Economic Incentives for Recyclable Waste Separation and Recycling in China

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Acknowledgments

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EXECUTIVE SUMMARY

The rapid economic development and urbanization in China, engender new requirements for environmental management in the new era. In 2017, the enactment of a mandatory policy on waste separation in Chinese cities was followed by a series of policies and measures aimed at achieving the formation of behavioral habits of urban residents in waste separation. This thesis attempts to answer the question of Whether economic incentives, as a tool for waste separation, have been strongly implemented in China has been determined, and the current operation status and factors affecting the operation have been clarified.

Firstly, conducted a review of academic papers and literature. At first, it summarized the literature related to waste separation in China and clarified cases and reasons for failures in waste separation. Next, it organized literature regarding economic incentives and waste separation and explained the role of economic incentives in waste separation systems. Following that, it compared operational models and their advantages and disadvantages of economic incentives in other countries. Finally, it explored the potential of economic incentives from multiple perspectives including policies and regulations, management institutions, scope, funding mechanisms, technology, stakeholder collaboration, resident participation rates, and recycling rates.

Secondly, analyzed the economic incentive in China's waste separation, especially focusing on the current mainstream point system. Initially, it revealed that there were 466 resource waste separation point system projects in China from 2019 to 2022, using data from China's Tender Information Network. It examined the characteristics of 46 cities that are implementing waste separation projects as a national policy (mandatorily) and analyzed the indicators affecting the operation with Ordinary Least Squares (OLS). Furthermore, this chapter examined the roles of various stakeholders in the implementation of these systems from multiple angles.

Finally, based on the findings of the last chapter, to verify whether incentive mechanisms can motivate residents' waste segregation behavior in the long term. waste separation activities were investigated in the city of Dongying, China, to implicate how local community residents' waste separation participation and collection activities change over time cross-sectionally under the influence of a point system, a financial incentive mechanism. A least squares dummy variable (LSDV) analysis was used to investigate local waste separation behavior in 98 communities over a 22-month period. The results showed that community residents' waste participation and recycling behavior tended to grow in the early stages and gradually showed saturation and no growth in the middle and later stages. This result implies limitations of the incentive mechanism, for example, it can only motivate a proportion of residents to participate in waste separation; for those residents who are not affected by the financial incentive, it is recommended that education or coercion be used to get them to separate their waste.

Keywords: Waste separation and collection, economic incentive, point system, regression analysis, China

Chapter 1 Introduction

This chapter provides the dissertation overview and covers the research background, objective, and questions. It presents the research methodology and framework, an introduction to the case study area, and how data were gathered. Additionally, it provides the significance of the study and a brief introduction to each thesis chapter.

1.1 Research Background

Effective solid waste management is critical for achieving sustainable development in municipalities. Urban cities worldwide have grown significantly in the last half-century, and experts forecast that this trend will continue. Increased populations and rapid urban buildup put enormous stress on municipalities, especially in developing countries (Hondo et al. 2020). Without proper solid waste management services and practices, there is little chance of achieving the related Sustainable Development Goals (SDGs).

Globally, over 2 billion people lack access to basic household solid waste collection services (UNEP and ISWA 2015). In Asia, except for a few high-income countries, such as Japan, the Republic of Korea, and Singapore, collection rates are low, with only 44% in South Asia and 71% in East Asia and the Pacific (World Bank 2018). As a result, open dumping of waste continues to be the most deployed waste management approach, especially in cities in low- and middle-income countries, including 79% in South Asia, 64% in Southeast Asia, and 51.5% in South and Central Asia (World Bank 2018).

In Asia, an estimated 1.2 billion tons of municipal solid waste was generated in 2016, and this figure is anticipated to increase to 1.5 billion tons by 2030 and 1.9 billion tons by 2050 (World Bank 2018). Despite this alarming increase, managing municipal solid waste (MSW) remains a low priority for most Asian cities. Moreover, municipal solid waste disposal in Asia relies heavily on landfill sites due to lower costs than recycling, incineration, or composting (Hondo et al. 2020). Rapid urban expansion, failure to separate waste at source, complicated collection processes, open dumping, and unregulated GHG emissions are critical problems exacerbating Asia's solid waste management problem (Dhokhikah and Trihadiningrum 2012).

An effective and simple measure lacking in most developing countries is the concept of waste separation. When adopted, it greatly reduces the amount of waste destined for dumpsites. However, residents are not motivated to change their consumption habits and waste disposal practices due to a lack of information about the negative health and environmental implications of ever-expanding landfill sites and open dumping (Hondo et al. 2020). Additionally, because of the lack of coordination between various industries and gaps in the current policies toward improving solid waste management problem, it is challenging to convince citizens to adopt better household practices, such as sorting and recycling. Citizens need to be informed about the importance of waste separation and should be accountable for their waste disposal practices.

In 2017, the central government of China mandated waste separation policies, under which local governments, pressured by a "top-down" approach, initiated numerous measures to promote waste sorting behaviors among residents. The ensuing economic incentive systems for waste separation across various cities in China have surfaced several questions: Can economic incentive systems genuinely motivate residents to participate in waste separation? Will residents develop a habit of waste separation due to these incentives? Have other developed countries like Japan and South Korea previously implemented such measures to promote waste sorting among their citizens? Can these economic incentive systems assist with waste management in China effectively?

Against this backdrop, this study delves into the effectiveness of economic incentives on waste separation, contrasting the waste separation economic incentives of other countries, discussing the economic incentive-based waste separation practices adopted in China, and evaluating their applicability in different regions/cities. Furthermore, this research explores the operation modes and costs, and through case studies, examines the consistency and regularity between different cities within the economic incentive models.

1.2 Research Objective and Questions

As the most populous country in the world, China's waste management strategies have a profound impact on global environmental protection. According to research by Zhang et al. (2019), China is one of the largest waste producers globally, and its methods and strategies in waste handling demonstrate exemplary effects on global environmental governance. Additionally, China's innovative policies in the field of waste classification and recycling deserve in-depth study. The "Internet+ Recycling" model, as described by Wang et al. (2021), which utilizes smart recycling bins and mobile applications to encourage public participation, represents a unique practice compared with other developing countries.

China's unique socio-cultural background and rapid urbanization process have significantly influenced waste management and recycling strategies. Zhao et al. (2019) emphasize the importance of understanding this cultural background in designing and implementing effective economic incentive mechanisms. China's rapid urbanization has brought new challenges in waste management and resource recycling, as noted by Chen et al. (2022), who point out that this process presents new requirements for the effective implementation of waste classification and recycling strategies. This not only helps to thoroughly understand the uniqueness and strengths of the Chinese model but also provides a reference for other countries in environmental governance. Therefore, researching China's economic incentive model for waste classification and recycling is of significant theoretical and practical importance for promoting environmental protection and sustainable development in China and globally.

Basic on the background, the **Research objective** of this study aims to investigate the economic incentive model for waste separation and recycling currently operational in China. Through review and analysis of diverse literature (academic studies and grey literature, such as policy documents, reports by government, industry and research institutes and web pages), the operating mechanism of this model and its role in behavioral intervention are clarified. Additionally, through case studies, the factors affecting its operation are identified. By conducting a comparative analysis with the reward mechanisms implemented in other countries, the study ultimately seeks to analyze and identify an economic incentive model for waste sorting that is suitable for China. Detail research questions need to be clarified as following:

Research Questions:

- **Operational Dynamics and Outcomes:** How do these economic incentive waste separation models operate and what are the outcomes and operational costs associated with them?
- **Consistency and Regularity:** Is there consistency and regularity in the economic incentive waste separation models across different cities?
- **Longevity and Profitability:** What is the longevity of the economic incentive waste separation model in shaping waste separation behaviors and is it profitable?
- **Government Role and Specificity:** Is it a government initiative and is it a unique method of waste separation to China?

The focus of this study is twofold: Firstly, it describes, through a literature review, four typical waste collection incentive models around the world and exemplifies their operating mechanisms and influencing factors. Subsequently, the research examines the waste classification incentive models currently in operation in China and discusses the differences between models supported by mandatory policies in cities and those in cities without such policies. It will categorize these models and identify the factors that influence their development.

1.3 Research Methodology and Framework

1.3.1 Research Methodology

Referring to the above research objectives and questions, this study primarily employs the following research methods to collect and analyze data. The specific content is as follows:

1.3.1.1 Data Collection

(a) Literature Review

Based on the provided documents, this study primarily employs methods of literature review to collect detailed information about the point systems in different cities. Through an in-depth examination of government reports, academic articles, policy documents, and other relevant publications, this study can gain a comprehensive understanding of the operational status and effects of the various point systems.

(b) Secondary Data Review

Secondary data are collected by obtaining and reviewing relevant documents, records, files, and related studies. Through secondary data collection, the concepts and theories related to economic incentive waste separation systems such as bonus point system, point system, and Green banks are reviewed for a better understanding to develop research theme, questions, and analytical framework. Moreover, both qualitative and quantitative data on economic incentive waste separation systems policies, approaches, and their operation information were collected through the records from the China Tendering and Bidding Information Network and other relevant reports.

(c) Case Studies

By conducting detailed analyses of specific case studies of point systems in selected cities, this study can delve into the practical operations and implementation challenges of these systems. Case studies allow for an in-depth comparative analysis of point systems in different cities, revealing the strengths and weaknesses of these systems.

(d) Field Observation

The field observation was done to visually inspect the existing condition of point systems, the characteristics of the research location and its surrounding environment, and to obtain actual operational data through conversations with responsible personnel. Data on the community environment and operational characteristics obtained from field observations will be analyzed as data on influencing factors in Chapter 4.

1.3.1.2 Data Analysis

The focus of data analysis is to perform detailed examinations of the collected data using both quantitative and qualitative methods. By conducting comparative analyses of different cities' point systems, this study aims to uncover common patterns and significant differences in the implementations of these systems and assess how these differences impact the effectiveness of the systems.

(a) Modeling

To predict the long-term effects and sustainability of various point systems more accurately, this study will also employ modeling methods. By constructing precise mathematical models and running multiple simulation scenarios, this study can assess the impacts of different system variables on waste separation and recycling rates. The detailed modeling was described later in Chapters 3 and 4.

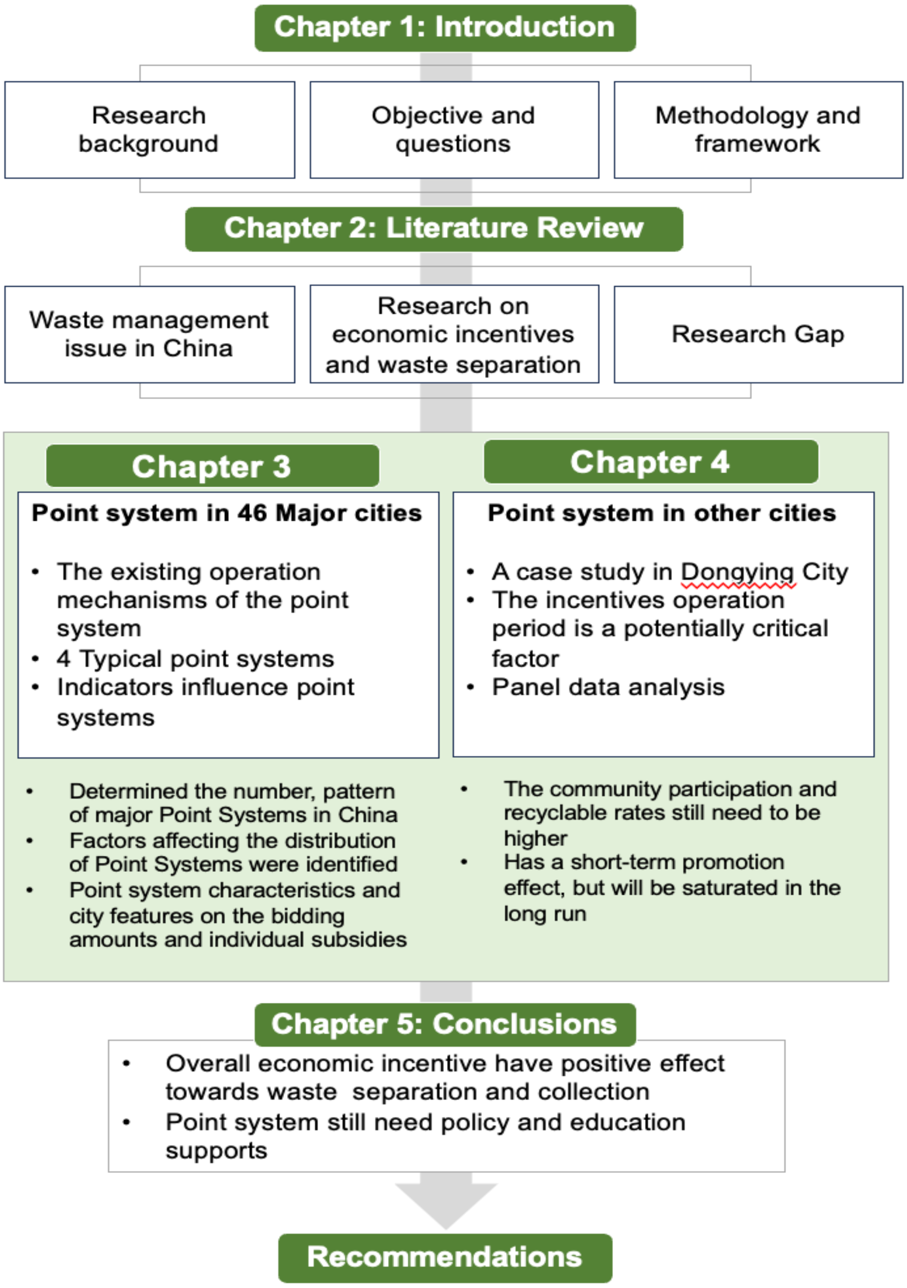
(b) Descriptive analysis

The descriptive analysis is mainly applied in this research in which the qualitative analysis is for the description and analysis of the implementation process and the mixed-method analysis is used to delineate the specific characteristics of different point systems and describe attitudes towards the reward mechanism from the perspectives of government, enterprises, and residents. Detailed explanations concerning data collection, as well as the analytical frameworks for each research objective, will be elucidated separately in Chapters 4, 5, and 6 respectively.

1.3.2 Research Framework

The research starts with a holistic approach by analyzing the policies and context of waste separation and recycling in China and focuses on the point systems across various cities. It initiates a comprehensive literature review on waste separation issues and economic incentives in China, focusing on their applications and impacts in waste management systems.

Thesis Structure:



This thesis is structured into five main chapters, each detailing a critical aspect of the research.

Chapter 1: Introduction
This chapter lays the foundation of the research, providing the background, defining the research questions and objectives, detailing the research framework and methodology, highlighting the significance and innovations of the research, and outlining the structure of the thesis.

Chapter 2: Literature Review
This chapter offers a comprehensive review of existing literature on waste separation issues in China and the role of economic incentives in waste separation. It delves into various subtopics such as waste separation and collection and economic incentives in the waste separation system, culminating in a summarized view of the existing knowledge base in the domain.

Chapter 3: Economic Incentives for Waste Separation in China: Point System
This chapter provides an in-depth analysis of the point-based waste separation systems in China, discussing their distribution, types, and key influencing indicators. It also examines the role of different stakeholders in the implementation of these systems and evaluates their effectiveness and impact on waste separation and recycling practices.

Chapter 4: An Empirical Study of Economic Incentives for Waste Separation in China
This chapter conducts an empirical study on the point systems, focusing on their operational mechanisms, effectiveness, and impacts. It employs various research methods to analyze the collected data and draws insights into the operational success and areas of improvement for these systems.

Chapter 5: Conclusions
The concluding chapter summarizes the key findings of the research, offers recommendations for improving waste separation and recycling practices, discusses the limitations of the study, and suggests avenues for future research.

1.4 Research Significance and Innovation

The primary significance of this study stems from its exploration of economic incentives, specifically focusing on point systems, in fostering waste separation and recycling habits in China.

(a) Academic Contributions:

The research expands the existing body of knowledge by presenting a nuanced understanding of the economic incentives for waste separation in China. It delves into the operational mechanisms, effectiveness, and impacts of point systems, offering a multidimensional perspective on their role in promoting sustainable waste management practices. Furthermore, the study reviews and summarizes the waste recycling incentive system models of other countries that have achieved positive results, exploring the influencing factors of different models.

(b) Practical Contributions:

First, establishing Baseline Information. The research illuminates the existing practices, policies, and demands related to waste separation and recycling in China, addressing the scarcity of consolidated academic literature on this subject. It provides comprehensive insights into the current state of waste management, uncovering the intricacies of various incentive-based models employed across different cities. Second, enhancing Policy and Implementation Strategies. The insights derived from this study could potentially shape future waste management policies and strategies in China and other countries facing similar challenges. Identifying the strengths and weaknesses of the current models, provides a roadmap for optimizing waste separation and recycling systems, aligning with sustainable development goals and environmental conservation needs.

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Chapter 2 Literature Review

This chapter provides a literature review of concepts and theories related to the economic incentive for waste separation. It commences with issues pertaining to waste classification management in China, followed by a discussion on the concept of incentive measures and their application in waste separation. Subsequently, it delves into different types of incentive measures, the factors influencing them, and the challenges faced during implementation. Additionally, this chapter discusses case studies of economic incentives of waste collection in other countries around the world.

2.1 Waste Separation Issue in China

China's solid waste problem has become increasingly challenging as it promotes new urbanization (Tan et al., 2021). According to statistics, more than 10 billion tons of solid waste are added to China each year, with a total historical stockpile of 60–70 billion tons (Han et al., 2022). In addition to putting cities in a garbage siege, this poses a serious threat not only to the health of individuals but also to the development of a sustainable economic and social system as well as ecological civilization.

Waste separation is crucial for economic productivity and human well-being; however, addressing the issues of waste separation and forming a habit are challenging tasks in China (Cheng et al., 2022). To enhance equity, economic productivity, and environmental sustainability, addressing the waste sorting issues among urban residents is imperative. This implies higher living standards and a better living environment.

According to statistics from the Ministry of Environmental Protection, 256 medium or big cities in China generate nearly 180 million tons of garbage every year. At the current rate of growth, China's municipal solid waste production will reach 4.09 million tons by 2030 (Guo et al., 2017). While the potential environmental harm of garbage is less than that of wastewater and gas, harm may nonetheless be long-lasting on both human health and the environment (Siddiqua et al., 2020). The rapid growth of municipal solid waste not only increases the pressure on the prevention and control of pollution but also incurs public costs and environmental management (Hong et al., 2017). Landfill and incineration currently make up 98% of China's municipal solid waste treatment (Ding et al., 2021). The use of landfills results in the release of large amounts of CH4 and N2O, and smoke, fly ash, and slag.

In the waste management hierarchy, waste reduction is usually placed at the top, followed by reusing and recycling. Preferably, recycling or recovery of waste should be resorted only after doing everything possible to reduce the amount of waste at source (Yau, 2010). In view of the urgency created by limited landfill space and air pollution from incineration, waste recycling has been taken as an intermediary measure to tackle the waste problem. Aimed fundamentally at reducing environmental impact and fostering sustainability, waste recycling not only conserves energy and resources but also minimizes emissions from incineration and extends the operational lifespans of landfills (Ding et al., 2021; Reza, 2023).

Despite the advantages, the promotion of recycling is not an easy task. One should bear in mind that the success of waste recycling in a society is not only ascribed to the efforts paid by the Government but also the active participation of the general public (Gibovic et al., 2021). However, like other pro-environmental activities, the effectuation of waste recycling relies on collective action. With these characteristics, waste recycling is highly prone to a free-rider problem (Yau, 2010).

China has performed garbage collection and recycling operations for over ten years with less than satisfactory results. Some garbage is only classified into two types: dry and wet. What is worse, an amount of domestic garbage is not sorted before being thrown away, and toxic and harmful substances may be present in waste materials (Li et al., 2021). Tracing it to its cause, most old refuse classification models were in the form of top-down administration models. Citizens were required to carry out the rules directly and as instructed, which ignored their stake in the process. Therefore, a new type of waste management model is urgently needed (Guo et al., 2017).

