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Smart garbage management system for a sustainable urban life: An IoT based application

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ABSTRACT

Proper waste management is one of the major problems for densely populated urban areas. It is getting difficult day by day to lead a healthy, sustainable living in urban areas because of environmental contamination. Due to the lack of proper waste management approach, problems like an overflow of waste occurs that badly harm our environment. Polluted surroundings result in the spread of various kinds of diseases in an epidemic form. For developed and developing countries, waste management is a challenge to long-term development. Proper management of waste is getting tougher because of increasing population, urbanization, and industrialization. In this modern era of technology, we need to apply technology-based solutions to handle large amounts of waste for overpopulated urban areas. We have reviewed several recent research articles related to the smart waste management system, and almost all of them have some major limitations as well as progress. To ensure environmental hygiene and sustainable urban life, we have presented a smart IoT based integrated system consists of an identification system, an automated lid system, a display system, and a communication system. Arduino Uno is used as a microcontroller to synchronize all of the four systems. Sensors are used for identification and measuring the garbage level. The system provides the facility of continuous monitoring of the status of waste inside the garbage bin and shows the percentage filled up on liquid crystal display (LCD). The communication system uses a global system for mobile communications (GSM) module that will inform the corresponding authority to collect the waste when the garbage bin is filled up. The proposed waste management system is much more efficient than any other conventional waste management system as it reduces the use of manpower, avoids spillover of waste, saves time, more economical, and most importantly it is a completely automated system.

1. Introduction

Proper management of waste should be a priority to reduce environmental pollution and to ensure the safety of public health. In developing countries, waste management and awareness is an emerging concept. To ensure the sound environment and sustainable development, appropriate management of waste is a must. Nevertheless, in developing countries, due to lack of infrastructure and unsustainable practices have made waste management worst, which leads to environmental contamination. The open dumping and picking of waste within open dumpsites lead to serious health risks like skin infec-

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(a) (b)

Fig. 1. (a) An open dustbin, spreading bad odor and disrupting vehicular movement in Laksmibazar area of old Dhaka (collected from [6]), (b) The worst scenario of waste in Chittagong after Eid-Ul-Azha, polluting environment and hampers the normal urban life (collected from [7]).

tions and chronic diseases. In slum areas, the situation gets worst because of the high density of the population. It is a clear indication that environmental / health issues and poor waste management are interrelated.

The increase in population, urbanization, and industrialization increases the waste generation level throughout the world. More than 64% of the population in the developing countries and more than 84% in the developed ones will be in urban areas by 2050 [1]. Hence waste management is a global issue in terms of various environmental and social impacts.

The world generates 2.01 billion tons of municipal solid waste annually, with at least 33% that - extremely conservatively - not managed in an environmentally safe manner. Global waste is expected to grow to 3.40 billion tons by 2050. Worldwide, waste generated per person per day averages 0.74 kg but ranges widely, from 0.11 to 4.54 kg. The total quantity of waste generated in low-income countries is expected to increase by more than three times by 2050 [2].

Now, like other low-income countries, Bangladesh is one of the developing countries in the world, with a huge population within a small area. Dhaka is the capital city of Bangladesh, having an area of 306.8 km^2 [3]. Dhaka's 2020 population is estimated at 21,005,860, while 2030 may see as many as 27.3 million residents [4]. That indicates that Dhaka city is overpopulated. However, the waste management of Dhaka city is somehow overlooked by the local government. Around 234,000 deaths, including 80,000 in urban areas, due to environmental contamination and related health risks in 2015, making it one of the worst affected countries in the world [5]. A place like Dhaka city, where the density of people is high, just needs to provide an effective waste management system. A suitable approach that can manage waste in such a way so that it does not pollute the environment and ensure the safety of public health.

Fig. 1 (a) shows a garbage bin in the Laksmibazar area of old Dhaka. It is a regular picture of urban areas of Bangladesh. The waste management of urban areas of Bangladesh is not environment friendly. The dustbins have no lid over them, and most of them are placed on busy roads of urban areas. The dustbins are cleaned every day at the pick hour of the day when everyone goes to their workplace, and students go to their schools, colleges, or universities. Overflow of waste is seen frequently in almost all of the dustbins. Because of that, various kinds of infectious diseases are spread, and many people, especially children, losses their lives every year. The situation gets worst on Eid-Ul-Azha, which is the second-largest festival of Muslims. It is also known as 'Feast of Sacrifice'. Most of the people in Bangladesh are Muslims. On this day, Muslims sacrifice cow, camel, or ram. These animals are slaughtered in open space that badly affects the environment. A picture is shown in Fig. 1 (b), where the wastes are kept on busy roads of Chittagong generated because of Eid-Ul-Azha. The slaughtering of animals in open space and mismanagement of waste makes urban life miserable and causes the spread of different kinds of diseases. The waste generated from urban life can be different types, as a paradigm, plastic, leather products, and rubber, textile and wood, glass, metal, paper, organic matters, and others. Fig. 2 shows the different kinds of waste generated per day (in kg) in different cities of Bangladesh. It is seen that Dhaka and Chittaging city generates more waste than the other cities. Among the different types of wastes, the most generated wastes are paper and organic matter, and the other types of wastes have an insignificant amount.

Based on the above issues, this paper proposed an effective and efficient garbage management system. The proposed system uses sensors for identification of personnel and measuring garbage level. Continuous data regarding garbage levels are available for personnel through the display of the garbage bin. This smart garbage bin provides an automated lid to personnel. When there are personnel detected within a 30 cm range of the garbage bin, the lid opens if the garbage bin is not filled up and the rest of the time, it remains closed. The garbage bin also sends a message to the corresponding authority to collect waste when the bin is 100% filled up. Arduino Uno synchronizes the whole automated system. A real prototype of the proposed smart waste management system in a small-scale bin is designed and found satisfactory results. Therefore, in brief, the contributions of the paper are,

(i) It provides a very simple waste management system that is eco-friendly. It also can bring a great change in people's perspective towards messy urban life.

