifications via an alert mechanism.

10. **Paper: Design and development of smart Internet of Things–based solid waste management system using computer vision by Senthil Sivakumar Mookkaiah, Gurumekala Thangavelu** Et al **2022**

This paper presents an experimented effective computer vision-based MSW management solution with the help of the Internet of Things (IoT), and machine learning (ML) techniques namely regression, classification, clustering, and correlation rules for the perception of solid waste images. Classifying the wastages into biodegradable and non-biodegradable helps converting them into usable energy and disposing properly. The computational approaches can be programmed to classify wastes that help to convert them into usable energy. A ground-up built convolutional neural network (CNN) and CNN by the inception of ResNet V2 models trained through transfer learning for image classification. In addition, batch normalization and mixed hybrid pooling techniques are incorporated in CNN to improve stability and yield state of art performance. The proposed model identifies the type of waste and classifies them as biodegradable or non-biodegradable to collect in respective waste bins precisely.

11. **Paper: A deep learning approach for medical waste classification by Haiying Zhou, Xiangyu Yu, Ahmad Alhaskawi** Et al **2022**

The authors propose a deep learning-based classification method, in which ResNet is a suitable deep neural network for practical implementation, followed by transfer learning methods to improve classification results of the medical waste. This study provided a deep learning-based method for automatic detection and classification of 8 kinds of medical waste with high accuracy and average precision.

12. **Paper: A Garbage Classification Method Based on a Small Convolution Neural Network by Zerui Yang, Zhenhua Xia, Guangyao Yang and Yuan Lv 2022**

This paper proposes a garbage classification method based on a small convolutional neural network (CNN) to improve the efficiency of social garbage classification. An adaptive image-brightening algorithm is developed to average the brightness of the background in the image preprocessing stage, and a threshold replacement method is used to reduce shadow noise. The Canny operator is used to crop the blank background in the image. The neural network is optimized based on the MLH-CNN model to make its results simpler and equally efficient. The main focus is on the image-brightening algorithm the gives an enhanced image for better classification.

## Project Proposal:

The aim of this project proposal is to develop a complete pipeline of a Smart Waste Management and Classification System. Inspired by insights gained from the reviewed research papers, the vision is to create a seamless pipeline for optimizing waste management, utilizing sensor data from waste bins to monitor fill levels. Moreover, the paper[9] on "Waste Management and Prediction of Air Pollutants Using IoT and Machine Learning Approach" has provided valuable insights, to explore the possibilities of forecasting the air quality in the vicinity. Based on the bin levels, the system will generate notifications for waste collection. These timely alerts will reduce instances of waste overflow, improving the cleanliness of our community.

Furthermore, the system will employ image recognition technology to classify waste materials as recyclable or non-recyclable after storing the data to the cloud. In this project, we plan to incorporate certain pre-processing techniques, such as image enhancement as illustrated in the paper [12] titled "A Garbage Classification Method Based on a Small Convolution Neural Network". To overcome the constraints identified in the "Waste Object Detection and Classification" paper, which stemmed from a limited dataset, this project aims to enhance model generalization by gathering a more comprehensive set of real-world images. As a continuous stream of data is gathered, the focus will be extended to data visualization, allowing for an in-depth analysis of air quality concentrations, bin fill levels, and waste weights. The primary goal of this project is to enhance the efficiency of waste collection, minimize waste overflow, and promote recycling efforts in our community. Below is the overall workflow of the project proposal (fig 1).

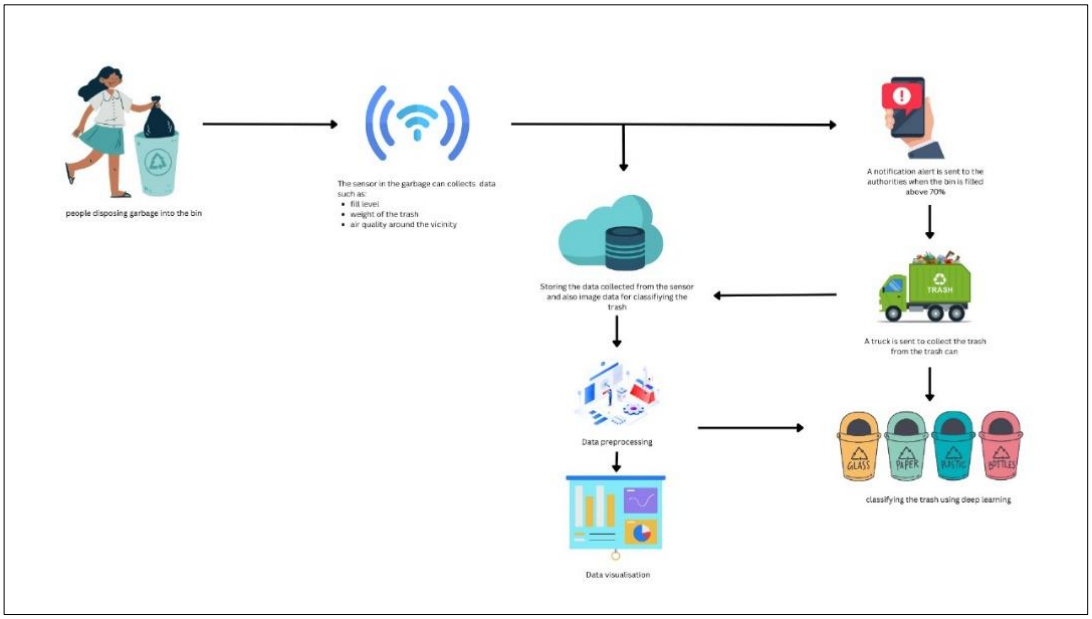


**Fig 1: PROJECT WORKFLOW**

## Challenges to be addressed :

- Variety - Data may come from various sources such as sensors in trash cans, GPS data from the waste collection vehicles, temperature etc. Integrating these diverse data is complex.

- The failure of the sensor to detect the trash and log the signals can lead to disruptions in the planned operations (Fault tolerance).
- Scalability issue may exist with increase in data volume, which must be handled.
- Data may be noisy, incomplete, or inconsistent, ensuring the quality and accuracy of the data is crucial for making informed decisions. Implementing real-time analytics on sensor data can be complex and resource-intensive.