Indonesian Journal of Electrical Engineering and Computer Science
Vol. 21, No. 1, January 2021, pp. 450~456
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v21.i1.pp450-456

A review of IoT-based smart waste level monitoring system for smart cities

A.A.I. Shah[1], S.S.M. Fauzi[2], R.A.J.M. Gining[3], T.R.Razak[4], M.N.F.Jamaluddin[5], R. Maskat[6]
[1,2,3,4,5]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perlis, Malaysia
[6]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Selangor, Malaysia

Article Info

Article history:

Received Apr 9, 2020
Revised Jul 8, 2020
Accepted Jul 26, 2020

Keywords:

Internet of things
IoT
Smart city
Smart waste monitoring system
Waste management

ABSTRACT

Smart cities are covering the population that are seeking the best lifestyle and fulfilling their needs. Through smart cities, necessary modern facilities using ICT emerging technologies such as the internet of things (IoT) had been installed to ensure the sustainability of the city. In the perspective of waste management, several different IoT-based solutions also had been proposed as an alternative to monitor and to ensure the health of communities. This paper reviews existing IoT-based solutions in smart cites' waste level management system to bring together the state-of-the-art. We performed reviews on 16 research articles from the past 5 years in the literature to provide a comprehensive review of different works on IoT-based solutions related to the smart waste level monitoring system, possible solutions and technologies used. The results obtained shows that existing solutions were similar in the platform used to integrate with the IoT technologies but had some differences in term of the used of sensors and communication technologies. The study also shows that many of the prior studies used Arduino Uno. Results from this study will assist the researcher, focusing on expanding further the used of different technologies or improved the existing system.

Corresponding Author:

S.S.M. Fauzi
Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA
Perlis Branch, 02600, Arau, Perlis, Malaysia
Email: shukorsanim@uitm.edu.my

1. INTRODUCTION

A smart city is a concept that has been widely used to make cities more efficient in describing new trends and goals [1-5]. These goals are different, and it depends on areas such as making greener cities by improving people's quality of life or saving energy [6]. Regardless of the application area or goals, one of the keys to this development is digital data and ICT infrastructure. With regard to the topic of this study, IoT-based tools are highlighted in order to play an essential role in supporting the effectiveness and sustainability of the city.

IoT is the extension to physical devices such as sensor and everyday objects through internet connectivity which these devices can communicate and interact with others over the internet [7-9]. They can be monitored and controlled remotely [10-14]. These data collected by devices can be sent to remote servers where it is stored, processed and used for tracking, monitoring, and ultimately making intelligent infrastructure or service management decisions [15-21].

In this regard, waste management is one of the core concerns in the smart city [22-25]. As nations around the world are developing, their concerns and accountability for a healthier and sustainable

environment are also increasing [26-28]. While developed countries are inventing and implementing smart solutions for waste management and bringing about substantial positive impacts, waste management seems to be a play out of the league for the underdeveloped or developing countries [29-32]. The overload of waste container is leading to an unhealthy and inhabitable environment that costs the government a tremendous amount of money with not at all positive impact [33, 34]. Therefore, wastes need to be packed, dumped, collected, transported, manipulated and appropriately recycled in such ways that waste becomes a precious wealth of the country. Those issues have become the major causes of building innovative systems.

Therefore, the main intention of this study includes, firstly, to synthesize and brings together the state-of-the-art of the different IoT-based solutions related to the smart waste level monitoring system, possible solutions and technologies used with a focus on the technique, the main sensor used, communication technologies and microcontroller in the design and implementation of IoT-based smart waste level monitoring system for smart cities. We performed an extensive review of existing research articles in the literature from the past five years. Secondly, by considering the findings in (1), this study intends to propose an IoT-based smart waste level monitoring system for smart cities. The next section outlines the methodology. Next, the results of the study are discussed in Section 3. The proposed architecture is explained in Section 4. Section 5 describes the discussion of the study. The final section concludes the study.

