Study on the Impact of Additional Recycling Bins in Public Areas on Urban Waste Reduction and Recycling Rate Enhancement---The Case of Four Seasons Garden on Huamu Road, Pudong, Shanghai

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Abstract: This study examines the extent to which increasing the number of recycling bins in public spaces can reduce waste generation and improve recycling rates in urban areas, with a focus on the Four Seasons Garden community in Shanghai's Pudong New Area. Through a mixed-methods approach combining field surveys, GIS spatial analysis, and case comparisons, the research evaluates the impact of bin placement, accessibility, and public engagement on recycling behavior. Findings indicate that while additional recycling bins enhance convenience and encourage waste sorting, their effectiveness depends on strategic placement in high-traffic areas, public awareness campaigns, and active community involvement. The study also highlights the potential of smart waste bins equipped with IoT technology to optimize collection efficiency and support sustainable urban development. However, limitations such as small sample size and subjective usage assessments suggest the need for broader, technology-enhanced future research. The results underscore the importance of integrating infrastructure improvements with behavioral and policy interventions to maximize recycling outcomes in smart cities and circular economies.

1. Introduction

In the face of growing global waste creation and fast urbanization, sustainable waste management in response to the circular economy has emerged as one of the 21st century's biggest concerns. Waste management is the process of collecting, transporting, recycling, and disposing of waste materials to minimize environmental impact and promote resource conservation. It involves strategies like recycling, composting, and proper disposal to ensure public health and sustainability. With urban areas accounting for the majority of the waste production, cities must adopt innovative solution to manage their waste effectively. Recycling plays a key role in sustainable waste management by keeping waste out of landfills, saving natural resources and cutting greenhouse gas emissions. However, achieving high recycling rates in cities remains difficult due to issues like poor infrastructure, lack of public interest and some logistical problems.

One idea to boost recycling rates is increasing the number of recycling bins in public spaces. The principle is clear: making it easier and more convenient to access can encourage better waste sorting and also develop a sustainable habit. Public spaces such as parks, streets, and shopping areas will produce significant amount of waste. The addition of recycling bins at these locations will help to reduce the amount of waste collected for landfills while better recycling valuable materials.

This paper explores the placement of recycling bins in the Four Seasons Garden on Huamu Road in Pudong New Area, Shanghai, and therefore raises questions about the implementation of sustainable development in a circular economy. The interactions are far more complicated, even though it is assumed that the more trash cans there are, the better the results will be. The efficacy of this recycling program may be impacted by a number of factors, such as behavior, logistics, regulation, and even the issues related to excessive bin placement and its correlates. For instance, opinions about the ease of the recycling system and environmental consciousness influence the public's propensity to utilize recycling containers. Additionally, logistical considerations such bin placement, design, and upkeep are crucial. Policies like incentives, legislation, and public education can also strengthen or

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weaken initiatives.

This paper provides a mixed-methods approach to understanding the impact of adding recycling bins to public spaces. Through case comparisons, the paper aims to provide insights into practice, identify barriers to implementation, and make recommendations for improving municipal waste management systems. Ultimately, the research question of this paper is posed: to what extent increasing the number of recycling bins in public places can reduce municipal waste generation and increase recycling rates. What are the advantages that the establishment of new garbage cans will bring in the context of smart cities and circular economy.

2. Literature Review

2.1. The Relationship between the Number of Recycling Bins and the Amount of Waste Produced

Previous studies have confirmed that the number and location of recycling bins have a significant effect on the amount of waste generated. The study found that increasing the number of recycling bins in public areas has a significant effect on reducing the amount of waste generated[1]. According to their study, not only the issue of installing recycling bins has been deeply discussed, but also there is a research discussion on the impact of the placement and access of recycling bins on the recycling behavior of individuals. Specifically, if the number of recycling bins is high and the location of the bins is reasonable, then citizens will be very willing to dispose of recyclables in the bins instead of throwing them away randomly. Also mentioned this point in their study and they found that the addition of an additional recycling bin to a public environment reduces the amount of waste generated by an average of 5 percent. This confirms the strong negative correlation between litter generated and more recycling bins.[2]

However, the large number of recycling bins is not the only influencing variable, but also related to citizens' awareness of the environment and types of recycling bins (e.g., mixed and separate) contribute a lot towards a larger output of generated waste. [3] For example, a larger efficiency in recycling can be attained through separate recycling bins, but only when citizens have proper awareness and information regarding the environment. Thus, a larger number of recycling bins alone cannot contribute towards a significant output of less generated waste, and must accompany citizens' awareness and knowledge regarding the environment.

