
PROTOTYPE OF INTERNET OF THINGS (IOT) IMPLEMENTATION IN WASTE MANAGEMENT TO SUPPORT SMART CITY MONITORING WITH ANDROID-BASED MOBILE APPLICATION USING FORWARD CHAINING METHOD

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ABSTRACT

Efficient waste management is one of the main challenges in supporting the implementation of the smart city concept. This research aims to develop a prototype of an Internet of Things (IoT)-based waste management system capable of monitoring the condition of waste bins in real-time through an Android-based mobile application. The system uses the forward chaining method to perform inference processes in decision making, such as identifying the status of the bin (empty, almost full, or full) based on integrated sensor data. The results of the study showed that the system was able to detect the volume of waste and also identify the types of waste with high accuracy reaching 90%, send automatic notifications to operators or users when the bin reaches a certain condition, and provide practical solutions to optimise the waste collection process. With these features, the system not only improves operational efficiency but also supports cost reduction and environmental impact. The resulting prototype is expected to be the first step in the application of IoT technology in urban waste management to support the realisation of smart cities.

Keywords: Internet of Things, Waste Management, Smart City, Mobile Application, Forward Chaining

1. INTRODUCTION

In the ever-evolving digital era, the Smart City concept has become the main focus of efforts to improve the quality of life of people in urban areas. One of the main challenges in implementing Smart City is efficient, sustainable, and environmentally-friendly waste management (Safitri et al., 2021). Traditional waste management systems often face various obstacles, such as the lack of accurate monitoring, suboptimal resource allocation, and lack of community participation (Damayanti et al., 2024; Somantri et al., 2023). These conditions can lead to waste accumulation, environmental pollution, and negative impacts on public health.

The application of Internet of Things (IoT) technology offers an innovative solution to overcome these problems. IoT enables the integration of various devices to collect, analyse, and deliver data in real-time (Rusvinasari & Risnanto, 2024; Wahjuni & Zakiah, 2022). By utilising IoT, waste management systems can be optimised through monitoring the condition of landfills (TPS), predicting emptying needs, and making data-based decisions. This technology is increasingly relevant with the use of Android-based mobile applications that can provide easy and fast access for relevant parties to monitor and manage the system effectively (Hardani & Hayat, 2020; Santika et al., 2024; Ismail et al., 2021).

Methods forward chaining is used in this system to support the rule-based decision-making process. This method works by starting from initial data (facts) and moving forward to find relevant conclusions (Ma'arif et al., 2019). This

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approach is very suitable for processing dynamic and real-time IoT data, so as to provide appropriate action recommendations (Sugiharni & Divayana, 2017; Putra et al., 2022; Buntulillin et al., 2025).

This research aims to design and implement a prototype of an IoT-based waste management system with Android mobile applications using the forward chaining method (Saputra & Zubaidi, 2021). This prototype is expected to be able to support Smart City monitoring more efficiently and support efforts to improve environmental sustainability in urban areas (Pratama et al., 2024; Hasanah, 2024; Kurniawan & Rahmawati, 2024).

2. METHOD

This research uses primary data and secondary data to obtain information. Primary data was generated through a series of direct measurements using IoT devices and the implementation of prototype trials. Secondary data was obtained through searching and analysing relevant literature, including scientific journals and reports related to IoT-based waste management and the Smart City concept.

The method used in this research uses a Research and Development (R&D) approach, where Research and Development (R&D) is a process consisting of steps that aim to produce new products or improve the quality of existing products (Waruwu, 2024). In addition, the forward chaining method is applied to support automatic data-based decision making in waste management systems (Pramana & Jasa, 2019). This research aims to develop a prototype IoT system for waste management and Android-based mobile applications. This prototype will be tested to support Smart City monitoring. Furthermore, the research process is visualised in Figure 1.

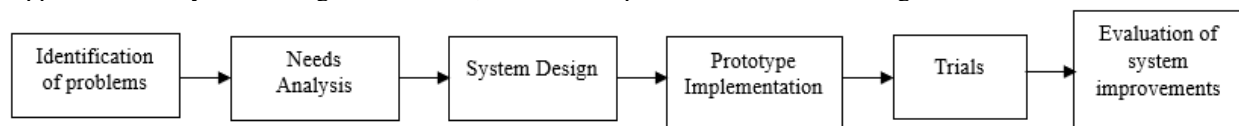


Fig. 1 Stages in the Research

In Figure 1, it can be seen that the research phase includes seven main steps. The process of diagnosing waste types (organic, inorganic, hazardous) can be integrated in each step as follows:

1. Literature Study

Collecting information from various sources related to IoT technology, waste management, and Android applications in the context of Smart City.