2. METHODOLOGY

This study employs a necessary systematic mapping study (SMS) steps [35]. An SMS is intended to encompass an exhaustive search. It aims to provide a thorough and repeatable analysis of all relevant literature. The five main steps in the method are: definition of research questions, searching for relevant papers, screening papers, keywording of abstracts, and data extraction and mapping.

2.1. Definition of research questions

With the objective of developing an understanding of the state-of-the-art research in IoT-based smart waste level monitoring system in smart cities, the following research questions drive this study:
RQ1: What IoT-based smart waste level monitoring system exists in the literature?
RQ2: What platform used to integrate with the IoT technologies
RQ3: What technologies proposed by the existing literature?

2.2. Searching for research papers

We performed an extensive search of the following electronic databases by using the keywords such as the internet of things, smart waste level monitoring system, and smart city. The keywords were combined using Boolean ***AND*** expression and ***OR*** expression. The databases searched were:

a) IEEE Xplore (http://ieeexplore.ieee.org)
b) ACM Digital Library (http://www.portal.acm.org/dl.cfm)
c) Elsevier ScienceDirect (http://www.sciencedirect.com)
d) Google Scholar (http://scholar.google.com)

2.3. Screening papers

The papers were examined based on the relevance to the research questions. First, we analysed the title, abstracts and keywords. The papers were classified into two categories based on the following inclusion (*I*) and exclusion (*E*) criteria:
I1: Paper should directly relate to IoT-based smart waste level monitoring system and smart cities
E1: Posters, panels, abstracts, presentations and article summaries

3. RESULTS

3.1. Overview of the study

The study reviewed 16 papers on the topic of IoT-based smart waste level monitoring system for smart cities. Table 1 shows the list of the reviewed papers (by year, source and number of citations). From Table 1, it suggests that studies on IoT-based smart waste management system for smart cities were very conducted in 2017 (44%) and 2016 (31%). Table 2 illustrates the list of papers by type of publication. Results from Table 2 suggests that 61% of the study related to IoT-based smart waste level monitoring system was published in a wide range of journals, whereas 31% was published in the conference proceedings.

Table 1. List of reviewed papers (by year and source)

Paper ID	Year	References	Source	Number of citations
P1	2017	[36]	International Journal of Advanced Engineering Research and Science	10
P2	2018	[37]	International Journal of Engineering & Technology	6
P3	2017	[38]	International Conference on Intelligent Computing and Control Systems	18
P4	2017	[39]	IOP Conference Series: Materials Science and Engineering	9
P5	2018	[40]	International Journal of Civil Engineering and Technology	7
P6	2017	[41]	MATEC Web of Conferences	10
P7	2016	[42]	IEEE Region 10 Annual International Conference	83
P8	2016	[43]	International Journal of Pharmacy and Technology	NA
P9	2019	[44]	International Journal of Innovative Technology and Exploring Engineering	NA
P10	2017	[45]	Proceedings of the 50th Hawaii International Conference on System Sciences	NA
P11	2017	[1]	International Journal of Trend in Scientific Research and Development	NA
P12	2016	[46]	IEEE International Conference on Emerging Technologies and Factory Automation	NA
P13	2016	[47]	International Journal of Advanced Research in Electronics and Communication Engineering	NA
P14	2017	[48]	International Journal of Innovative Research in Electrical, Electronics, Instrumention and Control Engineering	NA
P15	2016	[49]	International Journal of Computer Applications	NA
P16	2019	[50]	International Journal of Civil Engineering and Technology	NA

Table 2. List of reviewed papers (by type of publication)

Type of Publication	Percentage	Paper ID
Journal	69%	P1; P2; P3; P5; P8; P9; P11; P13; P14; P15; P16
Proceeding	31%	P4; P6; P7; P10; P12

3.2. What IoT-based smart waste level monitoring system exists in the literature?

Table 3 illustrates the focus of the paper reviewed. Based on previous studies, it is found that the most commonly used approach to address the problem is to prevent from the overloaded waste container. In order to achieve this, the container are designed to be equipped with waste level detection and this is done by implementing ultrasonic sensor [1, 39-51]. This shows that there is a consensus between researchers that the ultrasonic sensor is the most suitable sensor to achieve the level of waste in the container. However, some researchers have proposed a new approach to address the issue. The addition is to equip the waste container with a load cell which can measure the weight of the container [36-38] PIR sensor to detect a motion of object and humidity sensor to measure moisture and air temperature.

