

Smart Bin Concept for Effective Waste Management

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Article's Information	Abstract
<p>Received: 26.01.2026 Accepted: 19.03.2026 Published: 31.03.2026</p>	<p>Effective waste management, which includes processing garbage and reducing the amount of uncontrolled refuse areas, is the first step toward improving the environment. Waste classification and then recycling them into alternatives as raw materials could improve the environment including the quality of air and water. Using smart waste bins is one of the proposed solutions to deal with waste management processes. This work suggests an affordable design for smart waste trash, which could be considered as an intelligent solution for waste management. The system suggests using three colour-coded bins. Each bin is customised for specific types of waste, which are food waste, papers and metal cans or plastic waste. Mechanical sensors are used for each bin in order to weigh it and notify the workers that the trash is full. The other components of the suggested design are solar panel and remote-control system. The solar panel is used for lighting and to power surveillance cameras. The remote-control system is necessary to monitor the whole operation of waste management. The proposed system is recommended to be used in specific areas of society, such as universities, schools, hospitals and malls as a first step and then generalise it to include the whole city and even the public areas. Also, in order to feature the need for such smart waste bins in different places of the city, a questionnaire is proposed, and a survey is undertaken as part of this work. Hence, including smart waste management systems could ensure a significant advancement in urban planning. A significant acceptance has been gained for the suggested design, and the majority of participants have encouraged using those smart bins.</p>
<p>Keywords: smart cities, smart bins, waste management systems, sensors</p>	
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1. INTRODUCTION

In 2012, the concept of construction of smart cities has started in Latin America which is considered a big technological advancement toward innovation and sustainability to encourage urban living [1]. The European Smart Cities project was launched in 2007 to assess 70 medium-sized cities in Europe. The assessment was based on different criteria such as smart economy, smart people, smart mobility, smart

governance, smart environment and smart living. This project was considered the first systematic European study to address the concept of smart city [2]. Later in the early 2000s, the smart waste management concept started in the United States and Europe. Different methods and ideas have been found to implement smart waste management concepts, such as using sensors and Internet of Things (IoT) technology [3]. IoT is a network of devices embedded with sensors and software that work together for data collection and sharing purposes [4]. In order to improve the quality of life and promote sustainable urban growth, this concept was spearheaded by successive generations of inventors. One of the innovations that was motivated by smart waste management was smart waste bins. The smart waste bins concept is a developed idea for the old methods of garbage isolation and classification. This concept has evolved into more advanced solutions that can be used in many spaces of society, such as schools, hospitals, shopping malls, etc. Within the context of smart cities, three approaches, i.e. social approach, environmental approach and technological approach, could establish the basics of urbanisation. Smart cities are intended to manage environmental issues, alleviate the effects of climate change, and promote social and economic development. In addition to that, smart waste management using smart bins could offer people some services like motivational messages, charging via the bin's USP port upon depositing waste. The idea of smart bins will first be applied in controlled places such as universities, schools, and private sector companies and will then be expanded to include the whole city, which, of course, requires raising environmental awareness among the population. Despite the fact that the combination of IoT and smart waste management is not a new idea, its application could increase the effectiveness of waste management systems. These systems monitor the level of waste in the bins in real time and send indications to the control system to empty them [3]. Also, detecting the level of waste can help the system automatically keep the bin lid closed or open, even while people continue to dispose of waste. Combining IoT with Global Positioning System (GPS) and various types of sensors has improved waste separation, especially in urban areas [5]. Moreover, many proposals have been introduced and implemented to promote the idea of sustainable development in some Iraqi institutions like schools and universities [6]. One of these proposals is teaching students how to separate waste according to the labels on waste bins. This proposal enhances environmental consciousness and cultivates a culture of sustainability among youth, coinciding with wider initiatives to incorporate sustainable practices into educational settings. Digital image processing methods have also been employed for the separation of waste categories, such as image analysis, image enhancement, and feature definition [7]. Digital image processing and deep learning techniques have been used by researchers to photograph and sort different categories of waste [8], [9], [10], establishing a link between camera-captured images and image analysis. In [11], a Smart Dustbin System (SDS) was proposed using sensors, IoT, GPS, Artificial Intelligence (AI) and deep learning to address waste management issues. The SDS can reduce labour costs and improve hygiene, but the big challenge is real-time monitoring. A wireless smart dustbin system was designed to monitor waste levels in [12]. The design can detect when the dustbin is full and send notifications to the administration. It was tested only on a few bins, not for the whole city, where city-wide monitoring requires more powerful mobile networks. In [13], three modules were integrated with an Arduino microcontroller to implement a smart waste bin for solid waste management. The first module is for object detection, like a person standing in front of the bin to open the lid. The second module is to monitor the level of waste inside the bin. The third one detects smoke and foul odour. In [14], a study has focused on the connection between the current state of research and future direction regarding waste management in smart cities, especially in urban regions. Waste management in urban areas needs an integral approach that combines community engagement, IoT devices and sustainability. The study highlights the big role of technology with a community-driven approach. Sholihat et al. went to another opinion, namely that smart cities do not relate just to technology, they integrate multiple factors such as governance, citizen participation and innovation ecosystems [15]. Several publications from databases of Web of Science and Scopus have been reviewed by Singh et al., who identified the applications of AI in smart waste management. The work highlights AI techniques like deep