2.2 Research on economic incentives and waste separation

Implementing urban waste separation policies is crucial, and a key and effective strategy is to utilize economic incentives for waste separation.

2.2.1 Economic incentives

Economists often emphasize that "incentives matter." The basic "law of behavior" is that higher incentives will lead to more effort and higher performance (Gneezy, et al., 2011). Employers, for example, often use extrinsic incentives to motivate their employees. In recent years, the use of incentives in behavioral interventions has become more popular. Will financial incentives encourage higher contributions to public goods? Should programs to reduce smoking or to encourage exercise include a monetary incentive? These applications of incentives have provoked heated debate. Proponents of using incentives in behavioral interventions argue, for example, that monetary incentives can be helpful in getting people to study or exercise more (Thogersen, 2005). Opponents believe that using incentives in those areas could backfire, because extrinsic incentives may in some way crowd out intrinsic motivations that are important to producing the desired behavior (Gneezy et al.,2011; Varotto & Spagnolli, 2017).

2.2.2 Economic incentive in waste separation system

A variety of incentive-based strategies have been applied to encourage domestic waste separation. Their effects are also analyzed by field studies, suggesting that, (1) the overall effectiveness of economic incentives is still inclusive (Yau, 2010), with quite a few studies failing to demonstrate the successfulness of economic instruments in increasing waste separation behavior (Timlett and Williams, 2008); (2) individual-based incentives are usually more effective than those contingent on group performance (Harder and Woodard, 2007); (3) incentives could achieve more for residents with lower initial separating rate (Harder and Woodard, 2007).

2.2.3 Different types of Economic incentives waste separation system

There are several different types of economic incentives in the waste separation system. The detailed information will be shown as follows.

(1) Deposit-refund system – Sweden, Germany, the United States

A deposit-refund system (DRS), known as a deposit-return system, advance deposit fee, or deposit-return scheme, is a surcharge on a product when purchased and a rebate when it is returned. To solve the problem of end-of-use beverage packaging, many countries have built deposit-refund systems based on the principle of extended producer responsibility (EPR), which mainly includes advanced recycling fees, and subsidies for returns (Pires et al., 2015; Zhou et al., 2020; Figure 2.1). Many studies have shown that an appropriate deposit-refund system is the desirable economic environmental instrument (Pires et al., 2015; Zhou et al., 2020; Linderhof et al., 2019).

Initially, the deposit-refund system was applied in Sweden, Germany, some states in the United States, and Canada. At present, more than 40 countries in the world have implemented a deposit-refund system for end-of-use beverage packaging (Zhou et al., 2020). The deposit-refund system has also been gradually applied to other products, such as lead-acid batteries, motors, fluorescent lamps, pesticide bottles, and tires (OECD, 2019), however, the deposit-refund system has been most used for beverage packaging (Hogg et al., 2010). The application of the deposit-refund system has greatly reduced pollution and effectively recycled many recycled materials (Linderhof et al., 2019). It has also brought employment to the low-income population.

In the countries/regions that implement the beverage packaging deposit-refund system, more than 50% of the beverage packaging recovery rate has been achieved, and the recovery rate is even more than 90% (Consulting and Reloop, 2016;). The mechanism of the beverage packaging deposit-refund system varies from country to country. Each country's beverage packaging deposit-refund system has its own characteristics.

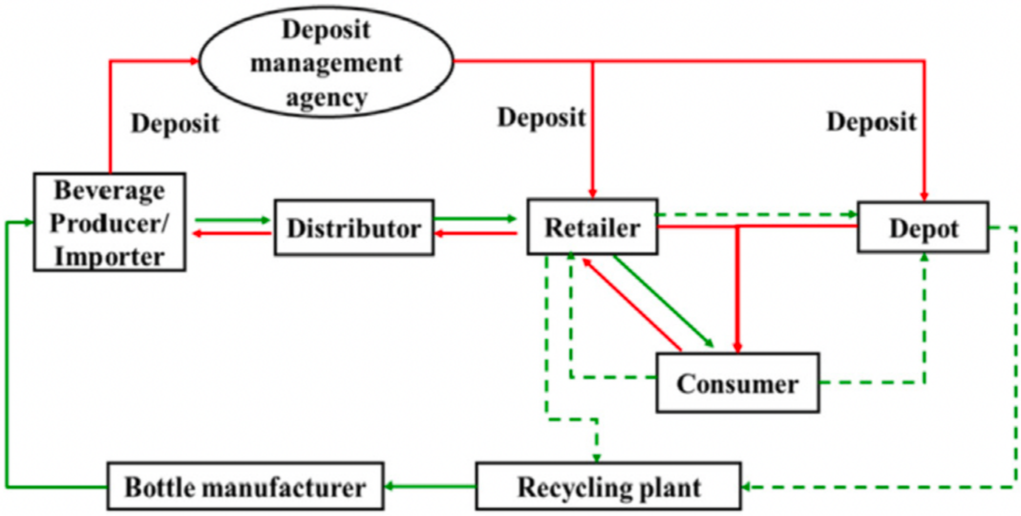

Figure 2.1 Operation mechanism of the beverage packing deposit-refund system

(Source: Zhou et al., 2020)

(2) Pay-as-you-throw (PAYT) –USA, Netherlands, Korea, and Japan

The definition of pay-as-you-throw (PAYT), also called unit-based pricing (UBP) program is a charging system in which people who dispose of waste are charged all or part of the waste treatment costs separately from their taxes (Yamakawa, 2003; Sakai et al., 2008).

The PAYT system of residential solid waste collection has been implemented in many parts of the world, including municipalities in the United States (Callan and Thomas, 2006), South Korea (Hong, 1999), the Netherlands (Dijkgraaf and Gradus, 2004; Allers and Hoeben, 2010) and Japan (OECD 2006; Usui and Takeuchi, 2012).

PAYT systems adopted in Japan can be roughly divided into two groups: simple unit-pricing programs and two-tiered pricing programs (Sakai et al., 2008). In simple unit-pricing programs, residents are charged in proportion to the amount of waste they generate for incineration and disposal, and the payment mechanism is simple, such as through the use of prepaid bags or stickers for waste. Normally, more than one size of bag is available in this type of program. Residents view this type of program as fair, and it is expected to be effective in reducing the amount of waste generated. Many municipalities have implemented this type of program. In two-tiered pricing programs, the rates charged for waste disposal change depending on the amount of waste generated. There are three types of two-tiered pricing programs. In the first type, the rates increase if a specified amount of waste is exceeded. In the second type, there is no charge up to a specified amount, but if that amount is exceeded, then there is a fee. The third type offers incentives to households that generate less than a specified amount of waste.

PAYT is thought to be an effective stepwise guiding policy for promoting the 3Rs. Changes in the mindsets of residents in response to PAYT have had an impact on waste control by reduction and reuse, which should be a priority of waste management. PAYT is also effective in promoting waste recycling. In particular, PAYT has had an enormous impact on waste reduction and recycling in combination with the use of complementary measures that also promote recycling (Oshima, 2006, Kusumoto, 2003).

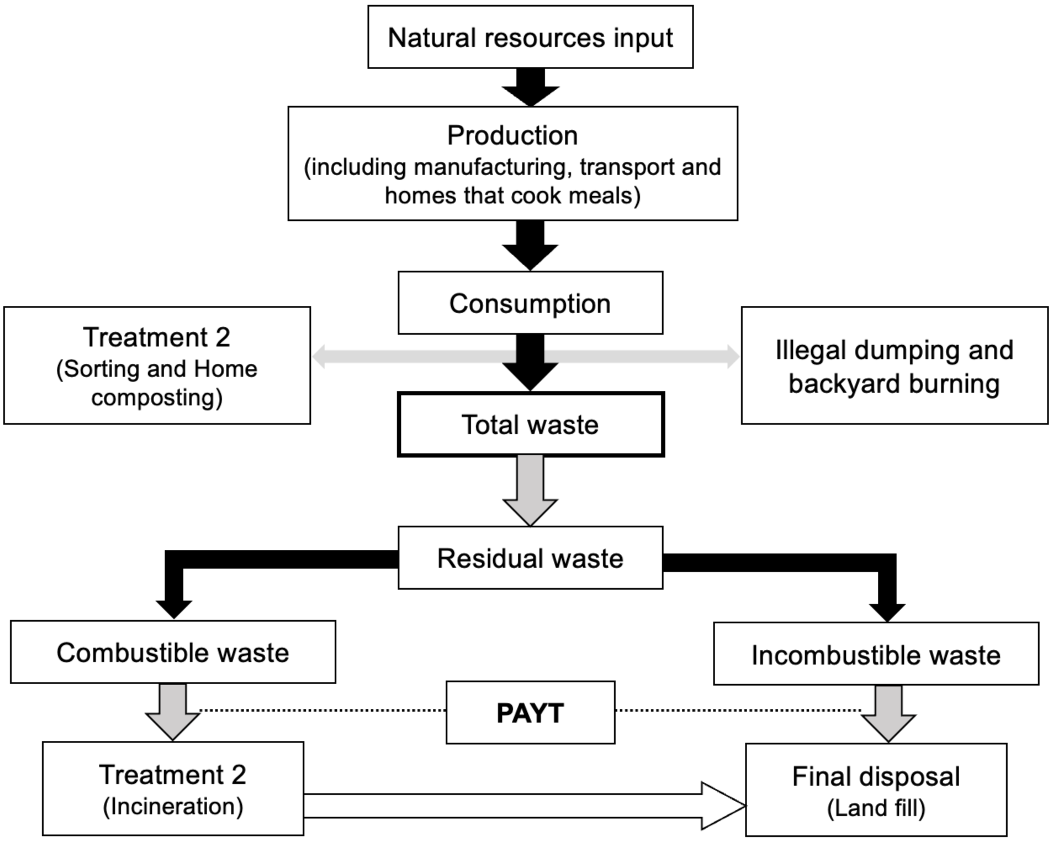

Figure 2.2 Operation mechanism of PAYT in Japan

(Source: refer to Sakai et al., 2008)

(3) Waste Bank -- Indonesia

Waste bank operates like a bank that people in a community, subdistrict, and district can use to deposit their garbage or extract money from the value of the garbage they provide to the facility (Wulandari et al., 2017; Kubota et al., 2020).

The management model of waste bank is almost the same as that of commercial banks where there are customers, bookkeeping, and management, in a commercial bank, the customer deposits money but in a waste bank customer deposits waste that has an economic value, while waste bank managers need to be creative and innovative and have an entrepreneurial spirit to increase income (Kubota et al., 2020; Figure 2.3).

Waste Bank developed in various cities in Indonesia such as in Bantul (2008), Malang (2010), Surabaya (2010), Gresik (2012), Cilacap (2012), Barat (2012) and growing to almost every city and regency in Indonesia (Khair et al., 2019).

The waste bank management model is not only helping to clean the environment but also has an economic benefit. Waste bank management model is also associated with the local community taking on and managing their own waste to reduce waste and also receive economic benefits. Khair et al (2019) describe the benefits of the waste bank to society not only helping to clean the environment but also extra cash for society. Waste bank teaches people to sort their waste, raising public awareness to process waste wisely to reduce waste going into landfill. The innovation of waste management through waste banks at the grassroots level can increase the income of poor people in the city (Wulandari et al., 2017; *Raharjo et al., 2020*).

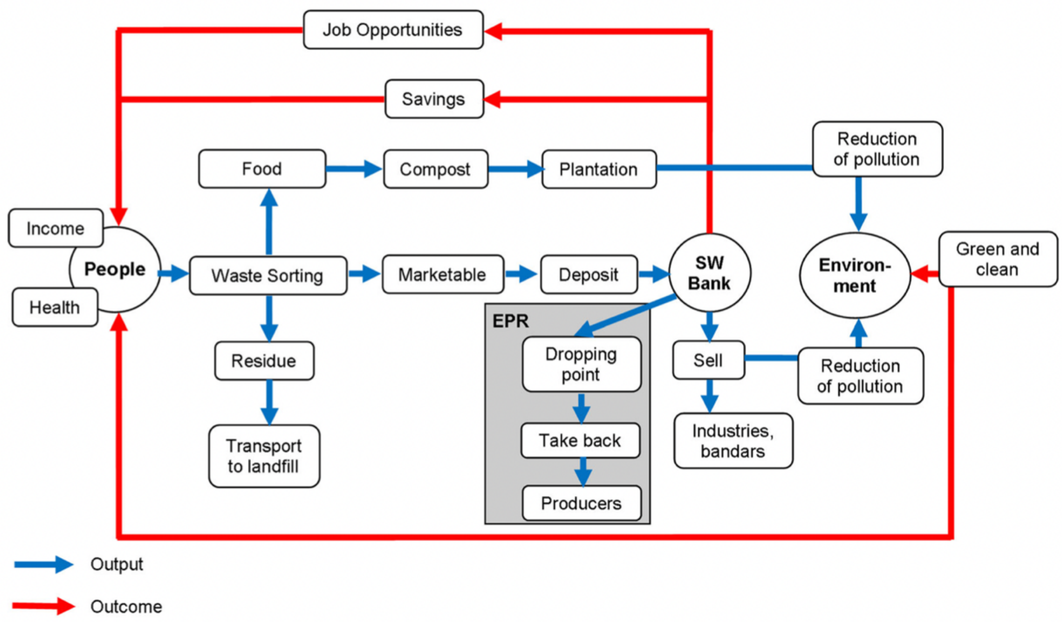

Figure 2.3 Operation mechanism of the Waste Bank

(Source: Raharjo et al., 2020)

(4) Bonus point system -- China

A bonus point system for refuse classification is an incentive system. Cities such as Beijing, Shanghai, Hangzhou, and Xiamen in China have employed these systems (Guo et al., 2017; Yan et al., 2021).

The intelligent garbage rooms of the system allow garbage identification, weighing, and bar code scanning, which are often placed near the gate of the quarter (In China, people often live in apartments. Usually, a quarter is made up of around 300 apartments, with 1000 residents).

For some big quarters, more than one intelligent garbage room will be used to minimize the distance garbage will need to be carried. Residents will be informed of the benefits of garbage sorting and some of the sorted garbage will be reused. The residents will receive different-colored bags, bar codes, and guide brochures.

An internet integration platform is used to keep track of bonus points and exchange the points for gifts. Before using the intelligent garbage room, residents must create an account on the internet integration platform. Residents take their sorted garbage to the intelligent garbage room, and the machine in the intelligent garbage room will identify the type of garbage and its weight. Residents will receive bonus points. By scanning the code, residents can credit their account. Finally, residents can exchange points for gifts through the platform. When using the platform, information about refuse classification is provided (Guo et al., 2017; Figure 2.3). The value of 1000 bonus points is equivalent to RMB 5 yuan, which can be used on the internet integration platform. In addition, residents can also use bonus points in designated supermarkets. There are also monthly, seasonal, and annual awards for people who earn the most bonus points.

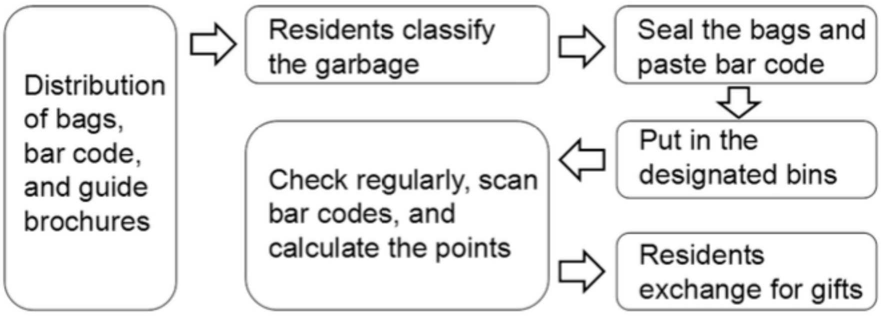

Figure 2.4 Operation mechanism of Bonus point system

(Source: Guo et al., 2017)

(5) Comparison of global economic incentive system for waste separation

Table 2.1. Comparison of global economic incentive system for waste separation

Type of Systems	Countries /Regions	System Description	Advantages	Disadvantages	Reference
Deposit-Refund System(DRS)	Sweden, Germany, USA	Extra charge on purchase, refunded upon return.	Effective recycling	Complex implementation, increase product cost.	Pires et al., 2015; Linderhof et al., 2019; Zhou et al., 2020
Pay-As-You-Throw (PAYT)	USA, Netherlands, South Korea, Japan	Charges are based on the amount of waste generated, promoting 3Rs.	Fair, effectively reduces waste volume.	Increase the burden on low-income households.	Yamakawa, 2003; Callan and Thomas, 2006; Sakai et al., 2008;
Waste Bank	Indonesia	Community service for depositing and extracting value from waste.	Cleans the environment, economic benefits.	Requires effective management	Wulandari et al., 2017; Kubota et al., 2020
Bonus Point System	China (Beijing, Shanghai, etc.)	Identification, weighing, and barcoding of waste in smart waste rooms.	Increases awareness of waste sorting, enables recycling.	Dependent on technology, requires internet platform support.	Guo et al., 2017; Yan et al., 2021

Table 2.1 summarizes and shows the definitions, advantages and disadvantages of the existing four economic incentive systems, which were introduced in the above content.

Firstly, the Deposit-Refund System (DRS) is widely implemented in Western countries, motivating consumers to recycle containers by setting product deposits. Its advantage lies in directly encouraging individuals to participate in recycling, thereby increasing recycling rates. However, promoting DRS in China may face challenges due to different consumer habits and inadequate recycling infrastructure (Cheng et al., 2023). Addressing these issues requires a deep understanding of local culture and social habits to formulate policies that better align with the actual situation in China.

Secondly, the Pay-As-You-Throw (PAYT) system incentivizes waste reduction by charging residents based on the amount of generated waste (Sakai et al., 2008). In China, due to differences in administrative enforcement and public awareness, the PAYT system may struggle to achieve its intended results. Effective implementation and widespread public awareness are key factors for the successful adoption of the PAYT system.

Waste banks, which reward waste recyclers with points or money, have been successfully implemented in Indonesia (Kubota et al., 2020). However, their success is partly attributed to the local economic and social structure, factors that may not be applicable in China. Promoting waste banks in China requires considering regional differences and adopting flexible strategies to adapt to local needs.

Lastly, the Bonus Point System incentivizes sustainable behavior by awarding points to waste segregators and recyclers. The system's advantage lies in cultivating public awareness and forming long-term habits, but its disadvantage is that noticeable effects may take time. In China, it is crucial to focus on promoting such reward systems among different groups to ensure widespread participation and maximize effectiveness (Guo et al., 2017; Yan et al., 2021). Therefore, this system has been introduced and is currently being popularized in China.

2.2.4 Elements of Economic Incentives Waste Separation System

(1) Policies and regulations

The effective management of solid waste is inseparable from the guidance of policy support. Policy text, as a carrier of policy information, is the basis for control, adjustment, and optimization of policy (Zhang, 2021). It is helpful to improve solid waste management by systematically reviewing the changing path of solid waste management policies and studying the focused content and development trend of solid waste management policies.

(2) Management institutions

The management institutions can provide scientific and reasonable standards and economic stimulation and guidance for recycling enterprises. Also, in order to involve stakeholders, the management institutions need to communicate with manufacturers, retailers, recycling enterprises, etc. The responsibility of the management institution is to coordinate the interests of recycling and act as effective supervisors Zhou et al., 2020. It should also act as a responsibility coordination platform for participants, by providing guidance on supporting policies to encourage stakeholders to bear the responsibility and obligation, and to promote the effective operation of the economic incentive waste separation system.

