Perception Study on IOT Based Waste Management System

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Abstract. The concern over proper waste management has been there for decades, but the increasing population and immense urbanization have made the masses accept it as a serious issue. The unhygienic surrounding originating due to over spillage of dustbins is degrading the environment, which gives birth to numerous health issues. With the conceptualization of the internet of things (IoT) over the last decade and enhancement in internet infrastructure, these have become an integral part of the human lifestyle. The upcoming 5G technology will revolution the way of communication between static and mobile IoT devices. This will enhance community access to IoT devices. Thus, this has led to the concept of a "Smart Waste Management System," an embedded system consisting of modern sensors, microcontrollers, memory, communication devices, etc. enabling real-time Monitoring for smart bins leading to reduce garbage collection cost and fuel consumption. This paper discusses a variety of IoT device's implementation and societal perception on challenges and opportunities concerning India. Descriptive research was carried out upon data collected, and statistical analysis was done to study the differences concerning demographic, psychographic, behavioral, and geographic segmentation. The research will also provide insight to companies as well as to the waste management authorities into the commercialization of the "Smart Waste Management System".

Keywords: Internet of Things (IoT), 5G, MSW, PPP, Smart Waste Management System (SWMS)

1. Introduction
The rapid growth in urbanization, industrialization, along with the growing population, has increased per capita municipal solid waste (MSW) generation. Establishing a sustainable waste management system is a major challenge with the growing urban population [4]. Inefficient waste management is leading to significant issues for the environment and human health. The major MSW management issues arise can be linked to:

- Inefficient service operations.
- Insufficient serviceable area.
- Inappropriate waste disposal.
- Inadequate policies and regulations.
- Lack of societal awareness.

As per the word banks report 'What Waste 2.0' report on SWM to 2050, neglecting the urgency to take action on waste management would shoot up the global waste by 70% of today's by 2050. Global
waste is expected to reach 3.4 billion tonnes from the 2.01 level of 2016 in the next 30 years [5]. There also exist differences in terms of waste generation and management. Developing countries are expected to face more critical and actuate problems. This makes it obligatory for the developing countries like India with rapid population growth to move to a more sustainable MSW management system [3].

According to the ICRIER report on SWM in India 2019, it is estimated the volume of waste to rise 125 million tonnes by 2031 from the current level of 64-72 million tonnes [2]. There is a need for a sustainable and modern system that would replace the traditional inefficient waste management system. This leads to the concept of smart waste management system implementation.

1.1 Internet of Things (IoT)
IoT is a modern embedded system consisting of modern sensors, controllers, and communication [6] device. It enables the data acquisition, analysis and transmits data to a remote database through communication devices. Communication enabling technologies are RFID, RFID, and wireless sensor networks i.e. RSN and WSN [7]. IoT devices will make a significant impact on various aspects of everyday life concerning efficiency, safety, and productivity. They can be applied across different industries such as manufacturing, healthcare, safety, retail, environment, logistics, food, and drug, etc [8].

1.2 Fifth-generation (5G) technology
5G is a fifth-generation mobile technology, which provides enhanced speed, low latency, and improved flexibility for wireless devices. It will create new dimensions for IoT device's full-duplex communication and application. IoT technologies such as M2M (machine to machine) communication along with data analytics are expected to change the world around. Its low latency and ultra-reliability enable its applications in sectors related to healthcare, logistics, safety, mission-critical control, automotive applications, etc [9].

1.3 Smart Waste Management System
It is a system consisting of different sensors, micro-controller units, communication devices, and central database server, enabling the efficient collection, routing, and disposal of waste, as shown in Figure 1.

1.3.1 Sensors
It converts a physical parameter into an electrical signal.
- Ultrasonic Sensor measures the depth of the filled garbage.
- LDR Sensor triggers the device on/off during day/night resp.
• Weight Sensor measures the weight of filled garbage.

1.3.2 Micro-Controller
It interconnects all sensors and communication devices, it receives the sensors data and transmits through communication devices e.g., Arduino Uno, Raspberry Pi, etc.

