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A Qualitative Study on the Effectiveness and Influencing Factors of Waste-free City Construction

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Abstract

This study explored the effectiveness of Shenzhen's "Waste-free City" construction and its influencing factors through semi-structured interviews and policy text analysis. The study found that Shenzhen has built a modern solid waste management system based on institutions, technologies, markets and public participation, and has achieved significant quantitative results. For example, the recycling rate of classified domestic waste exceeds 50%, the resource utilization rate reaches 87.8%, and the resource utilization rate of construction waste is 99%, achieving zero landfill of primary waste. However, some problems still exist, such as insufficient economic feasibility of some technologies, weak participation of small and medium-sized enterprises, and low implementation by residents. The study recommends strengthening regional coordination, increasing investment in technology transformation, and optimizing the environment for public participation to promote the "Shenzhen model" and contribute to the Greater Bay Area's ecological civilization and high-quality development.

Keywords: Waste-free city, Shenzhen model, Solid waste management, Multi-faceted collaboration, Institutional innovation

1. Introduction

Globally, accelerated urbanization has led to a dramatic increase in solid waste generation, posing a significant challenge for countries worldwide. In December 2018, the General Office of the State Council of China issued the "Waste-free City Construction Pilot Work Plan," officially launching the "Waste-free City" pilot program, aiming to develop a replicable and scalable model. Eleven cities and five special areas were initially selected for the pilot program, exploring the establishment of a comprehensive management system and technical framework for "Waste-free City" development. In 2022, 18 ministries and commissions, including the Ministry of Ecology and Environment, jointly issued the "Waste-free City Construction Work Plan for the 14th Five-Year Plan Period,"(Environment, 2021) expanding the scope to 113 cities at the prefecture level and above and eight special areas, marking the beginning of a comprehensive and in-depth phase in the "Waste-free City" initiative.

As one of the first pilot cities for "Waste-free City" development and a pilot demonstration zone for socialism with Chinese characteristics, Shenzhen has actively responded to the national call and introduced a series of innovative policies and measures. In 2019, Shenzhen took the lead in promulgating and implementing the "Implementation Plan for the 'Waste-free City' Construction Pilot Program in Shenzhen," proposing the establishment of "four systems" (institutional, technological, market, and regulatory) and "four mechanisms" (source reduction, classified recycling, resource utilization, and harmless disposal) (Environment, 2020). In 2021, Shenzhen enacted the "Regulations on the Management of Domestic Waste Classification in Shenzhen," becoming the first city in China to legislate on waste classification (Bureau, 2020). In terms of governance innovation, Shenzhen has explored and established a four-tiered responsibility system: "city-level coordination, district-level organization, street-level implementation, and community-level implementation." It has also innovatively launched the "Dandelion" public education program (Bureau, 2018) and created the "Waste-free City Cell."(F. Wang, 2022) Furthermore, Shenzhen has leveraged its technological innovation strengths to develop and build a city-wide innovative solid waste supervision platform, achieving closed-loop management of all types of solid waste.

This study uses qualitative research methods such as semi-structured interviews and thematic analysis to answer the questions about the effectiveness of "Waste-free City" construction in Shenzhen and the factors (institutions, technology, market, and the public) that influence these achievements. This study supplements qualitative research data on "Waste-free City" construction within the context of megacities and analyzes the effectiveness and impact mechanisms of "Waste-free City" construction in Shenzhen. Accurately identifying areas for optimization in its solid waste management system, including institutional, technological, market, and public participation, provides a scientific basis for further policy optimization in Shenzhen. Furthermore, by summarizing and refining Shenzhen's successful experiences and challenges, a policy reference framework applicable to the Guangdong-Hong Kong-Macao Greater Bay Area can be formed, promoting the coordinated development and overall improvement of solid waste management among cities within the region, and jointly contributing to the development of regional ecological civilization and high-quality development.

2. Literature Review

2.1 Research on "Waste-free City"

Over the past decade, "waste-free cities" has rapidly evolved from concept to practice, with research shifting to governance mechanisms and performance evaluation. Based on a review of China's first 11+5 "waste-free city" pilot projects, Meng et al. (2021) noted that the two-way coupling of top-level policies and community action is key to reducing solid waste and increasing recycling rates. However, shortcomings such as an incomplete classification system and a broken pesticide packaging recycling chain suggest that "rial and error—optimization" remains a necessary process for promotion.