2.1.1. Number of Recycling Boxes

The number of recycling bins not only lessens generated waste, but it is also an important factor in enhancing the recovery rate. Uncovered that a larger number of recycling bins could effectively boost the recovery rate.[3] According to this research, for a single additional recycling bin in a public environment, recycling rates increased by an average of 3%. This finding discloses a strong positive association between the number of recycling bins and the recovery rate. In addition, corroborated this finding by citing that the contribution played by the number and positioning of recycling bins in boosting recycling rates is most significant in urban environments. [4] In urban environments, for example, with high density and high volumes of waste, a larger number of recycling bins can boost recycling rates effectively.

Moreover, stressed that between the level of recycling bins and the level of recovery, a nonlinear relationship prevails. In their view, when a critical level of recycling bins is reached, an additional increase in the level of recycling bins will have a less and less significant impact in terms of raising the level of recovery. [5] What such a conclusion signifies is that a level of recycling bins must have an optimal level such that an additional rise in the level of recycling bins will no longer be economically efficient.

2.1.2. Recycling Bin Layout and Public Behavior

The layout of trash cans is an important factor in shaping citizens' behavior towards recycling. Have found that both access and location of trash cans have a strong impact on citizens' behavior

towards recycling.[2] This mean when trash cans can be seen and accessed with easies, citizens will have a high willingness to dispose the trash in to the correct place. Study also emphasize that trash cans' location need to coincide with citizens' daily activity routes.[2] For example, Seattle Public Utilities (2019) emphasizes that positioning trash cans in crowded areas such as transit stations, parks, and shopping centers aligns with public activity routes and significantly boosts recycling rates [6].

However, have argued that the position of recycling bins is not a sole deciding criterion. [3] They consist that public awareness and environment-related customs also contribute a lot towards recycling behavior. For example, even when positioning of recycling bins is rational, efficiency in recycling will not necessarily be high when public awareness concerning the environment is low. Hence, city administrators have to promote public education and propaganda and, at the same time, make location improvements in relation to recycling bins. A real-world example of this can be seen in San Francisco, where the city implemented a policy to improve recycling by strategically placing bins in high-traffic areas such as transit stations, parks, and shopping centers. In addition to the bin placement, the city launched an extensive public awareness campaign that included advertisements, social media outreach, and educational programs in schools to encourage proper recycling habits. The results were promising—recycling rates in the city rose by over 30% within the first year of the policy implementation. This example highlights that while bin location is important, it is the combination of strategic placement and public education that leads to meaningful improvements in recycling behavior.

2.2. Why is This Relative to Smart City

In constructing a smart city, waste management intelligence is a crucial aspect to promote the efficiency of cities and improve the living standards of citizens. Literature has shown that installing more garbage cans and rationally arranging their layout is a realistic approach to effectively improving the efficiency of garbage sorting and recycling in cities . [3] By placing garbage cans in areas of high flow such as subways, bus stops, and shopping streets, cities not only improve the convenience of garbage collection, but also use sensor technologies to monitor the overflowing status of garbage cans in real time, thus realizing intelligent management. [2] The intelligent layout of garbage cans avoids waste overflow and increases recycling ratios in accordance with the concept of "efficient resource management" in a smart city. In addition, thanks to advances in big data and Internet of Things technologies, garbage discharge data can be collected and analyzed to support future garbage bin layout and resource allocation.[1] In this manner, installing more garbage cans and rationally arranging their layout not only increases the ecological efficiency of cities, but also supports the construction of a smart city

3. Methodology

In this study, field survey and GIS technology have been incorporated together to assess effectiveness of increased density of garbage cans in a residential community in terms of enhancing efficiency in recycling. First, ArcGIS software was used to analyze the geographic location data of the community, draw a community map, and mark the locations and uses of the trash cans. By comparing the data of foot traffic density, residents' activity trajectory, and distribution of existing garbage cans, the optimal location of new garbage cans is derived. Specific operations include (1) importing community geographic information (e.g., building distribution, street network, public space, etc.); (2) collecting data on pedestrian flow mobility; and (3) analyzing the trash can arrangement as well as evaluating whether the new trash can setup locations cover areas of high pedestrian flow and are evenly distributed. Once the new locations are identified, this paper hopes to conduct a three-month field intervention to collect the amount of waste generated and recycled before and after the intervention, and to evaluate the effect of the intervention through statistical analysis for subsequent research. This study will also analyze the data on trash cans created by the authors in an excel spreadsheet to determine the current type of trash cans (e.g., recyclable, food waste), capacity (e.g., 120-140 L), and usage (e.g., "very good," "normal"). The study will also assess the management status of the garbage cans, including whether volunteers or managers are involved in waste sorting. Finally, the study will also investigate the participation of residents in waste sorting, as this may affect

the effectiveness of recycling.