1.3.3 Communication Devices
It allows the micro-controller to transmit the sensor’s data central database server.
- RFID system.
- Wi-Fi module.
- GPS/GPRS module.

1.3.4 Central Database And Mobile/Web Application
It receives, store, analysis data and make it available to a web browser, and mobile application.

2. Literature Review
A perspective is presented in [15] on the available technologies, protocols, and system architecture for an urban IoT system. It is emphasized the fact that there are immense design options for IoT systems but lack open and standardized protocols. The results of IoT solutions and service trials at an Italian city Padova are described to show the concept implementation of IoT paradigm to smart cities [16].

This paper [17] talks about the 2000's Municipal Solid Wastes (MSW) (Management and Handling) Rules provisions to make Solid waste management as the obligatory function of urban local bodies [1], whereas actual assigned at the last, either the duties are not carried out or discharged poorly leading to enumerable problems. It is extremely inefficient to use old, traditional, and obsolete systems and technology for collection, storage, processing, treating, and disposal. In most Indian cities, scientific and systematic storage of waste at sites is not in practice.

In [18] author proposed an IoT enabled Platform for the healthcare sector as a suitable self-management model for diseases. The Platform is composed of five elements: sensor device to send the patient medical data, a software device containing algorithm and sensor data, a mobile application to provide medical data to the user, and the last component to enables the communication between all components using unified API. This helps the user to monitor and manage his health by himself through the healthcare platform.

The [19] studies the impacts of rapid industrialization and urbanization in the last decade. Generating increased municipal solid waste and its characteristic change. The sustainable solution can be designed by accessing information about the characteristic generated waste. Thus, the availability of data is the limiting factor in MSW management.

This [20] paper proposes five essential IoT technologies for IoT-technology based product and services that are RFID, WSN, Middleware, cloud computing and, IoT application software along with three IoT categories to enhance customer approach that are Monitoring & control, big data, and business analytics, information sharing, and collaboration. It provides the NPV and real evaluation techniques to investment opportunities by the enterprises.

In [21] the author talks about the different visions of the IoT paradigm: things, internet, and semantic oriented. Different communication enabling technologies such as RFID, WSN, and RSN are compared concerning various application scenarios. It provides all potential application areas where the IoT can bring drastic changes e.g., transportation, healthcare, environment, etc.

A comparison is provided in [22] on different waste disposal methods considering cost and environmental impact. Suggesting avoiding landing-filling and using other waste treatment methods such as recycling, anaerobic digestion, composting, etc. these minimize the impact on the environment, increase energy recovery, and cost economic.
In [23] proposes a new system to enhance the collection efficiency of solid waste that integrates GPS tracking, passive RFID, GPRS, and camera. It mounts an RFID tag on the bin. An RFID-reader for the track is mounted on the truck to collect information of bins location in real-time with the help of GPS/GPRS and transfers instantly to a central database. A Digital map showing bins location gets available by the map server. Thus, the bin locations, their status, truck timing, and real-time position can be managed and monitor using this system[14].

In [24] describes the challenges of urban area Solid waste management. In this, the author has proposed an integrated system combining an integrated system of ZigBee* and GSM. The sensors are placed in the common garbage bins. When the garbage reaches up to the sensor level, the ARM 7 Controller gets triggered to send an indication to the garbage collection truck for immediate attention through SMS using GSM technology. ZigBee* is a two-way wireless networking standard.

In [4] integration of RFID and sensor technology imparts observation, identifying, and understanding capabilities to computers about the world. Enabling repairing, replacing, and recalling of things leading reduce waste, loss, and cost.

The importance is presented in [8] of developing low latency, low energy consumption, low cost, and low rate connection in 5G cellular networks. It highlights the challenges of implementation along with regulatory, policies, and business considerations.

In [9] highlights the incapability and challenges of traditional technologies to incorporate numerous IoT devices at the same time. The incremental increase in IoT applications will be the main challenge to be incorporated in the 5G network. Fifth-generation networks, IoT and big data will form the base for future IoT devices application[13].

