

# Integrating Smart Waste Collection in Tecuci Municipality: A Behavioral Study on User Response and Adaptation

**Viorel CALINESCU<sup>1,2</sup>**, **Catalina ITICESCU<sup>1,2</sup>**, **Lucian GEORGESCU<sup>1,2</sup>**, **Gabriel MURARIU<sup>1,2</sup>**, **Catalina TOPA<sup>1,2</sup>**

<sup>1</sup>Faculty of Sciences and Environment, "Dunarea de Jos" Univ. of Galati, Galati, Romania

<sup>2</sup>Rexdan Research Infrastructure, "Dunarea de Jos" Univ. of Galati, Galati, Romania

\*Correspondence: [kl\\_n\\_viorel@yahoo.com](mailto:kl_n_viorel@yahoo.com)

**Keywords:** management; optimization; waste; population; behavior;

**Abstract:** In a context of rapid technological change, the introduction of smart waste containers represents an innovative approach to improving the efficiency and sustainability of urban waste management. This study analyzes the behavioral adaptation of the population in Tecuci Municipality, Galați County, to the implementation of smart containers with controlled access, aligned with the objectives of the Integrated Waste Management System (SMID Galați). Quantitative data were collected through continuous monitoring of filling levels, collection frequency, and volumes by waste fraction, supplemented by qualitative observations regarding user compliance and misuse. Results indicate an initial transitional period marked by mixed behaviors, with gradual adoption correlating with the phased withdrawal of traditional containers. While selective collection rates improved and operational efficiency increased through route optimization, challenges persisted, including improper disposal when containers reached capacity and exclusion of certain waste generators such as commercial entities. These findings underline the dual impact of technological infrastructure and user behavior on system performance. The study concludes that achieving sustainable efficiency requires not only advanced collection technologies but also regulatory adjustments, targeted capacity allocation, and continuous public engagement to address behavioral and structural gaps. Recent research emphasizes the transformative role of AI and IoT in modern waste management, enabling smarter collection, sorting, and recycling processes (Lakhout et al, 2025).

## 1. Introduction

Urban waste management has become a major challenge for public administrations worldwide, driven by continuous population growth, accelerated urbanization, and changes in consumption patterns. These dynamics have led to a significant increase in the volume of waste generated per capita, placing substantial pressure on existing collection, transport, and disposal systems. Conventional waste management

infrastructures often struggle to adapt to fluctuating waste generation rates and to meet the objectives of environmental protection, resource efficiency, and circular economy principles. Consequently, the development of smart city infrastructures has emerged as a promising pathway for enhancing operational efficiency, reducing environmental impact, and supporting sustainable urban development (Khan et al., 2024).

In this context, smart waste management systems—based on IoT-enabled containers equipped with fill-level sensors, real-time monitoring capabilities, and access-control mechanisms—offer scalable and innovative solutions for improving selective waste collection. These technologies allow for the systematic collection of real-time data regarding container fill levels, usage frequency, and waste typology, which can be integrated into digital platforms for optimized route planning and dynamic resource allocation. IoT-assisted waste collection has demonstrated the potential to reduce unnecessary trips, lower fuel consumption, and decrease transport-related emissions (Hoque et al., 2024; Sah, 2025). The integration of AI-driven predictive models further enhances performance by enabling accurate forecasting of container fill levels and the optimization of collection schedules (Sah, 2025; Lakhout, 2025).

However, research shows that the success of these technological innovations depends not only on their technical reliability but also on user behavior and public acceptance. Issues such as improper waste fractioning, illegal dumping near collection points, and reluctance to adopt new disposal practices often undermine the operational benefits of smart systems (Cheema et al., 2022; Archip et al., 2023). As a result, behavioral factors must be approached systematically to ensure that technological solutions effectively support selective collection performance and circularity objectives (Lakhout, 2025., Hernández-Romero et al., 2024; Aloui et al., 2023; Mihai et al., 2024; Mihai, 2025).

Tecuci Municipality, located in Galați County, holds a strategic position within the county's Integrated Waste Management System (SMID Galați), benefiting from an established collection infrastructure and close proximity to the only compliant landfill in the region (Planul Județean de Gestionare a Deșeurilor, 2021). This positioning offers favorable conditions for the implementation of smart container systems and creates opportunities for integration with county-wide waste management strategies. Introducing smart containers at the local level is therefore not an isolated modernization effort but a critical step toward harmonizing local operations with the regional SMID framework.

The present study aims to analyze the adaptation process of Tecuci residents to the implementation of smart containers, evaluate the operational efficiency resulting from their deployment, and identify persistent behavioral and infrastructural barriers. The analysis integrates real-time sensor data from selective collection points, direct field observations, and information from the IT systems of the local operator and public authorities. The outcomes will provide a rigorous assessment of system performance and inform strategic decisions regarding the expansion of smart waste collection across Galați County. Furthermore, the adaptability of smart container infrastructures to emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and advanced data analytics highlights their potential to significantly improve waste management efficiency and contribute to regional sustainability objectives (Ali et al., 2020; Acharya et al., 2022).

## 2. Materials and methods

The study was conducted in the municipality of Tecuci (Galați County), where a network of 30 collection points equipped with smart containers is operational. These containers are designated for the five main waste fractions: paper/cardboard, plastic and metal, glass, biodegradable waste, and residual waste. The infrastructure is fully digitalized, with each container equipped with an electronic access system, fill-level sensors, automatic locking mechanisms, and modules for real-time data transmission to the digital platforms of Tecuci City Hall and SC CUP Tecuci SRL. This technical architecture enables not only continuous monitoring of fill levels but also the tracking of user behaviour and operational efficiency (Ilse María Hernández-Romero, et al, 2024).

The system was implemented in two distinct stages, designed to ensure a controlled transition from the traditional model to a fully digitalized one.

(1) *The adaptation stage (February–March)* represented the accommodation phase, during which traditional containers operated simultaneously with the smart ones. In this period, users were registered, received access cards, and were informed about the new selective collection system. This stage allowed for equipment calibration and the identification of any technical or behavioural malfunctions.

(2) *The full operational stage (April–May)* marked the complete transition to smart containers, creating a uniform and standardized monitoring environment. During this period, it became possible to consistently record volumes, collection frequencies, and operational incidents for all waste fractions.

Although the monitoring system covered all 30 collection points, the detailed analysis focused on a single point considered representative for the entire network. Its selection was based on three main criteria: central location in a highly accessible area, the presence of a constant and diversified user flow, and the full availability of uninterrupted datasets. Choosing a representative point allowed for an in-depth analysis while avoiding major contextual variations among the different neighbourhoods of the municipality (Komane, B., 2023).

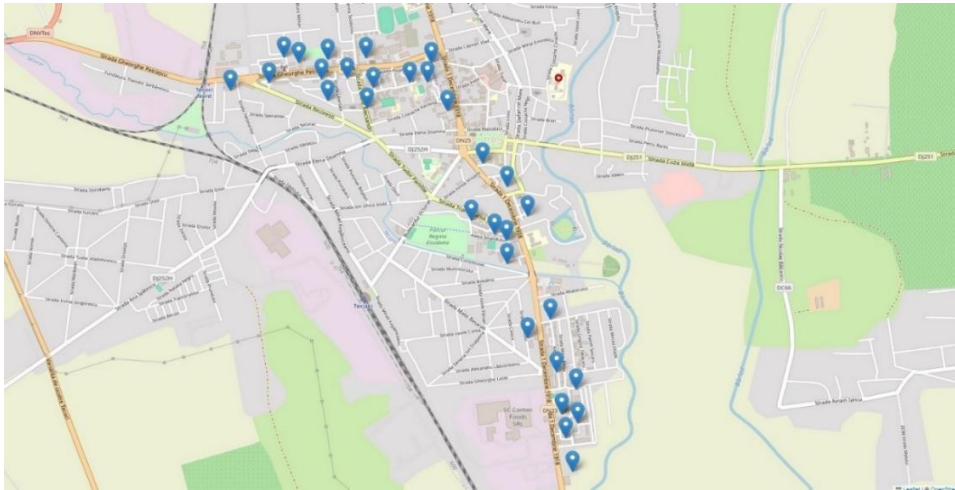
The indicators used in the analysis included: daily fill level ( $\text{m}^3$ ) for each fraction, collection frequency, contamination incidents, types of operational interventions (maintenance, unlocking, technical adjustments), and usage patterns derived from card-based user access. The datasets were processed in tabular form and visually represented through graphs (daily maximum fill-level curves) and heatmaps capturing temporal variations in fill levels. The analysis was descriptive in nature and aimed to identify seasonal fluctuations, recurring behavioural patterns, and potential inefficiencies in the operation of the system.

