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Smart Trash Bin Based on IoT Using Telegram and Load Cell Sensor for Waste Mass Monitoring System

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Abstract: A waste mass monitoring system enhances waste management effectiveness by automatically tracking the condition and fill level of smart trash bins. Smart trash bin design based on Internet of Things (IoT) uses a load cell sensor and Telegram notifications to monitor waste mass. The load cell sensor is connected to an ESP32 microcontroller, which acts as the system's primary controller. Measurement data is transmitted via an IoT framework to the Telegram application on the observer smartphone. The collected data is used to determine the load cell sensor's error and accuracy percentage, tested across a mass range of 5000 g to 50000 g, with an interval of 5000 g. This study used inorganic waste collected from the local community. The smart trash bin based on IoT was monitored throughout daily operations, with measurements taken from morning until night. The sensor's average error was 0.72%, with an average accuracy of 99.28%. A lower error rate corresponds to higher sensor accuracy. The first monitoring session from 08:17 to 22:33, with waste masses ranging from 78 g to 5011 g. The second session from 07:55 to 22:16, with ranging from 102 g to 10618 g. The third session from 07:38 to 22:18, with waste masses ranging from 485 g to 19361 g. The results show that the load cell sensor can continuously measure changes in waste mass and provide relatively stable data. Data from the smart trash bin based on IoT can be accessed remotely via Telegram, facilitating more effective and sustainable waste management.

Keywords: IoT; Load cell; Mass; Sensor; Smart trash bin; Telegram; Waste

Introduction

Waste has long been a problem in Indonesia, especially in urban areas, due to the community's socio-cultural and economic conditions. Increasing population, increasing activities, and changing consumption patterns have led to an increase in the volume, type, and characteristics of waste (Rahmawati & Syamsu, 2021). Population growth, people's consumerist lifestyles, and technological advances have led to a continuous increase in the volume of waste. If not managed properly, waste can cause various problems, including global warming. To date, many people still use the old waste management pattern of collecting, transporting, and disposing (Sholihah & Hariyanto, 2020). Most environmental problems arise from human activities, which are more complex than those that occur naturally (Rahman, 2021).

Based on data from the National Waste Management Information System (*Sistem Informasi Pengelolaan Sampah Nasional* = SIPSN) for 2025, waste management in Indonesia continues to face serious challenges. Currently, only about 25% (36,684 tons per day) of waste is successfully managed, while approximately 75% (105,483 tons per day) remains unmanaged. This situation indicates that a significant portion of waste still has the potential to pollute the environment and requires a more effective management system (Kemenlh, 2025). According to Mahyudin (2017), effective waste management is an integrated system that combines technology with local conditions. A waste mass monitoring system enhances waste management effectiveness by automatically tracking the condition and fill level of trash bins (Desnanjaya et al., 2023; Pamintuan et al., 2019). With advancements in sensor technology and the Internet of Things (IoT), such systems can be developed to transmit data in real time over the internet, making waste management more efficient, integrated, and sustainable (Ali et al., 2020; Kanade et al., 2021; Muliadi et al., 2020). Sensor

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characteristics, such as high sensitivity, are critical to achieving high sensor accuracy (Arifin, Hardianti, et al., 2019; Arifin, Samsu, et al., 2019; Yunus et al., 2021).

Several studies on smart trash bin monitoring systems typically use ultrasonic sensors to measure waste volume and surface level. Wardana et al. (2022) designed a smart trash bin that monitors waste volume using ultrasonic sensors; however, the system is not yet integrated with an IoT platform such as Telegram. Furthermore, ultrasonic sensors often lack accuracy because loosely packed waste, such as plastic bottles, can make a bin appear full even when the actual waste mass remains low (Memon et al., 2019). Therefore, integrating a load cell sensor to measure mass is necessary to develop an effective waste-monitoring system.