4. Results and Discussion

4.1. Recycling Bin Distribution

The results of field investigation show that the recycling bins in the Four Seasons Garden community of Huamu Road in Pudong New Area of Shanghai are mainly placed near the main pedestrian passage, which promotes the convenience of residents. Each bin has a capacity of 120-140 liters, suitable for typical community waste generation rates.[7] The observed recycling bins are effectively color-coded: black for non-recyclable waste and brown for compostable waste, in line with international standards established by organizations such as United Nations Environment Program and the World Health Organization, making it easier for residents to sort their waste.[8, 9]

Survey data showed that about 60 percent of recycling bins were rated as "very good" utilization, indicating active community involvement in waste separation. Instead, 40 percent showed "normal" use, suggesting that the area could benefit from greater public awareness or more strategic placement of bins. It is worth noting that all recycling bins are equipped with volunteers or managers, which greatly promotes the effective use of recycling bins. This finding highlights the critical role of management and active community involvement in successful recycling programs.[3]

A detailed examination of bin placement locations (latitude and longitude) reveals strategic positioning aimed at optimizing accessibility to residents and encouraging consistent use. In addition, all of the bins surveyed had active volunteers or managers monitoring usage, reflecting the efforts of the entire community to maintain effective recycling practices.

Through GIS analysis, spatial mapping of recycling bins in the Four Seasons Garden community of Huamu Road, Pudong New Area of Shanghai has identified locations with a low coverage of bins. As indicated in Figure 1, the current number of bins is not adequate in most high-traffic locations, particularly in the vicinity of community centers such as recreation spots and walking paths. Stipulates that the strategic deployment of more bins in areas where there is high activity can appreciably add to the efficiency of trash collection. For instance, the southern market entrance is directly linked with a principal traffic artery and experiences high foot traffic during peak hours, for example, morning and evening rush. [7] The inadequate provision of trash receptacles may cause overflows or improper disposal of garbage. Similarly, the central community square, which is used regularly for events and meetings, generates more rubbish than the current bin configuration can handle. Similarly, Tokyo’s waste management strategy emphasizes dense bin placement in residential areas with high pedestrian flow to maintain cleanliness, a practice that could inform improvements in Shanghai’s communities [10]. Additional recycling receptacles have been prioritized for installation in these communities, in order to more effectively meet community demands and encourage ongoing, sustainable waste management behaviors. Analysis of usage data shows that the effective utilization rate of garbage bins is consistently higher in areas with high pedestrian traffic. This finding highlights the importance of pedestrian convenience in promoting recycling behavior.[11]

Figure 1. Pudong New Area, Shanghai, China Sijiyayuan Trash Bin Spot Map (blue points)

The outcomes of this paper have crucial insights for policy makers and environmental advocates who seeks to design effective recycling programs. By highlighting the conditions under which recycling bin initiatives are most effective, it provides practical strategies for improving waste management systems and promoting sustainability in urban environments. Through this approach, it supports the move toward cleaner, more sustainable cities.

4.2. Bins and Smart Cities

With the rapid growth of economy, cities across the globe are looking for innovative ways to raise standards of living, optimize public services, and reduce environmental footprint. This trend has, therefore, given rise to the idea of smart cities—city regions with the incorporation of digital technologies, data analysis, and intelligent infrastructure that can better utilize resources and live sustainably.

The development of smart city solutions is apparent in various elements of everyday life. For example, smart transportation systems utilize real-time information to streamline the flow of traffic and minimize congestion; intelligent road lighting modifies light levels according to foot traffic to conserve energy; and smart water and energy meters enable households to track usage and prevent wastage. Not only does this make governance of cities more efficient, but it also enables citizens to become involved in creating more sustainable cities.

Building on this broader context, waste management is another critical area where smart technology can play a transformative role.