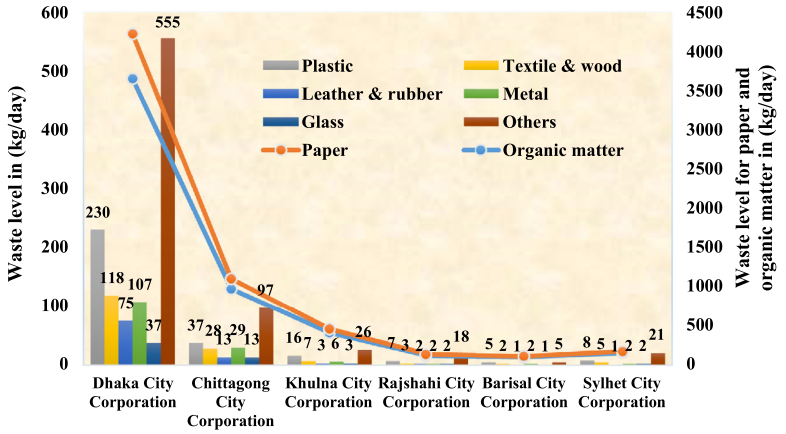


Fig. 2. Different kinds of waste generated per day (in kg) for different city corporations of Bangladesh (collected from [8,9]).

(ii) The proposed system is very much easy to handle than the traditional waste management system. It will also help to secure a worthy urban life.
(iii) The system also provides an automated lid that prevents any kind of physical contact with a garbage bin. With IoT based application, it helps to avoid the overflow and spreading of waste.

The presented work of the paper is organized into seven sections. The motivation behind the works, and the contribution of the proposed works in social and environmental aspects are presented in Section 1. The previous existing works, similarities of the existing works and the proposed one, positive impacts, and the research gap are presented in Section 2. The structure, components requirements, and methodology of the proposed smart waste management system are delineated in Sections 3 and 4, respectively. The developed software framework is detailed in Section 5. The performance test, result, and economic feasibility assessment are detailed in Sections 6 and 7, respectively. The ability to integrate the proposed smart garbage management system with the existing one is presented in Section 8. Finally, a conclusion is drawn in Section 9.

2. Analysis of existing IoT based smart waste management system

Different aspects of IoT based technology are covered in the literature for waste management solutions.

Imteaj et al. [10] proposed an android based application that provides the facility of informing city corporations or can notify volunteers to come forward. It also provides a platform for the user to take part in a clean city. The main advantages of this android based application are, users can detect nearby dustbin with location, available volunteers are visible on the map and can notify both the users, and volunteers using google push service. People can also file a report to the corresponding authority if any kind of problem arises. Malapur et al. [11] proposed an IoT based waste management system that provides an optimized path for collecting waste, saves time, and also economical. Dynamic scheduling is used to collect solid waste. The bins alert when the garbage bins are filled up. A user-friendly android app is developed which helps in the optimized collection of waste.

Nirde et al. [12] proposed an IoT based wireless solid waste management system for smart cities that helps municipal corporations in continuous monitoring of the waste level of dustbins remotely over a web server. It saves time and optimizes the cost. The corresponding authority gets informed through a message with the help of GSM placed in the dustbin when the dustbin is filled up. After that, the authority sends vehicles to an informed location to collect waste. The main objective of the proposed project is to ensure the enhancement of IoT based applications for collecting and managing waste efficiently to develop a smart city. Poddar et al. [13] proposed an integrated system for the waste management system, where smart garbage bins are embedded with a network of sensors. The system also enables the transmission of real-time data indicating the waste level of the bin. Kumar et al. [14] proposed an IoT based approach for a smart waste management system that helps to monitor the waste level of dustbins using sensors. An android based application is developed to integrate the whole system. It also provides information related to the waste level of bins situated in different locations.

Kumar et al. [15] proposed an IoT based smart alert system for garbage that helps to send an alert signal to the municipal web server based on garbage level in the dustbins for cleaning the dustbins instantly with proper verification. The whole system is supported by a joined module integrated with the facilitation of RFID and IoT. Baby et al. [16] proposed an intelligent waste alert system that alerts corresponding authority to collect waste from the bins which are going to be filled up. It will lead the garbage-trucks to only those areas where the garbage bins are critically filled. Information regarding garbage generation habits for a certain region is gathered using the 'machine-learning' concept. Prediction is made using this information about the amount of garbage that will be generated soon.

Wijaya et al. [17] presented a smart waste bin that will help in waste management to develop a smart city. To measure the garbage level and weight of the waste, sensors are used in the proposed smart waste bin. Pardini et al. [18] proposed a

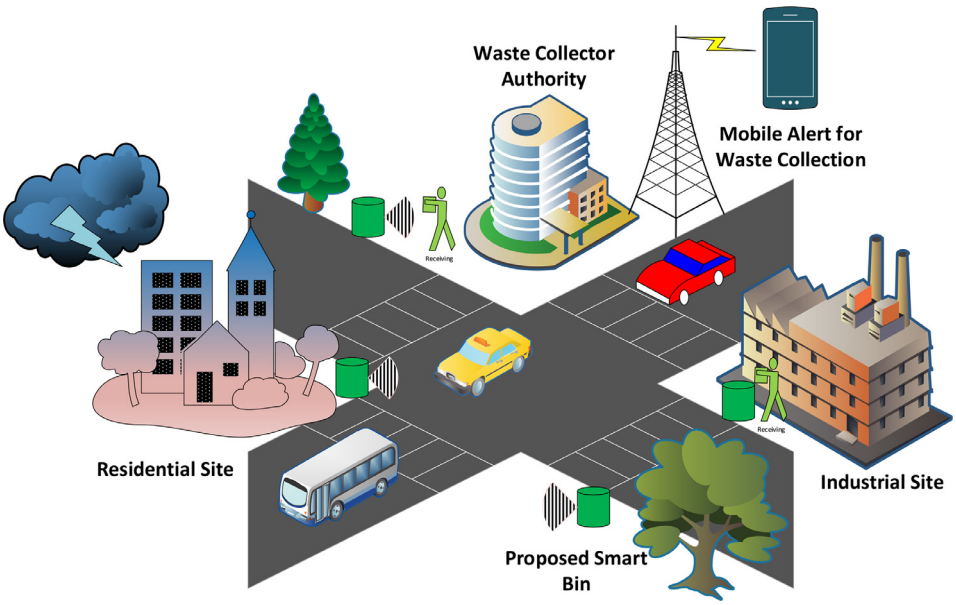


Fig. 3. An illustration of a smart garbage bin solution for proper waste management to ensure sustainable urban life.

smart waste bin for waste management in large urban areas that is an integrated system. The load cell sensors and ultrasonic sensors are used for identification, Global Positioning System (GPS) to determine the location and Global System for Mobile Communications (GSM) / General Packet Radio Service (GPRS) for the communication system. Using IoT based technologies, it suggests an efficient approach to contribute to different aspects of large cities like environmental, social, and economic, etc.