Tecuci Municipality is located in the north-western part of Galați County, functioning as a secondary urban center within the regional waste management network coordinated by the Integrated Waste Management System (SMID Galați). Its strategic position along key road connections facilitates the transportation of collected waste to transfer stations and treatment facilities within the county.

During the monitoring period, a total of 30 collection points were included in the study, each equipped with smart containers designed for selective waste collection.

Every point hosted separate containers for five main waste fractions: paper, plastic and metal, glass, biodegradable waste, and residual waste. The containers operate with controlled electronic access, which restricts unauthorized disposal and allows for accurate tracking of user behavior.

The spatial distribution of these collection points reflects both residential density and service accessibility, ensuring that all major neighborhoods are covered by the smart waste collection system. The geographical layout of the monitored points, is illustrated in Figure 1 and Figure 2.



**Figure 1.** Geographic distribution of the 30 monitored collection points in Tecuci Municipality.

The transition to the smart waste collection system in Tecuci Municipality was carried out in two main phases, ensuring a gradual adaptation of both infrastructure and user behavior.

The chronological stages of implementation, along with key operational milestones, are summarized in *Table 1* and *Figure 3,4,5,6,7,8,9,10*.



**Figure 2.** Location of Collection Point 1 and its Service Area

### 2.1 Implementation phases

The transition to the smart waste collection system in Tecuci Municipality was carried out in two distinct phases, designed to allow both infrastructure adjustments and user behavior adaptation. This gradual approach aimed to minimize service disruptions and resistance to change, while preparing the community for full adoption of the new system (Khosravani, 2023).

#### *Phase 1 – Adaptation stage (February–March)*

- Gradual removal of traditional open-access containers, following a planned schedule to avoid service interruptions.
- Installation of smart containers equipped with controlled electronic access, each fitted with sensors to measure fill levels and record data in real time.
- Parallel use of both smart containers and existing traditional containers, ensuring service continuity and allowing residents to familiarize themselves with the new technology.
- Distribution of individual electronic access cards assigned to each user or household, enabling access control and monitoring of waste disposal behavior.
- Organization of public awareness and training campaigns, including the distribution of explanatory materials, posters at collection points, and presentations within homeowners' associations.

#### *Phase 2 – Full operational stage (April–May)*

- Exclusive use of smart containers at all 30 monitored collection points in the municipality, with complete removal of traditional containers.
- Implementation of a standardized daily data collection system for all waste fractions, ensuring comparability of indicators between points.
- Continuous monitoring of fill levels to optimize collection routes and reduce unnecessary transport.
- Recording and analysis of contamination incidents for each fraction, aimed at identifying recurring problems and targeting educational actions in high non-compliance areas.
- Adjustment of collection logistics based on data insights, enabling cost reductions and improved operational efficiency.

The chronological stages of implementation, along with key operational milestones, are illustrated in *Figure 2*.

### 2.2. Monitored indicators

The performance evaluation of the smart waste collection system was based on a set of operational and behavioral indicators recorded throughout the monitoring period. These indicators were selected to capture both the technical functionality of the system and the patterns of user adaptation.

Although the smart waste collection network included **30 collection points** across Tecuci Municipality, the detailed quantitative dataset presented in this study was obtained from a single representative collection point. This location was chosen for its central position, consistent user flow, and accessibility for continuous monitoring. The

insights derived from this point are intended to serve as a reference model for understanding system performance at a larger scale (Andronache, Ş et al., 1999)

The main monitored indicators included:

- Daily fill level for each waste fraction (paper, plastic & metal, glass, biodegradable waste, and residual waste).
- Collection frequency for each container type, enabling calculation of average fill time.
- Incidents of contamination within each fraction, recorded and classified by severity.
- Operational interventions such as container maintenance or access control resets.
- User behavior patterns based on access card usage data, indicating frequency and timing of disposals.

A summary of the monitored fractions, container capacities, and collection frequencies for the representative collection point is presented in *Table 1*.

Data were collected using the monitoring software operated by Tecuci Municipality and SC CUP Tecuci SRL.

### 3. Results

This section provides a comprehensive overview of the findings obtained from the monitoring of the representative collection point equipped with smart containers. All figures, tables, and diagrams referenced in the results are included here in the order in which they are first cited in the main text. Each visual element is accompanied by a concise caption describing its content, while detailed explanations, contextualization, and interpretation are provided in the corresponding analytical sections (Choochote, P, et al., 2025).

The presentation of results is structured to reflect the key aspects of system performance, including daily fill-level dynamics for each waste fraction, collection frequency, contamination incidents, operational interventions, and user access patterns. By integrating quantitative measurements from sensors, card-based access logs, and operational records, this section provides a clear and systematic understanding of both the technical performance of the smart container system and the human interactions with it. The analyses presented here form the empirical basis for subsequent discussion, enabling the identification of operational trends, evaluation of efficiency, and assessment of the overall impact of smart container implementation on waste management practices in the municipality of Tecuci (Marseglia, et al., 2022).

Each collection point in the network is equipped with dedicated containers for five waste fractions: paper, plastic and metal, glass, biodegradable waste, and residual waste. In order to support spatial interpretation of the monitoring network, maps are provided indicating the location of each collection point, as well as main roads and neighborhood boundaries. These visual aids facilitate the analysis of user behavior and collection patterns in relation to urban geography, highlighting potential spatial differences in usage and performance across the municipality (Nourani et al., 2025).

This section aims to present the results in a structured and accessible manner, linking quantitative data to operational and behavioral insights. It establishes a foundation for understanding how smart container systems function in a real urban

context and provides a reference for improving waste management strategies in similar municipalities.

Table 1 presents the daily quantities of waste recorded for each fraction — paper, plastic and metal, glass, biodegradable waste, and residual waste — monitored at Collection Point 1 during the period from 1 to 28 February 2025. In addition to the absolute quantities, the table includes the corresponding fill levels for each day, which serve as a key indicator for evaluating both user behavior and the efficiency of collection operations. This detailed daily record allows for the identification of patterns in waste generation, the assessment of peak usage periods, and the detection of potential inefficiencies in the collection schedule. By providing a comprehensive overview of the monitored data, Table 1 establishes the foundation for subsequent analyses of operational performance and user interaction with the smart container system.

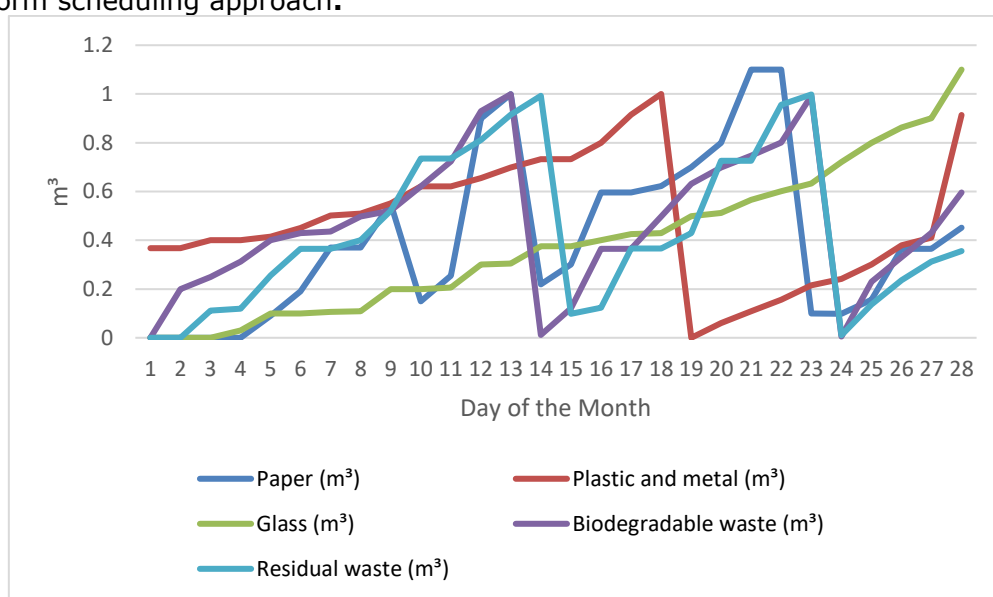
**Table 1.** Daily quantities of waste recorded for each fraction in the containers at Collection Point 1 (1–28 February 2025).