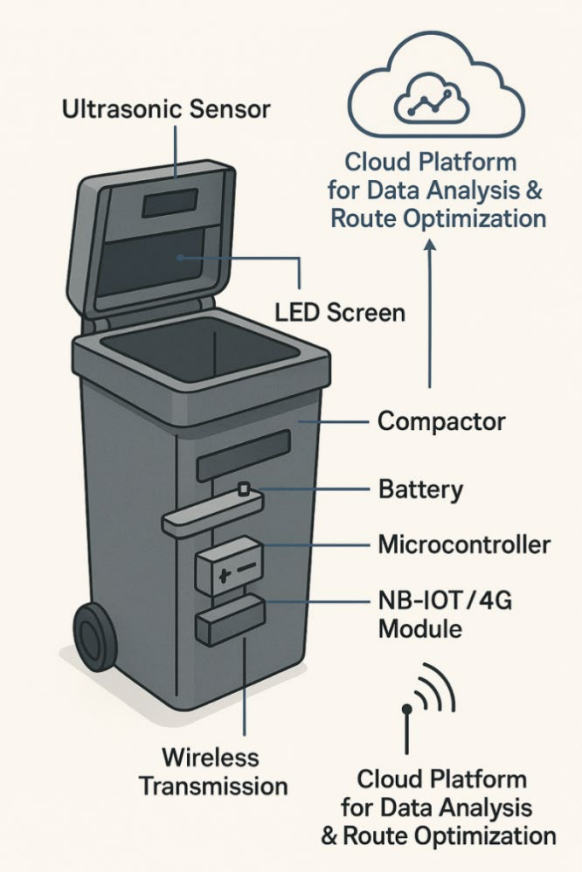

Figure 2. Example of Smart Trash Bin Sensing

In alignment with the development of smart cities, the incorporation of smart waste bins(figure2) can make waste management systems more efficient. For example, New York City's smart waste management initiatives, as documented in their 2020 annual report, utilize sensor-equipped bins to optimize collection routes and reduce operational costs [12]. This technology aligns with the vision of smart cities that detect fill levels in real time. When waste inside the bin reaches a pre-set threshold, the sensor triggers a signal that is transmitted wirelessly (usually via NB-IoT or 4G/5G) to a centralized cloud-based monitoring platform.

This platform aggregates data from all bins across the city and uses machine learning algorithms to optimize collection schedules and routes. Instead of sending garbage trucks on fixed routes, operators can now prioritize bins that are nearly full—reducing fuel consumption and operational costs. Additionally, some smart bins come with solar panels for energy autonomy, and compactors to compress waste, significantly increasing capacity before needing to be emptied.

Advanced models may also include RFID scanners to track what type of waste is being disposed, or digital displays to provide recycling instructions or environmental tips to users.

Since smart cities aim to utilize technology to enhance urban living, the implementation of such smart bins—especially in high-traffic areas like shopping districts, community centers, and transport hubs—helps reduce labor costs, avoid overflow, and improve public hygiene. Encouraging the use of smart waste bins is in line with China's national smart city development plan, and contributes to a more responsive, sustainable, and citizen-friendly urban environment.

Furthermore, the implementation of smart waste management systems aligns with the United Nations Sustainable Development Goals (SDGs), specifically Goal 11: Sustainable Cities and Communities and Goal 12: Responsible Consumption and Production. By improving waste segregation, simplification of collection procedures, and minimization of environmental effects, these initiatives go a long way in promoting the general objective of realizing sustainable urban development.

4.3. Implications

With growing environmental issues and the rise in urban wastes, the establishment of efficient recycling systems has become a necessity and not a choice. There is a need to foster the circular economy that seeks to get the most out of resources, minimize waste, and encourage sustainable consumption. [12] In the desire to create more sustainable cities and societies with reduced carbon footprints, the deployment of smart waste bins is not just a technological advancement but also an essential facilitator in achieving sustainable development goals.[9, 12]

To encourage the extensive and successful utilization of smart waste bins, a multi-level collective effort is needed—mobilizing action from national governments, local communities, and individual citizens.

4.3.1. At the National Level

It is essential that governments play a leading role in establishing the policy framework and institutional support. National governments need to establish clear standards and guidelines for smart waste management technologies, incorporating these into overall urban planning and sustainability initiatives. [13] Investment in digital infrastructure, such as Internet of Things (IoT) networks and cloud computing platforms, needs to be boosted to facilitate real-time tracking and data analysis.[8] As part of China's national strategy for the development of smart city projects, financial subsidies or incentives can be provided to local government agencies or private enterprises to encourage the installation of smart recycling infrastructures.[7] Additionally, it is important to initiate national campaigns in education to promote public awareness of responsibilities of recycling and the environmental gains associated with effective waste management.[3]