Aazam et al. [19] proposed a cloud-based smart waste management system. In the proposed system, the bins are embedded with sensors, can monitor the status of the bin, and capable of informing the waste level. It also can upload the status of the bin to the cloud. One can easily get the desired data from the cloud. It provides an efficient system with route optimization that helps in saving both fuel and time. Mdukaza et al. performed an analysis of existing IoT based solutions of the waste management system [20]. The analysis shows some major limitations of existing IoT based solutions like short-range capabilities, sensing accuracy varies in different weather conditions and encourage users to unauthorized access. This calls for further improvement in IoT based solutions of the waste management system.

To summarize the above-mentioned research work and the proposed system, a comparison is made in Table 1, which shows the technology used in the research work, the positive impact and limitations of them, and the similarities of the existing works with the proposed system. Almost all the works described above follow the same approach for waste management, focusing only on the collection of waste. The proposed waste management system mainly focuses on citizens as well as waste management authority providing the best possible features. It also ensures a sound green environment by eliminating agglomeration and spillover of waste on public roads.

3. Proposed smart garbage management system

An illustration indicating a complete scenario of the smart waste management system with the proposed smart garbage management system is shown in Fig. 3. The system consists of an identification system, an automated lid system, a display system, and a communication system. All these four systems are synchronized using the Arduino Uno microcontroller and are described below. The components used to implement the proposed garbage management system are shown in Fig. 4.

3.1. Identification system

Ultrasonic sensors are quite good at measuring amplitude, as the reflection of the sound wave does not depend on the object's shape [21]. That is the main reason this sensor is preferred for the identification of personnel as well as waste level measurement. This sensor can measure the distance of an object from 2 cm to 400 cm within the angle of 15° using an ultrasonic sound transmitter and receiver at room temperature. This sensor uses a single transceiver unit that is capable of transmitting and receiving ultrasonic sound. The sonic pulse generated is beyond the human ear listening range, and the sonic sound waves are reflected on the most solid objects. The transceiver determines the total time required to hit an object and to return to the unit using a timer. Two ultrasonic sensors (HC-SR04) are used for the identification process. One

Table 1
Analysis of some existing solutions to the smart waste management system.

Ref.	Different Aspects of Recent Research Works on Smart Garbage Management System			
	Similarities with the proposed research work	Technologies used	Positive impacts	Limitations
[10]	Notifies the authority	Android application, Open Street Map (OSM), Dijkstra algorithm	People can detect nearby dustbin's location, Social work booster	• It is an android based application that may help a little in the proper waste management
[11]	Checks the status of the bin with ultrasonic sensor and sends SMS to the collector	Ultrasonic sensor, GSM, Arduino, GUI for the collector, Genetic algorithm	Collector friendly software with the exact location of the bins	• Not user-friendly, • Practical implementation of the prototype is not mentioned, • Does not provide display and automated lid, • Has buzzer with no practical need
[12]	Monitors the waste level and sends message to the corresponding authority	Ultrasonic sensor, Strain gauges with a resistor (TAL220), PIC microcontroller, RF transmitter and receiver, Arduino, Ethernet shield, LCD, GSM module	Web page based remote monitoring of the dustbins	• Does not provide automated lid, • Does not show about percentage filled up on LCD
[13]	Provides automated lid system for different conditions and also have a display system	Arduino UNO, Ultrasound sensor, Proximity sensor, Temperature sensor, PIR sensor, LCD, Real-time clock, Servo motor, Ethernet shield	Road optimization to save time and fuel	• The automated lid may misbehave in certain conditions, • Provides poor information about how the communication system works
[14]	Checks the waste level of the bin and informs the authority	Cloud-based android application, LCD screen, LED, Ultrasonic sensor, Force sensor, Microcontroller is not mentioned	Allow users to find nearby bin	• Does not provide an automated lid and real-time condition of the bin
[15]	Checks the garbage level of the bin and notifies the authority	Arduino UNO, Ultrasonic sensor, RFID, Wi-Fi	Use an ultrasonic sensor only when it requires, Condition of the bin can be monitored by an app	• Practical implementation of the prototype is not mentioned, • Does not provide display and automated lid
[16]	Checks the waste level of the bin and informs the authority	Ultrasonic sensor, IR sensor, Raspberry Pi, Arduino UNO, Microsoft Azure, Power BI, IFTTT approach, LCD	Improve waste management by prediction	• Nothing is mentioned about the practical implementation of a prototype, • Does not provide display and automated lid
[17]	Checks the garbage level of the bin and reports the condition of the garbage bin periodically	Strain gauge, Ultrasonic sensor, Bluetooth module, GSM module, Mobile application	Web-based monitoring	• Does not provide display and automated lid
[18]	Checks the waste level of the bin and send data to the corresponding authority	Ultrasonic sensor, Weight module, Load cell, Temperature sensor, GSM/ GPRS shield, Arduino MEGA, Photovoltaic solar panel	Management of waste using a renewable power source	• The practical implementation of the prototype is not mentioned, • Does not provide display and automated lid
[19]	It can determine the waste level status	Only sensor and router is mentioned	Road optimization to save time and fuel of the vehicle	• The practical implementation of the prototype is not mentioned, • Does not provide display and automated lid

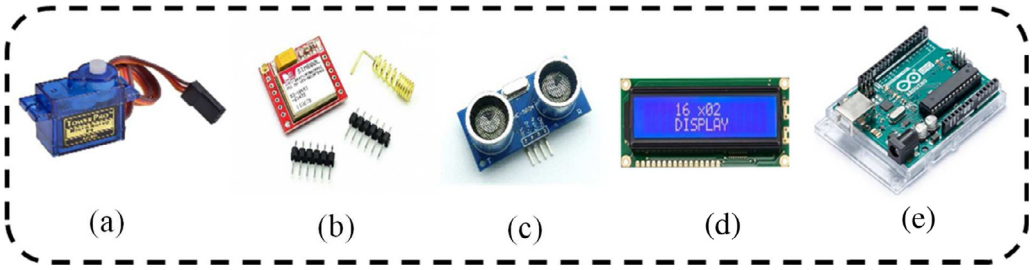


Fig. 4. Main utilized components in the proposed system (a) Servo motor, (b) GSM module, (c) ultrasonic sensor, (d) LCD, and (e) Arduino Uno.