(3) Scope

Currently, most economic incentive systems for recycling mainly focus on resource waste or commonly used products with high recycling value. For instance, the scope of deposit refund systems typically pertains to beverage packaging. Based on the experiences of over 20 countries, including Germany, Norway, and Sweden, the deposit refund systems in most countries and regions were initially applicable to commonly used products with large production scales and high recycling values, such as plastic bottles or aluminum cans for beer and beverages. Beverage packaging mainly includes packaging for mineral water and various other beverages (Zhou et al., 2020). Waste banks accept recyclable waste, such as plastic, paper, metal, and glass. The price per kilogram varies for different types of waste, and the waste received from residents is weighed according to waste category, recording the total price of the received waste

(Kubota et al., 2020). Recyclable waste through the point system is also mainly focused on resource waste, such as glass, tubes, plastic bottles, and cans. Some electronic devices (WEEE) are also included, and although kitchen waste may also be recycled in some places, the points that can be exchanged may be quite low (Guo et al., 2017)

(4) Funding mechanism

For funding mechanisms, different systems often use different mechanisms to offset operating costs. For example, the deposit-refund system used unredeemed deposits and material revenue offset operating costs. Unredeemed deposit is the expense paid by the consumer for the pollution of the beverage packaging, which can used to cover the cost of recycling. Meanwhile, end-of-use beverage packaging has a certain value. In some countries, the finance and container recycling fees are also used to support the operating costs of the deposit-refund system (Zhou et al., 2020). Bonus point systems and waste banks primarily rely on government financial subsidies and income from resource waste to offset operating costs (Guo et al., 2017; Kubota et al., 2020).

(5) Technology

According to previous surveys, even in collection models with an incentive system, one of the main reasons for collection difficulties is the scarcity of recycling channels available to individual users (Gibovic et al., 2021). One possible approach to providing individuals with unobstructed channels is to utilize information technology to facilitate communication between recycling practitioners and the general public. From this perspective, technology plays a significant role in economic incentive waste collection models, and some new business models relying on 'Internet + Recycling' have emerged accordingly (Zhang, 2019; Uganya et al., 2022). Essentially, 'Internet + Recycling' is based on several online platforms where participants can schedule on-site waste collection or transactions. This model is becoming increasingly popular due to its convenience and accessibility, as anyone can register an account on these platforms and conduct transactions. Moreover, using internet models for waste recycling enables data tracking, which includes functions such as information collection, data analysis, and flow monitoring.

(6) Stakeholder cooperation and its role

Each incentive model operates differently, and given the varying national conditions and stakeholders involved, effective cooperation among relevant beneficiaries is essential to ensure the successful operation of the system. For instance, according to Zhou et al. (2020)'s description, stakeholders in the operation of the German beverage packaging deposit-refund system include the Producer/Importer, Distributor, Retailer, Consumer, Reclaimer, Service Provider, and Retailer/Counting center (see Figure 2.5).

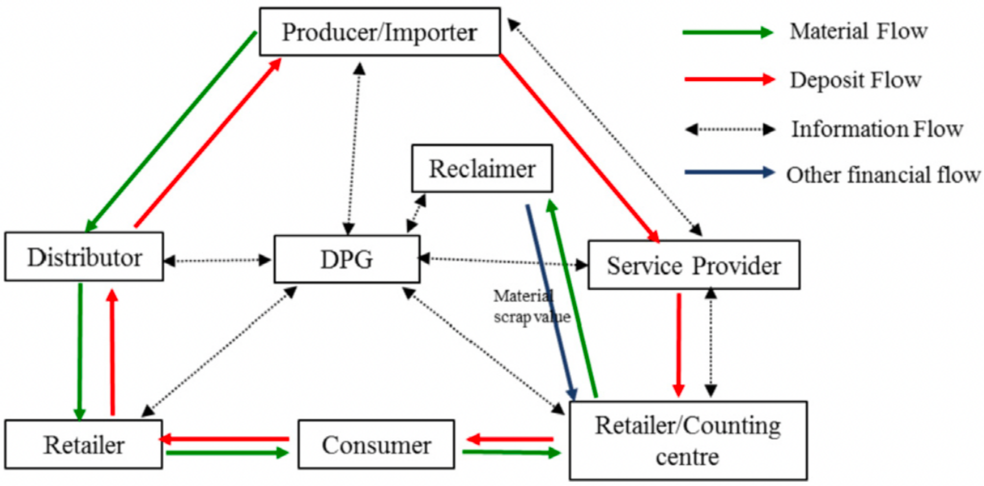

Figure 2.5 Stakeholders of the Germany beverage packing deposit-refund system
(Source: Zhou et al., 2020)

In Chinese cities like Beijing, Shanghai, and Hangzhou, stakeholders involved in the Bonus Point System include residents, the environmental protection industry, and the government sector (see Figure 2.6). The stakeholders involved in Indonesia's Waste Bank also include residents, the environmental protection industry, and the government sector.

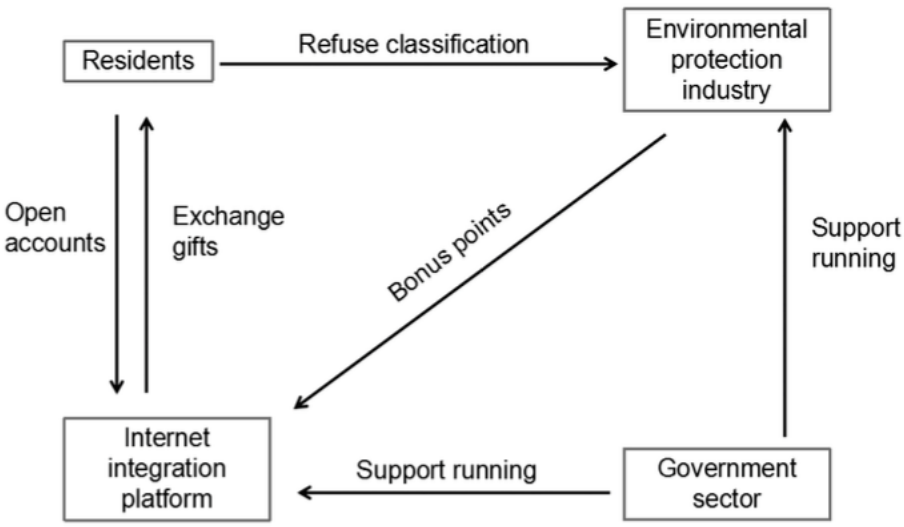

Figure 2.6 Stakeholders of the Bonus point system
(Source: Guo et al., 2017)

(7) Resident participation rate

Resident participation is one of the crucial indicators for validating the success of the incentive system model（Matsumoto, 2011; Zhang et al., 2015）. However, there are numerous factors influencing resident behavior in participating in household waste separation, such as convenience, short distances and strategic locations of recyclable collection points, accessibility and availability of waste bins, appropriate storage space at home, availability of curbside collection, high-frequency collection, clean appearance of recycling sites, and intelligent visual design of collection points (color, shape, capacity)（Knickmeyer, 2020）. Moreover, the easier the system is to understand and use, the more likely it is to be utilized, and vice versa. All these factors can potentially affect resident participation, even when reward points are offered. Therefore, it is necessary to consider these factors in addition to the reward points, to enhance residents' participation rate.

(8) Collection rate, recyclable rate and recyclable rate

Collection rate refers to the ratio of the total volume of waste collected by the recycling system（such as PAYT, and DRS）to the total volume of waste generated in a certain area. This rate reflects the coverage and efficiency of the recycling system. It can be calculated using the following formula:

Collection Rate = [Collected Waste Volume/Total Waste Generated] ×100%

A high collection rate indicates that a large portion of waste is being properly collected and managed, which is the first step towards achieving recycling and waste management goals.

Recycled rate refers to the proportion of waste that is recycled compared to the total amount of recyclable waste collected. This rate reflects the end-efficiency of the recycling system, namely the proportion of materials that are recovered from the waste stream and reused. It can be calculated using the formula:

Recycled Rate = [Volume of Waste Actually Recycled/Volume of Recyclable Waste Collected] ×100%

This rate is influenced by several factors, including the efficiency of recycling technology, market demand for recycled items, and losses during the recycling process.

Recyclable rate indicates the proportion of waste collected that is recyclable. Not all collected waste can be recycled, as it may be contaminated or technically unrecyclable. Therefore, the recyclable rate is usually lower than the collection rate. It can be calculated with the formula:

Recyclable Rate = [Volume of Recyclable Waste Collected/Total Waste Collected] ×100%

In summary, the collection rate, recyclable rate, and recycled rate are three different dimensions for measuring the effectiveness of waste management and recycling systems. Improving these rates is crucial for promoting the sustainable use of resources and reducing environmental pollution. Monitoring these indicators also helps policymakers and environmental managers to assess and improve recycling programs.

However, in the practical process of research and analysis, precise recycling data is often difficult to obtain. This situation can be caused by various factors: for example, the unavailability of data is often due to a lack of a unified and systematic data collection and management mechanism; meanwhile, private enterprises might be reluctant to share their recycling data publicly due to reasons such as trade secrets. Consequently, scholars and researchers typically have to rely on estimates or indirect data to analyze and evaluate the effects and impacts of various recycling models when conducting relevant research.

2.3 Summary

China grapples with an intensifying solid waste problem, contributing over 10 billion tons annually, with a historical accumulation reaching 60-70 billion tons. The pressing waste issue, beyond imposing a "garbage siege" on cities, jeopardizes individual health, sustainable economic and social development, and ecological stability. Although waste separation is vital for economic productivity and well-being, instilling a waste separation habit among the Chinese populace has proven to be a formidable challenge. The enormity of waste, if not managed effectively, threatens not only environmental health but also imposes economic strains and managerial burdens.

Economic incentives play a pivotal role in steering waste separation policies, with the foundational behavioral principle asserting that larger incentives yield greater effort and enhanced performance. While financial incentives have proven their efficacy in various behavioral contexts, their application in waste separation has yielded mixed results. The effectiveness, applicability, and potential pitfalls of economic incentives in waste separation warrant meticulous scrutiny to ascertain their validity in fostering pro-environmental behaviors and collective action.

The incentive system, such as Deposit-Refund Systems, Waste Banks, and Bonus Point Systems, has been implemented to stimulate domestic waste separation across various countries, including China and Indonesia. Each system operates on distinct mechanisms, ranging from surcharges and rebates in deposit-refund systems to a more bank-like operation for waste banks, and utilizing intelligent garbage rooms and internet integration platforms in bonus point systems. However, the ubiquitous challenge across these systems remains the optimization of operational mechanisms to enhance their efficiency and user-friendliness.

The underpinning elements of effective economic incentive systems in waste separation include robust Policies and Regulations, Management Institutions, defined Scopes of application, pragmatic Funding Mechanisms, adept use of Technology, and the cooperative involvement of various Stakeholders. These elements must be meticulously calibrated to address the specific waste management challenges and socio-economic contexts of different regions. A holistic approach that considers policies, technological interventions, stakeholder cooperation, funding, and management structures is imperative to navigate the complexities of waste management and recycling.

The Resident Participation Rate and Recyclable Rate serve as pivotal metrics to validate the success of incentive models. While resident participation is contingent upon numerous factors like convenience, accessibility, and system usability, the recyclable rate offers a direct insight into the system's efficacy in propelling recycling activities. Both metrics, however, are besieged by challenges such as the scarcity of recycling channels, difficulties in data acquisition, and the inherent intricacies in managing and encouraging widespread public participation in recycling activities. These challenges necessitate a nuanced, adaptive, and comprehensive approach to foster sustainable waste management practices.

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Chapter 3 Recycling and Separating Recyclable Waste: A Comparative Study of Incentive Systems in China

3.1 Introduction

China is estimated to produce more than 400 million tons of MSW per year. With urbanization and improving living standards waste generation is expected to increase. According to the 2017 China Statistical Yearbook, 215 million tons of MSW were collected and transported from 660 Chinese cities, up from 190 million tons in 2004, and representing about 1.1kg of waste generated per capita per day in urban areas (World Bank Book,2019). To form the habit of separating waste at the source, a mandatory policy of waste separation in 46 cities has issued in China in 2017(MOHURD, 2017). Some economic instruments have emerged in many Chinese cities, such as incentives and penalties, and subsidies for waste separation. Among these economic instruments, many studies have shown that an appropriate point system is the desirable economic environmental instrument (Steuer and Li, 2022; Zhang and Zhu, 2020).

The Point system (different names in different cities) for waste separation and collection was applied in many Cities in China. It is an incentive system for waste separation. Residents can earn reward points by putting the sorted waste into the designated equipment (intelligent garbage box) and can exchange those points for daily necessities (Guo et al., 2017; Sun and Asari, 2023). The application of the system has effectively recycled a large number of recycled materials, and it also provides data that can be collected for reference on the recycling of recyclable waste in China.

Therefore, recently there has been an increasing amount of research on point systems. At present, the research mainly focuses on theoretical analysis, system construction, and effective evaluation. First, Theoretical analysis: Zhang et al. (2015) issued the importance of an incentive-based system in promoting waste separation; Steuer et al. (2018) pointed out its advantages in resource recovery and informal waste recycling sector management. Second, System construction: Zhang (2019) designed a prototype of the blockchain-based mode for the collection of rural wastes in China; Uganya et al. (2022) explained IoT Based Intelligent Waste Management systems. Third, Effective evaluation: Xu et al. (2018) showed that economic inducement was more effective than social mobilization in promoting waste separation. Zhao et al. (2022) analyzed the effectiveness of extrinsic incentives for promoting rural waste sorting in China.

However, the existing research lacks a systematic summary of the current point system and an analysis of development trends. Meanwhile, due to the differences in city conditions between different cities, the specific operation methods for implementing the recyclable waste point system are not the same. Therefore, the objective of this study is to summarize, compare and analysis the operation mechanism and typical modes of the point system in China, to fill in the gaps in the existing research. The data and analysis of the incentive-based recycling scheme presented here can serve as a reference for various cities, enabling them to adopt suitable modes for waste sorting. Additionally, governmental authorities can utilize this data to provide appropriate financial and policy support when implementing these modes.

Based on the overall objective, three research questions were formulated to tackle the research objective and answer the aforementioned questions.
RQ 1 – What are the existing operation mechanisms and situation of the point system for waste separation in China?
RQ 2 – How many point systems are there in China and what are the differences?
RQ 3 – Which indicators influence the development and distribution of points systems in China?

3.2 Materials and Method

The study focuses on 46 cities' point systems in China. The 46 cities are those requiring mandatory waste separation depending on the waste separation policy in 2017. 46 cities are mainly composed of provincial capitals, key economic development cities and tourist cities. (See Appendix 1 for details.)

3.2.1 Data collection

In order to clarify the operation mechanism of the point system, the first step was to look for academic papers on point systems. The academic papers collection method was followed by Pieroni et al. (2019) method, which comprised a search and selection of existing incentive mechanisms for waste separation in China. The first approach is to search from journal papers. The search in Scopus and Web of Science (February 2023) (Table 3.1) resulted in 185 unique publications. In total, 73 publications were selected according to 2 criteria:

1) Waste type: recyclable waste related;
2) Incentive-based system

Table 3.1 Search parameters in Scopus and Web of Science

Database	Search string	Fields	Documents numbers	After filter	After removing duplicates
Scopus	("Incentive mechanism" OR "economic incentive" OR "Green point" OR "point system") AND ("waste collection" OR "waste separation" OR "waste sorting" OR "waste management") AND "China"	Article title, Abstract, Keywords	46	22	22
Web of Science		Topic	100	45	51
		Abstract	39	24	
Sum			**185**		**73**

Note: "filter" refers to the two criteria mentioned above (1. Waste type: recyclable waste related; 2. Incentive-based system), "After filter" means the result after two criteria on the searched files.

Among the selected articles, there were 14 studies focusing on Chinese residents' perception surveys supporting the point system recycling. Additionally, 4 articles discussed the point system development. 5 articles examined the support for incentive-based recycling in policy aspects. 14 articles focused on WEEE (Waste Electrical and Electronic Equipment) economic incentive recycling, and 8 articles explored the utilization of incentive-based recycling in rural solid waste management.

Furthermore, there were 14 articles as case studies specifically addressing the point system in China. These articles covered the following cities: Jinan City (Zheng et al., 2023), Changchun City (Steuer and Li, 2021), Xiamen City(Wang et al., 2018), Fuzhou City (Zhang and Zhu, 2019), Suzhou City (Meng et al., 2019), Hangzhou City (Xu et al., 2018), Beijing City (Tong et al., 2023), Shanghai City (Mu and Zhang,2021; Lu & Sidortsov, 2019; Zhou et al., 2019). One article (Guo et al., 2017) described the implementation of the point system in five cities: Beijing, Shanghai, Hangzhou, Xiamen, and Chengdu.

However, the above literature alone does not provide information on the establishment of point systems in other cities, and some local government reports do not contain explicit data on the point system. To overcome this barrier, the author utilized the China Tendering and Bidding Information Network (http://cebpubservice.cn), which is a Chinese government tender web page with all publicly available information to obtain information on point systems that obtained government bidding operations from 2019 to 2022, thereby supplementing the operational status of point-based recycling in other cities. The bidding information includes specific city details, target requirements, and investment amounts. The methodology used to acquire data on the recycling mode of recyclable waste constitutes a significant innovation in this study. The search in the tendering platform (March 2023) (Table 3.2) resulted in 4017 programs. In total, 466 projects were selected according to 3 criteria:

1) Point system;
2) Intelligent data platform;
3) Smart waste recycling bins

Table 3.2 Search parameters in China Tendering Platform

Source	Search string	Documents numbers	After filter
China Tendering and Bidding Public Service Platform	City Name + Waste Separation and Recycling Project	4017	466

Note: "filter" refers to the 3 criteria mentioned above (1.point system ; 2. Intelligent data platform; 3. Smart waste recycling bins)

3.2.2 Data analysis

The present study primarily combines quantitative and qualitative analysis methods. The quantitative analysis focuses on recording the distribution of point systems and analyzing the recycling data in different mode cases. The qualitative data is employed to analyze the operational information and factors that influences different recycling modes in different cities, including policy frameworks, stakeholder engagement, public awareness, and local contextual factors.

3.3 Result and Discussion

3.3.1 Overview of the waste separation point system in China

According to the review research on China's municipal solid waste (MSW), the general disposal method of household waste by community residents is to directly mix and discard the waste into the community bins for unified collection and transportation by the municipal authorities (see Figure 3.1). In the backend waste management, there are primarily two channels: waste incineration and landfill. Currently, the composition of China's waste management mode is approximately 52% landfill, 45% incineration, and 3% composting technologies (Ding et al., 2021; MOHURD, 2020). However, these waste management data do not include a significant amount of recyclable waste (Ding et al., 2021).

In China, since the early 1980s, the recycling of recyclable waste has been largely dominated by the informal waste collection sector. Most urban community residents sell recyclable waste such as plastic bottles, cardboard, glass bottles, etc., to informal waste collectors to generate income (Tong and Tao, 2016) (see Figure 1). According to the research conducted by Linzner, R., & Salhofer, S. (2014), approximately 0.56%–0.93% of the urban population, equivalent to 3.3–5.6 million people, are involved in informal waste collection and recycling activities in urban China.

However, recent policy shifts at both the central and local government levels have led to changes in the resource waste recycling methods. Firstly, the central government has increasingly emphasized sustainable development, thereby highlighting concepts such as circular economy, ecological civilization, and renewable resources on an overall scale. From 2013 to 2016, the major administrative authority in China, the State Council, issued numerous documents emphasizing the importance of waste sorting and recycling for sustainable development. In support of this trend, the National Development and Reform Commission (NRDC) and the Ministry of Housing and Urban-Rural Development (MHURD) issued the "Implementation Plan of Household Waste Classification System" in March 2017. This plan required 46 cities to implement mandatory waste classification policy (MWCP) and specified that the recycling rate of household solid waste (HSW) should exceed 35% by the end of 2020. As a byproduct of these laws and policies, new business modes for recyclable waste collection have emerged, primarily centered around community and online platforms for recyclable waste transactions. These transaction modes are mainly based on points as incentives, hence referred to as point systems in this study.

The point system is an incentive system for waste separation. Residents can earn reward points by putting the sorted waste into the designated equipment (intelligent garbage box) and can exchange those points for daily necessities. Residents usually use their mobile phones through WeChat or point system applications to register information. Generally, one household registers as one account, and each performance will get a bar code. When disposing of waste, it is necessary to use an intelligent garbage box to scan the bar code, and the points are stored in their accounts. These points can be exchanged for daily necessities on the online platforms set by the system. The process of the point system is shown in the red dotted frame of Figure 3.1.

Point system The types of waste collected are mainly recyclable wastes, such as plastic, paper, clothing, glass, etc. (Guo et al., 2017; Sun and Asari, 2023). It is voluntary for residents to participate so that other unsorted waste can be thrown into the original waste trash. The point system would not recycle other and unseparated waste.