4.3.2. At the Community and Social Level

Local governments, property management bodies, and social organizations must work together to ensure on-the-ground implementation. Urban communities would have to integrate smart waste bins in residential areas and commercial locations based on population density, pedestrian traffic, and waste generation patterns. [14] PPP can be launched to minimize operational expenses and foster technical efficiency.[8] The environmental NGOs and civil society groups can be effectively used to conduct outreach, community recycling initiatives, and monitoring the performance of smart waste infrastructure. [9] Efforts should also be made to link smart waste systems to existing environmental credit systems or green lifestyle programs in order to encourage long-term behavior change.[15]

4.3.3. At the Individual Level

The success of smart recycling systems ultimately depends on public participation. Individuals must cultivate stronger environmental awareness and a sense of civic responsibility.[3] Citizens should be encouraged to sort and dispose of waste correctly, follow bin use regulations, and engage in recycling in a positive way. Online platforms like mobile applications connected to smart garbage bins can educate and encourage users by making them aware of their recycling behavior or incentivizing environment-friendly activities in terms of reward points.[7] Realizing the vision of a truly circular and resource-efficient world relies on every individual considering waste segregation as a normal part of their routine life.[8]

By bringing into effect a combined strategy that coordinates top-down policy direction with bottom-up behavioral changes, smart waste bin systems can be instrumental in augmenting urban environmental management and accelerating the transition towards a sustainable, smart, and livable tomorrow.[15]

4.4. Limitations and Research Difficulties

Despite the positive results, some limitations were encountered during the study. First, the sample size was relatively small and limited to a single residential community, which limits the generalizability of the findings in a broader urban context. The number of bins surveyed is limited and may not adequately represent the different recycling behaviours in different urban Settings. To address this limitation, future studies should expand the sample size to include multiple communities with diverse demographic and socio-economic characteristics. Incorporating data from various residential areas can enhance the external validity and applicability of the findings to other urban environments.

Second, the assessment of bin usage is largely observational and subjective, relying heavily on the judgment of volunteers and investigators. Quantitative measures such as waste weight or filler level sensors are not used, which may result in inaccurate or biased reported utilization. o overcome this, future research should employ objective monitoring technologies, such as smart bins equipped with IoT-based sensors that can record real-time fill levels and waste types. Integrating automated data collection methods would reduce observer bias and provide more accurate and consistent measurements.

In addition, the absence of a temporal dimension to address waste disposal patterns limits the ability of the study to determine changes in bin use at different times of the day or week, which can have significant implications for management strategies. Future studies should incorporate temporal analysis by collecting data over extended periods to identify patterns in waste disposal, enabling the development of adaptive waste management strategies that account for peak usage times.

Future studies should incorporate quantitative, objective bin utilization measurements, larger and more diverse sample groups, and comprehensive temporal analysis to improve the robustness and generalizability of the findings. By addressing these limitations, future studies can provide more reliable insights into community recycling behaviors and optimize waste management policies effectively.

5. Conclusion

This research aimed to explore to what extent increasing the number of recycling bins in public spaces could reduce waste generation and improve recycling rates in urban communities. Based on the combination of field surveys, GIS spatial analysis and evaluation of bin usage within the Four Seasons Garden community in Shanghai, in can be concluded that increasing in bin availability—when combining with strategic placement and public engagement—can positively influence the recycling behavior and promote more effective waste management.

The results indicate that while adding more bins can improve accessibility, the real impact can be only achieved when this is coupled with public awareness, maintenance and location design that matched to human activity patterns. This aligns with the finding which emphasize the importance of

behavioral factors in successful recycling outcomes.[3] The study took a small-scale approach to reflect on how circular economy principles and the United Nations sustainable development goals can be implemented in everyday urban life. The community investigation also illustrates that localized waste management can contribute to broader sustainability agendas. The results met initial expectations that physical infrastructure affects human behavior but also revealed the limits of infrastructure alone does not achieve maximum recycling rate which highlights the need in integrating both social and technological approaches.

Although this research was limited to one residential community, the methodology effectively addressed the research question and provided practical insights into urban recycling strategies. Based on the evaluation, practitioners should consider improve infrastructure designs, locations and the amounts while providing educational and policy-based initiatives to maximize recycling efficiency in urban environments.

By focusing on a local urban context, this paper contributes a grounded citizen level perspective to discussion about recycling and sustainability. It demonstrates how the circular economy is not just a policy but can be embedded in everyday life thus making global goals tangible at local level.

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