2. Problem Identification

Identify the main problems in urban waste management, such as the lack of real-time monitoring, inefficient waste transport routes, and low community participation.

3. Needs Analysis

Identifying hardware needs such as IoT sensors (ultrasonic, weight, and gas), communication modules, and software for Android-based applications and web-based dashboards. There are several instruments or needs used in this research, namely:

IoT sensors: Ultrasonic, weight, and gas

a. Communication modules: Wi-Fi and GSM

b. Software: Android app and web dashboard platform

c. Communication protocol: MQTT

d. Inference engine: For forward chaining implementation.

4. System Design

Designing IoT system architecture, including sensor workflows, data communication, mobile applications, User Inter-face (UI) and User Experience (UX) android dashboard applications for waste management. The system design is carried out in two stages, the first is the hardware design which includes sensors to detect the volume of waste, communication modules (Wi-Fi, LoRa, or GSM), then the next stage is the design of the software which includes the backend for data management, android applications for monitoring, Application of the forward chaining method to automate data-based decision making, such as when is the optimal time for waste collection based on the condition of the trash can. The mechanism of the forward chaining method is shown in Figure 2.

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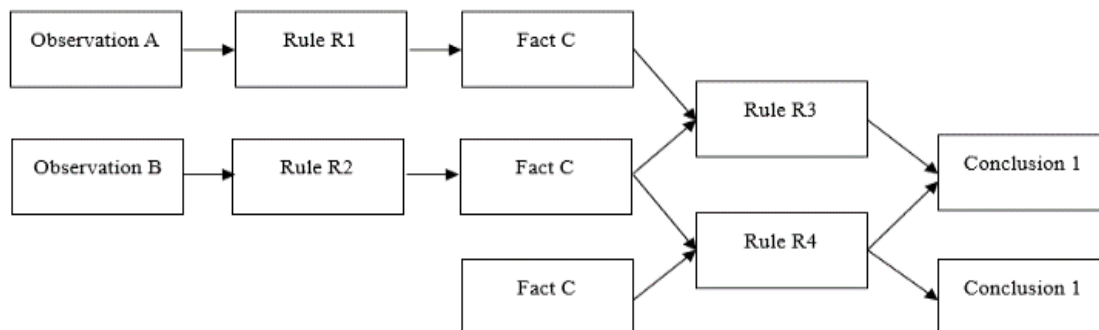


Fig. 2 Forward chaining method

Based on figure 2 above illustrates the forward chaining method for decision making in IoT waste management systems. Although the actual visual is not visible in this context, forward chaining generally follows this pattern:

Forward chaining process (typical structure):

- Start with known facts (sensor data) – e.g., bin is 75% full.
- Apply rules (if-then conditions) – e.g., *IF bin fullness > 70%, THEN flag for pickup.*
- Infer new facts – Based on the rules applied to sensor data.
- Repeat the process – Continue applying rules to newly inferred facts.
- End when a conclusion is reached – e.g., *Schedule pickup for bin #3.*

5. Prototype Implementation

The prototype implementation involves integrating the sensor with a microcontroller such as Arduino or ESP32. Furthermore, developing an Android application with main features such as data visualisation and notifications.

6. Testing

Testing the prototype to evaluate system functionality, such as measurement of sensor data (waste volume, weight, and gas), real-time data transmission via the MQTT protocol, application of forward chaining to decide actions such as sending notifications to waste managers if the waste bin has reached a certain capacity.

7. Evaluation of System Improvement

In the system improvement, improvements will be made based on the test results, the system will be improved and optimised to better suit user needs such as sensor accuracy, data transmission speed, and ease of use of the application. The evaluation results are used to improve the prototype.

3. RESULT DISCUSSIONS

This chapter will present the results of the research that has been conducted, followed by an in-depth discussion to analyse the findings. The results of this study were obtained through Research and Development and a forward chaining approach was used to support automated decision-making. The research was conducted in urban areas that have significant waste problems, such as TPS (Temporary Disposal Sites), and the period of implementation of this activity is 6 months, starting from the data collection stage and ending with prototype testing.