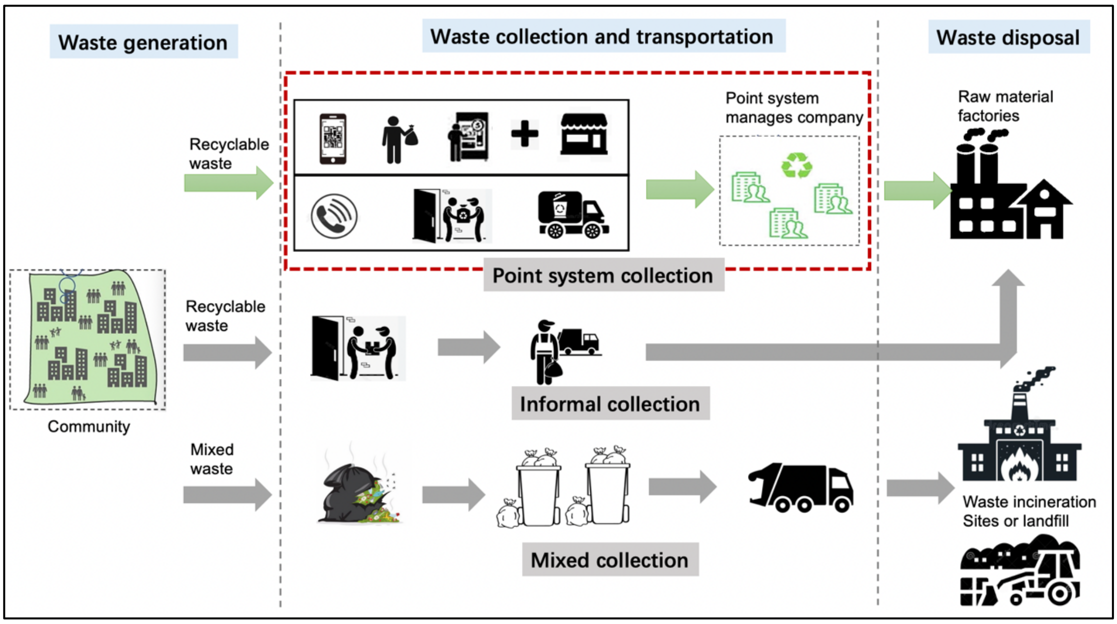


Figure 3.1 Scheme for general community waste collection and disposal in China

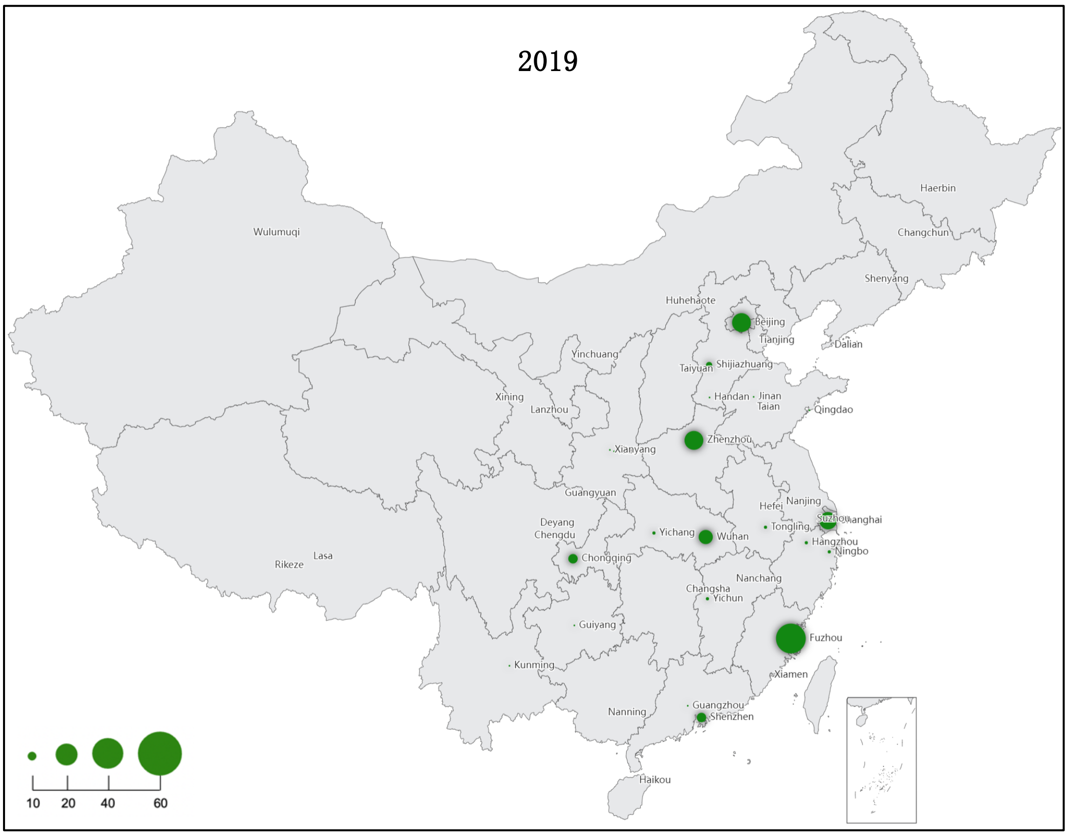
(Source: Created by the author based on data from prior literature)

Figure 3.2 Intelligent garbage box and environmental protection house

(Source: Photographed in Shanghai on 2021.10.9 and in Dongying City on 2021.11.1)

3.3.2 Distribution of point system in China

Figure 3.3 shows the number and distribution trend of point systems in China from the year of 2019 to 2022.



2019
Haerbin
Wulumuqi
Changchun
Shenyang
Huhehaote
Beijing
Tianjing
Dalian
Yinchuang
Taiyuan
Shijiazhuang
Xining
Lanzhou
Handan
Jinan
Taian
Qingdao
Zhenzhou
Xianyang
Guangyuan
Hefei
Nanjing
Suzhou
Deyang
Chengdu
Yichang
Wuhan
Tongling
Hangzhou
Ningbo
Lasa
Rikeze
Chongqing
Nanchang
Changsha
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Fuzhou
Kunming
Xiamen
Guangzhou
Nanning
Shenzhen
Haikou
10
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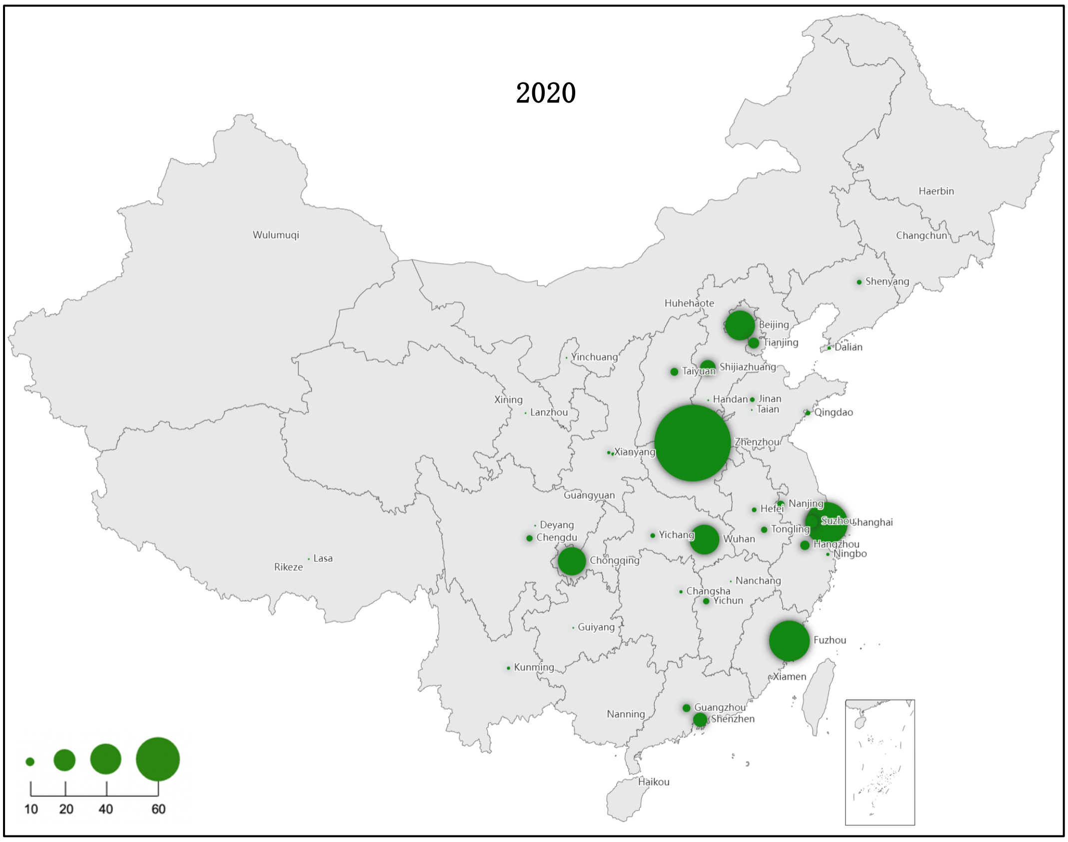
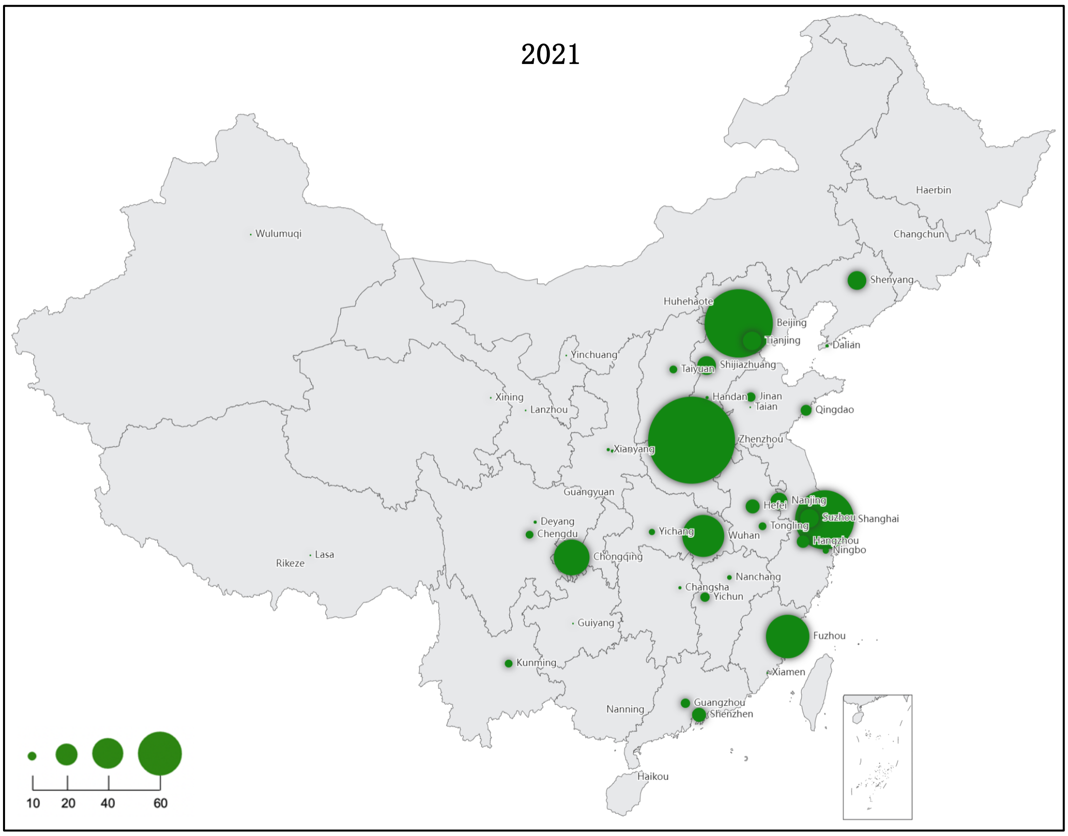


2020
Haerbin
Wulumuqi
Changchun
Shenyang
Huhehaote
Beijing
Tianjing
Dalian
Yinchuang
Taiyuan
Shijiazhuang
Xining
Lanzhou
Handan
Jinan
Taian
Qingdao
Xianyang
Zhenzhou
Guangyuan
Nanjing
Hefei
Deyang
Chengdu
Yichang
Tongling
Wuhan
Ningbo
Lasa
Rikeze
Chongqing
Nanchang
Changsha
Yichun
Guiyang
Fuzhou
Kunming
Xiamen
Guangzhou
Nanning
Shenzhen
Haikou
10
20
40
60



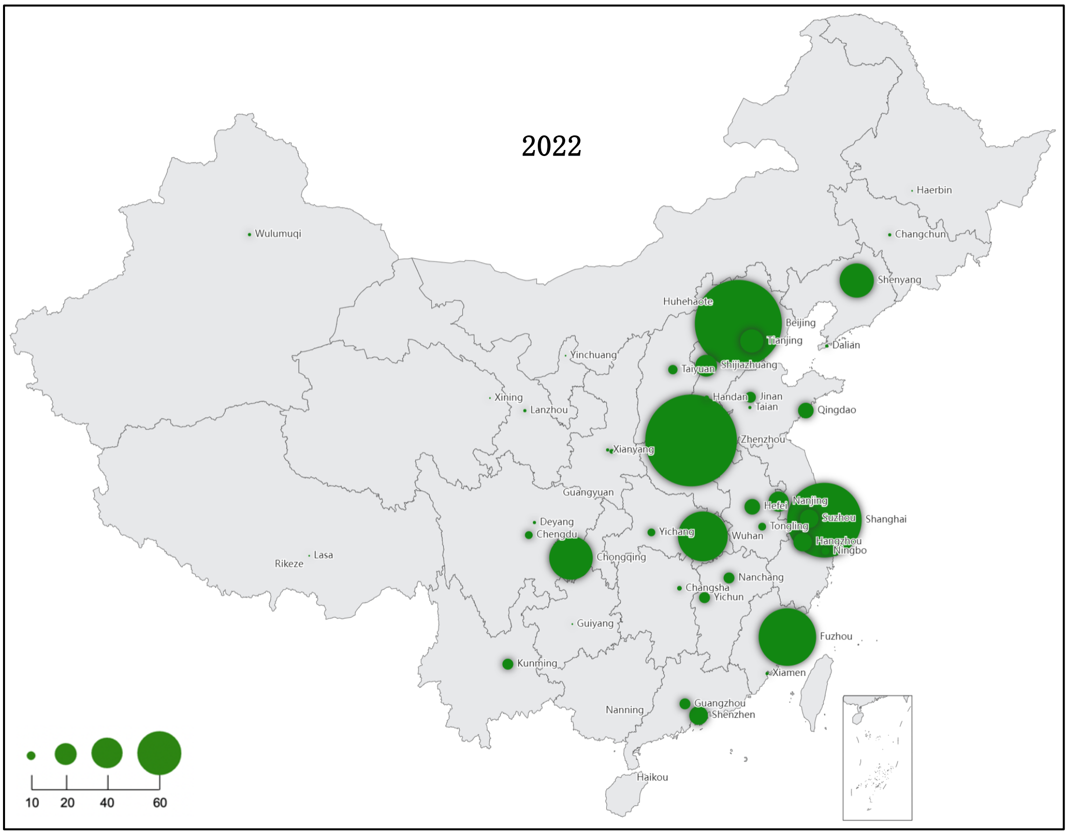


Figure 3.3 The distribution of points system in China from years of 2019~2022

(Source: Created by the author based on data from China Tendering Platform)

Note：Green indicates the number of point systems, with larger green dots indicating larger numbers

The Figure 3.3 indicate a gradual increase in the number of point systems from 2019 to 2022. The initial implementation of such systems began in cities like Beijing, Shanghai, Zhengzhou, and Fujian in 2019, and the trend continued to expand. By 2022, a notable pattern emerged, with Beijing, Shanghai, Zhengzhou, Fujian, and other cities serving as centers for the establishment of these systems. The central region, including Wuhan and Chongqing, also witnessed a significant presence of point systems, likely due to their status as key cities in China's economic development. Notably, the number of point systems centered around Beijing surpassed those in the southern regions, suggesting Beijing's role as the political center and the subsequent spread of waste separation policies from this starting point. In contrast, the Northwest and Northeast regions of China showed minimal or no presence of point systems.

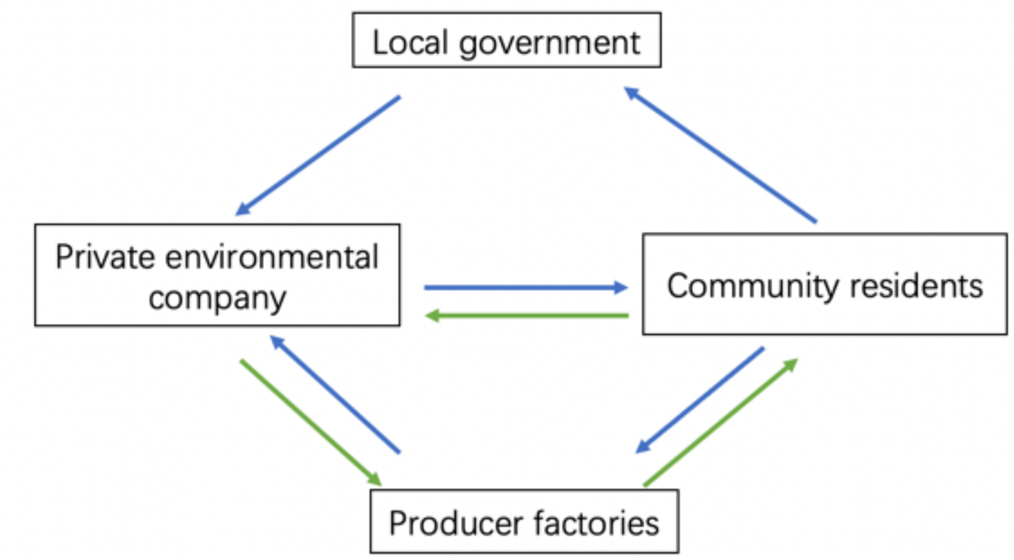
In conclusion, the analysis of the collected data provides several key findings. From January 2019 to December 2022, a total of 466 point systems have been implemented or are currently in operation throughout 46 cities. However, there are significant variations in terms of service duration, served population, and operational funding. Moreover, the implementation of point systems exhibits regional disparities. Over the period from 2019 to 2022, the number of point systems gradually increased, with notable contributions from cities such as Beijing, Shanghai, Zhengzhou, Fujian, Wuhan, Chongqing, and other central urban areas. In contrast, the Northwest and Northeast regions show limited or no presence of point systems, indicating the influence of China's political and economic centers in driving the adoption and dissemination of waste separation policies.

3.4 Typical Waste Separation Point System in China

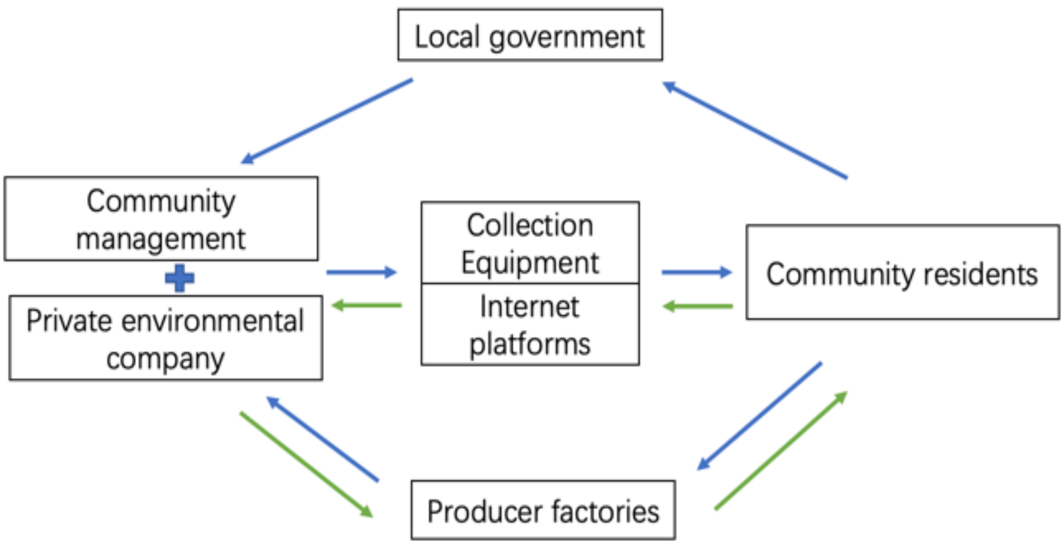
Based on the literature data and the winning bid information of the point systems, 466 point systems have been classified into 4 typical operational modes, taking into consideration the operational patterns of the point system and the classification modes of the deposit refund system which is the beverage packing collection system in developed countries (Zhou et al., 2020). Table 3 shows the characteristics of the four different point systems, which are differentiated according to the main implementing entity, implementer, collection method, incentive, waste type, and equipment types. The implementing entity is also the cost of the system, the implementer is to manage the operation of the system. There are two main methods of collection: door-to-door collection or on-site collection at community facilities. The incentives are points and most of the waste collected is recyclable waste. The equipment is either a smart recycling bin or a waste collection house. The next section will specifically analyze the content and cases of cities in detail.