| Day | Paper (m <sup>3</sup> ) | Plastic and metal (m <sup>3</sup> ) | Glass (m <sup>3</sup> ) | Biodegradable waste (m <sup>3</sup> ) | Residual waste (m <sup>3</sup> ) |
|-----|-------------------------|-------------------------------------|-------------------------|---------------------------------------|----------------------------------|
| 1   | 0                       | 0.367                               | 0                       | 0                                     | 0                                |
| 2   | 0                       | 0.367                               | 0                       | 0.2                                   | 0                                |
| 3   | 0                       | 0.401                               | 0                       | 0.25                                  | 0.112                            |
| 4   | 0                       | 0.401                               | 0.03                    | 0.312                                 | 0.119                            |
| 5   | 0.09                    | 0.415                               | 0.1                     | 0.4                                   | 0.256                            |
| 6   | 0.19                    | 0.45                                | 0.1                     | 0.429                                 | 0.365                            |
| 7   | 0.37                    | 0.501                               | 0.106                   | 0.436                                 | 0.365                            |
| 8   | 0.37                    | 0.509                               | 0.109                   | 0.497                                 | 0.401                            |
| 9   | 0.55                    | 0.551                               | 0.2                     | 0.521                                 | 0.521                            |
| 10  | 0.15                    | 0.621                               | 0.2                     | 0.621                                 | 0.735                            |
| 11  | 0.255                   | 0.621                               | 0.206                   | 0.723                                 | 0.735                            |
| 12  | 0.9                     | 0.655                               | 0.3                     | 0.929                                 | 0.812                            |
| 13  | 0.999                   | 0.699                               | 0.305                   | 0.999                                 | 0.915                            |
| 14  | 0.219                   | 0.732                               | 0.375                   | 0.012                                 | 0.993                            |
| 15  | 0.3                     | 0.732                               | 0.375                   | 0.121                                 | 0.099                            |
| 16  | 0.596                   | 0.8                                 | 0.4                     | 0.365                                 | 0.123                            |
| 17  | 0.596                   | 0.915                               | 0.425                   | 0.365                                 | 0.366                            |
| 18  | 0.622                   | 1                                   | 0.429                   | 0.498                                 | 0.366                            |
| 19  | 0.7                     | 0                                   | 0.499                   | 0.632                                 | 0.429                            |
| 20  | 0.799                   | 0.06                                | 0.512                   | 0.699                                 | 0.726                            |
| 21  | 1.1                     | 0.109                               | 0.566                   | 0.747                                 | 0.726                            |
| 22  | 1.1                     | 0.156                               | 0.601                   | 0.801                                 | 0.956                            |
| 23  | 0.1                     | 0.215                               | 0.633                   | 0.992                                 | 0.998                            |
| 24  | 0.099                   | 0.241                               | 0.721                   | 0.005                                 | 0.01                             |
| 25  | 0.156                   | 0.3                                 | 0.799                   | 0.23                                  | 0.136                            |
| 26  | 0.365                   | 0.379                               | 0.863                   | 0.331                                 | 0.236                            |
| 27  | 0.365                   | 0.411                               | 0.901                   | 0.431                                 | 0.312                            |
| 28  | 0.452                   | 0.914                               | 1.1                     | 0.596                                 | 0.356                            |

Figure 3 illustrates the temporal evolution of daily peak fill levels for all monitored waste fractions at Collection Point 1 over the 28-day observation period. Distinct accumulation patterns are evident across fractions, reflecting differences in waste generation rates as well as collection scheduling. The paper and plastic-and-metal fractions display pronounced cyclical peaks followed by sharp decreases, indicating regular emptying events triggered near predefined capacity thresholds.

In contrast, the glass fraction exhibits a slower and more gradual increase in fill level, suggesting lower disposal frequency and a reduced need for frequent collection. Biodegradable and residual waste fractions show higher variability, with rapid accumulation over short time intervals and abrupt decreases, pointing to intensified daily use and more frequent operational interventions.

On several days, multiple fractions approach or slightly exceed nominal capacity, highlighting periods of increased pressure on the system. Overall, the figure demonstrates differentiated user behavior and distinct operational dynamics among waste fractions, supporting the need for fraction-specific collection strategies rather than a uniform scheduling approach.



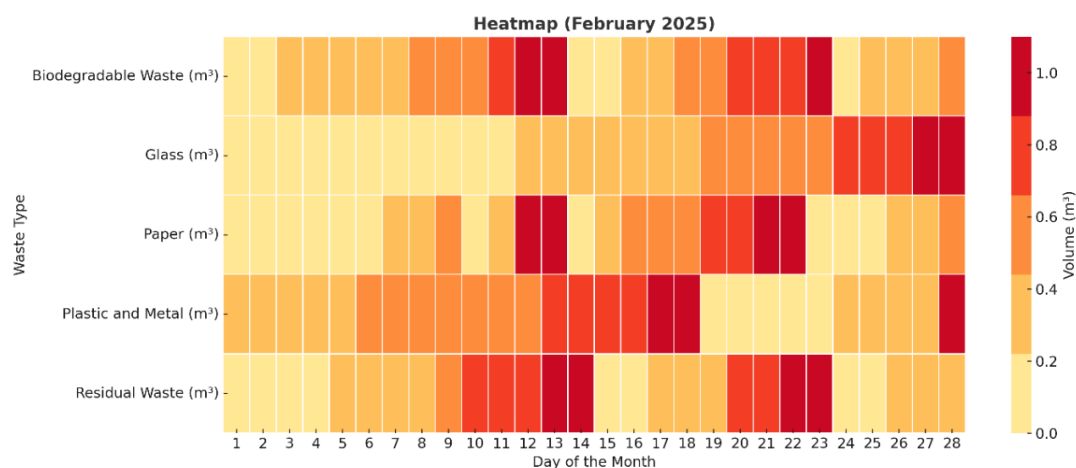
**Figure 3.** Peak fill levels for each waste fraction recorded daily at Collection Point 1 (February 2025).

Figure 4 presents a heatmap illustrating the daily variation in container fill levels for the monitored waste fractions at Collection Point 1 throughout February 2025. Color intensity represents the recorded volume (m³) for each fraction, with darker shades indicating higher levels of container utilization.

The visualization reveals distinct temporal patterns and clear differences among waste types. Plastic and metal, biodegradable, and residual waste frequently reach higher fill levels, indicating rapid accumulation and sustained pressure on container capacity. In contrast, the glass fraction is characterized by lower fill levels during most of the observation period, suggesting slower accumulation rates. The paper fraction shows an intermediate pattern, with clearly defined peak days followed by reductions associated with collection operations.

The heatmap provides a concise visual summary of daily fill-level dynamics and differing operational behaviors across waste fractions, complementing the analysis of daily peak fill levels presented earlier.

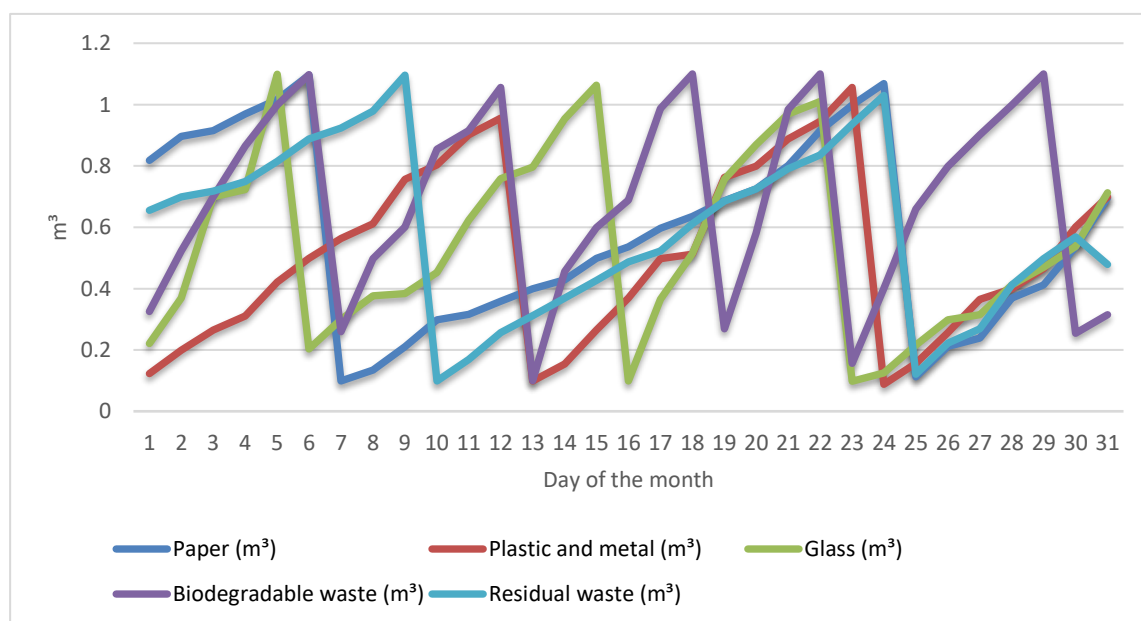
Figure 5 illustrates the daily peak fill levels for all monitored waste fractions at Collection Point 1 throughout March 2025. The data reveal clear temporal patterns over the observation period, with recurring fluctuations and distinct peak events, particularly for biodegradable and residual waste, indicating periods of increased waste generation and intensified container use.