Table 3. Focus of the study

Paper ID	The focus of the study
P1	Real-time monitoring of the level of garbage in garbage bins and optimized route for garbage collecting vans
P2	Provide an efficient and cost-effective waste collection management
P3	Monitor status of dust bins remotely over the webserver
P4	Notify the corporations to empty the bin on time when garbage reach max level
P5	Monitor the amount of waste filling in it by sending information about filing status
P6	Measuring the garbage level by type of garbage in real-time
P7	Giving the municipal web server an alert signal for instant dustbin cleaning with proper verification based on the level of garbage filling
P8	The level of garbage in the dustbins is detected with the help of sensor systems, and communicated to the authorized control room through the GSM system
P9	Monitoring waste management
P10	Improve on waste monitoring and collection in public trash bins
P11	Makes a normal dustbin smart using ultrasonic sensors for garbage level detection, display and sending a message to the concern department person updating the status of the bin using GSM modem
P12	Accurate fill-level estimation with a tiny data-load fingerprint, regarding the specific use case on waste-bins
P13	To avoid garbage are overloaded and prevent from creates unhygienic environment
P14	Monitor the garbage bins and provide information on the level of garbage collected in the garbage bins via a web page
P15	It can alert the municipality to collect the waste in a bin on time and help clean up the environment
P16	monitor fill level of solid waste in each of the containers using ultrasonic sensors

3.3. What platform used to integrate with the IoT technologies

Moreover, the analysis performed shows that there are two different solutions to the waste level monitoring system using IoT. For instance, 75% of the study developed a waste level monitoring system using IoT devices which operates by sensing the level of waste in the container and send notification or alerts to the appropriate authorities when the bin is full through the web application. The communication of this information was achieved using SMS text messages. The rest of the papers or 19% of it have proposed an approach to monitor the container through a mobile application. This may suggest that the mobile application is not compatible with this waste management field. 6% of the study used both web and mobile application as a platform. Platform used to integrate with IoT as shown in Table 4.

Table 4. Platform used to integrate with IoT

Paper ID	Integrated platform used
P1, P3, P5, P6, P8, P9, P10, P12 – P16	Web application
P2	Web and mobile application
P4, P7, P11	Mobile application

3.4. What technologies proposed by the existing literature?

Table 5 illustrates the comparison of the paper reviewed, in particular, the tools or component used to send container status to the receiver side is short-ranged and required installation tools that make them not to be practical in a city application. Most of the papers do not have location tool that alerts the receiver of the location of the overloaded container [1, 36-40]. Only a few papers have done a location provided which through Wi-Fi or GSM module [1, 36, 42-44]. Moreover, it identified the relevance of choosing appropriate technology when designing IoT-enabled waste collection. That is, technology has fewer limitations and can work excellently in many or different scenarios. Thus, the communication tools used from the bin to the receiver side is of importance when implementing such a solution. The technology should have extensive coverage. The location tool used to send the container status should be able to state the location and unique ID of the container so that it can differentiate between those containers [37].

Table 5. Sensors used in the study

Paper ID	Main Sensor		Location Functionality
	Ultra sensor	Others	No
P1	X	Load cell, Humidity Sensor	Yes
P2	X	Load cell, Humidity Sensor	No
P3	X	Load cell	No
P4	X	-	No
P5	X	-	No
P6	X	-	No
P7	X	Radiofrequency identification (RFID)	Yes
P8	-	Infrared Sensor	Yes
P9	X	-	Yes
P10	X	-	No
P11	X	Liquid Crystal Display	Yes
P12	X	-	No
P13	X	-	No
P14	X	-	No
P15	X	-	No
P16	X	-	No