The [10] discusses the incapability of present wireless technologies to meet 5G wireless technology demand as well they can’t be employed for LPWA. The 5G technology integrated with IoT is expected to utilize unlicensed and unused spectrum band that can be accessed through low-power-wide-area networks (LPWANs) like ZigBee, Lora, WI-FI, SigFox, and NB-IoT.

In [11] proposes a 5 G-based network framework for cyber-physical IoT's integrating multiple sensors, actuators, and central-controller enabling full-duplex communications. An energy-efficient algorithm for allocation of power and channel allocation is proposed and optimized for maximizing sum energy efficiency in each allocated channel [12].

3. Research Objective

The paper's objective is to present a thorough discussion over the current challenges in waste management, provide insight into Smart Waste Management System, and study society's perception of IoT-based waste management system.

4. Research Methodology

A quantitative type of research was carried out in the study. For data collection, primarily questionnaire for statistical findings and unstructured interviews were used.

The method used for sampling was Convenience and Snowball random sampling to get responses on the questionnaire.

The questionnaire was floated until the number of responses reaches a desired number of 100 was reached. A total of 125 responses were collected through the questionnaire.

Questionnaire questions were designed to capture the respondent’s socio-economic as well as demographic background data. The questionnaire was divided into mainly three parts:

- General profile information of respondents.
- Perception and knowledge of the current waste management system.
- Perception and attitude about the implementation of the new proposed SWMS.

To measure the understanding of respondents about the questionnaire, a small pilot study was conducted on 35 respondents.
After the data collection, responses were taken out in a spreadsheet, and data cleaning was carried out in Microsoft Excel 2019 and SPSS v26 was used for statistical analysis. Descriptive, exploratory, and Bi-variate correlation tests were conducted.

5. Finding and Discussion
5.1 Respondents Profile
Out of the total of 125 respondents who participated in the study, the obtained responses are summarized in Table 1.

- Gender: 74.4% were male, and 25.6% were female.
- Age: 89.6% were of age group 15-29 years, 10.4% were from 30-44 years. There was no participant from the other two age groups.
- City tier: most of the respondents were from tier3 cities (83.2%), tier2 and tier1 stand at second and places, respectively.
- Geographical area: 79.2% were residing in the urban area and 20.8% were in the rural.
- Table 1 gives the respondent’s profile.

| Description        | Response | Freq | %    |
|--------------------|----------|------|------|
| **Gender**         |          |      |      |
| Male               | 93       |      | 74.4%|
| Female             | 32       |      | 25.6%|
| Subtotal           | 125      |      | 100.0%|
| **Age**            |          |      |      |
| Below 15           | 0        |      | 0.0% |
| 15-29              | 112      |      | 89.6%|
| 30-44              | 13       |      | 10.4%|
| 45-59              | 0        |      | 0.0% |
| 60 Above           | 0        |      | 0.0% |
| Subtotal           | 125      |      | 100.0%|
| **Tier city**      |          |      |      |
| Tier 1             | 1        |      | 0.8% |
| Tier 2             | 20       |      | 16.0%|
| Tier 3             | 104      |      | 83.2%|
| Subtotal           | 125      |      | 100.0%|
| **Geographical area** |       |      |      |
| Urban              | 99       |      | 79.2%|
| Rural              | 26       |      | 20.8%|
| Subtotal           | 125      |      | 100.0%|

5.2 Practice and Altitude
The respondents have been analyzed on the basis of their practices and attitude in the current waste management system. The obtained responses are summarized in Table 2.