Based on the description above, we will develop an IoT-based smart trash bin system that uses a load cell sensor and Telegram to monitor waste mass. This research aims to design a smart trash bin based on IoT, assess the load cell sensor's accuracy, and implement a waste mass monitoring system. This research is novel because it develops an IoT-based smart trash bin monitoring system that uses a load cell sensor to measure waste mass and sends automated notifications via Telegram. A key advantage of this system is its ability to monitor waste mass automatically and in real time by integrating a load cell sensor with IoT technology, it allows remote access to measurement data via Telegram. The system also sends automated notifications when waste mass reaches predefined thresholds, helping monitor trash bin status, improve waste collection efficiency, and support more effective, sustainable waste management.

Method

This research focuses on developing an IoT-based smart trash bin design that uses Telegram notifications and a load cell sensor to monitor waste mass. The waste mass monitoring system uses a load cell as its primary sensor. A load cell sensor with a measurement capacity of 50000 g is used to measure the mass of waste inside the bin in real time. This sensor connects to an ESP32 microcontroller module, which serves as the system's main controller and processes the load cell's measurement data. Subsequently, a program is uploaded to the ESP32 microcontroller to ensure the system functions according to the established design. The research flowchart is presented in Figure 1.

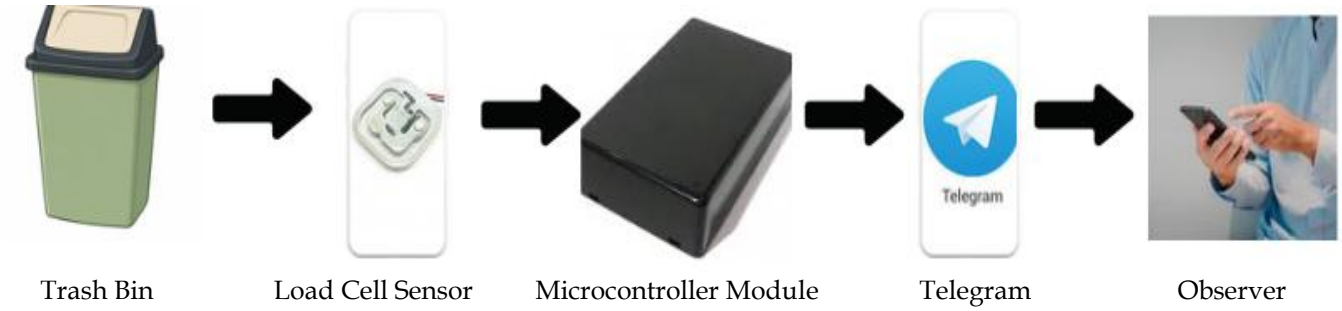


Figure 1. Research flowchart for the design of a smart trash bin based on IoT

Measurement data is displayed via the Telegram application on the observer's smartphone. To verify that the system operates correctly, the mass measurements obtained from the load cell are compared against measurements taken using measuring instruments that meet Indonesian National Standards (*Standar Nasional Indonesia* = SNI), is a digital scale. The collected data are used to determine the error and accuracy of the load cell sensor using equations (1) and (2) (Ikano et al., 2024; Yunus et al., 2026).

$$Error = \left|\frac{m_{digital\ scale} - m_{sensor}}{m_{digital\ scale}}\right| x\ 100\% \quad (1)$$

$$Accuracy = 100\% - Error \quad (2)$$

The determination of sensor error and accuracy is performed using 10 samples from masses ranging from 5000 g to 50000 g, with an interval of 5000 g. Once the sensor meets the feasibility standard of <5% error, the IoT-based smart trash bin is deployed to monitor waste mass. The waste used consists of inorganic materials collected from the local community. The system operates throughout the day, measurement time from morning to night, to periodically send notifications via Telegram, whether the trash bin is full or not.

Result and Discussion

Designing a smart trash bin based on IoT that uses Telegram for waste mass monitoring begins with determining the load cell sensor's accuracy. Data collection uses mass values ranging from 5000 g to 50000 g, with 5000 g intervals between measurements. Testing is conducted by comparing the values read by the load

cell sensor against those from a digital scale. The test results are presented in Figure 2.