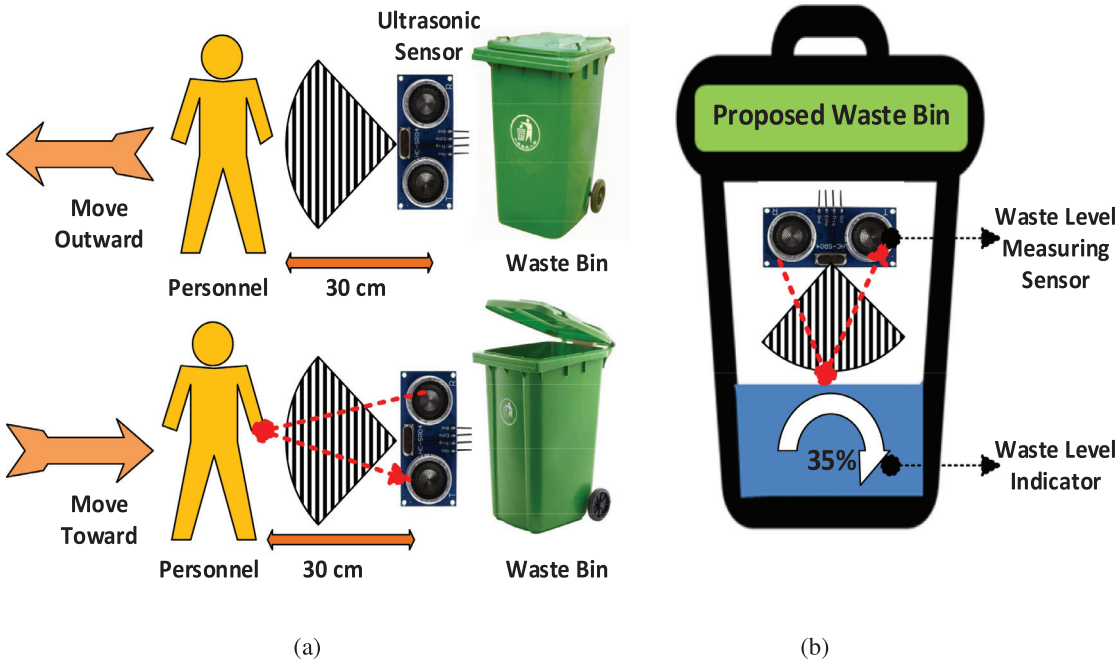


Fig. 5. (a) Ultrasonic sensor used for the identification of personnel in front of the smart garbage bin. (b) The ultrasonic sensor used for measuring the waste level inside the smart garbage bin.

ultrasonic sensor placed on the front side of the garbage bin helps to detect personnel within a certain range as shown in Fig. 5 (a). The other one placed inside the bin helps to determine the waste level of the smart bin as shown in Fig. 5 (b).

3.2. Automated lid system

Servo-motor provides an automated system for the lid of the garbage bin. It is a rotary or linear actuator that can maintain an angular or linear position perfectly. It ranges up to 90 degrees in each direction (clockwise and anti-clockwise) [22]. Servo motor (SG90) is placed in such a way so that it can make the lid of garbage bin automated. If there are any personnel detected within the range, the lid will open automatically and will remain open till the personnel is within the detection range. If the garbage bin is filled up, the lid will not open though there is personnel detected within the detection range.

3.3. Display system

LCD (16×2) is used as a display system. It is an output module which can print 32 characters at once. There is an ultrasonic sensor set up inside the bin that monitors the garbage level inside the bin continuously, and the percentage filled up is displayed on LCD.

3.4. Micro-controller system

Arduino board is used for the automation of the whole system. Arduino board provides a simple prototype of a microcontroller [23]. It controls the whole system, the interactions, and the synchronization of the sensors. It reduces energy loss

through sensors and servo motor by allowing voltage to flow through them only when they need it. It also controls the GSM module used for the communication system. Arduino board consists of 8 bit Atmel AVR microcontrollers with complementary components including 16 MHz crystal oscillator that may be variants with a ceramic resonator and 5V linear regulator to facilitate programming and incorporation into other circuits [24]. A program is installed in the Arduino board to control the whole system in an automated way.

3.5. Communication system

GSM SIM800L module is used for the communication system. All the information related to the garbage level of the garbage bin is transmitted using this GSM module. This chip allows us to build a 2G network for a device or computing system [25]. The phone calls and text messaging can be done using a GSM sim. If the garbage bin is filled up, the garbage bin will send a message to the corresponding authority to collect the waste.

GSM SIM800L is a quad-band module that works on frequencies GSM 850 MHz, EGSM 900 MHz, DCS 1800 MHz, and PCS 1900 MHz with features GPRS multi-slot class 12 / class 10(optional) [25]. It supports the GPRS Coding Schemes CS-1, CS-2, CS-3, and CS-4, providing different levels of error detection and correction based on the requirements for the data being sent and the radio frequency signal conditions. It has 88 LGA pads, an IP architecture, and provides all the hardware to interface between customers' boards and the module. Based on the data need to be transmitted, and many other factors, GSM/GPRS technology was taken into consideration. Besides the license, the cost is low for the 2G network, and there is no need for investments with infrastructure.

4. Methodology

An integrated Arduino program is developed to synchronize the identification system, automated lid system, microcontroller, display system, and communication system. An ultrasonic sensor is attached to the front side of the garbage bin. The transmitter of the ultrasonic sensor emits an ultrasonic sound that is beyond the human ear listening range, and the receiver receives the reflected sound waves by the solid objects. Therefore, if there are any personnel detected within a certain range, the lid will open automatically with the help of a servo motor set up in the upper portion of the garbage bin. A 30 cm range was set up for the proposed identification system. After the lid being opened, one can put garbage inside the garbage bin, and the lid will remain open until the personnel is within the detection range. Finally, if the personnel leave the detection range, the lid will close automatically. A +5 V power supply is used to power the system. The electrical connection between all the components used to develop the proposed system is shown in Fig. 6. A closed bin is presented here to avoid interference with the external factors like animals and unusual weather conditions that can cause littering of waste. The garbage level inside the garbage bin is continuously monitored by an ultrasonic sensor set up inside the garbage bin. The ultrasonic sensor transmits ultrasonic sound, and the sound waves get reflected by the waste inside the garbage bin. There is a time gap between transmitting ultrasonic sound and receiving the reflected sound waves. With the help of this time gap, the percentage filled up inside the garbage bin is calculated. The calculated numeric data is displayed with the help of the LCD placed in front of the garbage bin.

The calculation for the conversion of distance to percentage filled up used for the proposed system is given below,

$$\text{Distance, } D = [(V * t)/2] \tag{1}$$

Where t is the ping time from the sensor, and V is the velocity of the sound.

$$\text{Percentage filled up} = [100 - (100/H) * D] \tag{2}$$

Where H is the height of the garbage bin and D is the converted distance.

After the garbage bin is filled up, the display will show 100% filled up. This will disable the automated lid system. If there are personnel detected within the detection range, the lid will not open, and a message will be sent to the corresponding authority through GSM to collect the garbage. After the corresponding authority collects the garbage, the garbage bin will be reusable, and the automated lid system will be enabled again. For lucid understanding, a flow-chart illustrating the working of the proposed system is delineated in Fig. 7.