- Mode for the internet: 94.4% have either one or two modes to connect to the internet followed by others.
- Internet accessibility: a massive 97.6% have access to the internet in their area.
- Waste constituents: 36.8% is dry, 58.4% is wet and 4.8% is both types of waste.
- Waste disposal: 41.6% put their waste in nearby dustbins, whereas 47.2% said the waste is collected by municipal corporation vans.
- Waste segregation: only 42.4% have a system of waste segregation into dry and wet at their place whereas 50.4% didn’t have any such system.
Table 2: Practice and Altitude

| Description | Response | Freq | %  |
|-------------|----------|------|----|
| Which means you use to connect to the internet? | One Modes | 80 | 64.0% |
| | Two Modes | 38 | 30.4% |
| | Three Modes | 4 | 3.2% |
| | Four Modes | 3 | 2.4% |
| | Total | 125 | 100.0% |
| Do you have access to the internet in your area? | Yes | 122 | 97.6% |
| | No | 3 | 2.4% |
| | Total | 125 | 100.0% |
| The main constituent of waste generated? | Dry Waste | 46 | 36.8% |
| | Wet Waste | 73 | 58.4% |
| | Both Dry & Wet | 6 | 4.8% |
| | Subtotal | 125 | 100.0% |
| Place you dispose of your generated waste? | Community Dustbins | 52 | 41.6% |
| | Open Area | 6 | 4.8% |
| | Near to Home | 8 | 6.4% |
| | Municipal Corporation Van | 59 | 47.2% |
| | Subtotal | 125 | 100.0% |
| Do you have a system to segregate different types of waste? | Yes | 53 | 42.4% |
| | No | 63 | 50.4% |
| | Maybe | 9 | 7.2% |
| | Subtotal | 125 | 100.0% |

5.3 Knowledge and Adaptability
The respondents have been analyzed on basis of their knowledge and adaptability for the new proposed smart waste management system. The obtained responses are summarized in Table 3.

- PPP model: 56% agreed to contribute to the PPP model, whereas 44% neglected to contribute.
- IoT and 5G: On an avg. around 67% know the benefits of IoT and 5G. On the other, hand around 33% never heard about them.
- Smart Management: Around 52% (avg.) have heard of the SWMS and smart dustbins.
Table 3: Knowledge and Adaptability

| Description Response                                               | Freq | %  |
|--------------------------------------------------------------------|------|----|
| You ever heard of the PPP model in the waste management system?    | Yes  | 70 |
|                                                                   | No   | 55 |
|                                                                   | Total| 125|
| Do you know about IoT and its working?                            | Yes  | 80 |
|                                                                   | No   | 45 |
|                                                                   | Total| 125|
| Have you ever heard of something like Smart Waste Management System?| Yes  | 75 |
|                                                                   | No   | 50 |
|                                                                   | Total| 125|
| Are you acquainted with the word smart dustbins?                  | Yes  | 55 |
|                                                                   | No   | 70 |
|                                                                   | Total| 125|
| Have you heard about 5G and its benefits?                         | Yes  | 88 |
|                                                                   | No   | 37 |
|                                                                   | Total| 125|

5.3.1 Analysis: The following 16 variables were used for analysis, these items are:
1. How satisfied are you with the Present waste collection system in your area?
2. How satisfied are you with the frequency of waste collection intervals in your area?
3. The present internet connectivity (4G, WIFI, etc.) in my area is satisfactory.
4. Waste management is a concern and should be tackled on a priority basis.
5. Society lacks awareness of proper waste management.
6. The government holds the sole responsibility for waste management.
7. I will contribute to the PPP model if it is implemented in my area.
8. I agree to pay a Nominal charge for accessing IoT Devices and the internet.
9. I would recommend others all extend support to the authorities.
10. I would segregate the waste if the new system is implemented in my area.
11. IoT-based solutions are cost-effective and efficient.
12. IoT based solutions can solve the present waste management issue.
13. I am comfortable using App (like OLA, Uber) to dispatch my waste to its right destination.
14. IoT-based smart technology would change the world around me.
15. 5G technology will revolutionize the IoT system.
16. Overall the 5G technology will change the world you know if implemented properly.