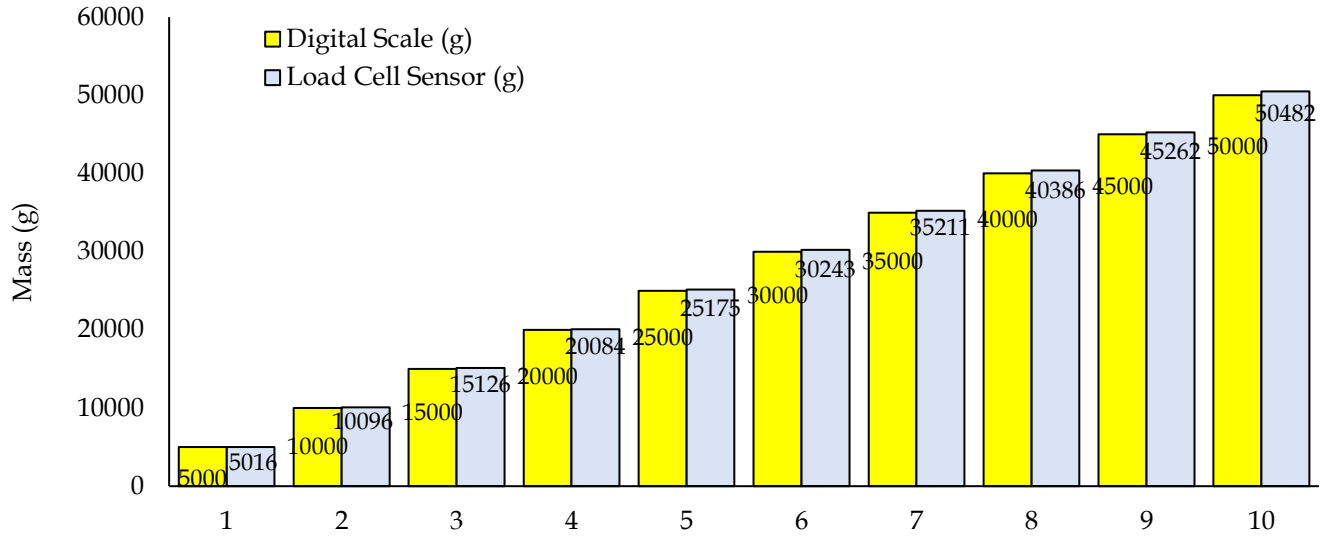


Figure 2. Comparison of mass values between a digital scale and a load cell sensor.

Based on Figure 2, the mass measurements from a load cell sensor and a SNI measuring instrument show relatively consistent values across test samples. Samples weighed on a digital scale ranged from 5000 g to 50000 g, while the load cell sensor values displayed via Telegram were also consistent, ranging from 5016 g to 50482 g. As the sample mass increases, both the load cell sensor by via the Telegram application and the digital scale record higher values. These results indicate that the load cell sensor measures waste mass with high precision. This finding aligns with research by Pasha et al. (2022), which used a load cell sensor in an IoT-based waste monitoring system and showed that sensor readings increase proportionally with waste mass. The sensor automatically transmits the data via an IoT network, enabling real-time monitoring and triggering notifications when the waste container reaches a specific threshold. This aligns with research on smart trash bins based on IoT, which use automated data transmission and user notifications through a monitoring platform (Dari et al., 2025). Furthermore, the values obtained from the load cell sensor and the digital scale were used to calculate the error and accuracy, as shown in Table 1, using equations (1) and (2).

Table 1. Determination of error and accuracy of load cell sensor

Sample	Mass (g)		Error (%)	Accuracy (%)
	Digital Scale	Load Cell Sensor		
1	5000	5016	0.32	99.68
2	10000	10096	0.96	99.04
3	15000	15126	0.84	99.16
4	20000	20084	0.42	99.58
5	25000	25175	0.70	99.30
6	30000	30243	0.81	99.19
7	35000	35211	0.60	99.40
8	40000	40386	0.97	99.04
9	45000	45262	0.58	99.42
10	50000	50482	0.96	99.04
Average			0.72	99.28

The measurement data in Table 1 show that the load cell sensor readings differ only slightly from those of the digital scale used as the reference instrument. The resulting error ranges from 0.32% to 0.97%, with an average error of 0.72%. The average sensor accuracy is 99.28%, indicating that the load cell sensor is highly accurate and reliable for real-time weight measurement (Indah & Wildian, 2022). The sensor's average error remains well within the measurement tolerance limit of <5% (Hidayat et al., 2024; Ikano et al., 2024; Yudoyono et al., 2025). A lower sensor error value corresponds to higher sensor accuracy. The higher the accuracy value, the better the sensor (Yunus et al., 2026). This demonstrates that the load cell sensor exhibits linear

characteristics and operates stably after calibration (Hakim et al., 2025).