**Figure 4.** Heatmap for the daily variation in container fill levels for five waste fractions (February 2025).

Paper, plastic and metal, and glass fractions also display cyclical patterns, characterized by gradual increases in fill levels followed by sharp decreases associated with collection operations. These patterns reflect both collection frequency and user disposal behavior. In comparison, the glass fraction shows a more moderate accumulation pattern, while paper and plastic and metal exhibit intermediate patterns with regularly recurring peaks.

Overall, the figure highlights dynamic patterns in waste generation and collection processes at the monitored point, underscoring the importance of adaptive, fraction-specific collection strategies to effectively manage variations in fill levels over time.



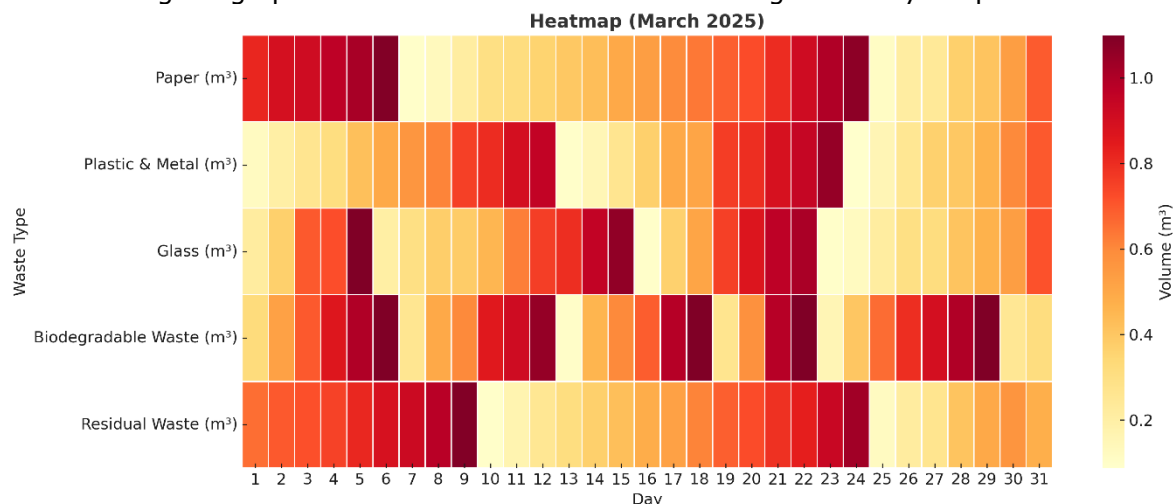
**Figure 5.** Daily peak fill levels recorded for each waste fraction at Collection Point 1 during March 2025.

Figure 6 presents a heatmap of daily waste volumes recorded during March 2025 for each monitored waste fraction. Color intensity reflects container fill levels (m³), with

darker shades corresponding to higher volumes approaching or exceeding the 1 m<sup>3</sup> threshold, while lighter shades indicate lower recorded volumes.

The visualization highlights distinct temporal patterns among the waste fractions. Paper and residual waste exhibit pronounced peaks during the first and last weeks of the month, indicating periods of intensified accumulation and increased pressure on container capacity. In contrast, glass and biodegradable waste display more irregular patterns, with significant fill levels occurring primarily in the middle of the month.

Heatmap provides a concise overview of the temporal distribution of waste volumes and differing usage patterns across waste fractions during the analyzed period.



**Figure 6.** Heatmap for the daily variation in container fill levels for five waste fraction in March 2025 for each waste fraction

Figure 7 illustrates the daily maximum fill levels recorded for all monitored waste fractions during April 2025. The data show a high frequency of maximum values, approaching or reaching the 1 m<sup>3</sup> threshold, across nearly all fractions throughout the observation period.

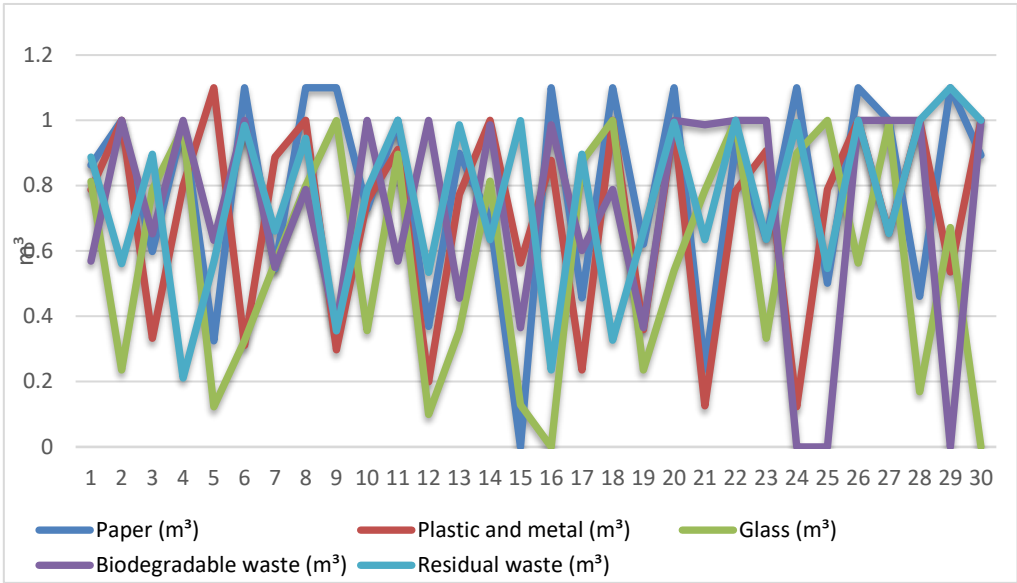
Daily trends are characterized by strong and rapid fluctuations, with no clear temporal regularity, in contrast to the more structured behavior observed in previous months. The frequent alternation between high fill levels and abrupt decreases indicates an intense and irregular use of the collection point, with accumulation events occurring on an almost daily basis.

The absence of temporal regularity may be associated with significant variability in user disposal behavior, as well as contextual factors specific to the analyzed period, such as seasonal cleaning activities or temporary changes in waste generation volumes. The figure highlights a phase of elevated operational pressure and increased unpredictability in container fill dynamics.

Figure 8 presents a heatmap illustrating the daily container fill volumes recorded during April 2025 for each monitored waste fraction. Darker red shades indicate days when containers reached or approached their maximum capacity, while lighter shades represent lower fill levels.

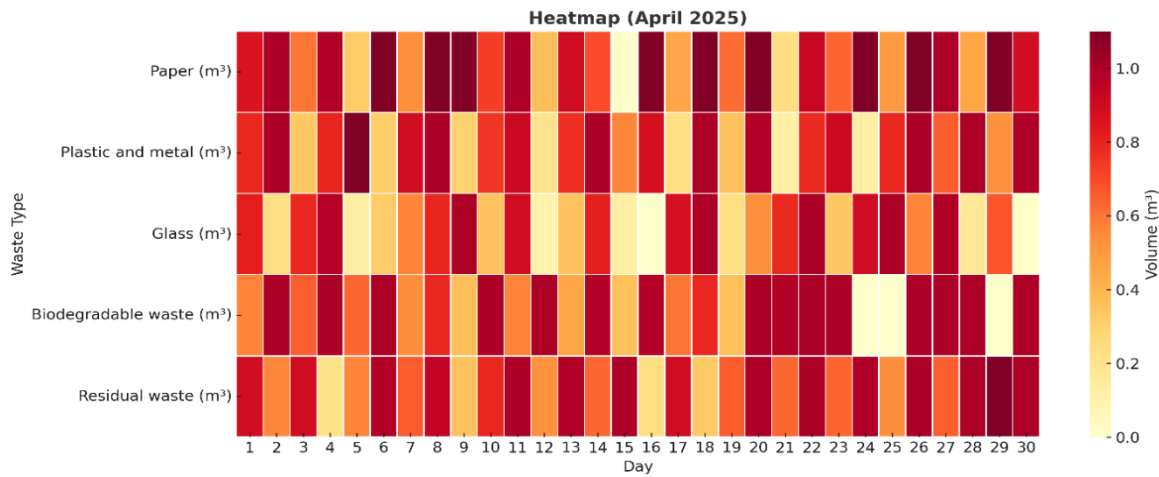
Most waste fractions display consistently high fill levels throughout the month, particularly paper, plastic and metal, and residual waste. This distribution indicates intensive and sustained use of the collection point, resulting in continuous operational

pressure on container capacity. In contrast, the glass fraction shows greater variability, with several days characterized by moderate to low accumulation levels.



**Figure 7.** Daily peak fill levels recorded for each waste fraction at Collection Point 1 during April 2025.

Taken together, the heatmap confirms the high intensity of waste disposal activity during April 2025 and highlights distinct differences among waste fractions in terms of fill-level consistency and accumulation dynamics.