learning, computer vision, machine learning and IoT-based systems that are applied to recycling, segregation, waste collection and disposal. The authors found that there was a significant growth in this research area post-2018. Also, the study showed that in spite of the strong international collaborations between European and Asian organisations (for example), a lack of standardised datasets was found, which reduces the ability to compare results [16]. The concept of smart city was analysed in [17], and pioneering applications in cities like London, New York and Seoul were evaluated. The authors relied on the *Eden Strategy Institute's Top 50 Smart City Government Ranking* covering 235 possible smart cities across the world in 2020/2021, based on ten indicators. The study discussed the accomplishments and defects of smart cities and concluded that a balance is required between technological innovation, social engagement, and governance to achieve technological innovation. A study outlined the essential criteria for developing a smart city using Singapore as a case study. Singapore's Smart Nation initiative focuses on three factors: digital government, digital economy and digital society. Integrating these factors can improve the quality of life and reinforce businesses' growth. However, the big challenge that faces the transformation into a smart city is data security risks. Protecting citizens' information requires a very robust system to counter potential cyber threats [18]. Tetiana But et al. investigated the Smart City concept in European Union (EU) countries in terms of economic development. The use of modern technologies can help raise travel experiences and manage the tourism industry more effectively. The concept can improve the quality of life and support the sustainability of the environment. However, some obstacles to its development should be overcome, such as citizens' lack of trust in sharing their personal data via the internet. Also, a Smart City means a robust digital system is required to protect against cyberattack risks [19].

This paper presents a simple and cost-effective proposal to raise the role of automated waste bins in addressing environmental challenges. In addition to that, a questionnaire was distributed to a sample of the population to measure their acceptance of the proposed design. The rest of the paper is organised as follows: the proposed method is introduced in sections 2 and 3. Section 4 presents the smart bin questionnaire. The design constraints are explained in Section 5. The analysis of the results in Section 6. Section 7 concludes the paper.

2. METHODOLOGY

The proposed design is composed of three different colour-coded waste bins. Each bin has a specific colour which represents a specific type of waste. The purple bin for cans, the green bin for food waste, and the blue one for paper waste. Each bin is equipped with a mechanical sensor for weight detection, which provides an indication when the bin is likely to be full. Since the weight changes depending on the type of garbage, food waste is commonly heavier than the other two types: paper and can waste. Solar energy cells are required in the design to power the system, where they supply electricity from sunlight. The generated electricity will be used to operate the cameras and for lighting purposes. A photovoltaic cell, which is a technology for converting sunlight directly to electricity to power a Light Emitting Diode (LED), is used to illuminate during nighttime. To monitor waste bin management and assist in optimising waste collection schedules, cameras are employed. Optimization of collection schedules is accomplished by continuous tracking of bin fill levels. Data will be sent wirelessly to the control system through Wireless Fidelity (Wi-Fi) technology to inform the authorized personnel which bins are empty and which are full. The system will be monitored 24 hours per day without needing electricity. The data collected by cameras and sensors can help adjust and reschedule waste collection.

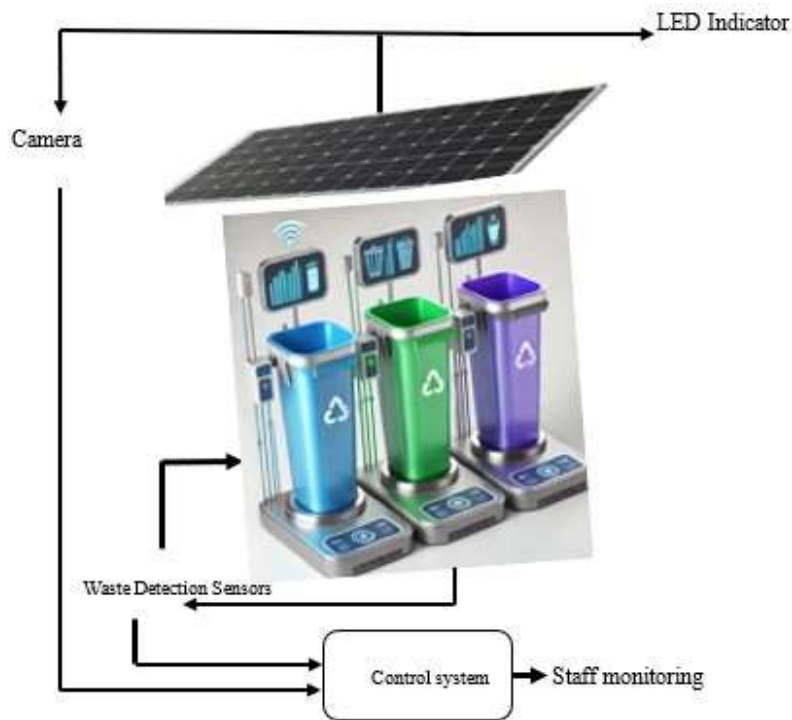


Fig. 1. Smart Bin Model

Figure (1) depicts a smart bin model that is designed to facilitate the waste management process, promote recycling and provide a user-friendly experience. It features a minimalistic structure with separate compartments for plastic and metal waste, ensuring efficient sorting at the point of disposal.

The following components are used in the design:

- Solar-Powered System – A small solar panel on top powers the bin, making it energy-efficient and sustainable.
- Power Management (Battery). It stores energy and distributes it to different components.
- LED Indicator – A simple LED light notifies users when the bin is full, helping optimize waste collection schedules. (LED Indicator– Alerts users when the bin is full.)
- Digital Display for Notifications – A small screen provides basic messages or alerts, encouraging responsible disposal habits.
- Digital Display – Shows notifications, such as motivational messages or alerts.
- Microcontroller (Processing Unit) – Processes input from sensors and controls the separation mechanism.
- Waste Separation Mechanism – Sorts waste into designated compartments.