5. Software framework development

An Arduino language-based software is developed for the proposed smart garbage management system. An Arduino IDE is required to run the software. The software is compatible with Linux, OS X, Microsoft Windows platform, and licensed under Apache License 2.0 (details are given in Appendix A1 and A2). The framework of the developed software code is divided into five parts, as shown in Fig. 8. They are (i) to implement code for the outside ultrasonic sensor so that it can identify personnel within a certain range, (ii) to operate the servo motor for certain conditions to open the lid, (iii) for operating the inner ultrasonic sensor to measure the garbage level, (iv) to display the percentage filled up on LCD, and (v) to send SMS through GSM when the garbage bin is filled up. Therefore, the mains function of the developed software is to properly manage the waste collection and disposal efficiently. The proposal of smart waste management is believed to be an effective solution to keep the urban residence safe from infectious diseases and also keep the environment clean and

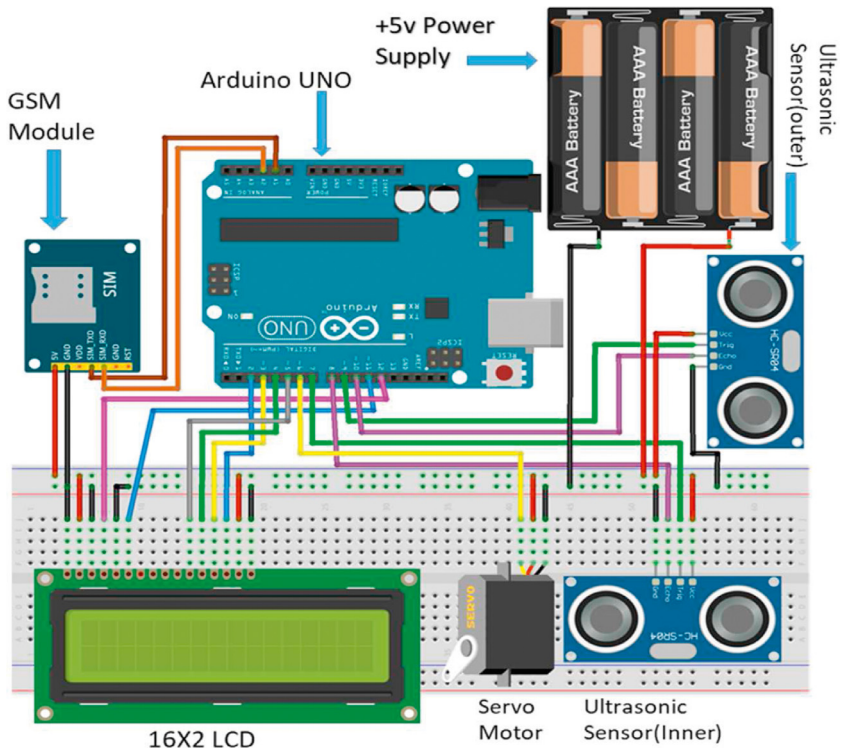


Fig. 6. Electrical connection diagram for the whole automated system of smart garbage bin.

free from unwanted odor. The algorithm used for the proposed smart waste management system is presented in Algorithm 1, indicating each part of the developed software. Any developer can follow the steps to reproduce and enhance the code for further development. The code is also uploaded in Github and can be downloaded and cited through the link "https://github.com/mdbshuvo/Smart-Waste-Management-System".

Algorithm 1: For the automation utilized in the proposed smart waste management system

1	//Check if there is any person in front of the bin and check the garbage level inside the bin.	Algorithm instruction for the outside ultrasonic sensor
2	Begin	
3	//Calculation of distance of personnel & waste level	
4	t=pulseIn(echo, HIGH); //t= total time required to transmit and receive signal	
5	dis=(int)(t*(0.034/2));	
6	End	
7	Begin	Algorithm instruction for the inner ultrasonic sensor
8	float per=(100-(100/24)*id); // Calculate the garbage level in percentage(id means inner distance in cm and height of prototype is 24 cm)	
9	lcd.clear();	Algorithm instruction for presenting waste level in LCD
10	if(per>100) per=100;	
11	lcd.print(per);	
12	lcd.print(" %");	
13	lcd.setCursor(0,1);	
14	lcd.print("filled up");	
15	Then	Algorithm instruction for servo motor operation
16	timer = 0 & state = 0;	
17	If (od<30) //od means outer distance in cm	
18	If(state_motor != 0) //if lid is closed	
19	Then myservo.write(0);//open the lid	

(*continued on next page*)

```
20      state_motor = 0;
21      End If
22      End If
23      Else If (state_motor != 1) //if od>30 and the lid is open
24      Then
25      myservo.write(180);// close the lid
26      state_motor = 1;
27      End If
28      End
29      Else If (state_motor != 1) //when per =100
30      Then
31      myservo.write(180);// close the lid
32      state_motor = 1;
33      If (timer < 3)                          Algorithm instruction for sensing message to the
34      Then                                    corresponding authority
35      timer++;//this one for sending message
36      else
37      timer = 0;
38      If (state == 0)// send message only when state=0
39      Then
40      SendMessage();
41      state=1;// avoid sending message again & again
42      End If
43      End If
44      End
```

6. Performance test and result

A prototype of a smart garbage bin is developed practically for the smart garbage management system. The smart bin consists of an identification system, an automated lid system, a display system, and also can communicate with the waste management authority. A program is installed in the Arduino board and used as a microcontroller to control the whole system in an automated way. The complete structure of the bin and its working procedure is already mentioned in this paper. Different components mentioned in the paper to develop the prototype is shown in Fig. 9. Fig. 9 (a) presents the pictorial view of the proposed system, and Fig. 9 (b) shows the ultrasonic sensor used for the identification of personnel in front of the garbage bin.

Finally, the prototype was checked for different conditions to observe whether it works perfectly or not. The status of different incidents is mentioned in Table 2, where there is always personnel within the detection range of the smart bin. Fig. 10 shows the percentage filled up showed on LCD for these practical observations.

From the above Table 2, it is clear that when the bin is 100% filled up, the automated lid did not work. Which means it will reduce the problem of overflowing of garbage in the garbage bin. This overflowing of waste badly pollutes our environment, as there is no lid in our conventional garbage bin. One of the main demerits of the conventional waste management system is its inefficiency. The corresponding authority collects waste in the morning of each day and goes to every garbage bin to collect waste. It is a major limitation of the traditional system as the amount of waste for every place is not the same. There are such places where garbage bin needs to be cleaned twice or thrice a day to remove the problem of overflowing of garbage. There are places where a garbage bin needs two or more days to be 100% filled up. For this reason, the conventional waste management system is a complete waste of workforce and time. On the other hand, the proposed

Table 2
Practical observation for different conditions of smart garbage bin.