Based on the paper reviewed, much prior literature proposed a prototype that is using Arduino as the microcontroller to operate their system software. Some of them are using Raspberry pi-3 [36, 46], other than that are using a different microcontroller such as PIC16F877A [38], mbed LPC1768 [41], Long Rage Wide Area Network (LoRaWAN) [45] and ARM LPC2148 controller & IR wireless [47]. Results in Table 6 also suggests some of the paper reviewed need an external communication technology which allows to retrieved and transmitted data thought internet connection. Therefore, without communication technology, the prototype cannot receive or transmit any data or information. This will be one of the disadvantages when using a microcontroller that did not provide any communication with the internet. Besides, their basic microcontroller.

Table 6. Communication technologies and microcontroller used

Paper ID	Communication technologies	Microcontroller
P1	ESP8266 (Wi-Fi)	Raspberry pi-3
P2	ESP8266 (Wi-Fi)	Arduino Mega
P3	RF transmitter	PIC16F877A
P4	ESP8266 (Wi-Fi)	Arduino Uno
P5	GSM modem	Arduino Uno
P6	ESP8266 (Wi-Fi)	mbed LPC1768
P7	GRPS, ESP8266 (Wi-Fi)	Arduino Uno R3
P8	GSM modem	Arduino Uno R3
P9	Wifi module, GPS	Arduino Uno
P10	GSM module	Long Rage Wide Area Network (LoRaWAN)
P11	GSM modem	Arduino Mega 2560
P12	RFID	Raspberry Pi
P13	Wifi module	ARM LPC2148 controller and IR wireless
P14	RFID	Arduino Uno
P15	Zigbee, GSM	Arduino Uno
P16	ESP8266 (Wi-Fi)	Arduino Uno

4. DISCUSSION

Therefore, based on the results obtained from the paper reviewed, improvement and innovation must be geared to the management of waste in our cities to ensure a healthy environment and prevent from diseases and infections. In order to achieve that, integrating different sensors and making them communicate with each other is vital; this is due to the container must be able to automate detect in their essential operation. Besides their basic operation, the waste container needs to be able to send the location to identify the container from which the location is located. Additionally, to enhance the efficiency of a smart waste level monitoring system, a monitoring system should be made available as well so that it can benefit analysts greatly as they will have the amount of data available to be analysed that will lead to better decision making in the future.

5. PROPOSED ARCHITECTURE OF IoT-BASED SMART WASTE LEVEL MONITORING SYSTEM

In order to address the problems caused by overload waste in a container, this study is proposing an improvement to the current IoT-based Smart Waste Level Monitoring System with the used of IoT and cloud computing technologies. Waste containers are strategically situated within the communities, and the fill level of waste in each of the containers is detected using ultrasonic sensors. The sensor data is transmitted to an IoT cloud platform, via a Wireless Fidelity (Wi-Fi) communication link. At different fill levels, the system is designed to different graphic to represent the current waste level in the system using different colour and to alert relevant authorities in real-time for necessary action. Figure 1 illustrates the proposed architecture of the system.