Further, five variable was created from the above factors by combining multiple variables.

a) Satisfaction_Present_System = (Item_a + Item_b + Item_c)
b) Awareness_Present_System = (Item_d + Item_e + Item_f)
c) Perception_Attitude_Smart = (Item_g + Item_h + Item_i + Item_j)
d) Perception_Attitude_Iot_ = (Item_k + Item_l + Item_m)
e) Perception_Attitude_5G&App =(Item_n + Item_o + Item_p)

5.3.2 Reliability and Normality Test
For the reliability test, Cronbach’s alpha test was carried on the created variables. The computed alpha value was **0.751** that met the inter-item reliability criteria of alpha >0.70.
A normality test was also conducted and the variable data were found to be normally distributed. Table 4 gives the reliability test in the alpha calculation.

**Table 4: Reliability test Alpha calculation**

| Cronbach's Alpha | Alpha-Based on Std Items | Number of Items |
|------------------|--------------------------|----------------|
| .751             | .776                     | 5              |

5.3.3 Pearson Correlation test

The Bi-variate correlation test was conducted for computing correlation between different variable pairs. Table 5 shows the correlations statistics.

**Table 5: Correlations Statistics**

|       | A             | B             | C             | D             | E             |
|-------|---------------|---------------|---------------|---------------|---------------|
| **A** | Pearson r value | 1             | 0.231**       | 0.353**       | 0.192*        | 0.188*        |
|       | Significance  | 0.010         | 0.000         | 0.032         | 0.036         |
| **B** | Pearson r value | 0.231**       | 1             | 0.424**       | 0.474**       | 0.277**       |
|       | Significance  | 0.010         | 0.000         | 0.000         | 0.002         |
| **C** | Pearson r value | 0.353**       | 0.424**       | 1             | 0.711**       | 0.576**       |
|       | Significance  | 0.000         | 0.000         | 0.000         | 0.000         |
| **D** | Pearson r value | 0.192*        | 0.474**       | 0.711**       | 1             | 0.664**       |
|       | Significance  | 0.032         | 0.000         | 0.000         | 0.000         |
| **E** | Pearson r value | 0.188*        | 0.277**       | 0.576**       | 0.664**       | 1             |
|       | Significance  | 0.036         | 0.002         | 0.000         | 0.000         |

**. Significance of Correlation at the 0.01 level (2-tailed).**

**. Significance of Correlation at the 0.05 level (2-tailed).**

From the test, it is found that:

- The “Satisfaction_Present_System” was weakly correlated with the perception variables of the new system which shows dissatisfaction towards the present system for waste management.
- The “Awareness_Present_System” was positively moderately correlated with the perception variables of the new system which shows the awareness towards waste management issues.
- The “Perception_Attitude_SWM” was positively correlated with $r_1(.711)$ “Perception_Attitude_IoT” & $r_2(.576)$ “Perception_Attitude_5G&App” which shows a positive attitude towards tackling waste management issues with IoT and 5G technologies[25].
- The “Perception_Attitude_IoT” was positively correlated to $r(.664)$ “Perception_Attitude_5G&App” which shows a positive vision towards revolutionizing IoT devices with 5G technology.

6. Conclusion

Through this paper, the concept and working of IoT based smart waste management system have been described along with its integration with the revolutionary 5G technology. The increasing urbanization and population growth make it high time to revolutionize the present MSW management system to a
Sustainable Smart Waste Management System. The IoT devices with 5G have the potential to create more dimensions for smart objects in the field of transportation, healthcare, safety, etc. The study conducted has provided society’s perception of the new system against the old one. It gives an insight into the awareness, attitude, and practice that exist in society for waste management. The study reveals that there exists a positive attitude for the changes as more than half of the respondents are aware of the term IoT and 5G technology and knows its benefits. The study also highlights the challenges such as the existence of incompetent internet network infrastructure that can act as barriers for SWMS. An agreement can be seen to address waste management as a priority.

Countries like Denmark, Finland, Sweden, etc. are already have moved to SMWS from the traditional waste management system. Initiatives like informal participants i.e. PPP model Pune and ICT application in Indore city awarded the cleanest city in India laid the path for others to move to Smart Waste Management System.

The pace in technological improvement strongly indicates IoT along with 5G will be implemented on an extensive level around the globe in the coming years. As the present technology has laid the foundation for the IoT concept, addressing challenges will make it commercially viable in everyday life.

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