Table 3.3 Four typical modes of point system

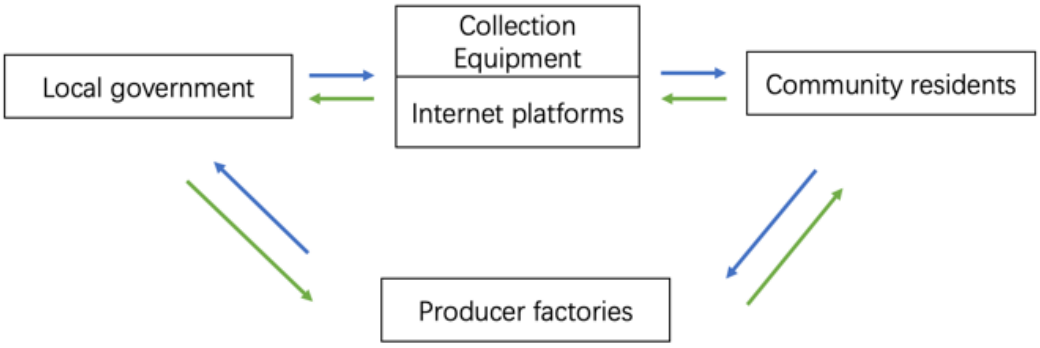
Type	Implementing entity(Cost)	Implementor	Collection method	Incentive	Waste type
(a)	Government	Private	Door to Door	Point	Recyclable waste
(b)	Government	Private	Station(recycling bin/ house)	Point	Recyclable waste
(c)	Government	Government	Station(recycling bin/ house)	Point	Recyclable waste
(d)	Private	Private	Door to Door	Point	Recyclable waste



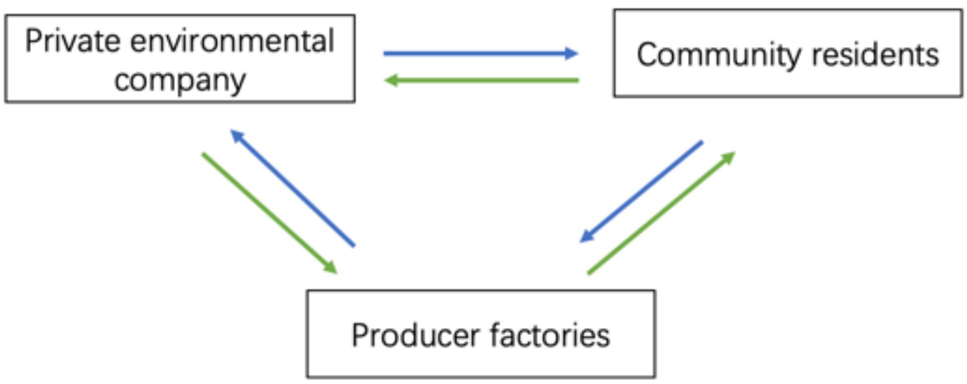
(a) Government-Private mode: Door-to-Door collection



(b) Government-Private mode: Station collection



(c) Government-Government mode: Station collection



(d) Private-Private mode: Door-to-Door collection

Figure 3.4 Operation mechanism of 4 typical modes of point system

(Source: Created by the author based on data from China Tendering Platform and literature)

3.4.1 (a) Government-Private mode: Door-to-Door collection

The system mechanism of this mode is shown in Figure 3.4-(a). The mode is based on the local government's request for environmental management, followed by a tender process within the local municipality, with local companies qualified to manage the environment putting forward proposals for bidding. Residents pay a tax to the government for waste management; the government provides financial subsidies to the private company and the private company is rewarded with points for obtaining waste from residents for recycling. The waste is obtained by the environmental companies from the residents and then processed 2 times and sold as raw material to the back-end factories for product manufacturing, which is eventually sold again to customers. Thus, from this diagram, it can be seen that the private sector receives finance from two main sources, the first being financial subsidies from the government: the second being the re-selling of resource waste.

The main reasons for this mode for door-to-door collection are, firstly, to reduce costs, the cost of equipment; secondly, to avoid conflicts with local community management and not to set up areas for waste collection, which can reduce the exchange of supervisors as well as operators in the front section, etc. The third point is that it eliminates the need for residents to carry rubbish and provides direct door-to-door service, saving the residents time. The key to a reasonable operation of this mode is to promote and guide residents to sign up for the online platform, and they are guided by the points mode and participate voluntarily.

It is known from prior research that the representative company for this mode is FEIMAYI. In 2014, FEIMAYI (Fly Ant) was incorporated in Shanghai to engage in the recycling of used clothes. The main feature is that customers make appointments on the WeChat platform, and FEIMAYI arranges for courier staff to collect the clothes at residents' homes. In 2018, the recycling scope of FEIMAYI was extended to other recyclable waste, e.g., paper waste, plastic waste, glass waste, and so on. Its business covers more than 300 cities in China, with 2 million platform users and 30,000 tones of used clothes recycled annually (FEIMAYI Dynamic information, 2023).

3.4.2 (b) Government-Private mode: Station collection

The system mechanism for this mode is shown in Figure 3.4-(b). The mode is still a public tender by the government. It is tendered within the local municipality, with local companies qualified in environmental management putting forward proposals for bidding and the government selecting the best company and proposal for implementation, with financial assistance and eventual supervision. This mode differs from the first mode in that it features skillful smart recycling bins or recycling houses in the community, therefore requiring cooperation with community property management and the exchange of information with front-end services.

This mode is the most frequently occurring mode, which currently covers almost 41 out of 46 cities in China. This mode has received full recognition from local governments in China and has been repeatedly emphasized in Chinese media. Moreover, it has also garnered considerable attention in academic research.

According to the literature papers, the representative case is the Bonus Point system in Beijing, Shanghai, Hangzhou and Xiamen City (Guo et al., 2017). This system is being implemented in several locations such as Beijing, Shanghai, Chengdu, and Hangzhou. The intelligent garbage room in this mode is capable of identification, weighing, and barcode scanning. These garbage rooms are often placed near the entrance of residential communities. Residents are required to sort their waste into seven categories of recyclable waste. Prior to using the smart garbage bins, residents create an account online to receive rewards. Subsequently, residents can redeem their points for gifts through the platform. The properly sorted waste is sent to a compression station, where it undergoes filtering, cleaning, deodorization, and compression before being sold to recycling factories. The revenue generated is used to support the operation of the integrated internet platform.

3.4.3 (c) Government-Government mode: Station collection

This mode is primarily led and managed by the government and its relevant departments. Residents residing within the jurisdiction are provided with point cards or green accounts, enabling them to accumulate points through proper waste disposal practices. This mode is characterized by a wide range of service coverage and is supported by the cooperation of several large enterprises (Figure 3.4-(c)). For example, Shanghai's Green Account is supported by the governing bodies of Shanghai City Investment (Group) Company Limited, Bank of China Shanghai Branch, and Alipay, under the guidance of the Shanghai Greening and Amenities Administration. The support provided by these enterprises differs from (b) mode, as they primarily do not engage in operational and managerial activities. Instead, their involvement is limited to instances where the government requires online point circulation or assistance from platforms like Alipay for online transactions.

A representative case is the "Green account" in Shanghai. In 2009, in order to incentivize residents to participate in waste sorting, the Shanghai Municipal Government, in collaboration with the Bank of China, introduced the concept of household "Green Accounts" where points are accumulated through waste classification (Lu and Sidortsov, 2019; Zhou et al., 2019). These points can be redeemed for daily necessities such as milk, and shampoo, and can also be used for utility bill deductions. The government has promoted the benefits of waste sorting and Green Accounts through television, newspapers, and websites. According to the 2018 Shanghai Green Account Annual White Paper, there were 5.3 million Green Account holders.

3.4.4 (d) Private - Private mode: Door-to-Door collection

This mode has been less commonly observed; a more representative instance is the "Ant Recovery system" in Changchun City. It does not receive financial support and does not establish equipment within the community, instead focusing on door-to-door collection. In comparison to numerous other conventional recycling systems in China, this mode operates in a bottom-up fashion, as depicted in Figure 3.4-(d). One unique achievement of this system is its effective incorporation of informal stakeholders into a formal umbrella framework (Steuer & Li, 2022).

“Ant Recovery system”, established in 2017, is a collaborative effort between the Changchun Recycling Association (CRA) and the local migrant workers' association. It primarily focuses on the collection of various waste streams, including metals, paper, plastics, WEEE (Waste Electrical and Electronic Equipment), glass, and rubber (Steuer & Li, 2022).

The approach taken in Changchun City signifies a significant innovation, possibly informed by lessons learned from past experiences in China, as it departs from the conventional strategy of initially imposing taxes on collectors However, certain regulatory measures are still in place.

Firstly, a moderate material procurement price benchmark has been established to prevent abnormal profits and recycling monopolies by waste buyers in the Ant Recovery system. Secondly, large-scale sorting and separation centers provided by Ant Recovery trucks are required to record transaction volumes and transmit the data to the CRA in real-time, thereby providing a quantitative basis for designing more sophisticated waste recycling strategies in the future. Thirdly, the pilot program employs specific requirements and standards, including designated locations, operating hours, and vehicle criteria for Ant Recovery stations. The placement of collection points will be determined by the district administrative departments, with each collection point expected to cover approximately 4,000-4,500 households. Strict spatial service boundaries are delineated, prohibiting any unauthorized activities.

3.4.5 Distribution and Investment of Typical Point System across 46 Cities

Figure 3.5 presents an analysis of the distribution and investment amounts of four modes of point systems implemented across 46 cities. In the figure, we observe that Zhengzhou city has the highest number of point systems with 60 systems, followed by Beijing with 56 systems, and Shanghai with 49 systems. There is a decreasing trend in the number of systems from top to bottom. The bottom five cities (Haikou, Hohhot, Guangyuan, Nanning, and Rikaze) do not have any official or documented records of point systems, indicating that these cities have not implemented any point-based recycling systems yet.

Among the four modes of point systems, mode (b) has the highest proportion, accounting for the majority of the 466 systems, with 421 systems being of mode (b). Mode (a) is the next most prevalent, with nearly all 46 cities having implemented this mode. Based on the available information and intelligence, mode (c), has only been observed in Beijing and Shanghai. This mode requires significant policy and financial support, limiting its successful implementation to a few cities in China. Mode (d) has been identified in Hangzhou and Changchun cities.

Additionally, the red line in Figure 3.5 represents the financial investment (winning bid) of each city in the point system. This data is derived from 466 bidding documents (excluding mode (d) as it did not receive operational funding through bidding). Figure 4 demonstrates that as the number of point systems increases, the government's investment amount tends to rise. However, there are exceptions to this trend. For instance, Shenyang and Hefei cities exhibit significantly higher investment amounts compared to other cities. After verifying the data, it was found that the high winning bid in these cities can be attributed to the large number of households served by certain point systems. For example, the winning bid amount for Shenyang's point system was 315.27 million CNY, with two projects targeting 320,000 and 278,000 households, resulting in awarded amounts of 16.081487 million CNY and 32.830296 million CNY, respectively. Hefei City also presents a similar case, with a coverage of 311,000 households in one pilot operation of the point system.

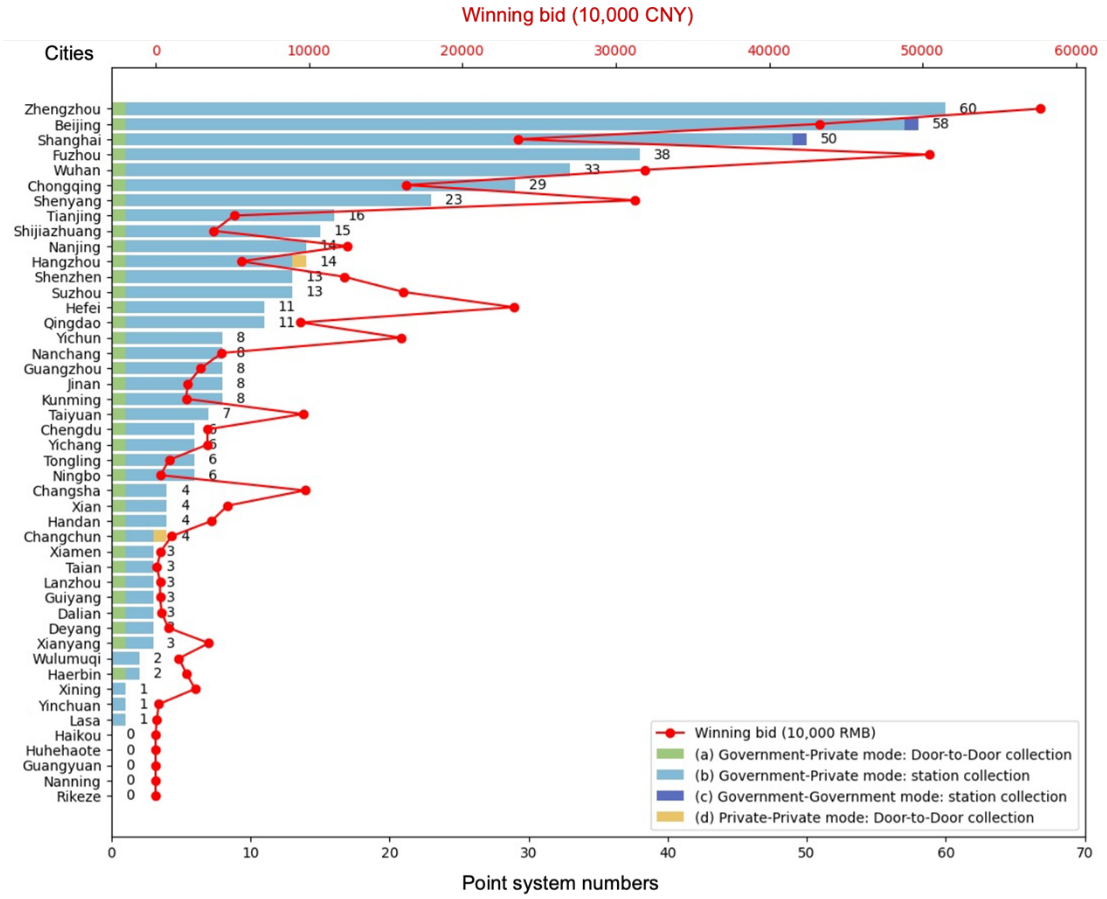


Figure 3.5 Distribution and investment of the 4 types of point systems in 46 cities

(Source: Created by the author based on data from China Tendering Platform)

3.5 Key Indicators Influence the Point System

3.5.1 Factors affecting the development of point systems

The aim of the point systems is to encourage all residents to participate in waste separation and to develop waste separation and recycling behavior. The key to the success of a points system is the cooperation of government, company, and residents. This study conducts a comparative analysis of the four-point systems from the perspectives of government, enterprises, and residents, building upon the existing literature.

Firstly, from the government's perspective, the main selected factors are "Political performance" and "Regulatory costs".

Political performance: Due to the top-down approach in China, the government views waste classification projects as important policies and opportunities to showcase their governance achievements. By promoting waste classification, the government can demonstrate its accomplishments in environmental protection and sustainable development, thereby enhancing its image and public approval. The successful implementation and outcomes of waste classification projects can serve as significant indicators for government propaganda and officials' career advancements (Peng et al., 2020).

Regulatory costs: Waste classification projects require substantial government resources for supervision and management. The government needs to establish regulatory mechanisms, develop relevant policies and regulations, train personnel, and conduct publicity and education campaigns. These regulatory activities require manpower, material resources, and financial support, resulting in certain cost pressures. The consideration of regulatory costs by the government aims to ensure the effective operation of waste classification projects and seek optimal resource allocation and utilization efficiency within limited resources (Zhou et al., 2020; Peng et al., 2020).

By selecting "Political performance" and "Regulatory costs" as factors influencing waste classification projects, the government aims to showcase its governance achievements and achieve political and economic benefits, while also addressing concerns related to project supervision and resource management. This choice helps the government achieve environmental goals, enhance its image, and ensure the effective operation of waste classification projects. As a critical factor for successful government regulation of this mode, the recycling rate or amount is essential. However, due to the fact that much of the data is held by private enterprises, it is not possible to obtain accurate data values through publicly available sources. The current existing literature relies on estimating the overall recycling volume based on surveys conducted for a limited period, which still does not provide accurate and reliable data. Therefore, this study omits this key factor.

Second, in terms of company (government) operations, the factors chosen are "Transportation costs" and "Financial budget constraints"(Mu and Zhang, 2021; Zhou et al., 2020).

Transportation costs: Firstly, transportation methods are the primary distinguishing factor among the four modes. Whether to establish collection points or directly collect waste at the doorstep determines the transportation distance. The point system requires enterprises to collect and transport resource waste. Transportation costs are an important consideration for enterprises in waste classification. These transportation costs include expenses related to manpower, vehicles, fuel, and time. Enterprises need to assess and control transportation costs to ensure the sustainability and economic viability of waste classification projects (Zhou et al., 2020).

Financial budget constraints: Enterprises need to consider financial budget constraints when implementing waste classification projects. Such projects may require significant investment in equipment procurement, personnel training, and promotional activities. Therefore, a higher financial budget is advantageous for the later-stage promotion and operation. Enterprises need to develop effective waste classification strategies based on a balance between costs and benefits, meeting both environmental protection requirements and operational feasibility.

By selecting "Transportation costs" and "Financial budget constraints" as factors influencing waste classification projects, enterprises aim to control operational costs, improve transportation efficiency, and enhance economic benefits. Additionally, financial budget considerations ensure the sustainable development of waste classification projects within limited resources. Enterprises need to develop effective waste classification strategies based on a balance between costs and benefits, meeting both environmental protection requirements and operational feasibility.

Third, from the perspective of residents, the factors chosen are "Time cost of waste classification" and "Point rewards after waste classification".

Time cost of waste classification: Waste classification requires residents to invest additional time and effort to learn classification rules, sort waste, and dispose of it into the corresponding containers. Waste classification may require residents to make extra preparations and sorting efforts in their daily lives, thereby increasing their time cost. Therefore, residents consider the time cost associated with waste classification when deciding whether to participate, weighing it against the allocation of time for other daily activities.

Point rewards after waste classification: By correctly classifying and disposing of waste, residents can earn a certain number of points, which can be redeemed for gifts, discounts, or entry into prize draws. The point rewards after waste classification can increase residents' motivation to participate, making them more willing to invest time and effort into waste classification (Mu and Zhang, 2021).

Residents choose "Time cost of waste classification" and "Point rewards after waste classification" as factors influencing their participation in waste classification projects. On the one hand, they consider their own time benefits and the allocation of daily time. On the other hand, they value the rewards and incentives that can be obtained through participating in waste classification. Based on a balance between time cost and point rewards, residents decide whether to actively engage in waste classification projects to achieve dual goals of environmental protection and personal benefits.