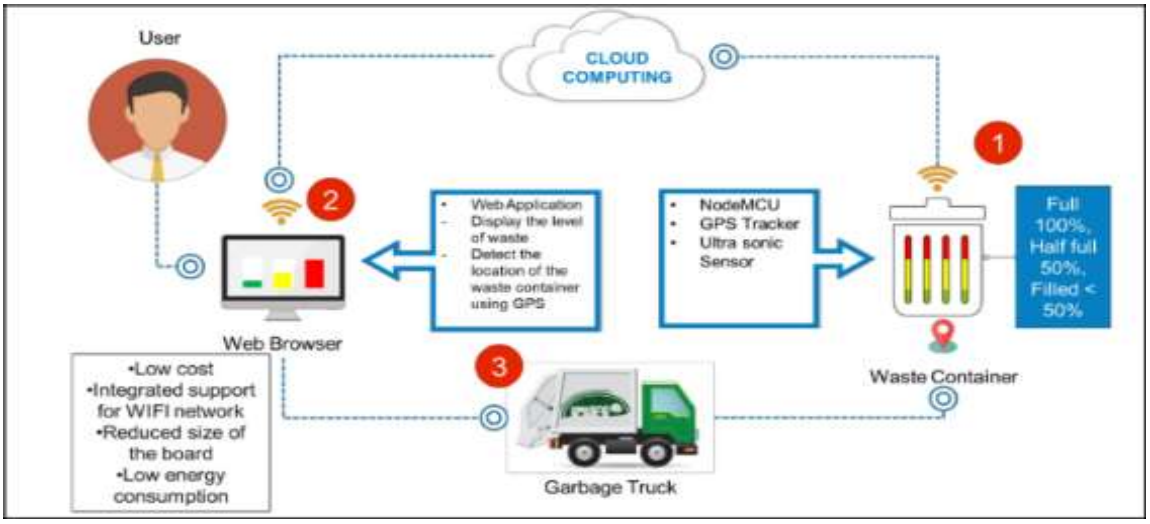

Figure 1. System architecture of the proposed system

6. CONCLUSION

This study contributes to research on smart waste level monitoring system by synthesising the literature on the current state-of-the-art. This study is crucial as it provides a clear overview of the state-of-the-art of the development and implementation of the smart waste level monitoring system. An in-depth review suggests that the existing solutions were similar in the platform used to integrate with the IoT technologies but have some differences in term of the used of sensors and communication technologies. The study also shows that many of the prior studies used Arduino Uno. In future research, we intend to identify the requirement of the proposed system.

REFERENCES

[1] Rao, P. R., Kumar, S. S., & Prasad, C. R., "Garbage monitoring system using Arduino," *International Journal of Trend in Scientific Research and Development*, vol. 1, no. 6, pp. 808–811, 2017.

[2] Achmad, K. A., *et al*, "Smart city readiness based on smart city council's readiness framework," *International Journal of Electrical and Computer Engineering*, vol.8, no. 1, pp. 271–279. 2018

[3] Meijer, A., & Bolívar, M. P. R., "Governing the smart city: a review of the literature on smart urban governance," *International Review of Administrative Sciences*, vol. 82, no. 2, pp. 392–408, 2016.

[4] Khan, S. U., Niazi, M., & Ahmad, R., "Critical success factors for offshore software development outsourcing vendors: A systematic literature review," *2009 Fourth IEEE International Conference on Global Software Engineering, Limerick*, 2009, pp. 207-216.

[5] He, Y., Stojmenovic, I., Liu, Y., & Gu, Y., "Smart city," *International Journal of Distributed Sensor Networks*, vol. 10, no. 5, 2014.

[6] Batty, M., *et al*., "Smart cities of the future," *European Physical Journal: Special Topics*, vol. 214, no.1, pp. 481–518, 2012.

[7] Xu, L. Da, He, W., & Li, S., "Internet of things in industries: A survey," *IEEE Transactions on Industrial Informatics*, vol. 10, no. 4, pp. 2233–2243, 2014.

[8] Lin, J., *et al*, "A survey on internet of things: Architecture, enabling technologies, security and privacy, and applications," *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1125–1142, 2017.

[9] Stankovic, J. A., "Research directions for the internet of things," *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 3–9, 2014.

[10] Ramly, R., Sajak, A. A. B., & Rashid, M., "IoT recycle management system to support green city initiatives," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 15, no. 2, pp. 1037–1045, 2019.

[11] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M., "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, 2013.

[12] Oriwoh, E., & Conrad, M., "Things' in the internet of things: Towards a definition," *International Journal of Internet of Things*, vol. 4, no. 1, pp. 1–5, 2015.

[13] Tzounis, A., Katsoulas, N., Bartzanas, T., & Kittas, C., "Internet of things in agriculture, recent advances and future challenges," *Biosystems Engineering*, vol. 164, pp. 31–48, 2017.