Incident no.	Amount of garbage inside the bin	Identification system	Automated lid system	Measuring and display system	Communication system
1	A very small amount of garbage	Successful	Operate	5%	-
2	A small amount of garbage	Successful	Operate	15%	-
3	Amount of garbage is increased	Successful	Operate	35%	-
4	Amount of garbage is increased further	Successful	Operate	65%	-
5	Garbage level is increased more than the previous one	Successful	Operate	85%	-
6	Bin is filled up with garbage	Successful	Did not operate	100%	Successful

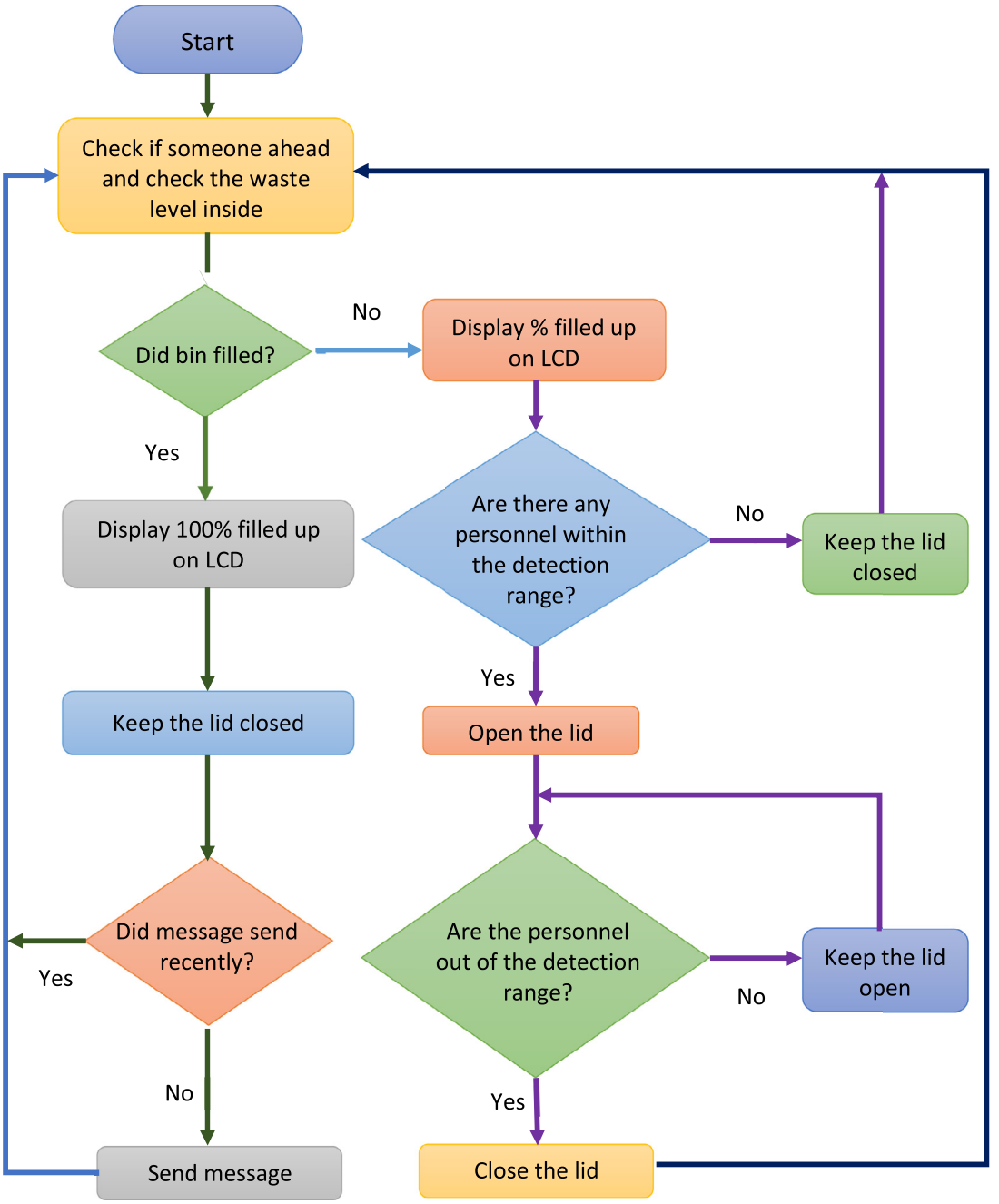


Fig. 7. Flow chart for the automated system of smart garbage bin.

waste management system is capable of overcoming this kind of problem. In the above Table 2, incident 6 indicates that the bin is 100% filled up. When the bin is 100% filled up, it will send a message with the location of the garbage bin to the corresponding authority to collect waste.

Fig. 11 (a) shows the ultrasonic sensor used for the measurement of waste level inside the garbage bin. Fig. 11 (b) shows that when the garbage bin is 100% filled up, automatically, a message will be sent to corresponding authority with location to collect waste. That means the authority does not need to go everywhere each day to collect waste, which will reduce the use of manpower in vain, and it will also save time and fuel for vehicles. From the above discussion, it can be concluded that the proposed waste management system is much more efficient than the conventional waste management system.