Table 3.4 Comparison of the four-point system modes

	Factors	**(a) Government-private mode: Door-to-Door collection**	**(b) Government-private mode: Station collection**	**(c) Government-Government mode: Station collection**	**(d) Private-private mode: Door-to-Door collection**	**Reference**
Government	Political performance	Middle	High	High	Low	Peng et al., 2020
	Regulatory costs	Middle	Middle	High	Low	Zhou et al., 2020
Company/ Government	Transport costs	High	Middle	Low	High	Zhou et al., 2020
	Financial budget constraints	Middle	Middle	Low	High	Mu and Zhang, 2021
Residents	Time costs	Low	High	High	Low	Mu and Zhang, 2021
	Point rewards	Low	High	High	Low	Mu and Zhang, 2021

Firstly, from the perspective of the local government (see Table 3.4), the implementation of the point system requires forming a pilot mode that can accomplish its objectives and promote performance and facilitate learning from neighboring cities. Therefore, modes (b) and (c) are the most conducive to government performance. But at the same time, from the government's point of view, the cost of regulatory efforts needs to be considered. Therefore, the mode in (b) Government-private mode: Station collection is the one the government will implement the most.

Secondly, from the perspective of the company business, its implementation of a point system needs to consider whether it can be carried out to maximize profits through economic returns and back-end operations. From Table 3.4, the transportation costs for the (b) and (c) modes are relatively low due to the setting up of recycling points within the community. The mode in (c) is relatively low since it is government-run and can use the transport system that would otherwise transport the waste. From the perspective of financial budget constraints, the (d) mode without government subsidies is the most financially stressful; the (c) mode, which is government invested government managed and operated, is the least financially stressful; the (a) and (b) modes are in the middle of the range in terms of financial stress and still ultimately need to be accepted by the government. Therefore, in summary, the (b) and (c) modes are relatively better.

Finally, from the residents' perspective, their expectation of participation in the points system is to maximize the utility and achieve a high return on points for the least amount of time spent on waste separation. Comparing the four modes in Table 3.4, we can see that for modes (a) and (d), although the time cost is low, the return on points is also low; for modes(b) and (c), although the return on points is high, the time cost is also high. Therefore, residents' interest in participation is approximately the same across the four modes.

In summary, by comparing the results of the above three perspectives, the most likely of the four modes to achieve a long-term effective mechanism is mode (b) Government-private mode: Station collection. This result coincides with the result in Figure 3.5, the mode that is currently being promoted on a large scale in China. Therefore, it is recommended to implement the (b) mode, which involves three-party benefits, in new cities. However, for the previously mentioned Shenyang and Hefei cities, where the coverage of one point system has already expanded to over 35,000 households, it is highly likely that a more comprehensive (c) mode, managed and operated by the government, will be established in the future. Although the (c) mode may increase the government's operating costs, it allows for the collection of accurate recyclable waste data. Furthermore, considering the development of an aging population in China, both the (a) and (d) modes, which involve door-to-door collection, could provide the most convenient services to residents. Additionally, building upon the door-to-door collection services, these modes could also incorporate other functions related to the well-being and health of the elderly population.

3.5.2 Factors affecting investment in the Points System

This section leverages bidding data from the Points System for recyclable waste collation spanning 46 cities from 2019 to 2022. The dataset encompasses investment amounts for each project, as well as the size of the serviced population and the duration of service. Notably, most of the data for (a) mode stems from a national chain of recyclable waste collation, precluding specific information regarding the serviced population and service duration. Likewise, (c) mode services lack clearly defined service time frames and population coverage, while (d) mode lacks concrete data support. Consequently, this study exclusively focuses on analyzing the (b) mode scenario.

In order to provide municipal administrators with a more precise grasp of the investment costs associated with the (b) mode Points System, we conducted a descriptive analysis of investment amounts and fundamental characteristics for each city's Points System.

Table 3.5 Descriptive analysis of investment in point system of 46 cities

Variables	Obs	Mean	Std. Dev.	Min	50%	Max
Winning bid (10,000 CNY)	425	905.42	1465.14	26.64	395.17	14276
Winning bid per household per month (CNY)	298	17.34	14.55	0.20	14.39	90.30
Service duration (month)	410	16.03	9.95	2.00	12.00	60.00
Service Population (household)	304	84929.46	3.1e+05	998.00	28338.0	3.6e+06
Population density (persons/km2)	425	1593.67	1545.10	29.28	1333.70	8851.20
GDP per capita (10,000 CNY/person)	425	13.36	4.08	4.64	13.82	19.01
Per capita daily waste generation (kilograms)	425	0.78	0.25	0.22	0.82	1.50

Source: China Tendering and Bidding Public Service Platform +City statistical yearbooks

Winning bid per household per month (CNY) = Winning bid (10,000 CNY)/(Service duration(month)* Service population(household))

The dataset presented in Table 3.5 comprises a total of 425 records for various recyclable waste collation projects. However, due to incomplete data on the number of serviced populations and service duration in the original bidding documents, the number of observations for "Winning bid per household per month (CNY)" is limited to 298. The majority of points systems in this study had a service duration ranging from 12 to 60 months, with the minimum population size served to be 998 households, while the maximum reached an impressive 3.6 million households.

Additionally, the descriptive analysis of basic city characteristics reveals significant variations in population density among the 46 cities. However, approximately 50% of the cities exhibited relatively high population densities, with a median value of 1333.7 persons/km². Furthermore, the distribution of per capita GDP across the cities shows considerable disparities, with 50% of the cities having per capita incomes of around 13.82 10,000 CNY/person. Concerning per capita daily waste generation, based on statistics from the United Nations, the average falls within 1.1 kilograms, while from Table 3.5, the average value is 0.78 kilograms which the average amount of waste generated is below the United Nations statistics data. There are cities with minimum values as low as 0.25 kilograms and maximum values as high as 1.50 kilograms.

Nevertheless, approximately 50% of the cities have per capita waste generation close to 0.82 kilograms.

To achieve the research objectives, a statistical approach was employed to compare the investment amounts in (b) mode points systems across different cities. By examining the impact of influencing factors, the aim is to support the implementation of future points systems to avoid excessive or insufficient funding, which could burden city finances and hinder the sustainable development of points systems.

Based on the displays in Figure 3.5, it is conceivable that the duration of service and the size of the serviced community population in the points system could affect the Winning bid and Winning bid per household per month. Additionally, it can be inferred that city characteristics, such as population density, per capita GDP, and per capita daily waste generation, might influence the Winning bid.

Consequently, two hypotheses were tested: (1) variations in the size of serviced populations and service duration affect Winning bid per household per month in points systems, and (2) different city characteristics, such as population density, per capita GDP, and per capita daily waste generation, influence the Winning bid. To validate these hypotheses, Ordinary Least Squares (OLS) regression analysis was utilized. To ensure data accuracy, the statistical analysis was restricted to the 298 projects with explicitly defined values.

For the first hypothesis, the expected sign is positive, suggesting that an increase in the size of the serviced population and service duration could lead to an increase in Winning bid per household per month. This is because a larger serviced population or longer service duration might require more resources and funding. For the second hypothesis, the expected sign could be either positive or negative, as the impact of city characteristics on Winning bid could be complex and multifaceted. By validating these hypotheses, we can better understand how to effectively design and implement points systems to avoid undue burdens on city finances while ensuring their sustainable development.

The regression mode is given by:

$$Y = \alpha_0 + \alpha_i X_i + \varepsilon$$

Where Y is the dependent variable representing the Winning bid per household per month and the winning bid amount obtained for each points system project. X_i represents independent variables, including the system establishment time, number of serviced populations, service duration, city's per capita GDP, population density, and per capita daily waste generation. α_i represents the coefficients of the independent variables, and ε denotes the error term.

Table 3.6 Regression results in investment of point system

VARIABLES	(1) Ln Winning bid (CNY)	(2) Winning bid per household per month (CNY)
Ln population served (household)	0.587***	-4.266***
	(15.05)	(-7.00)
Ln service duration (month)	0.348***	-5.559***
	(3.52)	(-3.60)
Ln per capita daily waste generation	-0.373*	-10.095***
(kilograms)	(-1.84)	(-3.18)
Ln GDP per capita (10,000 CNY/person)	0.560***	10.469***
	(2.61)	(3.12)
Ln Population density (persons/km2)	-0.338***	-4.255***
	(-3.78)	(-3.05)
Constant	5.472*	171.626***
	(1.73)	(3.48)
Observations	298	298
R-squared	0.484	0.236

*Note: Ln denotes that a natural logarithm was used in the analysis. Robust t-statistics are in parentheses. ***p < 0.01. **p < 0.05. *p < 0.1.*

Table 3.6 presents the regression results pertaining to the investment aspects of the point system. The table displays two distinct modes, labeled as (1) and (2), each examining different dependent variables. Regarding the variable "Ln population served (household)," the coefficient values of 0.587*** and -4.266*** are observed in modes (1) and (2) respectively. The highly significant ***p < 0.01 underscores the remarkable positive correlation between the population served number and the Winning bid, and the negative correlation between the population served number and the Winning bid per household per month. Similarly, for the variable "Ln service duration (month)," the coefficient values are 0.348*** and -5.559*** in modes (1) and (2) respectively. The highly significant ***p < 0.01 underscores the remarkable positive correlation between the PS service duration time (month) and the Winning bid, and the negative correlation between the PS service duration time (month) and the Winning bid per household per month.

The variable "Ln per capita daily waste generation (kilograms)" showcases coefficient values of -0.373* and -10.095*** in modes (1) and (2) respectively. For the variable "Ln per capita daily waste generation," a higher coefficient magnitude signifies that regions with greater waste generation tend to have lower values for both dependent variables. This indicates that higher waste generation is associated with reduced operational funding and subsidies within the point system. This negative relationship can be explained by the increased costs and challenges associated with managing and processing higher amounts of waste. Regions with greater waste generation might necessitate higher expenditures for waste collection, transportation, and processing, leading to a decreased number of financial resources available for the point system.

The variable "Ln Population density (persons/km2)," coefficient values of -0.338*** and -4.255*** are noted in modes (1) and (2) respectively. The negative coefficient values suggest that regions with higher population densities tend to receive lower bids and monthly subsidies. This can be attributed to several factors. In densely populated areas, the cost of waste collection and transportation may be lower due to shorter distances, which could lead to reduced operational expenses for waste management services. Moreover, higher population density might indicate a greater environmental awareness and cultural inclination towards recycling and waste reduction, thus resulting in a higher participation rate in the point system, even with lower incentives.

"Ln GDP per capita (10,000 CNY/person)" is associated with coefficient values of 0.560*** and 10.469*** in modes (1) and (2) respectively. The highly significant ***$p < 0.01$ signifies the substantial positive correlation between per capita GDP and both dependent variables. Regions with a higher per capita GDP tend to have more financial resources available for various initiatives, including waste management systems and often exhibit a stronger commitment to environmental sustainability and waste management practices. Greater awareness of environmental issues and a higher standard of living can lead to increased demand for effective waste management systems, which may necessitate larger investments in the point system.

3.6 Conclusion

The objective of this study is to summarize and analyze the implementation of the Points System in China, enrich the research on incentive mechanisms for waste collection systems, and provide valuable insights for policymakers. The study identified a total of 466 operating points systems in China, primarily categorized into four modes: (a) Government-private mode: Door-to-Door collection, (b) Government-private mode: Station collection, (c) Government-Government mode: Station collection, and (d) Private-private mode: Door-to-Door collection. Among these modes, the (b) mode was the most prevalent, operating in 41 out of 46 cities, accounting for 91% (425 systems).

In examining the factors influencing the distribution of point systems, this research explored the perspectives of governments, companies, and residents. The analysis led to the conclusion that the (b) Government-private mode: Station collection was the most suitable operating mode from all three perspectives and had the highest potential for sustainable replication. This finding aligns well with the current status quo. Additionally, the study discussed the feasibility of other modes in future societal development, such as the potential effectiveness of modes (a) and (d) in complementing other services in an aging society.

Furthermore, this study analyzed the impact of point system characteristics and city features on the establishment of government-winning bidding amounts and individual subsidies (Winning bid per household per month). It was found that the number of serviced populations and service duration had a positive effect on the total investment amount while having a negative impact on individual subsidies. Per capita daily waste generation and population density exhibited negative correlations with both dependent variables, while per capita GDP demonstrated a positive correlation with winning bidding amounts.

Though the point system has been successful in some cities, it does not indicate that it will be successful in others. However, it is important to understand existing systems and learn from their experiences. It is clear that current cities in China need to implement sustainable collection, recycling, and reuse through the point system, which is an important issue for sustainable development.

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3.8 Appendix

3.8.1 Appendix 1: The information of 46 cities in China

City name	City type	Waste generation (10,000 tones/2021)	Population (10,000 person)	Area size (km^2)
Beijing	provincial capital	784.2	2188.6	16410
Chengdu	provincial capital	548.95	2119.2	14335
Fuzhou	provincial capital	157.3	842	11968.53
Guangzhou	provincial capital	808.8	1881.06	7434.4
Guiyang	provincial capital	142.5	610.23	8034
Haerbin	provincial capital	188.8	988.5	53186
Haikou	provincial capital	139.54	290.8	3126.82
Hangzhou	provincial capital	453.06	1237.6	16850
Hefei	provincial capital	209.71	963.4	11445
Huhehaote	provincial capital	72	349.6	17200
Jinan	provincial capital	287.6	933.6	10244.45

Kunming	provincial capital	203.01	850.2	21012.54
Lasa	provincial capital	47.45	86.79	29640
Lanzhou	provincial capital	150.7	438.43	13100
Nanchang	provincial capital	116.99	643.75	7195
Nanjing	provincial capital	290.46	942.34	6587.02
Nanning	provincial capital	153.43	874.16	22100
Shanghai	provincial capital	955.1	2489.43	6340.5
Shenyang	provincial capital	274	911.8	12860
Shijiazhuang	provincial capital	127.25	1122.35	13504
Taiyuan	provincial capital	172.99	539.1	6988
Tianjing	provincial capital	335.7	1373	11966.45
Wulumuqi	provincial capital	164.25	407	13800
Wuhan	provincial capital	479.5	1364.89	8569.15
Xian	provincial capital	393.87	1316.3	10752
Xining	provincial capital	91.2	247.56	7660
Yinchuang	provincial capital	41	288.2	9025.38
Changchun	provincial capital	206.48	908.72	24592
Changsha	provincial capital	868.51	1023.93	11819
Zhenzhou	provincial capital	258.84	1282.8	7567
Chongqing	provincial capital	670.3	3212.43	82402
Dalian	key economic cities	253	745	12574
Deyang	key economic cities	28.47	345.9	5911
Ningbo	key economic cities	416	961.8	9816
Qingdao	key economic cities	304	1025.67	11293
Xiamen	key economic cities	192.5	528	1700.61
Shenzhen	key economic cities	826	1768	1997.47
Guangyuan	tourist cities	23.4	228.3	16319
Handan	tourist cities	78.1	936.69	12066
Rikeze	tourist cities	10.95	79.81	179240
Suzhou	tourist cities	402.53	1274.83	8657.32
Taian	tourist cities	95.6	547.22	7762
Tongling	tourist cities	39.5	130.1	2991.87
Xianyang	tourist cities	33.79	421.3	10196
Yichang	tourist cities	50	401.76	21000
Yichun	tourist cities	141.89	497.11	18700

Chapter 4 Economic incentive in enhancing community waste separation and collection: A panel data analysis in China

4.1 Introduction

In 2017, in order to solve waste separation at the source, the Chinese government promulgated a mandatory garbage classification policy to require 46 key cities, including Beijing and Shanghai, to implement compulsory waste separation at the source in the hope that those 46 cities might establish successful waste separation models by carrying out various types of waste classification pilot projects (Chen, 2020). In this context, Chinese cities could be divided into two kinds of cities based on the mandatory policy, 'mandatory separation cities' and 'non-mandatory separation cities'. Unlike those 46 'mandatory separation cities', more than 600 cities belong to 'non-mandatory separation cities' in China. Those non-mandatory cities have no clear, mandatory policies or regulations to manage waste classification at the source. However, regardless of whether it is mandatory or non-mandatory, local governments have launched multiple means of promoting various explorations of urban waste classification in an effort to explore effective waste classification models, such as seeking citizen opinions, organizing volunteer activities, encouraging private enterprises to participate in the pilot operation of waste classification, etc.

So far, many cities have been reported to have successfully implemented waste separation pilot projects focused on case studies in 46 mandatory cities, such as Shanghai, Beijing, and Hangzhou. In those case studies, the main reasons for successful pilot projects are promulgating mandatory policies and economic incentive introduction (Xu et al., 2018; Zhou et al.,2019; Li et al., 2019; Zhou et al., 2019). Identifying the reason for the success and actual situation of the waste separation pilot project is very important for China to effectively modify suitable waste separation policies and actions in the future. For example, if, without mandatory government policies, the economic mechanism still positively impacts waste separation in the start-up period, then those non-mandatory cities in China could widely introduce the economic mechanism in community waste separation activities. Therefore, this paper aims to discern the contribution of the point system, widely introduced as an economic mechanism in many Chinese cities, to activity concerning the separation of waste at the source. In order to explore the impact of the point system, this study used a non-mandatory city as a case study.

4.1.1 Previous Studies on incentive mechanisms

Economic incentives have already been applied to encourage domestic waste separation. For example, Yau (2010) took 122 private housing estates in Hong Kong as a research target and found that reward schemes have a significant positive relationship with the per-household weight of recyclables collected. Additionally, incentives could achieve more for residents with a lower initial separation rate (Harder & Woodard, 2007). Those researchers suggest that incentives can be given individually and act as feedback about individual performance, increasing their willingness to contribute (Thogersen, 2005). However, some researchers suggest that using incentives in those areas could backfire because extrinsic incentives may crowd out intrinsic motivations important for producing the desired behavior. In other cases, incentives might have the desired effects in the short term, but they still weaken intrinsic motivations. Thus, once the incentives are removed, people may pursue the desired outcome less eagerly (Gneezy et al.,2011; Varotto & Spagnolli, 2017).

4.1.2 Research Purpose and Significance

Synthesizing the insights from this literature, it can be speculated that the operation period of the incentive mechanism, if it is too long, will require that input costs increase and may not have a sustained long time positive impact on waste separation behavior. If it is too short, it is also detrimental to the formation of resident waste-sorting behavior. Therefore, an appropriate operating cycle period plays a vital role in the success of waste separation. However, systematic empirical evidence about the effects of recycling incentives on waste separation behavior still needs to be discovered. The incentives operation period as a potentially critical factor needs to be addressed. As a result, there is a gap in the literature. This study attempts to fill this gap by investigating the changes in the point system's operating time on waste sorting participation and recycling and by identifying the factors influencing changes in participation and recycling.

4.2 Methods and Materials

4.2.1 Point System in China and Dongying City

Point system in China

The point system has been introduced and implemented in many cities in China. It has different names in different cities, such as ‘Bonus Point system’ in Beijing (Guo et al., 2017), ‘Green Account’ in Shanghai (Xiao et al., 2020), and ‘Green Points’ in Hongkong (Yau, 2010). This research referred to this system as the ‘Point system’.