A sensor that is needed to detect the weight of the bin is a mechanical sensor, also known as load cells [20]. This sensor could detect some physical changes like vibration, force, pressure and weight and then convert them into electrical signals. The operating principle of mechanical sensors is that when weight or pressure is applied, the spring or metal rod becomes deformed. This deformation results in a change in the resistance values of the spring. A Wheatstone bridge is used to convert this change in resistance into an electrical potential difference. Finally, an amplifier and filter are used to amplify the electrical signal, producing an accurate reading of the weight or force [21], [22]. There are different types of weight sensors depending on

the size of the bin. For instance, a 5-kilogram sensor is suitable for small bins, as shown in figure (2). For higher weights, other sensors are available [23], [24].



Fig. 2. Load Cell 5 Kg (straight bar) [23]

Figure (3) shows the HX711 load cell amplifier, which is connected to the straight bar sensor to read the load cell signals and measure the weight. Finally, the arrangement will be connected to the ESP32 to read the output of HX711 and send it to the control room via Wi-Fi technology. The suggested microcontroller is ESP32, as it has integrated Wi-Fi and Bluetooth, which in turn eliminates the need for external communication modules [23].

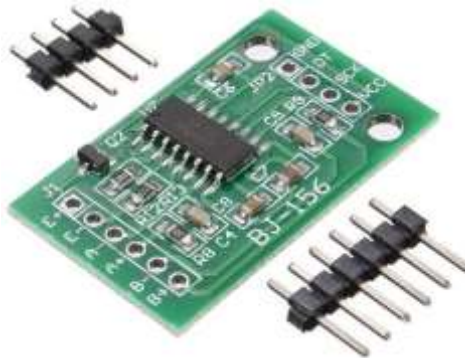


Fig. 3 . HX711 Dual-Channel Module [23]

The following procedure explains how to calculate the weight for a load cell sensor (strain gauge) after receiving an analogue signal [25]:

$$Weight (Kg) = \frac{V_1}{V_{ref}} * \frac{Cap_rated}{Vo_rated} \quad (1)$$

Where V_1 is the load cell signal voltage in (millivolt), V_{ref} = load cell reference voltage in Volt, Cap_rated is the load cell rated capacity in Kg, and Vo_rated is the load cell rated output (1mV/V).

In this work, a mechanical sensor is needed to sense the weight of the bin, which gives an indication that the bin is likely full.

A block diagram of the proposed system illustrates the decision-making process, as depicted in figure (4).

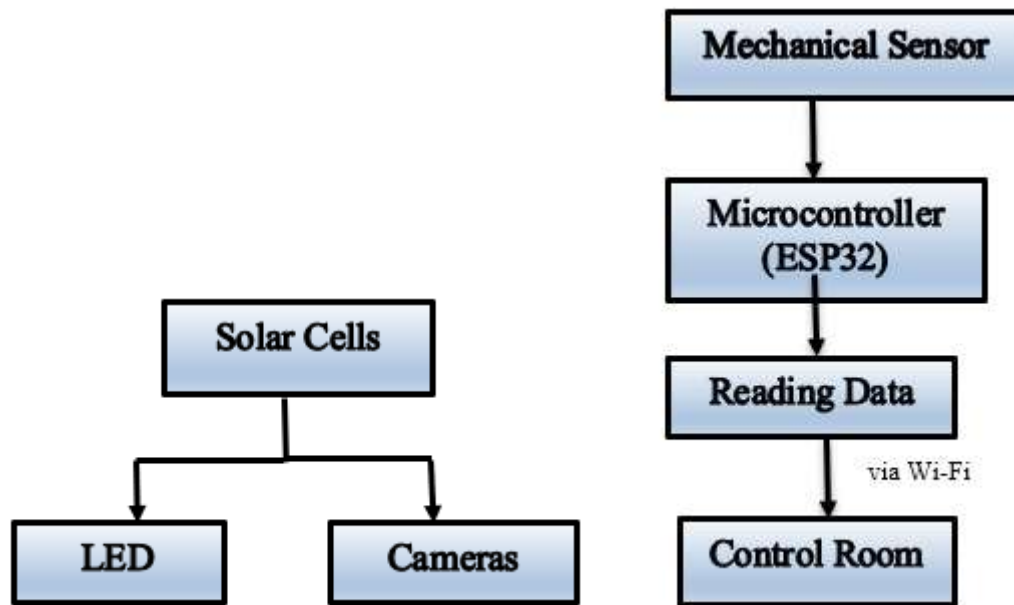


Fig. 4. Block Diagram of the Proposed System

3. USAGE AND IMPLEMENTATION

- Indoor locations like universities, schools, shopping centres, and cafes are allocated places to place smart bins as a first step, which will help with easy waste separation.
- The use of the system is very simple, and this simplicity will encourage people to dispose of waste in the proper place instead of throwing it on the floor.
- Smart bins innovation contributes to protecting the environment from pollution, especially air and water pollution and will be generalized for implementation across all cities.