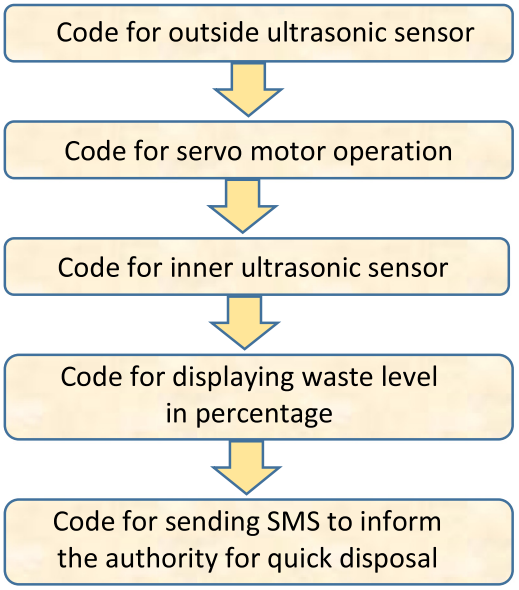
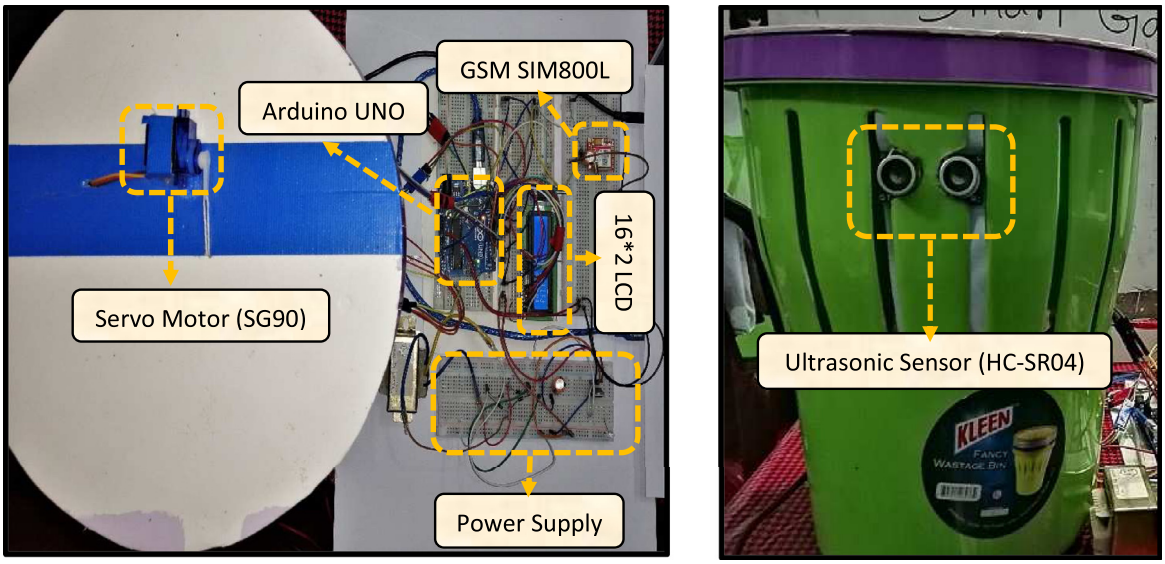


Fig. 8. Framework of the developed software for the proposed smart garbage management system.

7. Economic feasibility assessment

Another purpose of this project is to make the proposed waste management system as cheap as possible. A cost in BDT is presented in the following Table 3 needs for the construction of the proposed smart bin.

Therefore, a total of $15.51 (BDT 1304) is required for the construction of the proposed prototype of the smart bin, which is a very low cost. The cost of the power supply is not included in the above Table 3 because integrated chips for power supply and microcontrollers are available in the market for a very low price. Therefore, the mass production of this smart bin will make it's cost reasonable. The proposed garbage management system also avoids unnecessary use of manpower



(a) (b)

Fig. 9. (a) Different components used for the practical implementation of the proposed smart garbage bin. (b) Front view of the developed prototype of the proposed smart garbage bin.

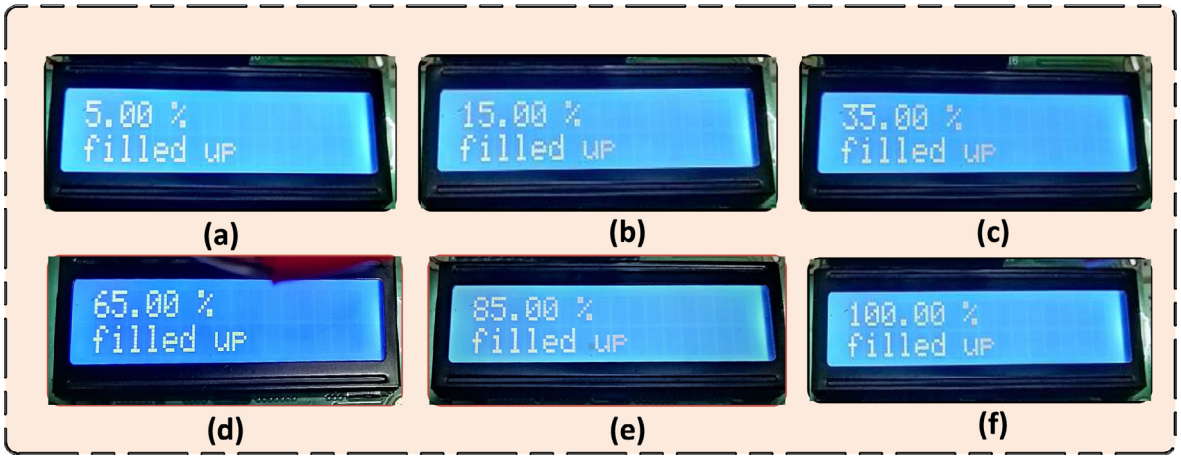
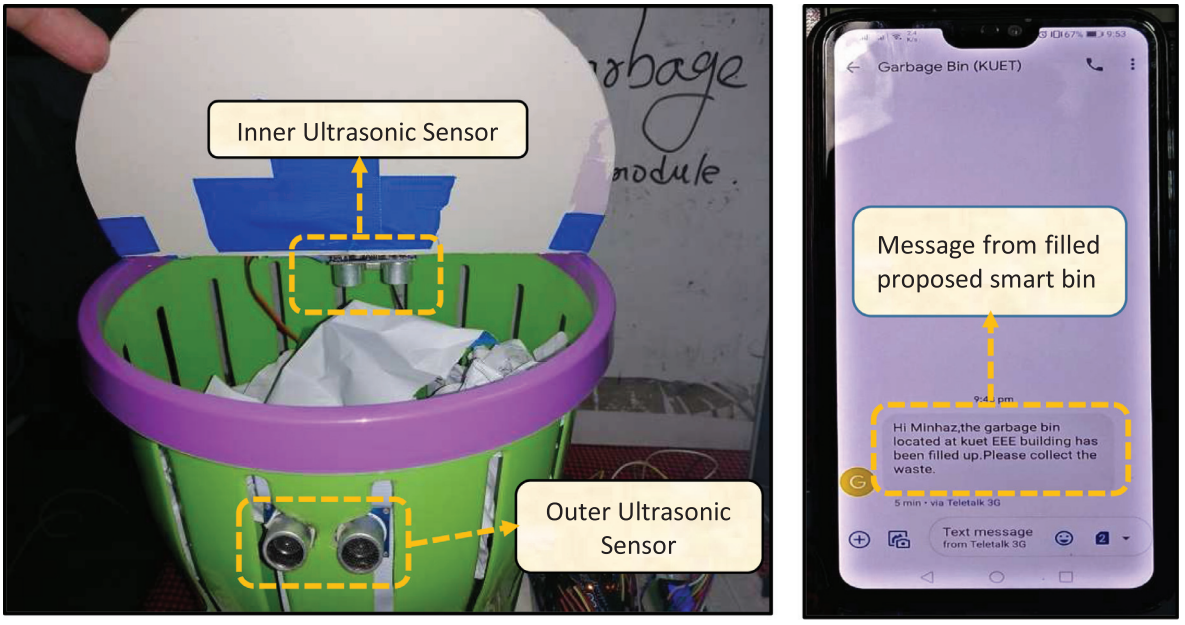


Fig. 10. Percentage filled up showed on LCD for the different waste levels (a) 5%, (b) 15%, (c) 35%, (d) 65%, (e) 85%, and (f) 100% of the smart garbage bin.