[14] Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D., "Sensing as a service model for smart cities supported by Internet of Things," *Transactions on Emerging Telecommunications Technologies*, vol. 25, no. 1, pp. 81–93, 2014.

[15] Yaqoob, I., *et al*, "Internet of things forensics: Recent advances, taxonomy, requirements, and open challenges," *Future Generation Computer Systems*, vol. 92, pp. 265–275, 2019.

[16] Rghioui, A., & Oumnad, A., "Internet of things: Surveys for measuring human activities from everywhere," *International Journal of Electrical and Computer Engineering*, vol. 7, no. 5, pp. 2474–2482, 2017.

[17] Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M., "Internet of things for smart cities," *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 22–32, 2014.

[18] Gregorio, F., González, G., Schmidt, C., & Cousseau, J., "Internet of Things," in *Signal Processing Techniques for Power Efficient Wireless Communication Systems*, Springer International Publishing, pp. 217–245, 2020.

[19] Talari, S., Shafie-Khah, M., Siano, P., Loia, V., Tommasetti, A., & Catalão, J. P. S., "A review of smart cities based on the internet of things concept," *Energies*, vol. 10, no. 4, p. 421, 2017.

[20] Braun, A., "A framework to enable offshore outsourcing," *International Conference on Global Software Engineering (ICGSE 2007)*, pp. 125–129, 2007.

[21] Sun, Y., Song, H., Jara, A. J., & Bie, R., "Internet of things and big data analytics for smart and connected Communities," *IEEE Access*, vol. 4, pp. 766–773, 2016.

[22] Kodali, R. K., & Gorantla, V. S. K., "Smart solid waste management," *Proceedings of the 2017 3rd International Conference on Applied and Theoretical Computing and Communication Technology*, pp. 200–204, 2018.

[23] Vanolo, A., "Smartmentality: The smart city as disciplinary strategy," *Urban Studies*, vol. 51, no. 5, pp. 883–898, 2014.

[24] Liu, L., "IoT and a sustainable city," *Energy Procedia*, vol. 153, pp. 342–346, 2018.

[25] Kim, T. hoon, Ramos, C., & Mohammed, S., "Smart city and IoT," *Future Generation Computer Systems*, vol. 76, pp. 159–162, 2017.

[26] Shyam, G. K., Manvi, S. S., & Bharti, P., "Smart waste management using Internet-of-Things (IoT)," *Proceedings of the 2017 2nd International Conference on Computing and Communications Technologies*, pp. 199–203, 2017.