4. SMART BIN QUESTIONNAIRE

To highlight the importance of the smart bin concept in developing country communities, including Iraq, a survey was conducted among various samples of community groups such as waste collectors, students and shopping centre employees. The survey involved 100 participants of different ages, females and males. The majority of the participants encouraged the installation of such bins; however, a portion of them had no prior knowledge of the idea itself. Recycling is one of the most effective and equitable methods for protecting the environment. Many advantages can be obtained from recycling, such as the reuse of paper waste, getting organic fertilizers from restaurant food residues and encouraging the reuse of some stuff such as notebooks, pens and metal cans. In addition, raising environmental awareness mainly among schoolchildren plays an important role in promoting a culture of waste recycling, which will result in creating a conscious society that recognizes the significance importance of recycling. Figure (5) depicts the set of questions and corresponding answers that were used in the questionnaire.

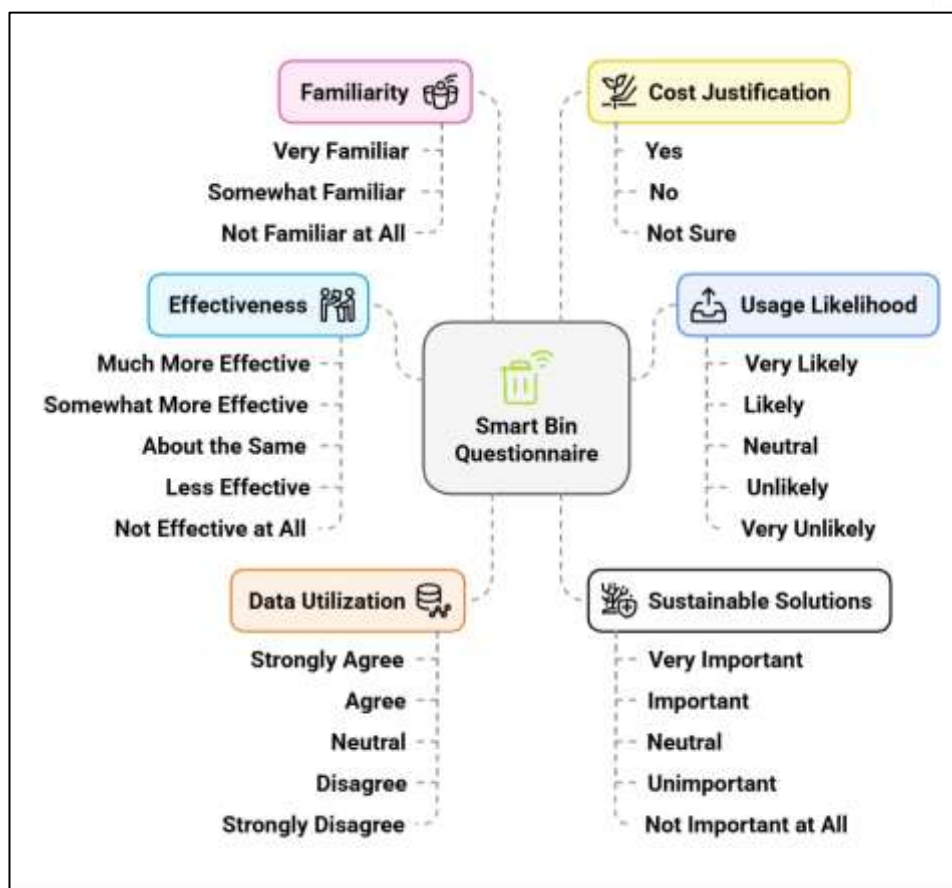


Fig. 5. Questionnaire Form of Questions and Answers

5. RESULTS AND DISCUSSION

In this paper, a smart bin design was introduced, and a planned questionnaire was distributed to evaluate the effectiveness of the technology. Six key factors that might affect using the smart waste bin have been included in the questionnaire by using a line chart. The factors are Familiarity, Cost Justification, Effectiveness, Usage Likelihood, Data Utilization, and Sustainable Solutions.

Figure (6) shows the chart of the answers to the first question in the questionnaire, which concerns Familiarity. It indicates that the participants are very familiar with the smart bin concept, as the answer of 'very familiar' has the largest proportion. For the Cost Justification factor, most of the participants were 'Not Sure' as shown in figure (7). The answer of 'Much More Effective' to the third question (Effectiveness), has the largest proportion, which means that the majority of the volunteers recognized the effectiveness of the smart bin concept, as shown in figure (8). For the Usage Likelihood factor, most participants have chosen the 'Very Likely' answer, as shown in figure (9) which means that they strongly recommend the smart bin concept. Figure (10) shows the Data Utilization chart. The chart indicates that the 'Strongly Agree' answer has the largest proportion, which means the majority of the volunteers support the importance of data utilization. Figure (11) depicts the chart of the sixth question, i.e. Sustainable Solutions. The chart shows that 63% of the participants agreed on resorting to sustainable solutions.