1. Literature Study

Based on the results of the literature study, Internet of Things (IoT) technology has great potential in supporting efficient and integrated waste management. IoT sensors such as ultrasonic, weight, and gas enable the detection and classification of waste types based on relevant parameters. This technology has also been used in the context of Smart City to provide real-time data visualisation through Android apps, which makes it easier for users to monitor the status of waste and receive notifications for further action. The most relevant waste classification methods include grouping into three main categories:

- Organic Waste: Requires rapid detection due to its decomposable nature.
- Inorganic Waste: Focus on collection and processing for recycling.
- Hazardous Waste: Requires special attention due to its hazardous nature and requires specific treatment.

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2. Problem Identification

From the analysis, some of the main problems in urban waste management include:

- a. Organic Waste: The absence of an optimal system to detect the volume of rapidly decomposing waste, thus increasing the risk of environmental pollution.
- b. Inorganic Waste: Inefficiency in recycling collection and processing.
- c. Hazardous Waste: Lack of supervision of hazardous waste that requires special handling.
- d. General Issues: Lack of real-time monitoring system, inefficient transportation routes, and lack of data integration at the city scale.

3. Needs Analysis

The results of the needs analysis to support IoT-based waste management solutions are as follows:

a. Hardware:

- 1). Ultrasonic Sensor: To detect the volume of waste.
- 2). Weight Sensor: To measure the weight of the garbage.
- 3). Gas Sensor: To identify harmful gas content or odor from organic waste.
- 4). Wi-Fi and GSM Communication Module: To support real-time data transmission to the central server.

b Software:

- 1). Android Application: Provides a user interface to display waste type data, provide management recommendations, and notifications.
- 2). Web-based Dashboard: For broad-scale monitoring of waste data, including statistical analysis.
- 3). MQTT Communication Protocol: Used to ensure efficient data delivery with low latency.

c Inference Engine:

- 1). Uses a forward chaining method to determine waste categories (organic, inorganic, hazardous) based on sensor data. This inference engine enables automated and fast decision making.

4. System Design

In this study, there are units used to measure various parameters in the IoT application prototype system in waste management as follows:

a. Sensor Data Measurement Unit

The IoT system is equipped with various sensors to measure waste-related data. The units of measurement used include:

- 1) Waste Volume: Liter (L): Measures the capacity of the filled trash can.
- 2) Weight of Waste: Kilogram (kg): Used to measure the total weight of waste in each bin.
- 3) Hazardous Gas: Part per Million (ppm): Measures the concentration of harmful gases such as methane (CH₄) or carbon dioxide (CO₂) around the bin.

b. Time Unit

Time units are used to record system activities and data analysis:

- 1) Sensor Data Capture (Seconds - s): Refers to how often the IoT sensor records data. This interval ensures that updates are received in near real-time without overwhelming the system.
- 2) Notification Delivery (Seconds - s or Minutes - min): Indicates the duration it takes for alerts or updates to be sent from the IoT device to the connected Android application. The delivery time may vary depending on network conditions and system load

c. Distance and Location Units

This unit is used to determine the location and route of waste transportation:

- 1) Location Distance (Meter - m or Kilometer - km): Measures how far the waste bin is from the waste management facility.
- 2) GPS Coordinates (Decimal Degrees - °): Indicates the exact location of the bin or the transportation vehicle.

d. Energy and Power Units

To support energy efficiency, these units are used in the system:

- 1) Electrical Power (Watt - W): Shows how much energy the sensors and other modules are consuming
- 2) Battery Capacity (Milliampere-Hour - mAh): Tells how much energy the battery can store to keep the device running.

e. System Performance Units

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These units are used to evaluate the effectiveness of the system:

- 1) Data Transmission Speed (kbps): Measures how fast data moves across the network
- 2) Waste Transportation Route Efficiency (km/L): Measures how fuel-efficient the waste collection vehicles are on their routes

f. User Satisfaction Unit

Assessment of user satisfaction with the application is carried out using a Likert scale of 1-5, with the following interpretation: 1 (Very Dissatisfied), 2 (Dissatisfied), 3 (Neutral/Moderately Satisfied), 4 (Satisfied), and 5 (Very Satisfied) This scale is used to determine the level of user satisfaction with application functionality and user convenience.