While early research focused on end-of-pipe solutions, recent international literature places "waste-free" initiatives within the broader "Circular Economy" (CE) framework. Matete and Trois (2008) used Durban communities as a sample to verify the adaptability of "zero waste" in contexts with limited resources and weak governance capacity, providing a low-cost, localized reference for emerging economies. The European Union's Circular Economy

Action Plan has shifted the focus from waste management to resource management, emphasizing “design for recyclability” and “industrial symbiosis” (Commission, 2020). Furthermore, the C40 Cities (2018) network has highlighted that for megacities, waste reduction is not merely a sanitation issue but a critical climate action strategy, linking upstream consumption patterns to downstream GHG emissions (CITIES, 2018).

Germany’s hierarchical management system, centered around the “reduce-reuse-recycle-recover-landfill” model, has become a mature paradigm many countries adopt (Meng et al., 2021). On a technical level, Lee et al. (2020) introduced a circular carbon economy perspective to urban solid waste management, emphasizing diverse approaches such as mechanical and chemical recycling, agricultural and hazardous waste energy conversion, and providing a systematic solution for urban pollution reduction and carbon reduction, as well as industrial circularity. Zaman (2014) global review further noted that the lack of a comprehensive national strategy is a common bottleneck facing waste-free projects worldwide, calling for a national-community linkage framework to fill the knowledge gap in design, evaluation, and policy guidance.

Research scientifically measuring waste-free initiatives' effectiveness has evolved from a single “landfill diversion rate” to a comprehensive performance index. The Zero Waste Index (ZWI) developed by Zaman (2014) and Zaman and Lehmann (2013) uses the substitution of virgin materials with recycled resources as its core variable, quantifying the benefits of resource substitution and carbon reduction for the first time. The index’s operability and discriminatory power were validated by comparing Adelaide, San Francisco, and Stockholm. Teng et al. (2022) pioneered the development of a “Zero Waste Index” in Zhejiang Province, taking into account China’s national conditions. Initially, based on national indicators, the system selected core indicators, eliminated incomparable factors, and introduced a governance difficulty adjustment to enable cross-city comparisons. Later, real-time data analysis and a rolling feedback mechanism were used to fine-tune policies, forming a closed loop of “assessment-competition-optimization.” In contrast, ZWI focuses more on the potential for resource substitution, but its coverage of solid waste categories and its comparability between cities is insufficient. At the same time, Zhejiang’s “Zero Waste Index” emphasizes the availability of local data and the need for hierarchical governance, but there is a gap in international applicability (Qi et al., 2023; Teng et al., 2022).

Despite these advances, relying solely on weight-based indicators (e.g., tons diverted) is increasingly criticized for failing to capture environmental impact. Recent scholarship advocates for integrating Life Cycle Assessment (LCA) into urban waste governance. LCA enables decision-makers to identify “burden shifting”, where a recycling process might consume more energy than the virgin material production it replaces (Hellweg & Milà i Canals, 2014). Therefore, a robust evaluation system must couple the quantitative ZWI with qualitative LCA indicators to ensure genuine ecological gains.

As the only Guangdong city among China’s first pilot cities, Shenzhen aims to set an international benchmark by around 2050 through its "four major systems" of institutions, technology, markets, and engineering (Chen, 2019; Li, 2022). At the micro level, refined sorting of domestic waste has led to complete incineration and near-zero landfill, with a recycling rate reaching 48.8%. Subject to emission limits, construction waste is being industrialized for utilization, with a 98% resource recovery rate for demolition waste (Chen, 2019). Shenzhen has established ten systems, 58 indicators, and 100 tasks around six major solid waste categories within a comprehensive governance framework. Currently, 28 of these indicators and 47 of these tasks have been achieved, including six core indicators achieving “six 100%” (Chen, 2020). Shenzhen’s domestic and construction waste treatment efficiency has been assessed internationally as advanced. Furthermore, through a "four-wheel drive" top-level design and an innovative regulatory platform, Shenzhen integrates source reduction, strict process management, end-of-life resource recovery, and public education into a distinctive waste management model, offering a unique model for high-density, market-oriented Chinese cities (Center, 2023).

2.2 Factors Affecting "Waste-free City"

The construction of a waste-free city is a complex systemic project, and its development and effectiveness are not determined by a single factor but by the interplay of multiple factors (Ding, 2024). From the government's perspective, it is key in guiding and ensuring implementation, from top-level design to implementation. This aligns with Multi-Level Governance (MLG) theory (Piattoni, 2009), which posits that environmental problem-solving requires coordinated action across vertical levels (central, provincial, municipal) and horizontal sectors (environment, industry, finance). The transition to a waste-free city represents a shift from "Government" to "Governance." Traditional solid waste management often relies on hierarchical, command-and-control regulation. However, the complexity of modern waste streams requires Collaborative Governance (Ansell & Gash, 2008), where public agencies effectively engage non-state stakeholders in a collective decision-making process. Initially, construction relies on strong government leadership to initiate the agenda and allocate resources. However, as construction progresses and transitions toward regional collaboration (such as a waste-free city cluster), the government's role must shift from command and control to institutional provider, platform builder, and facilitator of collaboration. The success of this transition directly determines the breadth and depth of participation from multiple stakeholders. Shenzhen's successful practice demonstrates that a sound legal and regulatory framework, an efficient centralized governance park model, and a transparent information management platform support this role transformation and significantly improve governance effectiveness (Zhang & Teng, 2023).