The point system is an incentive system for waste separation. Residents can earn reward points by putting the sorted waste into the designated equipment (intelligent garbage box) and can exchange those points for daily necessities. Residents usually use their mobile phones through WeChat or point system applications to register information. Generally, one household registers as one account, and each performance will get a bar code. When disposing of waste, it is necessary to use an intelligent garbage box to scan the bar code, and the points are stored in their accounts. These points can be exchanged for daily necessities on the online platforms set by the system. The process of the point system is shown in Figure 1:

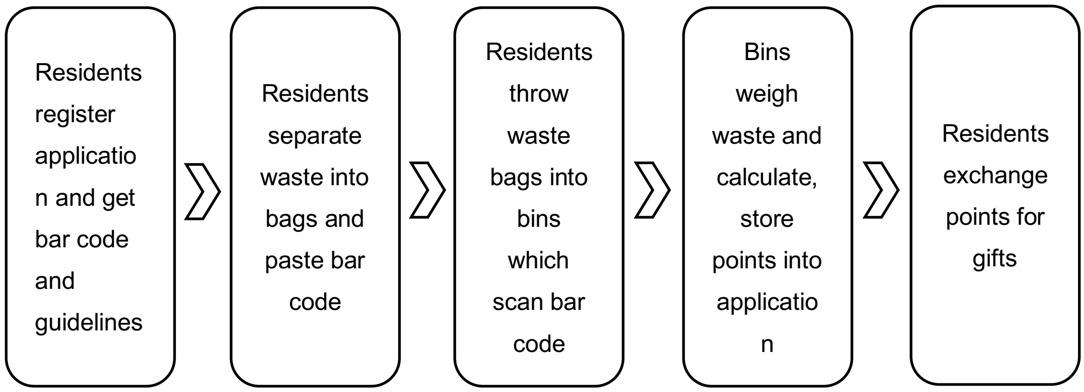

Figure 4.1 Process of waste separation and collection with the Point system

(Source: Created by the author refer to Guo et al., 2017)

Point system in Dongying City

Dongying City is classified as a non-mandatory city in northern Shandong Province, China. It is an oil industry city that emerged from the Shengli Oilfield. Therefore, the city's industries are mainly state-owned enterprises related to oil exploration and manufacturing. The research area is Dongying District, the central district of Dongying City. This district has 404 communities and 190,284 families with a population of 547,643. Dongying District generates six hundred tons of domestic waste daily (Dongying City Statistics Bureau, 2021). Therefore, the average daily domestic waste generation per household is 3.15kg.

In 2020, Dongying City planned a waste separation pilot project in Dongying District and invited public bidding. In June 2020, the government made a 3-year contract with Dongying Huizhong Environmental Protection Co., Ltd. to implement the waste separation pilot project by the point system. The contract period is from September 2020 to September 2023. The contract requires that the participation rate of demonstration communities reach 50% in the first year and 85% in the second year, achieving the replicable model in the third year. Besides, the Dongying District Urban Management Bureau cooperates, supervises, and accepts results. Dongying Huizhong Environmental Protection Co., Ltd. is responsible for the point system implementation and management.

The point system in Dongying City is slightly different from mandatory city models. Due to the permission of the community space, in addition to setting up an intelligent garbage box, there is also an environmental protection room in the community. The environmental protection room is a house of about 20 square meters, where residents can exchange their points for daily necessities, and the staff can work and communicate with the residents. Some rooms also take over the function of the community and express delivery simultaneously. Intelligent garbage boxes are open 24 hours, and environmental protection rooms are generally available from 8:00 to 19:00 every day except for national holidays.

Waste is divided into four types in Dongying based on the provisions of the 2017 waste policy. The four types are kitchen waste, recyclable waste, hazardous waste, and others. The types of collected waste considered by the point system are mainly separated recyclable waste, kitchen waste, and hazardous garbage. Recyclable waste could be exchanged and stored for reward points, while kitchen waste and hazardous waste cannot be exchanged for points (Table 1). Dongying's point system parallels the former community waste recycling system. It is voluntary for residents to participate so that other unsorted waste can be thrown into the original waste trash. The point system would not recycle other and unseparated waste.

Table 4.1 Point system collected waste type and exchange points in Dongying City

Class	Type	Name	Details	Unit	Points	RMB
Recyclable waste	Metal	Iron cans	Cookie tins, tea tins, milk powder tins, etc., excluding contaminated tins, such as hairspray tins	kg	40	￥0.40
		Aluminum cans	Beer cans, beverage cans, etc.	piece	5	￥0.05
		Other metal	Stainless steel and aluminum wire, etc.	kg	100	￥1.00
	Clothing	Old clothes	Clean old clothes which are not contaminated.	kg	40	￥0.40
		Old shoes	Clean shoes which are not contaminated.	kg	20	￥0.20
	Glass	Glass bottle	Beer bottles, red wine bottles, white wine bottles and other complete wine bottles (excluding ceramics).	kg	10	￥0.10
	Paper	Books	Used books and paper.	kg	100	￥1.00
		Newspapers	Newspapers.	kg	100	￥1.00
		Yellow paper shell	Packaging such as yellow cartons, such as express boxes, etc.	kg	100	￥1.00
		Color paper shell	Colored paper shell (covered with a layer of plastic film) packaging, including disposable paper cups, etc.	kg	60	￥0.60
	Plastic	Plastic bottle	Completely washed plastic beverage bottles, etc.	kg	100	￥1.00
		Plastic foam	Used for packaging foam, foam box and foam board, etc.	kg	100	￥1.00
		Other plastics	Except for unwashed take-out boxes and contaminated garbage bags, they will all be recycled, such as plastic trash cans.	kg	40	￥0.40
Kitchen waste			Discard unused vegetable leaves, leftovers, leftovers, peels, eggshells, tea residues, bones, etc. in the kitchen.		-	-
Hazardous waste			Toxic and hazardous waste: waste cosmetics, waste films, waste photo paper, waste fluorescent tubes, waste thermometers, waste rechargeable batteries, waste button batteries, etc.		-	-

（Note： RMB is the abbreviation for Renminbi which is the official name of China's currency； This column of RMB means the costs which the conversion of points into money. "-" means kitchen waste and hazardous waste cannot be exchanged for points）

The Dongying Point system receives its funding primarily from three sources. First, government financial support and subsidies, which comprise about 40% of all funding sources, are acquired through competitive bidding. Second is the back-end revenue from recyclable waste. The points in Table 1 are set at half the market price for resource waste. The recycled resource waste would be sorted and processed twice before being sold to the back-end factories as raw materials to generate revenue. About 50% of the revenue comes from this segment. Third is the online platform revenue, comprising about 10% of total revenue. The Point system application will place advertisements to earn advertising revenue fees. (Data acquired by point system managers.)

4.2.2 Data Collection and Analysis

Data collection

The data were collected from Dongying Huizhong Environmental Protection Co., Ltd. The point system data from September 2020 to June 2022 was chosen. The data include residents' basic information (age, gender, contact information, and occupation), the frequency and weight of waste separation and disposal per day, and the types of waste. Additionally, through field investigations and interactions with staff from different communities, information on the architectural types of various communities was collected. Kitchen and hazardous waste are not exchanged for points, and the weight accumulated is limited. Therefore, those wastes are not considered evaluation indicators. This paper selects the weight of recyclable waste and the number of participants as the evaluation indicators. Within the period, 3299 tons of recyclables were collected by 98 communities. At the same time, each community operation time is different. Some communities have been in operation for 22 months, and some have only been in operation for 10 months.

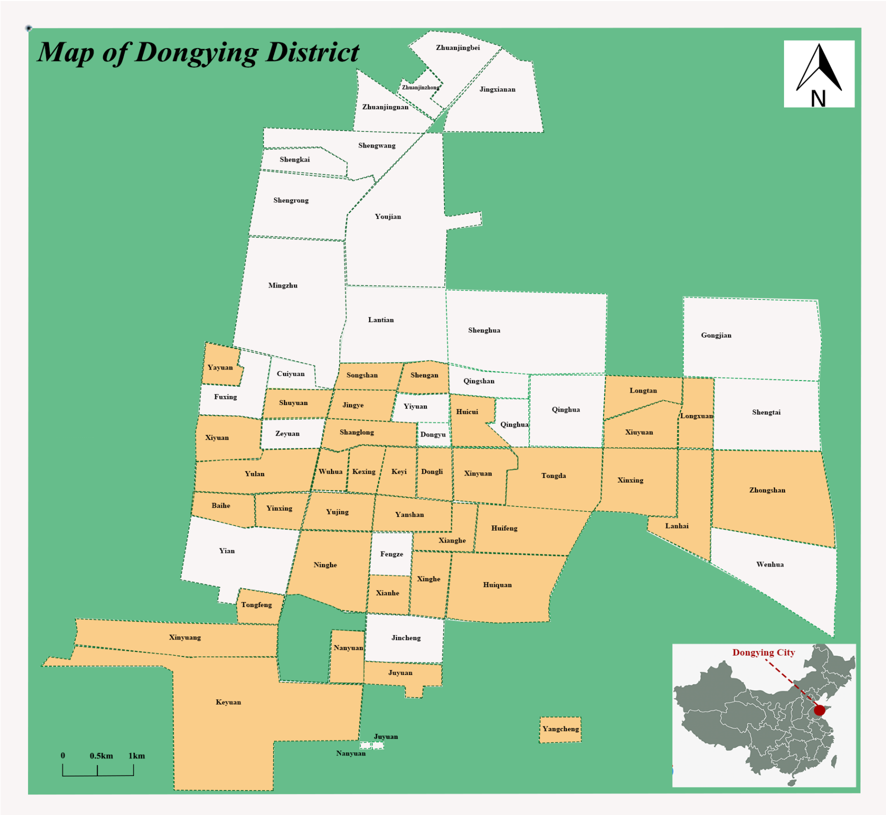

Figure 4.2 Map of Research Area

(Source: Point System operation area (yellow) until 2021.10)

Data analysis

Empirical framework

In the literature on incentives for lifestyle changes, enough incentive mechanisms had significant work in the short run, while in the longer run, the desired change in habits could disappear again (Gneezy, 2011). Therefore, the incentive mechanism is helpful in the short term, while whether it will continue to have an impact in the long term remains to be tested empirically. Based on this, this study hypothesizes that the impact of the incentive mechanism in the medium and long term is likely to be positive.

The empirical analysis in this study used several estimation methods. Firstly, the cross-sectional impact of Point System (PS) operation on community participation and collection was examined using the Ordinary Least Squares (OLS) method. Secondly, the effects of over-time variation in PS operation on community participation were explored. The panel Fixed Effects (FE) regression estimation method was displayed since this method is statistically preferred. Thirdly, the significant effect of over-time variation was estimated with panel Random Effects (RE) regressions. Fourth, the Least Square Dummy Variables (LSDV) estimate method is used for cross-section correlation problems in the model.

The base regression model is given by：

$$WS_i = \alpha_0 + \alpha_1 D_i + \alpha_2 D_i * D_i + \alpha_3 X_i + \varepsilon_i \quad (1)$$

This paper also uses panel regressions with FE and RE to estimate the impact of over-time variation:

$$WS_{it} = \alpha_i + \beta_1 D_{it} + \beta_2 D_{it} * D_{it} + \beta_3 X_{it} + \varepsilon_{it} \quad (2)$$

$$WS_{it} = \alpha_i + \mu_t + \gamma_1 D_{it} + \gamma_2 D_{it} * D_{it} + \gamma_3 X_{it} + \varepsilon_{it} \quad (3)$$

Where *i* and *t* indicate the communities and months, respectively; *WS* is the evaluation indicator of waste separation, here representing community participation numbers (P) and recycled waste weight (R); *D* is an explanatory variable, which represents Point System （PS） operation/influence time; This paper introduces the square of *D* to test the inverted U-shaped relationship between PS operation time and community participation numbers (P) and recycled waste weight (R); X_i represents a series of control variables which can be described in detail (Table 4.2).

Variables

Table 4.2 Description of Variables Used in Regressions

	Variables	Description	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables	Ln Monthly Participants	Natural log of Community monthly Participants number (household)	1710	4.41	0.93	0	6.19
	Ln Monthly recycled	Natural log of Community monthly recycled waste amount (kg)	1710	7.18	1.18	-.87	8.86
	Ln Paper waste	Natural log of Community monthly recycled paper amount (kg)	1710	6.12	1.24	-.92	8.36
	Ln Plastic waste	Natural log of Community monthly recycled plastic amount (kg)	1710	4.83	1.21	-2.3	6.82
	Ln Cloth waste	Natural log of Community monthly recycled cloth amount (kg)	1710	5.99	1.2	-1.39	8.29
	Ln Metal waste	Natural log of Community monthly recycled metal amount (kg)	1710	4.32	1.39	-3.91	6.93
	Ln Glass waste	Natural log of Community monthly recycled glass amount (kg)	1710	5.13	1.25	-2.3	7.97
Independent variable	PS operation time	Point system operation or influence time (month)	1710	9.76	5.78	1	22
Control variables	Community household number	Community household number (families)	1710	1031	570.5	206	3000
	Community residents attribute	Whether a community member dominated by financial support personnel such as civil servants, teachers, state-owned enterprise employees, 0=No, 1=Yes	1710	0.64	0.48	0	1
	Community building type	Villa area = 4; High-rise buildings (above 11 floors) = 3; Middle-rise buildings (7-11 floors) = 2; Low-rise buildings (below 6 floors) = 1	1710	1.76	0.94	1	4
	Equipment area	Whether it is placed with high foot traffic in the community, 0=No, 1=Yes	1710	0.63	0.48	0	1
	Equipment function	Whether equipment add other functions, such as express delivery, etc. , 0=No, 1=Yes	1710	0.19	0.39	0	1
	Community dummy	Scale from 1 to 105, 105 communities	1710	51.74	28.83	1	98
	Month dummy	Time dummies are created for 22 periods from September 2020 to June 2022.	1710	12.93	6.01	1	22

1) Dependent Variables

Undoubtedly, the widespread participation of the public is the key to the success of waste separation in a society since it requires a concerted effort of social members (Olson, 1965). Therefore, the number of Participants is often used as an indicator to assess the success of waste separation. At the same time, the amount of waste recycled is considered another essential indicator to test recycling capacity.

The primary purpose of this research paper is to explain how community participation and recycling activities are affected by point system operations after controlling for other determinants. Depending on the availability of data sources and literature papers, this paper chose monthly community participants as indicators to evaluate community participation levels; and monthly recycled waste weight as indicators to assess community recycling levels.

2) Independent variable

The independent variable is the point system operation time (month) which shows each community's waste separation activities changing under the influence of point system operation.

3) Control variables

Those control variables were divided into two main aspects.
First, the community attributes were selected, which are normative variables commonly used in empirical community waste separation evaluation studies. Specifically, community size, community building type, and community residents' essential attributes.

The number of residential households in the community was used to measure community size. The community house building type is measured by the actual building type in the community.

Based on the current building types of community in Dongying District, this variable could be divided into four classes: Villa District, High-Rise buildings (11+ stories), Mid-Rise buildings (7-11 stories level), and Low-Rise buildings (less than 6 stories). Based on the market price of building types in Dongying, the selling price per square meter is highest in the villa district, followed by high-rise, mid-rise third, and low-rise lowest. Thus, controlling for the variable of building types, it is possible to detect the effect of the living housing type on residents' waste-sorting behavior (Yau, 2010).

Community resident attributes are measured by 65% of the community's residential work characters. Depending on the characteristics of the Dongying community, those communities are generally a concentration of certain types of work members. For example, there are many civil service communities close to government institutions and many faculty staff communities close to schools in Dongying District. In addition, Dongying city has the famous Shengli oilfield and therefore has many oilfield-related state enterprises equipped with many oilfield communities. Those above communities' members, including those of civil service communities, faculty and staff communities, and oilfield communities, are financially supported by the government and are the first to learn about the importance of waste separation behavior by popularization or publicizing in their workplace. Apart from that, new communities are moved from rural areas through government administrative planning, known as new rural communities, and many commercial housing communities for purchase by the public, whose resident members are mainly business workers or general business employees. Those residents rely primarily on community publicity to receive information about waste separation activities. Depending on the actual situation, community resident attributes are divided into two main types, those with and without government financial support.

Second, the impact of the waste separation equipment on the results were control in this study, using the area where the equipment is placed as well as the function of the equipment for selection. Equipment placement is usually decided through consultation with the community property management agency; in some communities, the equipment is set near the community gates, gardens, or activity centers, which are convenient for residents and have high traffic flow. In other cases, the equipment is set up in isolated corners of the neighborhood where there is less daily foot traffic. Choosing equipment placement as a control variable could examine the effect of the convenience of equipment on residents' waste-sorting behavior.

The study also controls for the equipment function. In some communities, the environmental protection house is large and aesthetically pleasing. To motivate and curiosity the residents, functions such as courier collection and delivery and event handling are added to increase the stickiness of the residents' continued participation; in other communities, the environmental protection house only has a single recycling function. Therefore, using this as a control variable makes it possible to ensure that adding features to the equipment does not impact the results.

4.3 Results and Discussion

4.3.1 Measurement results of community participants and recyclable

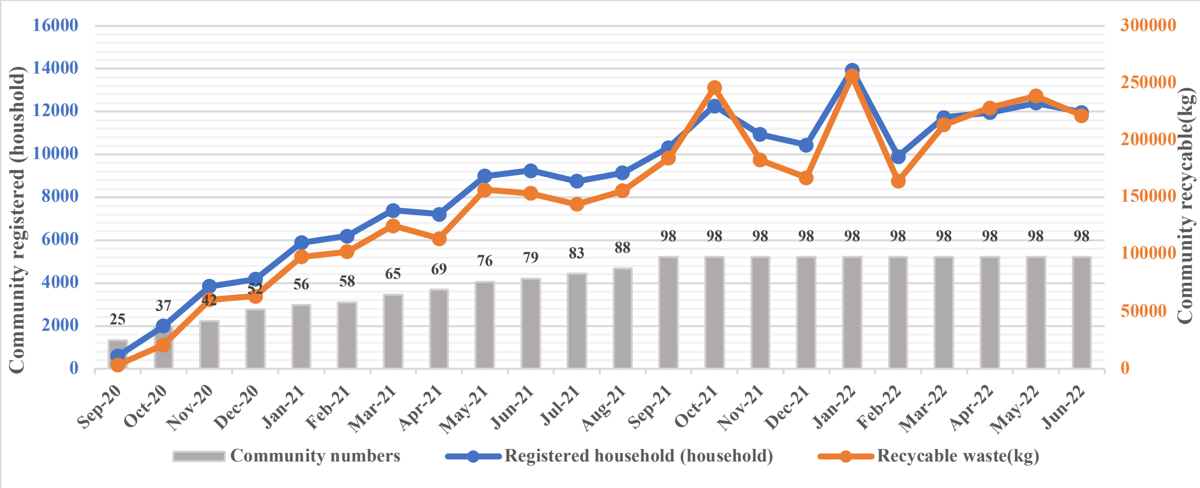

Figure 4.3 The trend of the monthly community participants and recyclables with the point system

(*Source: Created by the author based on the data collection)*

Figure 4.4 The trend of the monthly community participants and recyclables with the point system

(*Source: Created by the author based on the data collection)*

Figure 4.3 shows the trend in the total number of participants per month and the total amount of recyclables collected monthly in the 98 communities under the point system operation, advancing on a timeline. As the graph shows, the data before October 2021 showed a trend of substantial and steady growth; the reasons are (i) the stimulation of the point system operation, and (ii) the number of communities before October 2021 is constantly increasing. After October 2021, the data showed ups and downs and gradually tended toward a stable state. The highest peak during this period was in January 2022, when the number of participating communities was 98, the number of participants was 13945 households, and the amount of waste collected was 256075.2kg. The peak is due to the Chinese New Year on 1 February 2022, when there were a large number of gift-giving parties for friends and relatives in January, which might result in a large increase in recyclable waste. The sudden drop in February 2022 is due to the Chinese New Year holiday when residents of rented houses in the community return to visit their parents' homes, resulting in a sharp drop in the number of participants to 9899. In sum, through the results, the point system can indeed promote residents' participation in waste separation behavior.

4.3.2 Panel data regression results

Based on the above results, further empirical tests were carried out. this section compares the OLS, FE, RE, and LSDV estimations for empirical analysis (as shown in Table 4.3) with one other and selects the most suitable estimation method for the sample.