System design describes how a system will be realized and operated. This process covers the technical and functional details of the system. The design is done in two stages, first the hardware design and then the software design.

a) Hardware Design

In this hardware, the components used are:

- 1) Iot sensors: Ultrasonic, Weight and Gas
- 2) Communication Module: Wify and GSM
- 3) Communication Protocol: MQTT

Installation of the Ultrasonic Sensor can be seen in Figure 3 and all hardware is assembled as neatly as possible which can be seen in Figure 4.



Fig. 3 Ultrasonic Sensor Installation



Fig. 4 Overall Hardware Set

b) Software Design

The software design of this system is built on two main elements, namely:

- 1) Backend

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The backend is responsible for managing the sensor data collected from the integrated devices, including storing, processing, and presenting the data to the user application.

2) Android Application

The Android application is designed to support waste classification using the forward chaining method. The classification is carried out based on data collected from specific sensors:

- Ultrasonic sensors are used to detect the volume of waste.
- Load cells measure the weight of the waste.
- Gas sensors (e.g., MQ-series) are used to identify hazardous materials through the detection of gases such as methane (CH₄) and carbon dioxide (CO₂)

Using these sensors, the system classifies waste into three categories: easily decomposed (organic), recyclable (inorganic), and hazardous materials (B3). The classification rules were developed based on expert interviews with practitioners at the local waste management facility and supported by references from existing literature, such as the characteristics of organic, inorganic, and hazardous waste found in (Pratama & Wibowo, 2021), and sensor-based waste detection methods from (Rahmadani et al., 2022). The forward chaining method is applied through a set of logical rules, including

- a) If the volume is high and easily decomposed → categorized as Organic Waste.
- b) If it is not easily decomposed and can be recycled → categorized as Inorganic Waste.
- c) If it contains hazardous materials → categorized as B3 (Hazardous and Toxic Materials) Waste.

Waste classification using the forward chaining method in this system can be seen in Figure 5 below.

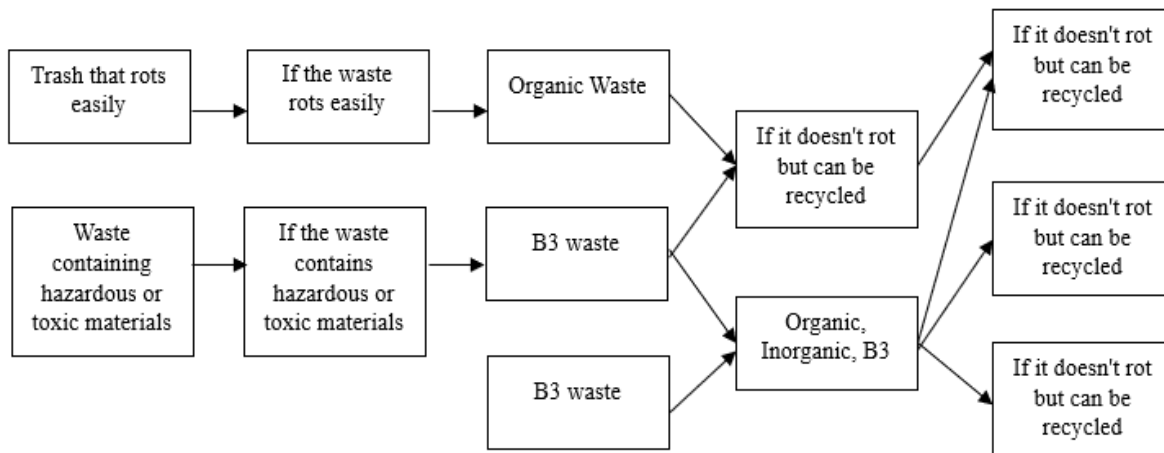


Fig. 5 Determining the type of waste using the forward chaining method

The results of the main page display on the Android application can be seen in Figure 6. This page has two types of user accounts, namely:

- (a) Admin account: In charge of adding and managing trash can locations. The display of the trash can location addition feature can be seen in Figure 7. In addition, the admin also has access to view user profile information, as shown in Figure 8.
- (b) Lead Account: In charge of monitoring the location of bins with the following indicators:
 - (1) Empty Trash: Marked with green text.
 - (2) Trash Fill: Marked with yellow text.
 - (3) Full Trash: Marked in red.