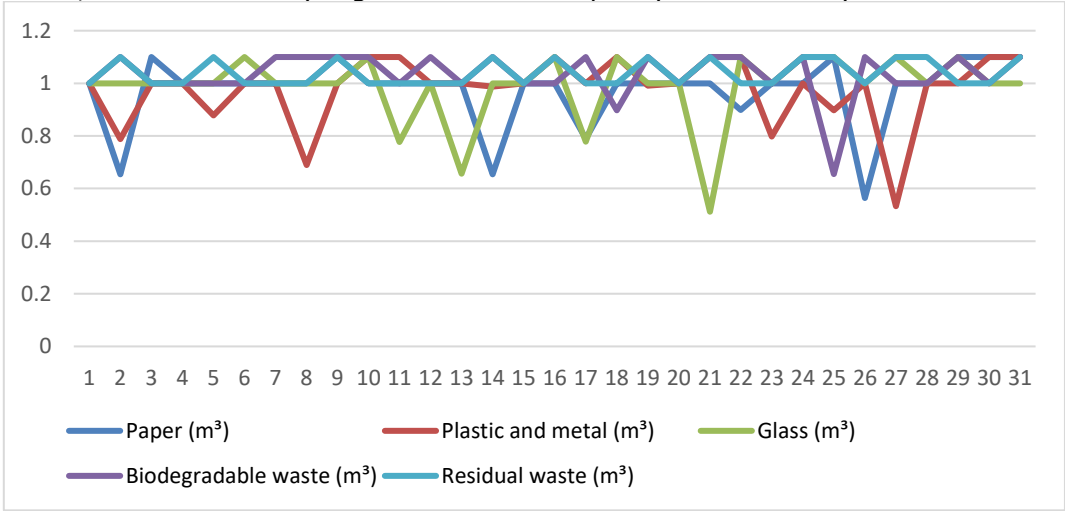


**Figure 8.** Heatmap for the daily variation in container fill levels for five waste fractions in April 2025 for each waste fraction

Figure 9 illustrates the peak fill levels recorded throughout May 2025 for the five analyzed waste fractions. The graph shows that most fractions maintained consistently high fill volumes, frequently approaching or reaching the container capacity limit of 1–1.2 m³.

Paper, biodegradable waste, and residual waste exhibit almost continuous maximum or near-maximum fill levels, indicating sustained pressure on collection capacity throughout the month. In contrast, the glass fraction shows occasional decreases in fill level, suggesting slightly lower generation rates or more effective collection on specific days. Plastic and metal waste also display minor fluctuations, but overall fill levels remain predominantly high across the analyzed period.

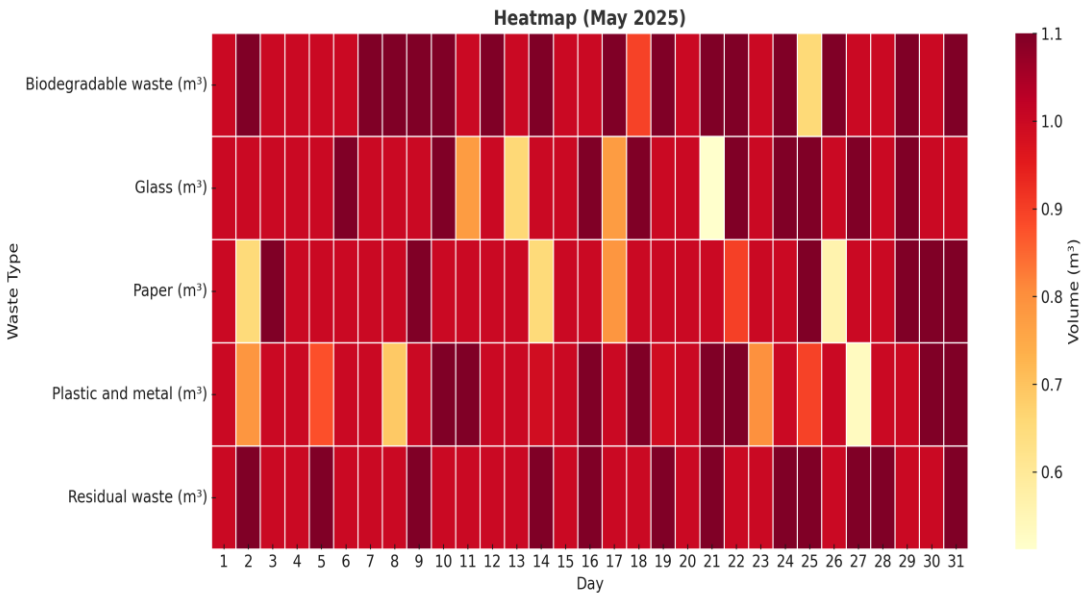
The figure highlights an intensive and sustained use of the collection point during May 2025, characterized by high container occupancy across nearly all waste fractions.



**Figure 9.** Daily peak fill levels recorded for each waste fraction at Collection Point 1 during May 2025.

Figure 10 presents a heatmap for May 2025, showing a consistently high container occupancy rate across all analyzed waste fractions. For most days of the month, fill levels are close to or reach the maximum container capacity (1–1.1 m³), indicating peak demand on the collection system throughout the period.

Residual and biodegradable waste fractions stand out by maintaining high fill levels over extended intervals, reflecting sustained pressure on collection capacity. In contrast, the glass fraction exhibits occasional decreases in fill level, while smaller fluctuations are also observed for paper and plastic and metal, suggesting intermittent variations in disposal rates for these fractions. From an operational standpoint, the data highlight the need for a frequent and well-synchronized collection schedule during May 2025 to prevent overflow incidents and ensure continued operational efficiency of the waste collection system.



**Figure 10.** Heatmap for the daily variation in container fill levels for five waste fractions in May 2025 for each waste fraction

#### 4. Discussion

The monitoring of the 30 selective waste collection points in Tecuci over several consecutive months provides a comprehensive overview of both technical performance and user behavior in the context of implementing smart waste containers. The collected data reveal clear patterns in filling rates, with certain waste fractions — notably biodegradable and residual waste — consistently reaching higher occupancy levels more rapidly than others. This behavior aligns with previous studies (Ampong et al., 2024), which confirm that organic and residual waste tend to dominate the municipal waste stream, especially in residential areas with mixed housing (Hlimoradiyan et al., 2025).

The temporal distribution of peaks in container occupancy, particularly the recurrent surges during weekends and immediately after public holidays, suggests a strong link to household consumption and disposal cycles. These observations are consistent with findings reported by (Leal Filho et al., 2016), where waste generation patterns were heavily influenced by social and cultural habits. In our case, the integration of smart containers provided not only real-time monitoring capabilities but also valuable insights into behavioral rhythms that can inform future adjustments to collection schedules.

An important observation is that during the initial stage of implementation, legacy (traditional) containers remained in use alongside the smart units. This parallel operation likely impacted user behavior by maintaining existing disposal habits and reducing the immediate transition pressure towards the new system. Studies such as (Kladnik et al., 2025) have shown that when multiple disposal options coexist, users may gravitate towards the most familiar, even if less efficient, option. In the Tecuci case, this factor should be considered when interpreting performance differences between the early and later stages of data collection (Khosravani et al., 2023).

From a fraction-specific perspective, the consistently lower filling rates for paper and glass, compared to biodegradable and residual waste, may be attributed to a combination of factors: limited public awareness of the importance of recycling these materials, logistical aspects related to packaging size and weight, and possible inconsistencies in public communication about proper sorting rules. This observation mirrors the findings of Alimoradiyan et al. (2025), who showed that differences in socio-economic context and infrastructure can lead to underperformance of certain waste fractions unless complemented by targeted educational and operational interventions.

In practical terms, the results indicate that smart containers significantly enhance the operational management of waste collection, particularly when integrated with route optimization software and responsive scheduling. The ability to track filling rates in real time enables the waste management operator (in this case, SC CUP Tecuci SRL) to adapt collection frequency to actual demand, thereby avoiding both overflow situations and unnecessary collection trips. However, as evidenced by the data, technology alone does not guarantee behavioral change — complementary strategies, including the removal of redundant infrastructure and targeted awareness campaigns, remain essential (Hernández-Romero et al., 2024).

#### 4.1. Limitations

While this study offers valuable insights, several limitations must be acknowledged. Firstly, the geographical scope was restricted to a single municipality, which limits the generalizability of the results to other regions with different cultural, demographic, or infrastructural conditions. Secondly, the co-existence of legacy containers during the early phase introduced a variable that cannot be fully isolated in the analysis, potentially skewing comparative interpretations. Thirdly, the study focused primarily on volumetric filling data, without directly quantifying contamination levels or the quality of sorting within each fraction. Such qualitative assessments could further refine the understanding of user compliance and system effectiveness. External factors — such as seasonal variation, weather conditions, and socio-economic changes — were not explicitly measured, although they may have influenced waste generation and disposal behaviors (Alimoradiyan et al., 2025).

