

# User-Centred Design Requirements for Technological Household Waste Management System

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## Abstract

In India, due to rapid urban population growth, the household waste management has emerged as an urban sustainability, that has increased the consumption patterns and creating pressure on the existing waste management infrastructure. This is resulting into increased landfill volume, that eventually leading increase in pollution level and health issues. According to the reports, in Delhi, around 12,800 tonnes of municipal solid waste is generated daily, which highlights that there is an urgent need for innovative and decentralized waste management solutions. This study is focused on the importance of user-centred design for household robotic waste management systems. This research also highlighted different aspects like waste generation patterns, waste segregation behaviour, bin usage practices, barriers to effective waste management, user concerns and the expectations of the respondents regarding robotic technologies. The data was collected using a structured questionnaire and analyzed using descriptive statistical techniques. According to the findings awareness regarding waste management is relatively high, household level segregation practices remain inconsistent due to factors such as lack of convenience, limited awareness, inadequate infrastructure and time constraints. The respondents have expressed strong interest in robotic systems capable of automatic waste segregation, odor control, compact storage and mobile application integration. The major concerns influencing technology adoption are reliability, maintenance cost, safety and privacy. Based on the study findings, a user-centred design framework is proposed to guide the development of intelligent household waste management systems. With the integration of household behavioural insights with technological innovations, the study contributes to sustainable product design and offers practical recommendations for researchers, designers, policy makers and urban waste management agencies that are seeking to enhance source-level waste management.

**Keywords:** Sustainable technology, household waste management, robotic waste management, user-centred design, smart waste systems, waste segregation.

## 1. INTRODUCTION

Rapid growth of urban population has significantly increased the quality and complexity of municipal solid waste generated worldwide [2]. Urban waste management has become one of the most pressing environmental and public health challenges, in developing countries such as India. For achieving sustainable waste management outcomes, households represent the primary source of municipal waste, making their participation essential. Many Indian cities continue to struggle with source (households) segregation, recycling efficiency, landfill dependency, and waste processing capacity, despite improvements in waste collection systems [5].

According to the Municipal Corporation of Delhi (MCD) report 2025, Delhi generates around 13,000 tons of municipal solid waste per day, this has been increased over recent years due to urbanization population growth, the change in the consumption patterns,

and time constraints. According to the MCD report 2026, the daily waste generation in Delhi is around 12,847 metric tonnes', which is putting a lot of pressure on the existing waste management infrastructure.

The segregation at household level can help in sustainable waste management, as it will help in improving the recycling efficiency, reduces burden on landfills and it will also facilitate in resource recovery. The municipal authorities have taken a lot of initiative related to waste segregation, for example installing different color dustbins according to the type of wastes but still segregation at household is lagging. At present according to the reports of MCD, around 55% of the waste which is generated at household is segregated, hence there is a significant scope of improvement.

The previous studies and MCD reports, shows that there is a need for innovative solutions to manage waste at household level. The emerging technological solutions and smart-home systems, create an opportunity to develop automating household waste management processes. The current challenges are- the waste is being segregated by the informal workers manually which causes human errors and also impacts their health, hence there is a need to improve segregation accuracy, it should reduce manual efforts, should take care of hygiene and controls odor. It should also support circular objectives. The technological solution should be capable in identifying the materials, sorting them, monitoring and managing the overall household waste that can transform the waste management from reactive disposal to proactive sustainability practice.

As technological innovation alone is not enough. There is a need to focus on the following parameters like- user acceptance, behavioral patterns, perceived usefulness, ease of use, and cost effective, which can lead to successful adoption of the smart technologies. There is a need to design a user-centered design, to align it with household needs, expectations and constraints. Hence, to develop a practical and acceptable solutions, there is a need to understand the current practices adopted at household for waste segregation and waste management, the challenges they face, and their recommendations for a technological solution.

This study is focused on identifying the above gaps by finding out the household waste management practices in Delhi, and knowing the design requirements for a technology-based waste management solution through user perspective. This research is based on human-centered approach that focuses on both identifying the behavioral patterns and technological design considerations. This study will examine different patterns like- waste generation patterns, waste segregation practices, waste storage and disposal behavior, the perceived barriers, user concerns, and the features that should be there in the technological solutions, that will help in establishment of the sustainable technological waste management system.

The findings of this study, can contribute to different fields like- for sustainable product design to design a human-centered technology design solution, can serve as a technical solution for waste management under smart city development, as a waste management innovation. Moreover, it also falls under India's broader objectives- to promote sustainable urban development, improving waste segregation at household level and advancement in smart city initiatives through technology-enabled solutions.