On the main page (Figure 5), there is an arrow that allows leaders to view the location of the trash bin in detail, as shown in Figure 8.



Fig. 6 Main Page Display

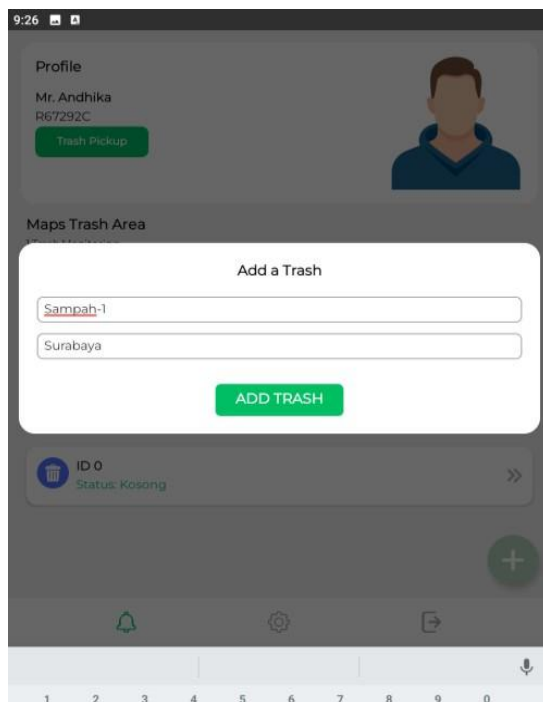


Fig. 7 Dumpster Addition View

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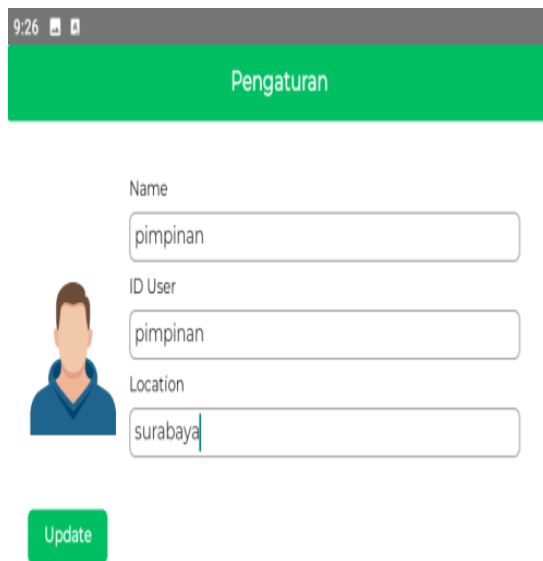


Fig. 8 Admin Profile View

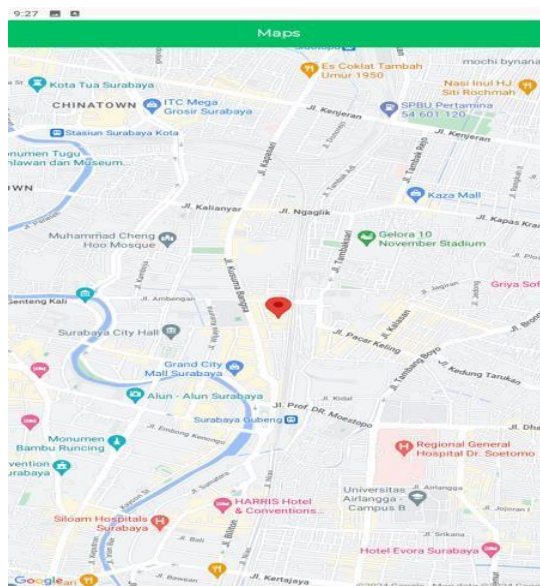


Fig. 9 Trash Can Maps View

In addition, the application can also identify types of waste, including organic waste marked in green, inorganic waste in yellow, and B3 waste in red, as illustrated in Figure 9. The classification model achieved a high accuracy of 90% in distinguishing these waste types, thereby supporting the system's reliability in practical waste sorting scenarios