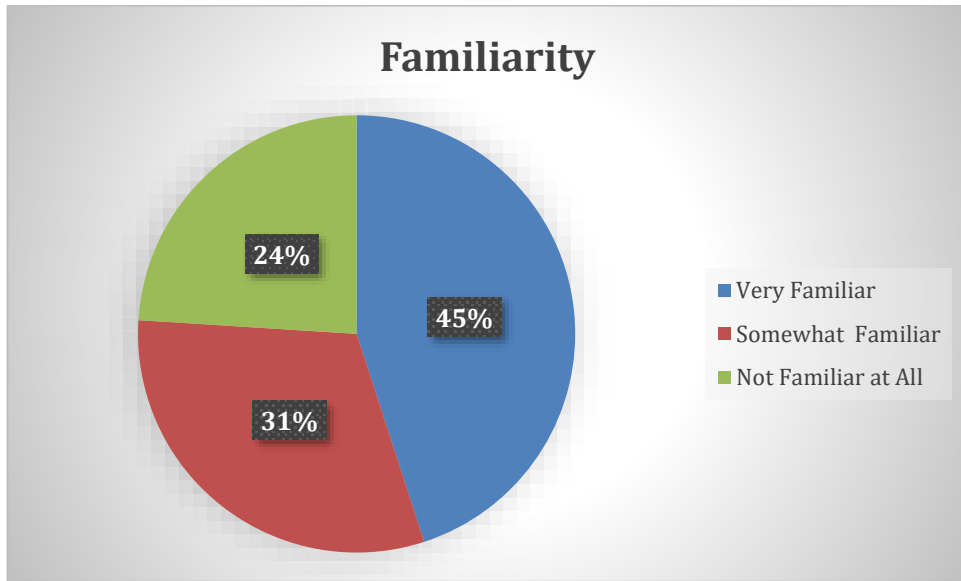


Fig. 6. Responses to the Familiarity Question

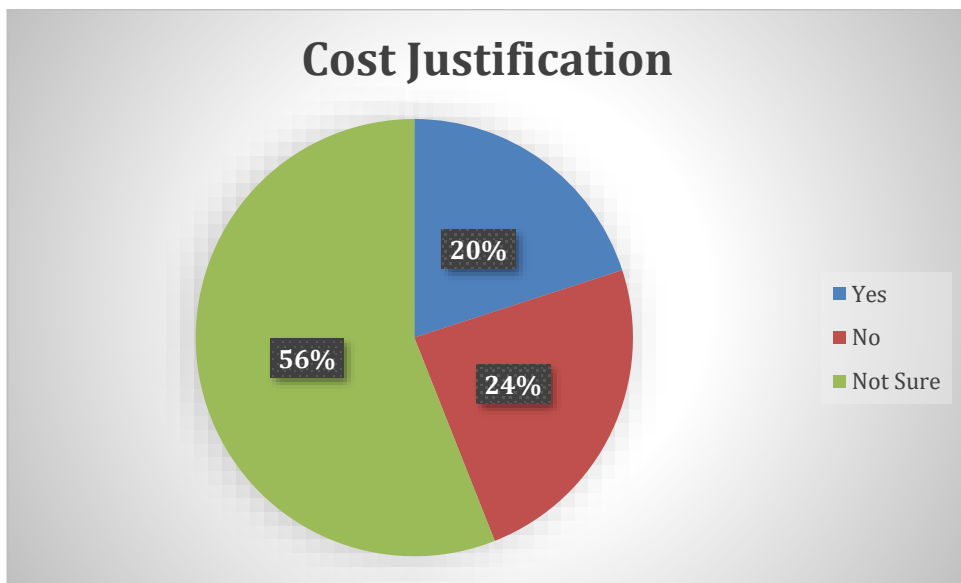


Fig. 7. Responses to the Cost Justification Question

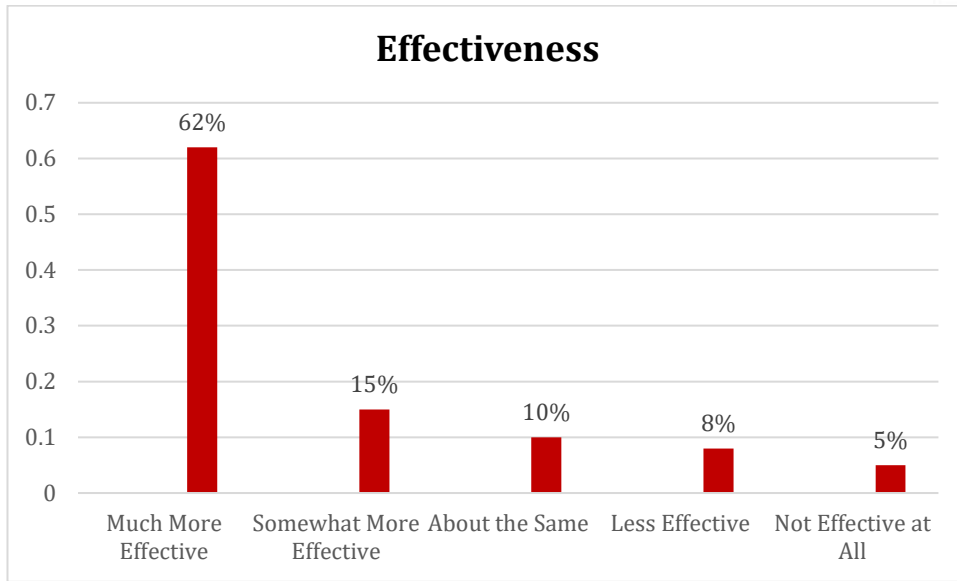


Fig. 8. Responses to the Effectiveness Question

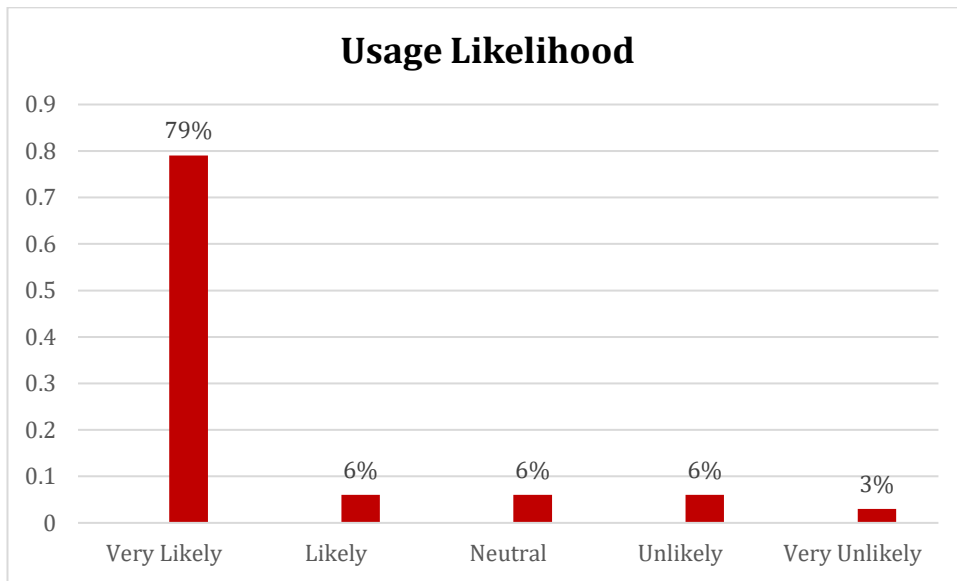


Fig. 9. Responses to the Usage Likelihood Question

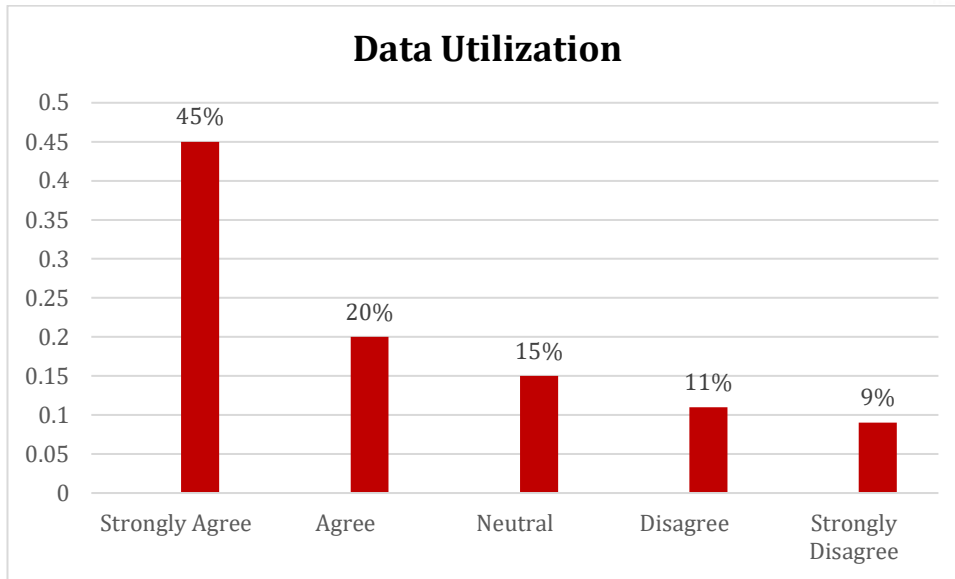


Fig. 10. Responses to the Data Utilization Question

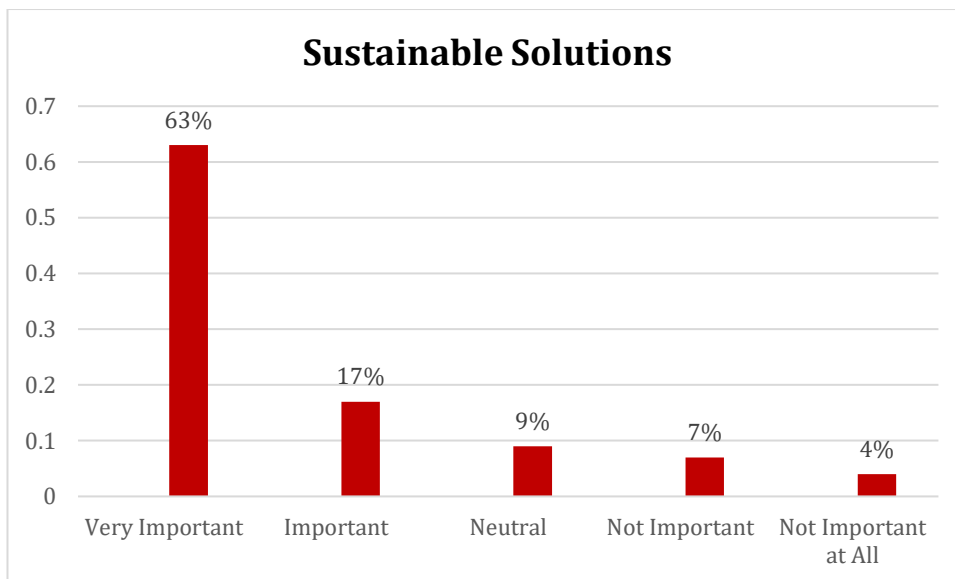


Fig. 11.: Responses to the Sustainable Solutions Question

Data representation of the questionnaire is shown in figure (12). The Usage Likelihood factor shows its strong significance as it has gained the highest relative value. This indicates that the Usage Likelihood is an important determinant in performance evaluation or decision-making. Also, the two factors- Effectiveness and Sustainable Solutions - have achieved notable values, which means their big importance in that assessment. In contrast, factors of Data Utilization, Cost Justification and Familiarity exhibit moderate scores, which reflect their lesser effect while still having some contribution compared to the top-ranking factors. While a line chart offers clarity, it can also give distortions, which make precise comparisons more challenging. Including data labels in the line graph (or chart) can enhance clarity and make interpretation

more accurate. Also, adding some statistical insights, for instance, percentage distributions or variance analysis, may enhance the interpretation of factor interactions. Future refinements in visualization methods may enhance clarity and data interpretation for every factor is depicted in Table (1).