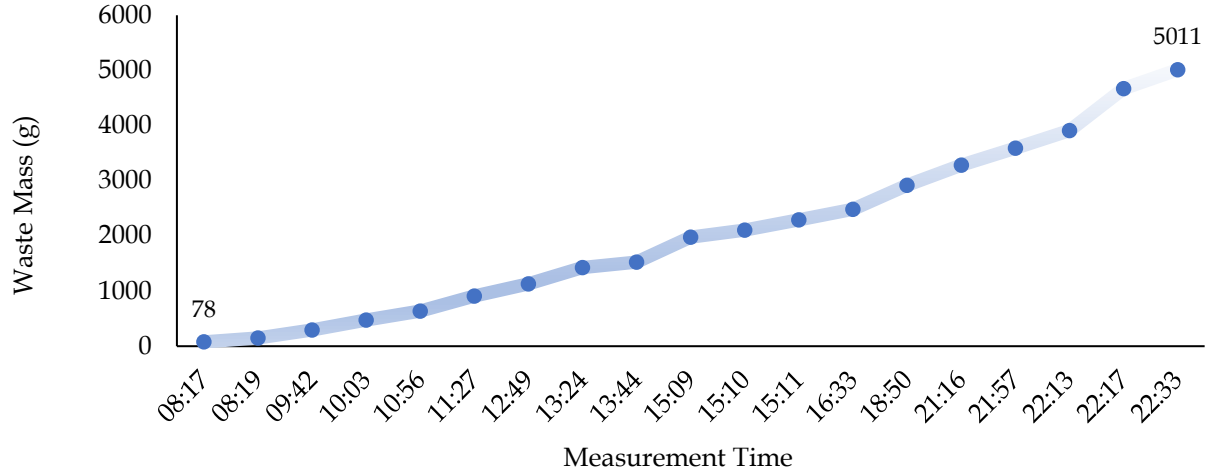


Figure 3. The first waste mass monitoring based on IoT

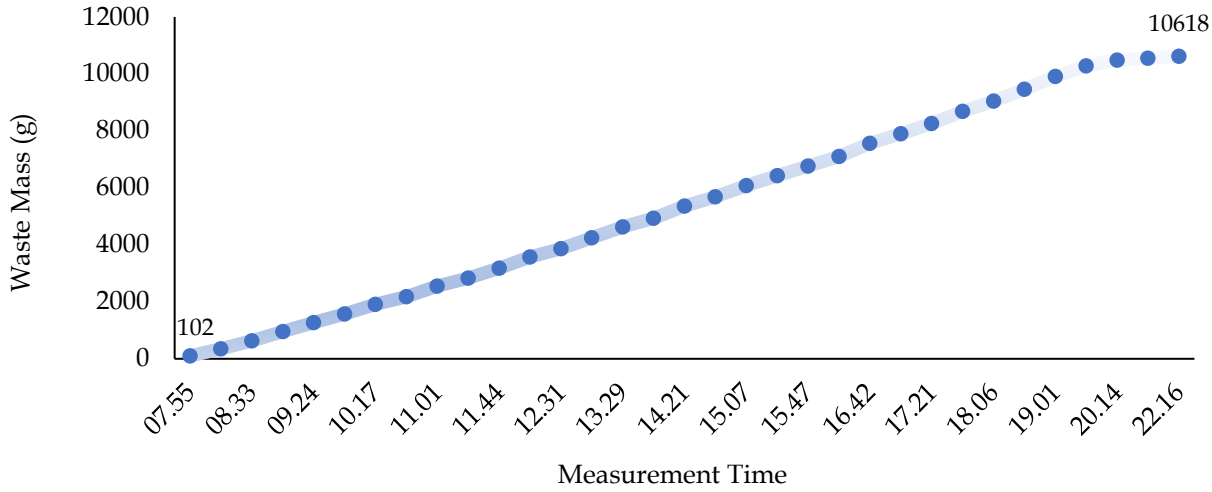


Figure 4. The second waste mass monitoring based on IoT

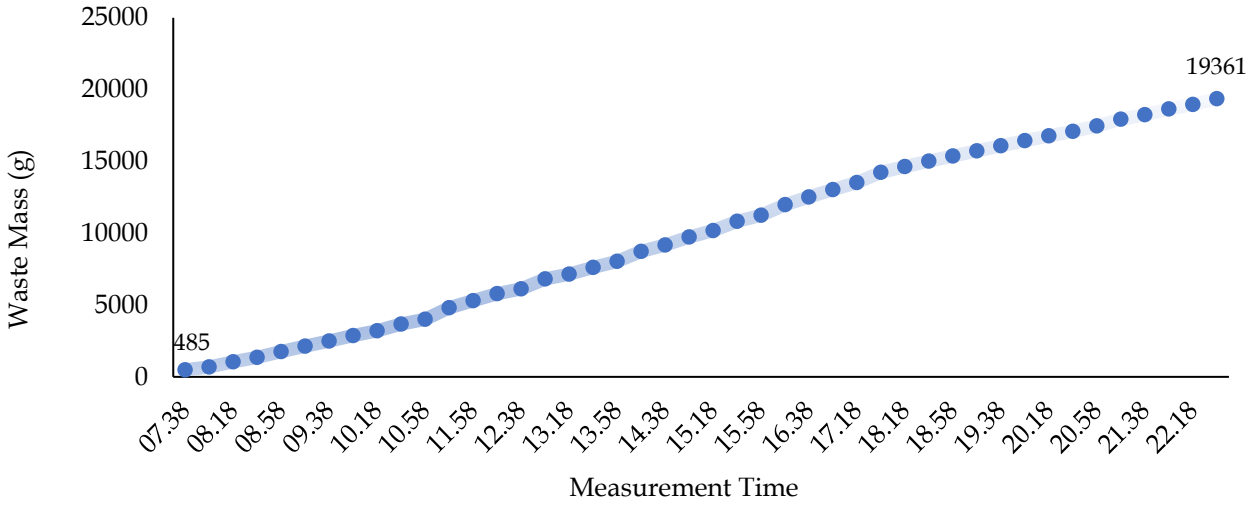


Figure 5. The third waste mass monitoring based on IoT

The load cell sensor demonstrates good, consistent performance during measurement. The results indicate that the sensor provides measurements very close to those of the reference instrument, reflecting a high degree of accuracy. The load cell sensor shows a relatively small margin of error when compared against standard measurement instruments SNI. Based on the calibration results, the load cell sensor exhibits a high level of accuracy, making it suitable for use as a measurement instrument for monitoring purposes. Furthermore, an IoT-based smart trash bin is employed to monitor the mass of waste. The observed data are delivered via Telegram notifications to the observer's smartphone. The load cell sensor was used to monitor waste mass three times.

Furthermore, the first monitoring of the IoT-based smart trash bin, measuring waste mass, is shown in Figure 3. Figure 3 illustrates the first instance of waste mass monitoring in an IoT-based smart trash bin. This monitoring was conducted during daily operational hours, with measurements taken from morning until night. The waste consisted of inorganic materials discarded by the local community. Monitoring took place between 08:17 and 22:33, during which the mass of waste deposited into the smart bin ranged from 78 g to 5011 g on Telegram notification. It can be observed that the waste mass increased as more residents disposed of their trash. This is because more waste entering the bin naturally increases its total mass (Noiki et al., 2021; Pardini et al., 2018).