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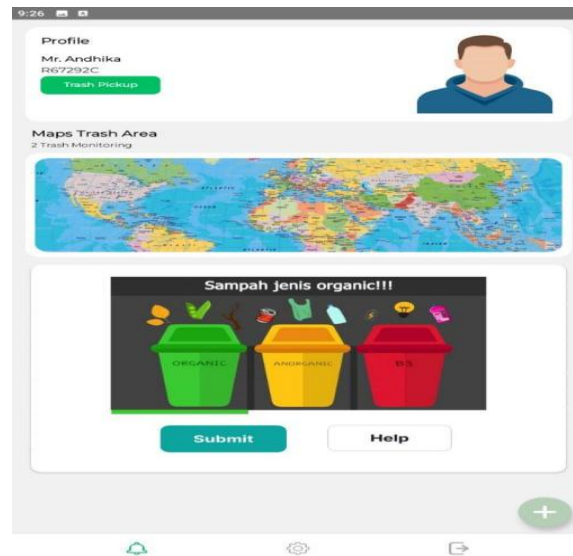


Fig. 10 Analyzing Waste Types

4. CONCLUSION

This research successfully designed and implemented a prototype of an Internet of Things (IoT)-based waste management system integrated with Android-based mobile applications using the forward chaining method. The developed system is able to monitor the level of fullness of trash bins in real-time, provide notifications to users, and recommend optimal management actions based on the collected data.

The use of forward chaining method is proven to be effective in supporting rule-based decision-making process, especially in processing dynamic IoT data. The Android-based mobile application provides easy access for cleaners and related parties to monitor the condition of trash bins and take appropriate steps. The system also has the potential to improve operational efficiency, reduce waste accumulation, and support environmental sustainability.

With the success of this prototype, this research has made a significant impact in the development of a smarter waste management system to support the Smart City concept. However, there are several aspects that require further development, such as integration with big data analytics, adding route optimization features for logistics efficiency, and testing on a wider scale. With further development, this system is expected to become a more comprehensive and useful solution in supporting environmental sustainability in the future.

5. REFERENCES

- Buntulillin, M. B., assiddiq Assiddiq, M., & Asqalani, M. A. H. A. (2025, May). APLIKASI SISTEM MONITORING TEMPAT SAMPAH BERBASIS IoT. In *Journal Pegguruang: Conference Series* (Vol. 6, No. 2, pp. 917-920). <http://dx.doi.org/10.35329/jp.v6i2.5348>
- Damayanti, P. A., Setiawan, R., & Firman, F. (2024). Analisis Pengembangan Smart City Di Kota Tanjungpinang. *WISSEN: Jurnal Ilmu Sosial Dan Humaniora*, 2(1), 79-103. <https://doi.org/10.62383/wissen.v2i1.43>
- Hardani, D. N. K., & Hayat, L. (2020). Penerapan Internet of Things (IoT) pada Sistem Pengendali dan Pengaman Pintu Berbasis Android. *Jurnal Riset Rekayasa Elektro*, 2(2), 59-68. <https://doi.org/10.30595/jrre.v2i2.9056>
- Hasanah, U. (2024). Implementasi Internet of Things (IoT) dalam Pengelolaan Tempat Sampah Pintar. *ABDISUCI: Jurnal Pengabdian dan Pemberdayaan Masyarakat*, 2(02), 37-45. <https://doi.org/10.59005/j-abdisuci.v2i02.111>
- Ismail, M., Abdullah, R. K., & Abdussamad, S. (2021). Tempat Sampah Pintar Berbasis Internet of Things (IoT)