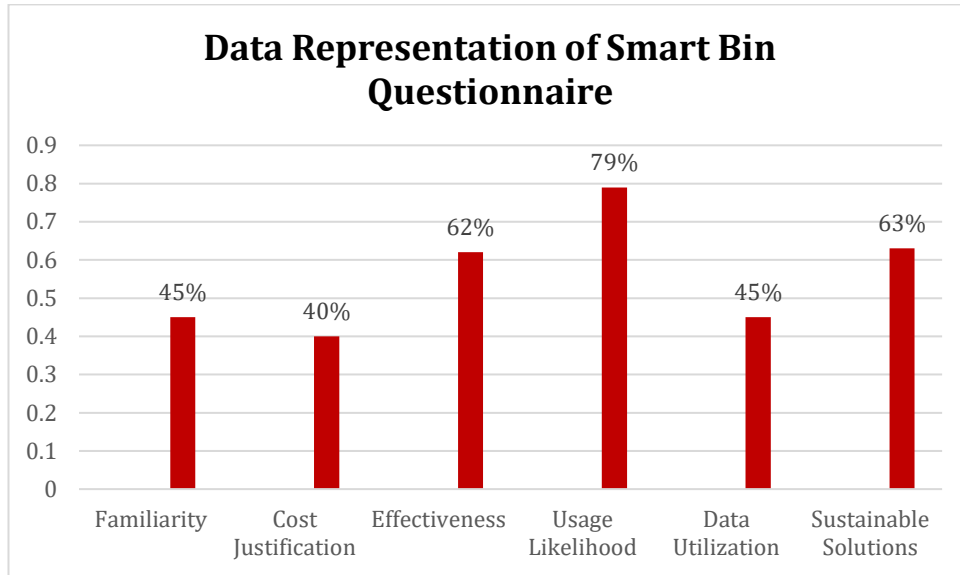


Fig. 12. Data Representation of Smart Bin Questionnaire

Table 1. Interpretability of the Questionnaire Data

Question	Approximate Answer	Explanation
Familiarity	Very Familiar	Respondents have some knowledge of smart bins but may not be experts.
Cost Justification	Not Sure	Many believe the cost of smart bins is justified based on the benefits.
Effectiveness	Much More Effective	Smart bins are perceived as effective in waste management.
Usage Likelihood	Very likely	High probability that people will use smart bins.
Data Utilization	Strongly Agree	Strong support for using data from smart bins for improvements.
Sustainable Solutions	Very Important	Sustainability is a key factor for respondents.

6. DESIGN CONSTRAINTS

The given smart bin design data lack direct sensor-based parameters, which are needed to obtain an optimal design. Therefore, it is necessary to integrate other parameters like real-time sensor data (continuous information), environmental conditions and user behaviour analysis. The examples of real-time sensor data are full level, weight, foot traffic, motion detection and odour level. In addition to that, peak usage times and waste type variations should be identified for various locations. Integration of AI-driven predictive

modelling, together with sensor readings, can play a big role in optimizing waste management systems. A cost-effective strategy may have some other parameters, such as notifications for scheduled emptying and solar-power activation to help balance energy use and maintenance costs. This improved dataset will support the waste management systems to obtain more adaptive and smarter waste disposal systems.

7. CONCLUSIONS

Proper waste management must be a priority for urban and developed countries to ensure a healthy environment with clean air and water. This requires effective waste management strategies and, in turn, significant funding from official authorities to encourage recycling and reduce the amount of waste sent to landfills. Also, sorting different types of waste into raw materials for recycling will offer several advantages. For instance, it can reduce production costs and recycling plastic instead of throwing it in rivers helps protect marine organisms. Therefore, smart waste bins are one of the proposed solutions to address waste challenges. In this paper, a smart waste bin design is proposed, and a structured questionnaire is conducted to measure the level of public acceptance for this technology. The results showed that using smart bins has a significant acceptance, where the majority of participants supported this idea, which reflects the important role of societies in achieving this goal.

Smart bin design is adaptable and implementable in Iraq. It could first be implemented and used in universities, schools, shopping malls and cafes and then be extended to the whole country. Applying smart waste management in Iraq will help create a healthy environment and generate different forms of energy.