#### 4.2. Implications for Practice

The findings from this research provide actionable recommendations for municipalities and waste management companies considering or currently deploying smart waste collection systems. Firstly, real-time data from smart containers should be fully integrated into route planning algorithms to ensure that collection is demand-driven rather than fixed-schedule-based. This approach can reduce operational costs, minimize fuel consumption, and lower greenhouse gas emissions. Secondly, the phased removal of legacy containers is strongly advised to prevent user confusion and accelerate adoption of the new system. Thirdly, public education must be continuous and strategically targeted — campaigns should not only inform residents of proper sorting practices but also clearly communicate the benefits of using the smart system, particularly for underperforming fractions like paper and glass (Aloui et al., 2023).

Moreover, the collected data can serve as a valuable feedback tool for both operators and policymakers, enabling the identification of problem areas (e.g., low participation points, recurrent contamination) and the implementation of localized interventions. In the broader context of sustainable urban waste management, the Tecuci case demonstrates that technological innovation, combined with behavioral insights and policy support, can significantly improve the efficiency and environmental performance of waste collection services. Decentralized waste-to-compost systems can further reduce the environmental footprint compared to traditional landfill-based methods, representing a valuable complement to modern waste management strategies (Ashraf et al., 2025).

Furthermore, the intelligent container system implemented in Tecuci is planned to be fully integrated into the Integrated Waste Management System of Galați County (SMID Galați). The results of this study will directly support the large-scale implementation of SMID, specifically at the county level, by providing operational benchmarks, behavioral insights, and data-driven recommendations that can be replicated in other municipalities. This integration will ensure harmonized operational data, coordinated collection routes, and comprehensive waste flow monitoring across

Galați County, enabling optimized resource allocation, improved efficiency, and full compliance with regional waste management objectives (Ghahramani, 2022).

## 5. Conclusions

The analysis of data collected from the 30 smart container collection points in Tecuci revealed clear trends regarding fill levels, collection frequency, and user behavior. The results indicate that residual and biodegradable waste consistently reached the highest fill rates, whereas paper and glass recorded lower values, suggesting both differences in selective collection habits and potential gaps in public awareness (Šomplák and Pluskal, 2025).

Daily monitoring allowed for the identification of recurring “peak fill” moments, particularly following weekends and certain local events. These peaks highlight the need for dynamically adjusting collection routes and frequencies to prevent container overflows and avoid illegal waste dumping around collection points. Smart waste management strategies must be embedded within broader socio-economic and policy frameworks to ensure their effectiveness and equity. The chapter Smart Waste Management argues that without aligning technological advances with supportive governance and inclusive economic models, their potential impact may remain limited (Brahim and Lahiani, 2025; Hoque et al., 2024).

The use of smart containers generated significant advantages, including optimized collection routes, reduced unnecessary trips, lower operational costs, and increased efficiency in resource utilization. However, the simultaneous presence of traditional containers during the initial phase negatively influenced the behavior of some users, underlining the importance of a complete transition to the smart infrastructure to fully reap the system’s benefits. Sustainable waste management practices in the Romanian literature emphasize the importance of combined approaches that integrate logistical optimization with legislative frameworks aligned to EU accession (Gogoncea, 2012).

This study provides a solid foundation for scaling the system to the entire Galați County through full integration into the Integrated Waste Management System (SMID Galați). Large-scale implementation, based on the data and conclusions presented, can ensure more efficient waste collection, significantly reduce costs, and increase recycling rates, while supporting the achievement of national and European environmental targets (Alimoradiyan et al., 2025).

**Acknowledgments:** The author wishes to thank the Municipality of Tecuci and the sanitation operator SC CUP Tecuci SRL for their support in providing the data necessary for the study, as well as for granting access to the software systems used to monitor the smart containers. Special thanks are also extended to the administrative and technical teams who facilitated the collection and processing of the data.

**Funding:** This research received no external funding.

## Appendix

The Appendix contains the complete tables with daily recorded data for each analyzed collection

point, the corresponding charts, and detailed maps of the locations. These supplementary materials support the interpretation of the results and can be consulted for a more in-depth analysis of user behavior and container fill levels.

**Author Contributions:** Viorel Călinescu: conceptualization and design of the study, data collection and processing, statistical analysis, interpretation of results, manuscript drafting, and final revision. Catalina Iticescu: Supervision, Conceptualization, final revision Lucian Georgescu: Supervision, Conceptualization Gabriel Murariu: processing, statistical analysis, interpretation of results Catalina Topa: Writing – review & editing

## References

1. Agentia pentru Protectia Mediului [http://apmgl-old.anpm.ro/upload/173207\\_PJGD%20Galati%2001\\_04\\_2021.pdf](http://apmgl-old.anpm.ro/upload/173207_PJGD%20Galati%2001_04_2021.pdf) (accessed on 18/03/2025)
2. Al Qurashi, R.S.; Almalki, M.; Alqahtani, S.; Alotaibi, T.; Alzahrani, A. (2025) *Smart Waste Management System for Makkah City using AI and IoT*. *ArXiv*, 1-10.
3. Ali, T.; Irfan, M.; Alwadie, A.S. *et al.* (2020) IoT-Based Smart Waste Bin Monitoring and Municipal Solid Waste Management System for Smart Cities. *Arab J Sci Eng* **45**, 10185–10198 <https://doi.org/10.1007/s13369-020-04637-w>
4. Aloui, N.; Almukadi, W.; Belghith, A. (2023) Towards an IOT Approach for Smart Waste Management based on Context Ontology: A Case Study. *Eng. Technol. Appl. Sci. Res.*, 13, 1, 10186–10191. <https://doi.org/10.48084/etasr.5530>
5. Ampong, R.O.; Miezah, K.; Banunle, A.; Amuah, E.E.Y.; Amoah, E.G. (2024) Comparative analysis of the effectiveness and efficiency of formal and informal waste collectors in urban waste management system. *Heliyon*, 10(20). <https://doi.org/10.1016/j.heliyon.2024.e39017>
6. Andronache, Ș.; Gavrilescu, Gh.; Groza, L.; Negruț, G.; Nicu, M.; Paraschiv, E.; Țau, S.; Vlăsceanu, D. (1999) *Monografia orașului Tecuci*. Tecuci.
7. Archip, B.C.; Banatean-Dunea, I.; Petrescu, D.C.; Petrescu-Mag, R.M. (2023) Determinants of Food Waste in Cluj-Napoca (Romania): A Community-Based System Dynamics Approach. *Int. J. Environ. Res. Public Health*, 20, 2140. <https://doi.org/10.3390/ijerph20032140>
8. Ashraf, A.I.; Mohareb, E.; Vahdati, M.; Abbas, F. (2025) Environmental life cycle assessments of decentralized municipal solid waste management: a novel waste-to-compost approach. *iscov Sustain* 6, 138. <https://doi.org/10.1007/s43621-025-00923-5>
9. Bostan, D. C. Gestionarea deșeurilor la S.C. Compania de Utilități Publice S.R.L., 2019, Tecuci
10. Brahim, M.; Lahiani, A. (2025) Smart Waste Management. In: Shahbaz, M.; Sharma, G.D.; Gedikli, A.; Erdoğan, S. (eds) *Global Pathways for Efficient Waste Management and Inclusive Economic Development*. Springer, Singapore. [https://doi.org/10.1007/978-981-96-5569-4\\_4](https://doi.org/10.1007/978-981-96-5569-4_4)