(a) (b)

Fig. 11. (a) Inner view of the practically developed prototype of the proposed smart garbage bin. (b) The message is sent to corresponding authority when the garbage bin is 100% filled up

Table 3
Price for different components used for the implementation of the prototype.

Product Name	Unit Price(BDT)	Quantity	Subtotal(BDT)
Arduino UNO R3(China)	450.00	1	450 .00
GSM SIM800L	399.00	1	399.00
Ultrasonic Sensor(HC-SR04)	80.00	2	160.00
Servo Motor(SG90)	175.00	1	175.00
16×2 LCD	120.00	1	120.00
Total = 1304.00			

(a) (b)

Fig. 12. (a) Different bins are used for the collection of waste in South Korea (collected from [30]). (b) Collection of waste in Shangai(China) using MSW classification policy (collected from [29]).

and vehicles. It can be concluded that the proposed waste management system will cost less money than traditional waste management systems.

8. Integration ability to existing waste management plan

The proposed smart waste management system is mainly developed to make the Dhaka city a better place to live in; however, it can be integrated with other cities' waste management plans. As the existing garbage management technique of Dhaka city is not automated or software-based, the government can apply the proposed garbage management system. Gradually and progressively, the government can take necessary steps to improve the system. By introducing the proposed garbage management system, the government can take the first step to make Dhaka a better place to live.

South Korea has been using an organized garbage management system called Jongnyangie [26]. It is an embodied waste management system for the effective collection of waste in South Korea [27]. Wastes are collected differently as food waste, general waste, recyclable items, or bulky items [28]. Different waste bins are used for different types of waste. The schedule is strictly followed to ensure proper waste management. Fig. 12 (a) shows a pictorial view of the waste collection procedure.

Effective results are found on Shanghai's (China) new Municipal Solid Waste (MSW) classification policy and its implementation. The Shanghai MSW management regulation was published in 2019. They have found the MSW classification system is an effective way to solve the waste management system. MSW classification policy divides the wastes into four types. They are recyclable, hazardous, wet, and dry waste. All four types of wastes are collected separately in different waste bins [29]. Fig. 12 (b) shows a pictorial view of waste collection using the MSW classification policy.

With rapid urbanization, India is facing a massive waste management challenge. Over 377 million urban people live in 7935 towns and cities. They produce 62 million tons of municipal solid waste per annum [31]. The government of India is working hard to solve their waste management problem. Ministry of Environment and Forests has introduced some waste management rules. Wastes are separated into domestic hazardous, wet, and dry type garbage. No person should throw, burn, or bury waste [32]. The concept of partnership in Swachh Bharat has been introduced. Many other rules are introduced to ensure proper waste management [33,34].

Countries like South Korea and China have already developed an environment-friendly waste management technique. Their waste management approach has shown some effective results. Many other countries are trying to follow their waste management procedure. As an example, India is trying hard to solve its waste management problem by following them. But it is quite difficult for countries like India or Bangladesh where the cities are overpopulated. India's biggest shortcoming is its poor waste management infrastructure. Countries like India or Bangladesh should emphasize collecting waste properly. On the other hand, countries like South Korea or China still uses traditional waste bin. These traditional waste bin can be replaced by the proposed smart garbage bin. Municipal governments can develop a system to monitor these smart waste bins according to their requirements. Nowadays, everything is becoming technology-based. Therefore, by using IoT based waste management, the efficiency of the existing waste management can be increased many times.

9. Conclusion

Population explosion, increasing industrialization, and rapid urbanization have to lead the world's environment into complete chaos. Due to the increased level of waste generation, gradually, it's getting difficult to survive in the densely populated urban area. Traditional waste management systems are a complete failure to handle such a large amount of garbage. The application of technology and its sophisticated service in every sector have made our life quite easy. It is high time to apply a technology-based approach to handle this increasing level of waste. A lot of research is going on regarding the proper waste management system. In this paper, we have proposed an IoT based integrated waste management system, which is a

completely automated system capable of sharing information. The proposed system provides an identification system that helps to identify personnel in front of the bin. It also helps to control the automated lid for certain conditions. An ultrasonic sensor placed inside the bin helps in the continuous monitoring of the garbage level, and the value is shown on the LCD placed in front of the bin. When the garbage bin is filled up GSM module helps to inform the corresponding authority to collect the garbage. An Arduino board is used to control the whole automated system. That is how the proposed system provides efficient management of waste, eliminating spillover of waste, and avoiding the spread of diseases. The success of the proposed waste management system lies in the welfare of human beings as it helps to ensure a worthy urban life.

Declaration of Competing Interest

None.

Appendix A1. Current executable software version

A2 Current code version

Table A.1
– Software metadata.

Nr	(executable) Software metadata description	Please fill in this column
S1	Current software version	1.1
S2	Permanent link to executables of this version	Not Applicable
S3	Legal Software License	Apache License 2.0
S4	Computing platform / Operating System	Linux, OS X, Microsoft Windows
S5	Installation requirements & dependencies	Arduino IDE
S6	If available link to user manual - if formally published include a reference to the publication in the reference list	None
S6	Support email for questions	sohag1603089@stud.kuet.ac.bd

Table A.2
– Code metadata.

Nr	Code metadata description	Please fill in this column
C1	Current Code version	1
C2	Permanent link to code/repository used of this code version	https://github.com/mdbshuvo/Smart-Waste-Management-System
C3	Legal Code License	Apache License 2.0
C4	Code Versioning system used	none
C5	Software Code Language used	Arduino Language
C6	Compilation requirements, Operating environments & dependencies	Arduino executable, Linux, OS X, Microsoft Windows
C7	If available link to developer documentation/manual	None
C8	Support email for questions	sohag1603089@stud.kuet.ac.bd

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