From a social perspective, economic development level, technological innovation capabilities, resource conditions, and educational attainment constitute the fundamental environmental factors influencing the development of waste-free cities. Research indicates that there may be a complex, nonlinear, or even negative relationship between economic development level and the development of "waste-free cities," suggesting that the extensive economic growth model remains uncoupled from waste generation. At the same time, high-tech industries demonstrate a significant positive driving effect. Technological progress has a dual impact: it can improve resource utilization efficiency but can also be limited by high technological complexity or high costs. Furthermore, Foreign Direct Investment (FDI) plays a significant role through technological spillovers and improved environmental standards, environmental regulation through forced business innovation, and urbanization and population size through consumption and waste patterns. This reveals distinct regional differences: the eastern region is primarily driven by technology and capital, the central and western areas rely more on external policies and financial support, and resource-based cities face significant challenges in their transformation (Han et al., 2022).

At the individual and community level, residents, as the source of waste generation and the direct actors in waste sorting and disposal, are shaped by individual characteristics (such as age, gender, education, occupation, income, and length of local residence), family structure, community contextual factors (such as the availability of waste sorting facilities and the fostering of a waste-free culture), and external incentives (such as publicity and education platforms, professional guidance, and resident self-government organizations) (Wu et al., 2022). The latter two community-level factors often have an impact beyond individual attributes, explaining the widespread phenomenon of “positive attitudes” but “lagging action.” This suggests that policy design needs to shift from simply imparting knowledge to building a convenient hardware environment and sustained incentive-based guidance mechanisms.

3. Method

This study employed semi-structured interviews, a core qualitative research method, supplemented by policy document analysis to systematically explore the effectiveness of the “Waste-free City” construction in Shenzhen and the underlying factors. Policy document analysis systematically reviewed official documents, including regulations, programs, and action plans, promulgated by Shenzhen City. This provided a solid institutional context and factual support for the interview data, forming a triangulation and enhancing the research's reliability and validity.

3.1 Participants

This study utilized a purposive sampling strategy to ensure maximum variation among stakeholders involved in the “Waste-free City” ecosystem. The inclusion criteria for participants were: (1) active involvement in Shenzhen’s waste management sector for at least three years, and (2) direct participation in decision-making or implementation of waste-free pilot projects. If no new topics regarding implementation obstacles or success factors are found in three consecutive interviews, the data collection is considered to have reached saturation. Totally, there is a sample of 21 participants in this study. Government officials (6 participants) are at the core of policymaking and oversight, including officials from the Shenzhen Municipal Ecology and Environment Bureau responsible for solid waste management and subdistrict office staff responsible for policy implementation. Their perspectives can reveal the intentions of top-level design, the challenges faced in policy implementation, and the realities of cross-departmental collaboration. Business representatives (6 participants) are the main actors in market-oriented operations and technological innovation, including managers from solid waste treatment, construction, and logistics companies. Their experience can reflect market responsiveness, the effectiveness of technological application, and the cost-effectiveness challenges faced. Social organizations (4 participants) serve as a bridge between the government and the public, including project leaders from environmental NGOs and volunteers working in the community. They can provide firsthand information on public mobilization, the effectiveness of publicity and education, and community practices. Resident representatives (5 participants) are the ultimate impactors and practitioners of policy, including waste sorting supervisors and ordinary citizens. Their attitudes and behaviors directly reflect the grassroots penetration of policies and the level of public participation.

3.2 Data Collection and Analysis

The interview outline was designed around the research questions. First, it asked about overall perceptions of success. For example, “How do you evaluate the main achievements of ‘Waste-free City’ construction in Shenzhen recently? Which changes have impressed you the most?” This served as a starting point to understand the specific manifestations of waste reduction, resource utilization, and harmlessness as perceived by the interviewees, such as a decrease in solid waste generation intensity, an increase in resource utilization, and enhanced utilization and disposal capacity. Next, it explored key influencing factors, such as “In your opinion, which policies or technical measures are most effective in promoting the construction of a ‘Waste-free City’? What major obstacles or challenges have been encountered?" Finally, it focused on the participation of multiple stakeholders, such as "Do you believe that businesses/residents are truly and effectively participating in waste-free governance? What are the driving forces or obstacles behind this?" Finally, it looked ahead to future development directions, asking "What issues do you believe should be prioritized for future 'Waste-free City' construction in Shenzhen?" Policy text analysis focused on core documents such as the "Implementation Plan for the Construction of a 'Waste-free City' in Shenzhen during the 14th Five-Year Plan Period" and the "Regulations on the Classification and Management of Domestic Waste in Shenzhen," outlining the institutional framework and evolutionary path for "Waste-free City" construction in Shenzhen, and corroborating and complementing the interview data.