[27] Al Nuaimi, E., Al Neyadi, H., Mohamed, N., & Al-Jaroodi, J., "Applications of big data to smart cities," *Journal of Internet Services and Applications*, vol. 6, no. 1, pp. 1–15, 2015.
[28] Dameri, R. P., "Erratum to: Smart city implementation," in *Smart City Implementation*, Springer, Cham, pp. E1–E1, 2017.
[29] Yadav, R., "Solid waste management," *Pollution Research*, vol. 34, no. 1, pp. 93–102, 2015.
[30] Lu, J. W., Zhang, S., Hai, J., & Lei, M., "Status and perspectives of municipal solid waste incineration in China: A comparison with developed regions," *Waste Management*, vol. 69, pp. 170–186, 2017.
[31] Jouhara, H., Czajczyńska, D., Ghazal, H., Krzyżyńska, R., Anguilano, L., Reynolds, A. J., & Spencer, N., "Municipal waste management systems for domestic use," *Energy*, vol. 139, pp. 485–506, 2017.
[32] Mmereki, D., Baldwin, A., & Li, B., "A comparative analysis of solid waste management in developed, developing and lesser developed countries," *Environmental Technology Reviews*, vol. 5, no. 1, pp. 120–141, 2016.
[33] Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., & Böni, H. "Global perspectives on e-waste," *Environmental Impact Assessment Review*, vol. 25, no. 5, pp. 436–458, 2005.
[34] Giusti, L., "A review of waste management practices and their impact on human health," *Waste Management*, vol. 29, no. 8, pp. 2227–2239, 2009.
[35] Petersen, K., Feldt, R., Mujtaba, S., & Mattsson, M., "Systematic mapping studies in software engineering," *12th International Conference on Evaluation and Assessment in Software Engineering (EASE)*, pp. 1-10, 2008.
[36] Mahajan, P. S. A., Kokane, A., Shewale, A., Shinde, M., & Ingale, S., "Smart waste management system using IoT," *International Journal of Advanced Engineering Research and Science*, vol. 4, no. 4, pp. 93–95, 2017.
[37] Yusof, N. M., Zulkifli, M. F., Mohd Yusof, N. Y. A., & Azman, A. A., "Smart waste bin with real-time monitoring system," *International Journal of Engineering and Technology*, vol. 7, no. 2.29, pp. 725–729, 2018.
[38] Nirde, K., Mulay, P. S., & Chaskar, U. M., "IoT based solid waste management system for smart city," *2017 International Conference on Intelligent Computing and Control Systems (ICICCS)*, Madurai, 2017, pp. 666-669.
[39] Anitha, A. "Garbage monitoring system using IoT," *IOP Conference Series: Materials Science and Engineering*, vol. 263, no. 4, 2017.
[40] Yerraboina, S., Kumar, N. M., Parimala, K. S., & Aruna Jyothi, N., "Monitoring the smart garbage bin filling status: An iot application towards waste management," *International Journal of Civil Engineering and Technology*, vol. 9, no. 6, pp. 373–381, 2018.
[41] Mustafa, M. R., & Ku Azir, K. N. F., "Smart Bin: Internet-of-Things Garbage Monitoring System," *MATEC Web of Conferences*, vol. 140, pp. 1-4, 2017.
[42] Kumar, N. S., Vuayalakshmi, B., Prarthana, R. J., & Shankar, A., "IOT based smart garbage alert system using Arduino UNO," *016 IEEE Region 10 Conference (TENCON)*, Singapore, 2016, pp. 1028-1034.
[43] Vijaynaidu, V. P., & Dhikhi, T., "Smart garbage management system," *International Journal of Pharmacy and Technology*, vol. 8, no. 4, pp. 21204–21211, 2016.
[44] Sai Suraj Yadav, P. V., Nagavardhan Reddy, L., & Revathi, M., "Smart waste management system," *International Journal of Innovative Technology and Exploring Engineering*, vol. 8, no. 11, pp. 1223–1227, 2019.
[45] Castro Lundin, *et al*, "Smart cities: A case study in waste monitoring and management," *Proceedings of the 50th Hawaii International Conference on System Sciences*, 2017, pp. 1392-1401.
[46] Karadimas, D., Papalambrou, A., Gialelis, J., & Koubias, S., "An integrated node for Smart-City applications based on active RFID tags; Use case on waste-bins," *2016 IEEE 21st International Conference on Emerging Technologies and Factory Automation (ETFA)*, Berlin, 2016, pp. 1-7.
[47] Navghane, *et al* "IoT based smart garbage and waste collection bin," *International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)*, vol. 5, no. 5, pp. 1576–1578, 2016.
[48] Chaware, P. D. S. M., Dighe, S., Joshi, A., Bajare, N., & Korke, R., "Smart garbage monitoring system using internet of things (IOT)," *IJIREEICE*, vol. 5, no. 1, pp. 74–77, 2017.
[49] S., S., & V., S., "SWACHH: An effective real time solid waste management system for municipality," *International Journal of Computer Applications*, vol. 149, no. 4, pp. 44–48, 2016.
[50] Atayero, A. A., *et al*., "Cloud based IoT-enabled solid waste monitoring system for smart and connected communities," *International Journal of Civil Engineering and Technology*, vol. 10, no. 2, pp. 2308–2315, 2019.
[51] Gopal, A., Mukhopadhyay, T., & Krishnan, M. S., "The role of software processes and communication in offshore software development," *Communications of the ACM*, vol. 45, no. 4, pp. 193–200, 2002.