The observations indicate that as more waste enters the container, the load cell sensor measures increasing mass. This demonstrates that the sensor can continuously detect changes in waste mass throughout the observation period. These findings align with research Prasetyo et al. (2025), which suggests that sensor-based waste monitoring systems can track trash bin status in real time, providing faster, more accurate information on waste levels. Furthermore, IoT technology enables the transmission of measurement data directly to a monitoring system, allowing users to stay informed about the bin's status and receive notifications when its capacity approaches the maximum limit (Damayanti & Noer, 2025). This confirms that a load cell sensor can continuously monitor waste mass, providing data that supports more efficient waste management.

Furthermore, the second monitoring of the IoT-based smart trash bin, measuring waste mass, is shown in Figure 4. Figure 4 illustrates the second monitoring session for the IoT-based smart trash bin, showing a continuous increase in waste mass, as tracked via Telegram notifications throughout the monitoring period. The waste mass increased incrementally from the beginning to the end of the observation. This relatively consistent pattern indicates steady waste accumulation. Monitoring took place between 07:55 and 22:16, with waste mass deposited into the smart bin ranging from 102 g to 10618 g. The waste consisted of inorganic materials collected from the local community. The observations show that the load cell sensor can continuously detect changes in waste mass and provide stable measurement data. This finding aligns with research Prasetyo et al. (2025), which explains that load cell sensors can be used to monitor waste weight in real-time, allowing for a more accurate assessment of the bin's status. Furthermore, implementing IoT technology enables automatic transmission of measurement data to a monitoring platform, allowing users to receive real-time updates on the bin's condition and notifications when its capacity reaches a predetermined limit (Damayanti & Noer, 2025).

Finally, the third monitoring session for the IoT-based smart trash bin, which measures waste mass, is shown in Figure 5. Figure 5 illustrates the third monitoring session for the IoT-based smart trash bin. The accumulated waste mass increased significantly throughout the monitoring period. Waste mass rose gradually until the end of the observation, indicating continuous waste disposal by the local community throughout the day. The monitoring took place from 07:38 to 22:18, with waste mass deposited into the smart trash bin ranging from 485 g to 19361 g. The test results show that the load cell sensor can measure changes in waste mass continuously, yielding relatively stable data. Integrating IoT technology enables transmission of this data to a monitoring platform, allowing users to assess the trash bin's status in real time and track waste accumulation more practically and efficiently (Damayanti & Noer, 2025). The increasing waste mass recorded during testing shows that the system can continuously monitor the smart trash bin's status. This result aligns with research Prasetyo et al. (2025), which states that using a load cell sensor in a waste monitoring system can provide real-time information on a trash bin's status based on measured changes in waste mass. Consequently, the developed Smart Trash system performs its monitoring function effectively, thereby supporting more responsive and optimal waste management.

Compared with the first and second monitoring sessions, the third session showed a higher cumulative waste mass. This indicates that the volume of inorganic waste disposal tended to increase throughout the monitoring period. Comparing results across these three sessions provides insight into the inorganic waste accumulation pattern during the study. Thus, this IoT-based smart trash bin design uses a load cell sensor to monitor waste mass in real time automatically. Measurement data can be accessed remotely and

automatically via Telegram. This IoT-based smart trash bin monitors bin status, improves waste collection efficiency, and supports more effective, sustainable waste management.

Conclusion

Desain of smart trash bin based on IoT that uses Telegram for waste mass monitoring begins with determining the load cell sensor's error and accuracy percentage. The sensor's average error was 0.72%, with an average accuracy of 99.28%. A lower error rate corresponds to higher sensor accuracy. The higher the accuracy value, the better the sensor. The first monitoring session from 08:17 to 22:33, with waste masses ranging from 78 g to 5011 g. The second session from 07:55 to 22:16, with ranging from 102 g to 10618 g. The third session from 07:38 to 22:18, with waste masses ranging from 485 g to 19361 g. The results show that the load cell sensor can continuously measure changes in waste mass and provide relatively stable data. Data from the smart trash bin based on IoT can be accessed remotely via Telegram, facilitating more effective and sustainable waste management.

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Author Contributions
Conceptualization, M.F.H. and M.Y.; Methodology, M.Y., I.I. and R.Y.; Writing—original draft preparation, M.F.H. and M.Y.; Writing—review and editing, M.Y. and M.F.L.

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Conflicts of Interest
The authors declare no conflict of interest.

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