## **2. RESEARCH METHODOLOGY**

### **2.1 RESEARCH DESIGN**

The research design used for this study is both quantitative and descriptive, which will include investigation of household waste management practices and in identifying the requirements for the user-centred technological waste management system. The location selected for this research study is Delhi, India. The research is focused on understanding the following parameters- waste generation patterns, waste segregation behaviour, waste storage, practices adopted for waste management, maintenance habits and the challenges faced by the household in domestic waste management.

Structured questionnaire was developed to collect demographic information, household waste generation pattern and amount, waste segregation practices, waste storage methods, frequency of cleaning waste bins, and the challenges faced in waste segregation. This study focuses on human-centred design, identifying the user needs, behavioural patterns, and everyday waste management practices for successful implementation of the technological waste management system.

## **2.2 Study Area**

The present study was conducted in the four zones of Delhi, India. Delhi being one of the largest metropolitan regions in the country and capital of India, faces rapid urbanization, population growth and increase in consumption level causes increase in the management of municipal solid waste, and hence increasing the volume of landfills. According to the reports, municipal solid waste generated in Delhi is around 13,000 tonnes daily, hence taken Delhi for this study, to identify the need of user-centred design, the technological waste management solution and the explore the existing challenges.

## **2.3 Sampling and Data Collection**

The primary data was collected through structured questionnaire. For this study, have selected 80 households from the four different zones of Delhi, 20 households from each zone (North Delhi, South Delhi, East Delhi, and West Delhi). The sampling methods used were convenience and purposive, to ensure that the responses represent different age groups, educational background, family sizes, and housing type.

The questionnaire was designed to gather information related to- demographic details, housing types, household size, waste generation patterns, waste segregation practices, waste storage, frequency of bin cleaning, barriers related to waste segregation and about the municipal waste services.

## **2.4 Data Analysis**

The data collected from the households was coded and analyzed using the descriptive statistical techniques. To examine the household management practices and to identify the patterns to design the technological waste management system, frequency distributions and percentage analysis was done. Using the collected data the following patterns were being analyzed – household waste generation patterns, waste segregation practices, waste handling responsibilities, waste storage methods, barriers in proper segregation and user requirements for technological waste management solutions. The findings from this study helped in defining the implications for the development of a user-centred technological waste management system.

# **3. RESULTS AND DISCUSSION**

## **3.1 Demographic Profile of Respondents**

In total 80 households have been selected for this study from four different zones of Delhi. Among them, majority of the respondents possessed higher education qualification, with 45% graduates, 30% postgraduates and 10% of them were PhD holders. This data indicates that the sample represented a relatively educated urban population capable of providing informed responses regarding waste management technologies.

Furthermore, regarding housing type 51.3% of respondents resides in apartments, while 45% lived in independent houses. Moreover, most households (66.3%) consisted of three to five family members.

### 3.2 Household Waste Generation Patterns

According to the analysis, organic waste constituted the largest portion of household waste generated in Delhi households.

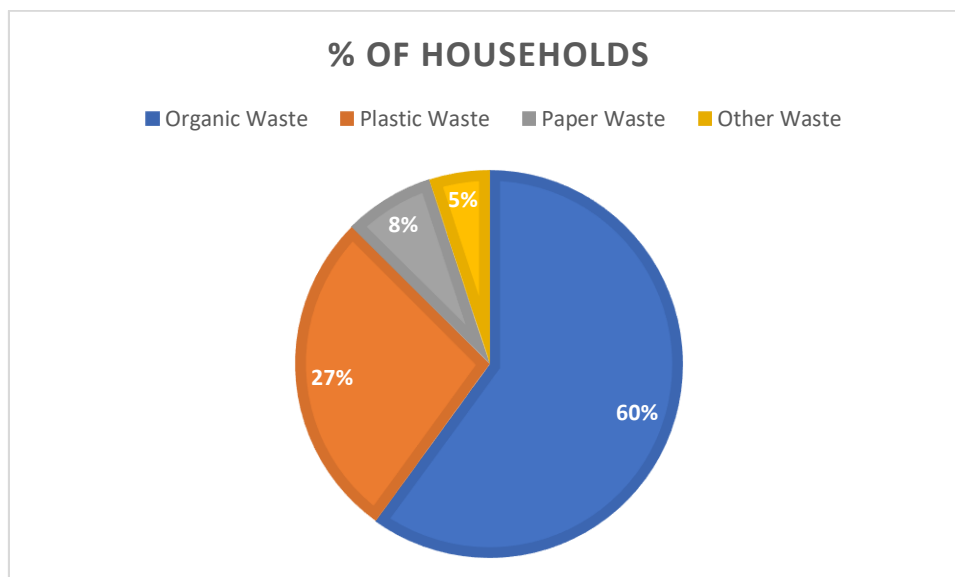


Fig.1: Type of waste generated at household level

Around 60% of respondents reported organic waste as their most frequently generated waste category, followed by plastic waste (27.5%), and paper waste (7.5%).