Table 4.3 Regression results in community participants and recyclable

	Ln Community Participants					Ln Community Recyclable				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	OLS	FE	RE	LSDV	LSDV.1	OLS	FE	RE	LSDV	LSDV.1
PS operation time	0.184***	0.188***	0.183***	0.183***	0.047***	0.252***	0.238***	0.247***	0.246***	0.073***
	(9.44)	(7.62)	(9.10)	(8.83)	(7.20)	(9.57)	(7.26)	(8.93)	(8.62)	(8.97)
PS operation time^2	-0.006***	-0.006***	-0.006***	-0.007***		-0.009***	-0.007***	-0.008***	-0.008***	
	(-7.82)	(-5.50)	(-8.07)	(-7.85)		(-8.22)	(-4.52)	(-7.57)	(-7.28)	
Ln Comm household	0.453***		0.410***	0.970***	0.984***	0.412***		0.349***	0.699***	0.716***
	(3.83)		(3.17)	(265.45)	(243.59)	(2.91)		(2.51)	(146.93)	(141.26)
Comm building	0.158***		0.154***	0.842***	0.787***	0.030		0.015	1.363***	1.294***
	(2.92)		(2.80)	(90.81)	(81.88)	(0.37)		(0.19)	(113.44)	(107.16)
Comm attribute	0.198*		0.225*	-1.343***	-1.339***	0.105		0.106	-2.266***	-2.261***
	(1.84)		(1.92)	(-1228.24)	(-1107.84)	(0.77)		(0.77)	(-1592.35)	(-1489.98)
Equip placement	0.127		0.149	-2.097***	-2.10***	0.174		0.225*	-2.707***	-2.710***
	(1.13)		(1.19)	(-3449.78)	(-3124.63)	(1.30)		(1.65)	(-3420.52)	(3211.50)
Equip function	-0.352***		-0.357*	-3.020***	-2.956***	-0.461***		-0.487***	-4.919***	-4.837***
	(-3.10)		(-2.94)	(-256.74)	(-237.00)	(-2.77)		(-3.01)	(-322.62)	(-308.86)
Constant	-0.064	3.291***	0.208	-3.691***	-3.183***	2.897***	5.491***	3.320***	-0.309*	0.337***
	(-0.08)	(20.33)	(0.24)	(-31.84)	(-42.28)	(2.67)	(30.15)	(3.24)	(-1.94)	(3.56)
Observations	1705	1705	1705	1705	1705	1705	1705	1705	1705	1705
R-squared	0.320	0.303		0.625	0.574	0.255	0.367		0.564	0.513
Hausman test		19.08***					12.76**			
Number of Comm		98	98				98	98		
Comm dummy	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Month dummy	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

*(Note： Ln denotes that a natural logarithm was used in the analysis. Robust t-statistics are in parentheses. *** p<0.01, ** p<0.05, * p<0.1)*

First, OLS models were used to check the relationship between participants and recyclables between variables. In the models where community participation is the dependent variable, the OLS estimation shows that the coefficient of PS operation time and PS operation time square are 0.184, -0.006, 0.252, and -0.009, respectively. Those data pass the significance test at the level of 1%. However, those OLS models did not introduce community and month dummy variables. The OLS estimation model may miss some variables that affect the community participant number and recyclable amount. Hence, it was decided not to use OLS in favor of FE and RE. Second, in the FE estimation, the coefficient of PS operation time and PS operation time square are 0.188, -0.006, 0.238, and -0.007, respectively. This time, the FE models introduced community dummy and month dummy variables, and the coefficient is significant at the 1% level. While community and equipment variables change very little over time, they are not brought into the FE estimation. Therefore, the results did not show up on the FE models. Third, RE models were used to estimate for empirical analysis. The coefficient of PS operation time and PS operation time square also have significance at the 1% level. At the same time, we needed to figure out whether the FE or RE models were more suitable for the research samples. The Hausman test is suitable for choosing between FE and RE models. In the models where the community participant is the dependent variable, the result of the robust Hausman test is 19.08； in the models where the amount of community recyclable is the dependent variable, the result of the robust Hausman test is 12.76. Both effects are significant at the 1% level. Hausman's test shows that the estimation gap between the FE and RE is too large, which indicates that FE results are more consistent than RE, so FE should be chosen. As mentioned above, a cross-sectional correlation problem exists in FE, so we used LSDV estimation to address this issue. The PS operation time and PS operation time square coefficients are 0.183, -0.007, 0.247, and -0.008, respectively, significant at the 1% level. Additionally, these results are very stable.

In summary, comparing the analysis results of OLS, FE, RE, and LSDV, the LSDV model is the most suitable for the sample data. Based on LSDV, PS operation time was used as the independent variable for the calculation, yielding results (5) and (10). The results show that when PS operation time alone was the independent variable, the results were 0.047 and 0.073, positively correlated with community participants and recyclables, showing a moderate growth trend. When PS operation time and PS operation time square together were the independent variables, the results show a state of growth at the beginning and no growth afterward, indicating saturation. The duration months at the peak of the PS operation time, as calculated from the regression coefficients in column (5) for Ln Community Participants, is approximately 50.23 months. The duration months at the peak for Ln Community Recyclable, as indicated in column (10), is approximately 57.72 months. The graphical effects are consistent with Figure 2, which means that they start with a positive correlation structure and tend to a saturated form after a specific time has been reached. These results confirmed the hypothesis.

In addition, from the results of (5) and (10), we know that control variables also significantly correlate with participants and recyclables. Among them, the community household number is positively correlated with the dependent variable, which means that when the community population is larger, participants and recyclables will also increase. The type of community building is also positively correlated with the dependent variables. This means the higher the housing unit price, the higher the number of participants and recyclables. The control variables with a negative correlation include the attributes of community residents, equipment placement, and equipment functions. This means that when the government financially supports the community residents, the garbage equipment is placed in the center of the community. at the same time , if the waste equipment has some functions (community activity functions, such as, community reading books activities)more than waste collection, the participants and recyclables was not increase as expect.

4.3.3 Heterogeneity analysis

Heterogeneity refers to how the impact of the point system on the amount of recyclables varies from community to community and from one type of waste to another. The easiest way to solve the heterogeneity problem is to divide the sample into subsamples according to the needs of the research questions and then use the LSDV model to estimate community participants and recyclables separately.

Community recycling volumes for different types of recyclable waste

When the different amounts of different types of waste are the dependent variables, the relationship between the results and the independent variable and control variables is shown in Table 4.

Table 4.4 LSDV model estimation results for different types of recyclable waste

	Paper waste	Cloth waste	Plastic waste	Metal waste	Glass waste
VARIABLES	(1)	(2)	(3)	(4)	(5)
PS operation time	0.078***	0.136***	0.154***	0.139***	0.201***
	(9.15)	(7.57)	(7.75)	(6.64)	(12.34)
Observations	893	883	891	871	864
R-squared	0.627	0.589	0.584	0.541	0.642

*(Note: Ln denotes that a natural logarithm was used in the analysis. Robust t-statistics are in parentheses. *** p<0.01, ** p<0.05, * p<0.1)*

According to the results in Table 4, when PS operation time is the independent variable, there is a positive correlation with the amount of waste collected. The point system operation time has a strong significant positive impact on glass waste (the coefficient is 0.201); it has the weakest positive impact on paper waste which is the largest percentage of recyclable collection. Therefore, it can be inferred that the amount of glass waste will continue to increase with the operation of the points system. The amount of recycled paper waste is relatively large and will not increase significantly with the operation of the incentive mechanism.

Participants and recyclables for different types of communities

When discussing the impact of the operation of the point system on the participants and recyclables of different communities, group regressions are performed on different communities. In order to verify the result, the author referred to the community attributes and the attributes and community building types and divided the sample into 6 groups for comparison. Some communities are financially supported by the government and communities that are not villa area communities, High-rise buildings communities, Middle-rise buildings communities and Low-rise buildings communities.

Table 4.5 Estimation results of LSDV model for different communities

	Groups	PS operation time	Observations	R-squared
Participants	**Financial support**	0.108*** (6.50)	550	0.623
	Non-financial support	0.092*** (3.57)	350	0.573
	Villa area	0.108** (8.02)	38	0.582
	High-rise buildings	0.118*** (4.51)	248	0.548
	Middle-rise buildings	0.090*** (4.08)	154	0.586
	Low-rise buildings	0.093*** (3.74)	460	0.586
Recyclables	**Financial support group**	0.147*** (6.80)	550	0.594
	Non-financial support group	0.162*** (4.56)	350	0.582
	Villa area	0.214* (3.51)	38	0.704
	High-rise buildings	0.171*** (5.18)	248	0.573
	Middle-rise buildings	0.151*** (4.89)	154	0.556
	Low-rise buildings	0.134*** (4.05)	460	0.591

(*Note：Ln denotes that a natural logarithm was used in the analysis. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1*)

The regression results show that when the dependent variable is community participants, the point system significantly impacts the financial support community group and the high-rise building community group (the coefficients are larger than other groups, 0.108 and 0.118, respectively). It means that when the residents of the community are financially supported, or when the community where the residents live is a high-building community, it is easier to use the points system to achieve better results. The number of community participants will continue to increase. When the dependent variable is the community recyclables, the point system has roughly the same impact whether or not it has financial support, but it also has a strong significant impact on the certification of the villa area (the coefficient is 0.214). This means that residents in high-building or villa areas communities may be more willing to separate their household garbage, and the amount of recyclable waste generation is larger than in other communities.

To sum up, residents in the high-rise buildings community and financial support community are more likely to participate in the point system. They are more likely to be affected by the incentive mechanism. On the contrary, residents in low-rise residences are less likely to affect by incentives to participate in waste-sorting behaviors. The results of this study are consistent with Ahsan et al. (2014) research which considered that waste management systems in high-rise residential buildings could be very effective and different from communities of other types of buildings for the following reasons: residents of high-rise buildings are higher-medium to upper-income group people with higher social and economic status. As a result, they are also more aware of social issues such as waste problems in local areas. Also, there is much more publicity related to waste classification that can be accepted by them from the employment unit. Therefore, the point system should provide more infrastructure and services in such communities.

4.4 Conclusion

The most important result of this study is to use empirical research to verify the promotion effect of the points system on the community participants and recyclable behaviors. First, the result shows that the point system plays a role in promoting community waste sorting behavior. However, the community participation and recyclable rates still need to be higher and have yet to reach the effect expected by Dongying City government. Second, the results showed that the point system has a short-term promotion effect on community residents' participation and recycling behavior. However, its effect will be saturated in the long run, and there will be no new participants and recycled volumes. Third, this study shows the factors that affect the amount of community participation and recycling, in addition to the impact of the incentive mechanism, including other indicators such as community household number, community attributes, community building types, equipment placement areas, and equipment attributes. Finally, through heterogeneity analysis, glass waste is more positively affected by the point system, and high-rise residential communities are more likely to participate in waste sorting behavior.

In summary, the results of this study confirm the effectiveness of economic incentives in promoting waste separation and recyclable behaviors, but at the same time, point out the shortcomings. With the long-term operation, the operating cost will continue to increase, and the participation and recycling rate saturation will occur. Therefore, the operation time of the incentive mechanism needs to be measured with system operational costs and the duration of the impact on resident behavior.

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Chapter 5 Conclusions and Recommendations

This chapter summarizes the main findings of the study and proposes recommendations for improving the implementation and design of China's point system, aiming to better develop sustainable waste separation and recycling in China in the future.

5.1 Conclusions

By conducting literature review, this study analyzes the current status and challenges of waste management in China and the role of economic incentives in guiding waste separation policies. It also introduced the implementation of incentive systems such as deposit-refund system, waste bank and points systems in various countries including China and Indonesia and provides recommendations for policies and regulations needed to implement an effective economic incentive system in waste separation. Besides, by conducting OLS and Panel data analysis, this research analyzes the implementation of the points system in China and uses empirical research to verify the promotion effect of the points system on community participants and recycling behaviors.

Chapter 2:

Based on the literature review (including academic papers and grey literature), this chapter shows the current waste management problems in China. With the development of the economy and urbanization in China, the amount of waste generation has increased rapidly, which makes the treatment and management became an urgent problem. According to statistics, more than 10 billion tons of solid waste are added to China each year, with a total historical stockpile of 60–70 billion tons (Han et al., 2022). Improper disposal of large amounts of waste will not only harm the health of residents and cause environmental pollution, but also cause a waste of resources, thus affecting sustainable economic and social development and ecological stability. Although waste separation is crucial to social development and people's health, instilling a waste separation habit among the Chinese populace has proven to be a formidable challenge. Concerning about environmental pollution, resource waste and the harm to human health, an effective waste management system is needed to reduce environmental and management burdens.

According to the foundational behavioral principle, larger incentives yield greater effort and enhanced performance. Therefore, economic incentives play a key role in guiding policies. Although financial incentives have proven their effectiveness in various behavioral contexts, their application in waste separation remains controversial. Proponents of incentives argue that, for example, financial incentives can help people study or exercise more. Opponents argue that using incentives in these areas can be counterproductive because extrinsic incentives may somehow crowd out intrinsic motivation to drive desired behavior.

Incentive systems such as deposit-refund systems, waste banks and bonus points systems have been implemented in various countries, including China, to stimulate domestic waste separation. However, a common challenge for these systems remains to optimize the operational mechanisms to enhance their efficiency and user-friendliness.

Fundamental elements for implementing an effective economic incentive system in waste separation include strong policies and regulations, which include Management Institutions, defined Scopes of application, pragmatic Funding Mechanisms, adept use of Technology, and the cooperative involvement of various Stakeholders. A comprehensive approach that takes into account policy, technical interventions, stakeholder collaboration, funding and management structures is essential to address the complexities of waste management and recycling. Besides, the Resident Participation Rate and Recyclable Rate face challenges such as scarce recycling access, difficulties in obtaining data, and inherent complexities in managing and encouraging broad public participation in recycling activities. These challenges require a nuanced, adaptable and comprehensive approach to promote sustainable waste management practices.

Chapter 3:

This chapter summarizes and analyzes the implementation of the points system in China and enriches the research on the incentive mechanism of the waste collection system through the analysis of the collected data. The study identified a total of 466-point systems currently operating in China, which are mainly divided into four models: (a) government-private modes: (a) Government-private mode: Door-to-Door collection, (b) Government-private mode: Station collection, (c) Government-Government mode: Station collection, and (d) Private-private mode: Door-to-Door collection. Among these modes, mode (b) is the most common, running in 41 of 46 cities, accounting for 91% (425 systems).

From the perspectives of governments, companies, and residents these three perspectives, (b) Government-private mode: Station collection was the most suitable operating mode from all three perspectives and had the highest potential for sustainable replication. This finding fits well with the current status quo.

In addition, the study discusses the feasibility of other models in future social development, such as the potential utility of modes (a) and (d) in complementing other services in an aging society. In addition, this study found that the number of people served, and the length of service have a positive impact on the total investment amount, while they have a negative impact on individual subsidies. Per capita daily waste production and population density are negatively correlated with both dependent variables, while per capita GDP is positively correlated with the winning bid amount.

While the points system has been successful in some cities, that doesn't mean it will be successful in others. However, it is important to understand existing systems and learn from their experiences. It is clear that China's current cities need to implement sustainable collection, recycling and reuse through a points system, which is an important issue for sustainable development.

Chapter 4:

This study verified the promotion effect of the points system on community participants and recycling behavior through empirical research. Empirical research results show that the points system plays a role in promoting community waste-sorting behavior. However, community participation and recycling rates have not yet reached the expected results of the Dongying Municipal Government, and they still need to be improved. In addition, the results show that the points system has a promoting effect on community residents' participation and recycling behavior in the short term. However, in the long run, its effect will be saturated, and there will be no new participants and no recycling volume. In addition, this study shows the factors that affect community participation and recycling volume. In addition to the impact of incentive mechanisms, it also includes other indicators, such as the number of community households, community attributes, community building types, equipment placement areas, and equipment attributes. Finally, through heterogeneity analysis, it was demonstrated that glass waste is more positively affected by the points system and that high-rise residential communities are more likely to engage in waste sorting behavior.

The results of this study confirm the effectiveness of economic incentives in promoting waste sorting and recycling behaviors, but also point out their shortcomings. With long-term operation, operating costs will continue to increase, and the participation rate and recovery rate will reach saturation. Therefore, the operating time of the incentive mechanism needs to be measured by the system operating cost and the duration of the impact on residents' behavior.

5.2 Research Limitations

Progress in research invariably encounters certain limitations. In this section, some of the constraints and restrictions possibly encountered in the study are elaborated.

Firstly, the research did not extend to compare the results under two scenarios: with mandatory policy support and without mandatory policy support. As a result, the actual impact and depth of policies on the implementation of the point system are unable to be clearly defined. For example, whether the existence of policies enhances resident participation or enhances the efficiency and effectiveness of the point system. Future research should explore in greater depth the specific modes of operation and effectiveness of the point system in the context of policy support.

Secondly, due to time and space constraints, this study has not conducted in-depth attitudinal analyses of the point system from the perspective of residents. For example, the reasons, attitudes, and motives of residents' acceptance, support, or opposition to the system were not explored in detail here. At the same time, the changes in the cleanliness of the community environment and the improvement in the quality of life of the residents after the use of the point system have not been adequately discussed and analyzed. An in-depth study of these issues will help us understand and assess the actual effects and social impacts of the points-based recycling system in a more comprehensive way.

Lastly, although this study has pointed out the problems of residents' participation rate and recycling rate, it has failed to analyze and explore in depth the specific reasons for the low participation and recycling rate of residents and the many possible factors behind them. For example, whether it is due to insufficient promotion in the community, low environmental awareness among residents, unattractive rewards for points redemption, or some other socio-economic factors that have led to the problem. These factors are important references for our in-depth understanding of the practical difficulties and problems in the operation of the system, and future research directions can be centered on exploring and analyzing these issues in greater detail.

5.3 Recommendations

Based on the findings and lessons learned from this study, several recommendations are proposed for the implementation and application of the point system, offering insights across various aspects, including policy, finance, technology, and education.

(1) Policy Aspect

According to the research results validated in Chapter 3, the 46 cities with mandatory national policy support saw a gradual increase in the number and investment in point systems over the four years from 2019 to 2022, during the process of national policy and government support. In contrast, as discussed in Chapter 4, Dongying City, without mandatory policy support, and environmentally focused private enterprises that operate management timely, introduced point systems locally under the attraction of interests and government subsidies. However, the participation rate of residents and the actual amount of recyclable waste recycled did not meet the expected targets.

In this context, it is clear that in China, especially in top-down public services like waste management, policy support is crucial for the implementation of point systems. Without national policy support, grassroots implementation or advancement of point systems will encounter various obstacles, hindering the commercial development of point systems. Moreover, in the absence of mandatory policies, residents are unlikely to form spontaneous behaviors for waste sorting, ultimately leading to a relative delay in the formation of waste sorting habits among residents of these cities compared to those in cities like Beijing and Shanghai. Furthermore, in cities with existing policy support, the point system should be implemented promptly to ensure active participation in waste separation and recycling activities from the government, enterprises, communities, and residents. Clear reward and penalty mechanisms should be established to ultimately instill a habit of waste sorting among residents.

(2) Financial Aspect

Through the research in Chapter 3, we have learned that currently, most of the points system models in China primarily rely on government financial subsidies to operate, such as (a) Government-private mode: Door-to-Door collection, (b) Government-private mode: Station collection, and (c) Government-Government mode: Station collection, with only a few examples adopting a commercial operation model (d) Private-private mode: Door-to-Door collection. Although Chapter 3 indicates that the funding sources for the point system can include not only government tax subsidies but also the price difference between selling recycled materials, and the price difference of goods on the online platform of the points recycling model, in reality, according to field investigations, many private enterprises state that 70% of their funding still comes from government subsidies.

Compared to the waste classification reward models operated in developed countries discussed in Chapter 2, such as the deposit-refund system (DRS) and Pay-as-you-throw (PAYT), the operational costs of the points system currently running in China are a significant factor limiting its large-scale development and implementation. Moreover, after 2023, the government tax subsidies for many points models are gradually decreasing. Therefore, many operating enterprises should also try to modify their operation models to increase revenue for operational costs, for instance, costs could be offset by the price difference in recycled materials or through advertising revenue utilizing internet systems, etc.

(3) Educational Aspect

In the results of Chapter 4, we learned that, even with the attraction of point systems, after one year, only 10% of the community residents continued to participate in waste separation, far from reaching the expected goals of the system. Therefore, prior research and the recommendations of this study suggest that while providing economic incentives, there should be both policy support and an enhancement of guidance on waste classification education, to prepare residents for forming a habit of waste sorting in the future. Otherwise, the initial operational costs and subsidies for the points system will become a waste of resources.

Therefore, local governments should, while supporting the system's operation, strengthen the popularization of environmental education. For example, conducting waste classification education in primary and secondary schools to firstly form a habit of waste sorting among students and influence their parents. Organizing waste classification education in residential communities and intensifying publicity efforts, etc. This not only enhances residents' environmental awareness but also, to a certain extent, improves the accuracy of waste classification, further enhancing the efficiency and effectiveness of the points system.