* Corresponding author



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- Dengan Sistem Teknologi Informasi. *Jambura Journal of Electrical and Electronics Engineering*, 3(1), 7-12. <https://doi.org/10.37905/jjeeee.v3i1.8099>
- Kurniawan, A. A., & Rahmawati, S. (2024). Smart Tong Sampah Pendeteksi Otomatis Sampah Organik & Anorganik Berbasis IoT Smart city. *Jurnal KomtekInfo*, 163-172. <https://doi.org/10.35134/komtekinfo.v11i3.564>
- Ma'arif, R. A., Fauziah, F., & Hayati, N. (2019). Sistem Monitoring Tempat Sampah Pintar Secara Real-time Menggunakan Metode Fuzzy Logic Berbasis IOT. *Jurnal Infomedia: Teknik Informatika, Multimedia, Dan Jaringan*, 4(2), 69-74. <http://dx.doi.org/10.30811/jim.v4i2.1571>
- Pramana, I. S., & Jasa, L. (2019). Analisis Penerapan Metode Forward Chaining untuk Rekomendasi Instalasi Local Area Network (LAN) Menggunakan Pengujian System Usability Scale (SUS). *Majalah Ilmiah Teknologi Elektro*, 166. <https://doi.org/10.24843/MITE.2019.v18i02.P03>
- Pratama, A. R., Sudrajat, J., & Seliwati, S. (2024). Monitoring Tempat Sampah Pintar Berbasis Internet of Things (IoT). *Jurnal RESTIKOM: Riset Teknik Informatika dan Komputer*, 6(3), 544-553. <https://doi.org/10.52005/restikom.v6i3.381>
- Putra, T. A., Assiddiq, M., & Basri, B. (2022, May). Sistem Monitoring Bak Sampah Berbasis Internet of Things. In *Journal Pegguruang: Conference Series* (Vol. 4, No. 1, pp. 429-434). <http://dx.doi.org/10.35329/jp.v4i1.2433>
- Rusvinasari, D., & Risnanto, A. S. (2024). Rancangan prediksi volume sampah TPA Kota Semarang dengan pendekatan sistem dinamik. *Journal of Data Science Theory and Application*, 3(1), 14-22. <https://doi.org/10.32639/jasta.v3i1>
- Safitri, M., Faridi, F., & Zulfian, M. R. (2021). Aplikasi smart trash bin monitoring system berbasis Internet of Things (IoT). *JIKA (Jurnal Informatika)*, 5(3), 391-399. <http://dx.doi.org/10.31000/jika.v5i3.5079>
- Santika, D. A., Sari, Z., & Akbi, D. R. (2024). Penerapan Metode Fuzzy Logic Pada Rancang Bangun Tempat Sampah Pintar dengan Sistem Monitoring Berbasis Cloud dan Internet of Things (IoT). *Jurnal Repositor*, 6(3). <https://doi.org/10.22219/repositor.v6i3.32651>
- Saputra, M. A., & Zubaidi, A. (2021). Rancang Bangun Smart Trash Can Berbasis IOT (Internet Of Things) Untuk Petugas Sampah Perumahan. *Jurnal Teknologi Informasi, Komputer, dan Aplikasinya (JTika)*, 3(2), 176-188. <https://doi.org/10.29303/jtika.v3i2.143>
- Somantri, Yustiana, I., Iklima, L. D., & Syahputra, H. H. (2023). Rancang Bangun Tempat Sampah Organik dan Non Organik Berbasis IOT dan Mobile Application. *JSI: Jurnal Sistem Informasi (E-Journal)*, 15(2), 3176-3188. <https://doi.org/10.18495/jsi.v15i2.119>
- Sugiharni, G. A. D., & Divayana, D. G. H. (2017). Pemanfaatan metode forward chaining dalam pengembangan sistem pakar pendiagnosa kerusakan televisi berwarna. *Jurnal Nasional Pendidikan Teknik Informatika: JANAPATI*, 6(1), 20-29. <https://doi.org/10.23887/janapati.v6i1.9926>
- Wahjuni, S., & Zakiah, R. A. (2022). Penerapan Konsep Internet of Things Pada Sistem Monitoring Volume Timbunan Sampah di Tempat Penampungan Sementara Kota Bogor. *Jurnal Ilmu Komputer dan Agri-Informatika*, 9(2), 114-126. <https://doi.org/10.29244/jika.9.2.114-126>
- Waruwu, M. (2024). Metode penelitian dan pengembangan (R&D): konsep, jenis, tahapan dan kelebihan. *Jurnal Ilmiah Profesi Pendidikan*, 9(2), 1220-1230. <https://doi.org/10.29303/jipp.v9i2.2141>
- Pratama, R., & Wibowo, A. (2021). *Smart Waste Management Using IoT-based Classification*. *Journal of Environmental Technology*, 9(2), 112-119
- Rahmadani, S., Putra, D., & Sari, N. (2022). *Implementation of Gas Sensors for Hazardous Waste Detection in Smart Bins*. *International Journal of Smart Systems*, 5(1), 45-53