REFERENCES

- [1] Escobar, A., J. Luna, and A. Caraballo, *Innovating smart cities in Latin America: Addressing regional urban challenges and opportunities*, Journal of Infrastructure, Policy and Development, 8(13), p. 8378, 2024.
- [2] Giffinger, R., C. Fertner, H. Kramar, R. Kalasek, N. Pichler-Milanović, and E. Meijers, *Smart cities: Ranking of European medium-sized cities*, Centre of Regional Science (SRF), Vienna University of Technology, Vienna, Final report, October 2007.
- [3] Mahajan, P. and A. Jain, *Survey paper on municipal solid liquid-based smart waste management system—Zero waste using Internet of Things*, International Journal of Engineering Sciences & Research Technology, 7(8), pp. 272–276, 2018.
- [4] Guo, J., *IoT Technology in Urban Waste Management: Smart Waste Bin Systems*, Highlights in Science, Engineering and Technology, ACME Publishing, Chengdu, pp. 452–458, 2024.
- [5] Jagtap, S., A. Patil, A. Gandhi, R. Bocharé, and A. Shitole, *Waste management improvement in cities using IoT*, Proceedings of the 2020 IEEE International Conference on Smart and Sustainable Technologies (SpliTech), IEEE, 2020.
- [6] Jabbar, S. I., *Different scenarios to activate sustainable development in Iraqi educational institutions*, 2nd International Conference on Engineering and Science to Achieve the Sustainable Development Goals, AIP, Tabriz, Iran, 3092(1), 2024. doi:10.1063/5.0199623.
- [7] Jabbar, S. I. and A. Q. Aladi, *Automated Contrast Enhancement of the MRI Video Imaging*, 2019 IEEE 13th International Conference on Application of Information and Communication Technologies (AICT), IEEE, Baku, Azerbaijan, pp. 1–5, 2019. doi:10.1109/AICT47866.2019.8981719.
- [8] Li, Y., H. Huang, Q. Xie, L. Yao, and Q. Chen, *Research on a Surface Defect Detection Algorithm Based on MobileNet-SSD*, Applied Sciences, 8(9), p. 1678, Sep. 2018. doi:10.3390/app8091678.

- [9] Redmon, J., S. Divvala, R. Girshick, and A. Farhadi, *You only look once: Unified, real-time object detection*, Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 779–788, 2016.
- [10] Zhao, Z. Q., P. Zheng, S. T. Xu, and X. Wu, *Object detection with deep learning: A review*, IEEE Transactions on Neural Networks and Learning Systems, 30(11), pp. 3212–3232, 2019.
- [11] M. P., S. Shoba, and A. Pandey, *A survey of smart dustbin systems using the IoT and deep learning*, Artificial Intelligence Review, 57(3), p. 56, 2024.
- [12] Reddy, P. S. N., R. N. Naik, A. A. Kumar, and S. N. Kishor, *Wireless dust bin monitoring and alert system using Arduino*, 2017 Second International Conference on Electrical, Computer, and Communication Technologies (ICECCT), pp. 1–5, 2017.
- [13] Afolalu, A., A. A. Noiki, O. M. Ikumapayi, A. T. Ogundipe, and O. R. Oloyede, *Development of Smart Waste Bin for Solid Waste Management*, International Journal of Sustainable Development and Planning, 16(8), pp. 1449–1454, Dec. 2021. doi:10.18280/ijstdp.160805.
- [14] Szpilko, D., A. de la Torre Gallegos, F. Jimenez Naharro, A. Rzepka, and A. Remiszewska, *Waste Management in the Smart City: Current Practices and Future Directions*, Resources, 12(10), p. 115, Sep. 2023. doi:10.3390/resources12100115.
- [15] Sholihat, A. and F. Yavuz, *Evaluation of Pioneering Smart City Applications Across the Globe*, Thinking of Urban Decoding Journal (TUDEJ), 1(1), pp. 25–44, Sep. 2024. doi:10.69992/0.2024.3.
- [16] Singh, J., El-Sappagh, S., Ali, F., Goyal, S. B., Kumar, M., *Smart waste management: a systematic review and scientometric analysis of artificial intelligence applications*, Springer Nature, Environment, Development and Sustainability, 2025.
- [17] Sholihat, A., & Yavuz, F., *Evaluation of pioneering smart city applications across the globe*, Thinking of Urban Decoding Journal (TUDEJ), NEU Press, Konya, Türkiye, pp. 25–44, 2024.
- [18] Sipahi, E. B., & Saayi, Z., *The world's first "Smart Nation" vision: the case of Singapore*, Smart Cities and Regional Development Journal, Konya, pp. 41–48, 2024.
- [19] But, T., & Mamotenko, D., *Increasing the economic development of the EU countries through the implementation of the "Smart City" concept*, Management and Entrepreneurship: Trends of Development, Zaporizhzhia Polytechnic, Zaporizhzhia, pp. 27–37, 2025.
- [20] TE Connectivity, Load Cell Technologies, TE Connectivity, [Online]. Available: <https://www.te.com/en/products/sensors/force-sensors/resources/load-cell-technologies.html>.
- [21] Monolithic Power Systems, Mechanical sensors, MPS Scholar – Learning Centre, Retrieved Jan. 24, 2026, from <https://www.monolithicpower.com/en/learning/mpscholar/sensors/different-types-of-sensors/mechanical-sensors>.
- [22] Al-Dahiree, S., M. O. Tokhi, N. H. Hadi, N. R. Hmoad, R. A. R. Ghazilla, H. J. Yap, and E. A. Albaadani, *Design and Shape Optimisation of Strain Gauge Load Cell for Axial Force Measurement for Test Benches*, Sensors, 22(19), p. 7508, Oct. 2022. doi:10.3390/s22197508.
- [23] Grobotronics, Load Cell 5kg Straight Bar, Grobotronics Online Store, [Online]. Available: <https://grobotronics.com/load-cell-5kg-straight-bar.html>.
- [24] Rite, E., *Load Cells: Types, How It Works, Applications, & Advantages*, Encardio Rite Blog, Dec. 9, 2020. [Online]. Available: <https://dev.encardio.com/blog/load-cells-types-how-it-works-applications-advantages>.
- [25] Beijer Electronics, Load Cell – Weight Calculation, Beijer Electronics Documentation, [Online]. Available: <https://www.beijerelectronics.com/docs/DIO/GT-3002/en/weight-calculation.html>.