11. Cheema, S.M.; Hannan, A.; Pires, I.M. (2022) Smart Waste Management and Classification Systems Using Cutting Edge Approach. *Sustainability*, 14, 10226. <https://doi.org/10.3390/su141610226>
12. Choochote, P.; Supakata, N. (2025) Urban food waste generation: A case study of Nonthaburi Municipality, *Thailand. Sci Rep*, 15, 18405. <https://doi.org/10.1038/s41598-025-00682-3>
13. Consiliul Județean Galați (2019) *Master Plan – Sistem de Management Integrat al Deșeurilor în Județul Galați*. Retrieved from: <https://www.cjgalati.ro/images/stories/hotarari2019/hot1-290119.pdf>,
14. Consiliul Județean Galați (2020) Hotărârea nr. 29 din 30 ianuarie 2020 privind proiectul *Sistem de management integrat al deșeurilor în județul Galați*. Retrieved from: <https://www.cjgalati.ro/images/stories/hotarari2020/hot29-300120.pdf>
15. Consiliul Județean Galați (2021) *Planul Județean de Gestionare a Deșeurilor*.
16. Consiliul Județean Galați <https://www.cjgalati.ro/images/stories/hotarari2020/hot29-300120.pdf> (accessed on 21/04/2025).
17. Consiliul Județean Galați. <https://www.cjgalati.ro/images/stories/hotarari2019/ph11663-16102019.pdf> (accessed on 25/04/2025)
18. Consiliul Local Tecuci. (2019) Referat de aprobare nr. 62606/29.10.2019 – *Sistemul de management integrat al deșeurilor în municipiul Tecuci*. Retrieved from: <https://www.cjgalati.ro/images/stories/hotarari2019/ph11663-16102019.pdf>
19. Ghahramani, M., Zhou, M., Molter, A., & Pilla, F. (2021) IoT-based route recommendation for an intelligent waste management system. *IEEE Internet of Things Journal*, 9(14), 11883-11892. <https://doi.org/10.1109/JIOT.2021.3132126>
20. Gogoncea, V. (2012) *Studii asupra optimizării managementului deșeurilor*. PhD thesis, niversitatea" Dunărea de Jos" din Galați.
21. Hlimoradiyan, H.; Hajinezhad, A.; Yousefi, H. *et al.* The operational municipal solid waste management policy focuses on identifying waste generation behavior across multiple levels in mega cities, a case study. *Discov Sustain.*, 6, 750, 2025. <https://doi.org/10.1007/s43621-025-01685-w>
22. Hoque, M.J.; Tayef, S.H.; Noman, A.A.; Bhuiyan, M.E.H; Ahmed, M.R. and Zilani, M.A.K. (2024) An IoT-based Smart Waste Management System for Efficient Waste Segregation and Collection," *International Conference on Innovations in Science, Engineering and Technology (ICISSET)*, Chittagong, Bangladesh, 2024, pp. 1-6, <https://doi.org/10.1109/ICISSET62123.2024.10939867>
23. Ilse María Hernández-Romero, Javier Camilo Niño-Caballero, Lucy T. González, Michael Pérez-Rodríguez, Antonio Flores-Tlacuahuac & Alejandro Montesinos-Castellanos, (2024), *Waste management optimization with NLP modeling and waste-to-energy in a circular economy*
24. Ketineni, S.; Chilakalapudi, M.; Dandamudi, S.; Sundaramoorthy, S.; Amesho, K.T.; Jayachandran, S. (2025) IoT-based waste management: hybrid optimal routing and waste

- classification model. *Environmental Science and Pollution Research*, 32(32), 19522-19545. <https://doi.org/10.1007/s11356-024-33418-3>
25. Khan, S.; Ali, B.; Alharbi, A.A.K.; Alotaibi, S.; Alkhathami, M. (2024) Efficient IoT-Assisted Waste Collection for Urban Smart Cities. *Sensors*, 24, 3167. <https://doi.org/10.3390/s24103167>
  26. Khosravani, F.; Abbasi, E.; Choobchian, S. et al. (2023) A comprehensive study on criteria of sustainable urban waste management system: using content analysis. *Sci Rep*, 13, 22526. <https://doi.org/10.1038/s41598-023-49187-x>
  27. Kladnik, V.; Schwarzböck, T.; Dworak, S. (2025) Assessing current practices and alternative scenarios for the management of public waste in the city of Vienna. *Waste Management*, 206, 115052. <https://doi.org/10.1016/j.wasman.2025.115052>
  28. Komane, B.L.; Mathonsi, T.E. (2023). Design of a Smart Waste Management System for the City of Johannesburg. *arXiv preprint arXiv:2303.14436*
  29. Lakhout, A. (2025) Revolutionizing urban solid waste management with AI and IoT: A review of smart solutions for waste collection, sorting, and recycling. *Results in Engineering*, 25, 104018. <https://doi.org/10.1016/j.rineng.2025.104018>
  30. Lakhout, A. (2025) Revolutionizing urban solid waste management with AI and IoT: a review of smart solutions for waste collection, sorting, and recycling. *Results in Engineering*, 104018.
  31. Leal, F.; W.; Brandli, L.; Moora, H.; Kruopienė, J.; Stenmarck, Å. (2016) Benchmarking approaches and methods in the field of urban waste management. *Journal of Cleaner Production*, 112, 4377-4386. <https://doi.org/10.1016/j.jclepro.2015.09.065>
  32. Marseglia, G.; Mesa, J.A.; Ortega, F.A.; Piedra-de-la-Cuadra, R. (2022) A heuristic for the deployment of collecting routes for urban recycle stations (eco-points). *Socio-Economic Planning Sciences*, 82, 101222. <https://doi.org/10.1016/j.seps.2021.101222>
  33. Mihai, F.-C. (2025) Circular Economy Transition on the Debate: Big Dreams but Harsh Realities. *Journal of Circular Economy*, 3(1). <https://doi.org/10.55845/MJAM2116>
  34. Mihai, F.C.; Ishchenko, V.; Iordachi, V.; Ivanova, V.; Dzebisashvili, N. (2024) Circular Economy and Waste Management in Eastern Europe. *Circular Economy*, 1(1), 57-95. <https://doi.org/10.7251/PRB2401057M>
  35. Ministerul Mediului, Apelor și Pădurilor. (2017). *Planul Național de Gestionare a Deșeurilor 2014–2020*. Retrieved from: [https://www.mmediu.ro/app/webroot/uploads/files/PNGD\\_vers5.pdf](https://www.mmediu.ro/app/webroot/uploads/files/PNGD_vers5.pdf)
  36. Mu, L., Wang, Q., Zha, F., Wang, J., Xu, R., & Piao, M. (2025). Contaminant transport in a municipal solid waste landfill: On-site assessment and numerical modelling of vertical barrier wall effectiveness. *Waste Management*, 205, 114978. <https://doi.org/10.1016/j.wasman.2025.114978>
  37. Nourani, V.; Baghanam, A.H.; Samadi, E.; Uzelaltinbulat, S. (2025) Predicting municipal solid waste generation using artificial intelligence: A hybrid approach of entropy analysis and

- SHAP for optimal feature selection. *Waste Management*, 205, 115012. <https://doi.org/10.1016/j.wasman.2025.115012>
38. Sah, R.R. (2024) IoT-Enabled AI Solutions for Efficient Smart City Waste Management. *Annals of Process Engineering and Management*, 1(1), 26-32.
39. Smailbegovic, U.; Kadric, E.; Glöser-Chahoud, S. (2025) Assessing the determinants of municipal solid waste generation in Europe: A machine learning approach. *Waste Management*, 205, 115033. <https://doi.org/10.1016/j.wasman.2025.115033>
40. Šomplák, R.; Pluskal, J. (2025). Modelling secondary waste composition using optimization and machine learning techniques: Case of the Czech Republic. *Waste Management*, 205, 115019. <https://doi.org/10.1016/j.wasman.2025.115019>
41. Song, W.; Elahi, E.; Hou, G.; Wang, P. (2025) Collaborative governance for urban waste management: A case study using evolutionary game theory. *Sustainable Cities and Society*, 126, 106380. <https://doi.org/10.1016/j.scs.2025.106380>



© 2025 by the authors. Licensee UAIC, Iasi, Romania. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY-NC-ND) license (<https://creativecommons.org/licenses/by-nc-nd/4.0>).

## Appendix

**Table 3.** Quantity of waste recorded in the containers at Collection Point 1 and their fill level, by day (1–31 March).