Moreover, in terms of quantity generated, around 46.3% of households produced less than 1 kg of waste daily, while around 45% generated between 1 and 2 kg. Only around 8.7% reported generating more than 2 kg of waste per day.

The above findings indicate that robotic waste management systems should primarily focus on handling organic and plastic waste streams, while remaining compact enough for households generating relatively small quantities of waste.

### 3.3 Waste Segregation Practices

According to the findings, only 22.5% of respondents reported practicing waste segregation at home, while 77.5% indicated that they did not segregate their waste. The findings highlighted a subsequent gap between awareness and the behaviour towards waste segregation practices. It was found that the respondents were aware, but the adoption part is missing due to various constraints, among which issues related to time and space were major. The respondents stated that to keep the waste properly segregated, they can't keep multiple bins at home. Hence, the technical waste management system should have multiple bins within, should have a technology through which the waste can be identified and have sorting capabilities to reduce manual segregation.

### 3.4 Household Responsibility for Waste Management

According to the findings, 44.4% of the female household members were responsible for waste handling, 32.5% were doing it through shared responsibility (both male and female in the house were equally contributing), and in 28.2% of the households waste is managed by the domestic helpers. The findings highlights that the technological waste management system should be designed according to different user set, depending upon the usage, ease of operation, and minimal maintenance requirements.

### 3.5 Waste Storage and Bin Usage Practices

The analysed data, showed that in most of the houses (77.5%) covered bins were used. In around 13.8% of the households plastic bags were used, while in around 8.7% households open baskets were used. The findings highlighted that the waste bins were frequently cleaned, maintaining the hygiene and also to the odour. Therefore, the technological waste management should also focus on enclosed storage compartments, and odour management mechanism.

### 3.6 Bin Maintenance Behaviour

According to the finding, around 63.8% of the households reported that they clean waste bins daily, while 31.3% of them clean the bins weekly. The frequency of bin cleaning highlights the concerns of the users regarding cleanliness, hygiene, and odour. Therefore, self-cleaning surfaces, antimicrobial materials, and odour-neutralization mechanism could significantly improve user acceptance of robotic waste management systems.

### 3.7 Barriers to Effective Waste Segregation

As per the findings, respondents identified several obstacles that prevent proper waste segregation as mentioned in Table 1.

Table 1: Barriers preventing proper waste segregation

| S.No. | Barrier           | Percentage (%) |
|-------|-------------------|----------------|
| 1.    | Lack of awareness | 41.2           |
| 2.    | No separate bins  | 27.5           |
| 3.    | Time constraints  | 26.3           |
| 4.    | Lack of interest  | 5              |

The predominance of awareness-related barriers indicates that the educational interventions remain important. Though, the significant influence of infrastructure limitations and time constraints suggests that automated systems can play a crucial role in improving waste segregation rates.

### 3.8 Perception of Municipal Waste Services

According to the findings, more than half of the respondents (55.8%) perceived municipal waste management services as only partially effective. While 33.8% expressed satisfaction, a smaller proportion reported dissatisfaction or uncertainty.

The above findings indicate opportunities for decentralized household-level solutions that complement existing municipal waste management systems.

### 3.9 Implications for Robotic Waste Management Design

According to the study findings, following are the important design requirements- automatic waste identification and segregation, compact size suitable for apartment living, covered and odour-controlled waste storage, minimal user intervention, easy cleaning and maintenance, multi-user accessibility, hygienic operation, and integration with smart-home ecosystems.

The above requirements collectively support the development of intelligent waste management systems capable of improving source segregation and enhancing household waste management efficiency.

## 4. CONCLUSION

This research study investigated household waste management practices among Delhi households to identify user-centred design requirements for robotic waste management systems. The findings indicate that although households demonstrate awareness of waste management issues, actual segregation practices remain relatively low. Furthermore, the findings highlighted that majority of the waste generated at household level is organic which is dumped wrapped in plastic bags, and were concerned about cleanliness and hygiene.

The findings of the study highlighted that there's lack of awareness, absence of separate bins, and time constraints were some of the identified barriers in terms of waste segregation. The following issues highlights the need of a technological waste management system, that can help in minimizing the constraints and smoothens the process of waste segregation.

Moreover, the technological waste management system should prioritize on building a compact design, low-maintenance operating, automatic waste segregation process and controls odour. It will help in reducing burden on the user, will improve the segregation rates, and will also supports the sustainable waste management objectives.

This study recommends a user-centred framework for household waste management. The proposed design requirements will be helpful from design perspective, for policy makers, and for researchers in creating solutions.

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