| Day | Paper (m <sup>3</sup> ) | Plastic and metal (m <sup>3</sup> ) | Glass (m <sup>3</sup> ) | Biodegradable waste (m <sup>3</sup> ) | Residual waste (m <sup>3</sup> ) |
|-----|-------------------------|-------------------------------------|-------------------------|---------------------------------------|----------------------------------|
| 1   | 0.818                   | 0.123                               | 0.221                   | 0.325                                 | 0.655                            |
| 2   | 0.896                   | 0.199                               | 0.369                   | 0.523                                 | 0.699                            |
| 3   | 0.915                   | 0.265                               | 0.699                   | 0.699                                 | 0.718                            |
| 4   | 0.969                   | 0.311                               | 0.723                   | 0.865                                 | 0.749                            |
| 5   | 1.016                   | 0.421                               | 1.099                   | 0.999                                 | 0.815                            |
| 6   | 1.096                   | 0.499                               | 0.203                   | 1.098                                 | 0.888                            |
| 7   | 0.099                   | 0.563                               | 0.299                   | 0.26                                  | 0.923                            |
| 8   | 0.134                   | 0.611                               | 0.377                   | 0.498                                 | 0.979                            |
| 9   | 0.211                   | 0.756                               | 0.384                   | 0.601                                 | 1.096                            |
| 10  | 0.298                   | 0.803                               | 0.453                   | 0.855                                 | 0.099                            |
| 11  | 0.316                   | 0.901                               | 0.623                   | 0.915                                 | 0.169                            |
| 12  | 0.359                   | 0.956                               | 0.759                   | 1.056                                 | 0.256                            |
| 13  | 0.399                   | 0.099                               | 0.796                   | 0.1                                   | 0.312                            |
| 14  | 0.429                   | 0.154                               | 0.954                   | 0.456                                 | 0.369                            |
| 15  | 0.499                   | 0.265                               | 1.063                   | 0.599                                 | 0.427                            |
| 16  | 0.536                   | 0.369                               | 0.099                   | 0.689                                 | 0.487                            |
| 17  | 0.597                   | 0.498                               | 0.365                   | 0.987                                 | 0.523                            |
| 18  | 0.635                   | 0.512                               | 0.514                   | 1.1                                   | 0.611                            |
| 19  | 0.687                   | 0.763                               | 0.756                   | 0.269                                 | 0.685                            |
| 20  | 0.725                   | 0.799                               | 0.869                   | 0.581                                 | 0.725                            |
| 21  | 0.801                   | 0.888                               | 0.969                   | 0.984                                 | 0.791                            |
| 22  | 0.915                   | 0.945                               | 1.01                    | 1.1                                   | 0.836                            |
| 23  | 0.999                   | 1.056                               | 0.098                   | 0.156                                 | 0.936                            |
| 24  | 1.069                   | 0.088                               | 0.125                   | 0.401                                 | 1.03                             |
| 25  | 0.112                   | 0.156                               | 0.216                   | 0.659                                 | 0.121                            |
| 26  | 0.212                   | 0.256                               | 0.298                   | 0.798                                 | 0.222                            |
| 27  | 0.239                   | 0.365                               | 0.315                   | 0.901                                 | 0.269                            |
| 28  | 0.369                   | 0.399                               | 0.412                   | 0.999                                 | 0.412                            |
| 29  | 0.412                   | 0.465                               | 0.469                   | 1.1                                   | 0.498                            |
| 30  | 0.536                   | 0.601                               | 0.537                   | 0.254                                 | 0.569                            |
| 31  | 0.696                   | 0.699                               | 0.713                   | 0.315                                 | 0.479                            |

**Table 4.** Quantity of waste recorded in the containers at Collection Point 1 and their fill level, by day (1–30 April).

| Day | Paper (m <sup>3</sup> ) | Plastic and metal (m <sup>3</sup> ) | Glass (m <sup>3</sup> ) | Biodegradable waste (m <sup>3</sup> ) | Residual waste (m <sup>3</sup> ) |
|-----|-------------------------|-------------------------------------|-------------------------|---------------------------------------|----------------------------------|
| 1   | 0.863                   | 0.788                               | 0.813                   | 0.569                                 | 0.888                            |
| 2   | 1                       | 1                                   | 0.236                   | 1                                     | 0.561                            |
| 3   | 0.598                   | 0.333                               | 0.789                   | 0.652                                 | 0.896                            |
| 4   | 0.988                   | 0.799                               | 0.978                   | 1                                     | 0.211                            |
| 5   | 0.325                   | 1.1                                 | 0.123                   | 0.633                                 | 0.566                            |
| 6   | 1.1                     | 0.311                               | 0.326                   | 1                                     | 0.985                            |
| 7   | 0.545                   | 0.888                               | 0.564                   | 0.549                                 | 0.661                            |
| 8   | 1.1                     | 1                                   | 0.799                   | 0.789                                 | 0.945                            |
| 9   | 1.1                     | 0.297                               | 0.999                   | 0.369                                 | 0.355                            |
| 10  | 0.729                   | 0.753                               | 0.356                   | 1                                     | 0.788                            |
| 11  | 1                       | 0.911                               | 0.896                   | 0.569                                 | 1                                |
| 12  | 0.369                   | 0.199                               | 0.099                   | 1                                     | 0.535                            |
| 13  | 0.899                   | 0.773                               | 0.356                   | 0.455                                 | 0.987                            |
| 14  | 0.699                   | 1                                   | 0.814                   | 0.987                                 | 0.635                            |
| 15  | 0                       | 0.563                               | 0.129                   | 0.365                                 | 0.999                            |
| 16  | 1.1                     | 0.878                               | 0                       | 0.987                                 | 0.236                            |
| 17  | 0.456                   | 0.236                               | 0.874                   | 0.601                                 | 0.896                            |
| 18  | 1.1                     | 1                                   | 1                       | 0.789                                 | 0.327                            |
| 19  | 0.621                   | 0.359                               | 0.236                   | 0.365                                 | 0.659                            |
| 20  | 1.1                     | 0.987                               | 0.541                   | 1                                     | 0.994                            |
| 21  | 0.239                   | 0.126                               | 0.786                   | 0.987                                 | 0.635                            |
| 22  | 0.923                   | 0.784                               | 1                       | 1                                     | 1                                |
| 23  | 0.637                   | 0.907                               | 0.333                   | 1                                     | 0.636                            |
| 24  | 1.1                     | 0.123                               | 0.899                   | 0                                     | 0.993                            |
| 25  | 0.501                   | 0.789                               | 1                       | 0                                     | 0.546                            |
| 26  | 1.1                     | 1                                   | 0.563                   | 1                                     | 1                                |
| 27  | 1                       | 0.654                               | 0.991                   | 1                                     | 0.653                            |
| 28  | 0.461                   | 1                                   | 0.169                   | 1                                     | 1                                |
| 29  | 1.1                     | 0.536                               | 0.672                   | 0                                     | 1.1                              |
| 30  | 0.893                   | 1                                   | 0                       | 1                                     | 1                                |

**Table 5.** Quantity of waste recorded in the containers at Collection Point 1 and their fill level, by day (1–31 May).

| Day | Paper (m <sup>3</sup> ) | Plastic and metal (m <sup>3</sup> ) | Glass (m <sup>3</sup> ) | Biodegradable waste (m <sup>3</sup> ) | Residual waste (m <sup>3</sup> ) |
|-----|-------------------------|-------------------------------------|-------------------------|---------------------------------------|----------------------------------|
| 1   | 1                       | 1                                   | 1                       | 1                                     | 1                                |
| 2   | 0.654                   | 0.788                               | 1                       | 1.1                                   | 1.1                              |
| 3   | 1.1                     | 1                                   | 1                       | 1                                     | 1                                |
| 4   | 1                       | 1                                   | 1                       | 1                                     | 1                                |
| 5   | 1                       | 0.878                               | 1                       | 1                                     | 1.1                              |
| 6   | 1                       | 1                                   | 1.1                     | 1                                     | 1                                |
| 7   | 1                       | 1                                   | 1                       | 1.1                                   | 1                                |
| 8   | 1                       | 0.689                               | 1                       | 1.1                                   | 1                                |
| 9   | 1.1                     | 1                                   | 1                       | 1.1                                   | 1.1                              |
| 10  | 1                       | 1.1                                 | 1.1                     | 1.1                                   | 1                                |
| 11  | 1                       | 1.1                                 | 0.777                   | 1                                     | 1                                |
| 12  | 1                       | 1                                   | 1                       | 1.1                                   | 1                                |
| 13  | 1                       | 1                                   | 0.657                   | 1                                     | 1                                |
| 14  | 0.654                   | 0.988                               | 1                       | 1.1                                   | 1.1                              |
| 15  | 1                       | 1                                   | 1                       | 1                                     | 1                                |
| 16  | 1                       | 1.1                                 | 1.1                     | 1                                     | 1.1                              |
| 17  | 0.789                   | 1                                   | 0.778                   | 1.1                                   | 1                                |
| 18  | 1                       | 1.1                                 | 1.1                     | 0.897                                 | 1                                |
| 19  | 1                       | 0.991                               | 1                       | 1.1                                   | 1.1                              |
| 20  | 1                       | 1                                   | 1                       | 1                                     | 1                                |
| 21  | 1                       | 1.1                                 | 0.512                   | 1.1                                   | 1.1                              |
| 22  | 0.899                   | 1.1                                 | 1.1                     | 1.1                                   | 1                                |
| 23  | 1                       | 0.798                               | 1                       | 1                                     | 1                                |
| 24  | 1                       | 1                                   | 1.1                     | 1.1                                   | 1.1                              |
| 25  | 1.1                     | 0.897                               | 1.1                     | 0.655                                 | 1.1                              |
| 26  | 0.564                   | 1                                   | 1                       | 1.1                                   | 1                                |
| 27  | 1                       | 0.533                               | 1.1                     | 1                                     | 1.1                              |
| 28  | 1                       | 1                                   | 1                       | 1                                     | 1.1                              |
| 29  | 1.1                     | 1                                   | 1.1                     | 1.1                                   | 1                                |
| 30  | 1.1                     | 1.1                                 | 1                       | 1                                     | 1                                |
| 31  | 1.1                     | 1.1                                 | 1                       | 1.1                                   | 1.1                              |