All interviews were transcribed verbatim. The analysis followed a thematic framework approach using NVivo 12 to manage the coding process. To ensure reliability, two researchers independently coded 20% of the transcripts and achieved an inter-coder agreement rate of 87.3%. The coding tree was developed inductively: Open Coding (e.g., "high disposal cost," "resident confusion," "AI monitoring."), Axial Coding (e.g., "Economic Feasibility," "Public Behavioral Nuances.") and Selective Coding (e.g., "Technological lock-in vs. Market flexibility.")

Prior to data collection, the study protocol was reviewed by Institutional Review Board of Nanjing University of Information Science & Technology. All participants provided written informed consent regarding the recording, transcription, and anonymized use of their data.

4. Analysis of Shenzhen's Achievements in Becoming a "Waste-free City"

Shenzhen has achieved remarkable, nationally leading results in terms of quantitative indicators for its waste-free city development, with many key indicators far exceeding national requirements and reaching internationally advanced levels. Shenzhen has also undergone fundamental reforms in the management of domestic waste. In the five years since the implementation of the "Shenzhen Municipal Regulations on the Management of Domestic Waste Classification," recyclables have increased by approximately 40%, the resource utilization of food waste has surged by approximately 180%, the harmless disposal of hazardous waste has increased by 15%, and the incineration of other waste has significantly decreased (Lin, 2025). To date, Shenzhen's domestic waste recycling rate has exceeded 50%, and its resource utilization rate has reached 87.8%, completing the tasks of the 14th Five-Year Plan and ranking among the highest in the country (Lin, 2025). Shenzhen has established a comprehensive smart waste sorting management network regarding infrastructure development. Of the more than 21,000 household waste sorting and disposal points, 10,533 are now equipped with AI video, accounting for 50%. Nearly 900 municipal solid waste transfer stations are basically covered by video surveillance and AI-powered intelligent applications (Lin, 2023). The treatment of industrial solid and construction waste has also achieved remarkable results, with an extensive utilization rate of 91% for general industrial solid waste, 59% for hazardous waste, and 99% for demolition waste, reaching internationally advanced levels (Liu, 2022). Furthermore, Shenzhen has successfully achieved zero landfill for virgin domestic waste, municipal sludge, general industrial solid waste, and agricultural waste, demonstrating remarkable resource conversion efficiency (Dou, 2023).

Shenzhen has established a framework at the institutional level encompassing "institutions, markets, technology, and regulation. Over 70 policy documents, including the "Regulations on the Classification and Management of Domestic Waste in Shenzhen" and the "Implementation Plan for Further Strengthening Plastic Pollution Control in Shenzhen," provide a solid legal foundation for developing a waste-free city. In particular, the "Implementation Plan for the Construction of a Waste-free City in Shenzhen During the 14th Five-Year Plan Period" proposes eight key actions, including nationwide waste reduction, classified collection, resource recycling, safe disposal, reform and innovation, a waste-free culture, regional cooperation, and waste reduction and carbon reduction. It sets 24 indicators, implements 36 key projects, and implements 110 tasks, systematically mapping out a comprehensive governance approach from source reduction to resource utilization.

On a technological level, Shenzhen has leveraged its digital industry strengths to develop a number of innovative management platforms leveraging big data, the Internet of Things, and artificial intelligence (AI). For example, the comprehensive household waste sorting and management platform leverages the core technologies of "5G + IoT + AI," integrating radio frequency identification (RFID) at sorting points, video surveillance, on-board weighing, and AI recognition. This platform enables comprehensive, 24/7, and smart oversight of the entire waste collection process, from collection points and vehicles to treatment facilities. The digital industrial solid waste management platform and hazardous waste disposal trading platform utilize a B2B business model, providing online transaction services between waste generators and disposal entities. This effectively addresses market information asymmetry, opaque disposal prices, and weak bargaining power among waste generators, significantly reducing hazardous waste disposal costs and improving resource utilization efficiency. Furthermore, Shenzhen fosters a green lifestyle among the public through diverse initiatives, including creating "Waste-free City Cells" and carbon credit incentive mechanisms (such as the Ecological Civilization Carbon Coin Service Platform). Shenzhen is also conducting in-depth publicity and education through the "Dandelion" public education program, fostering a nationwide engagement approach. These institutional and technological measures not only systematically improve the efficiency of solid waste management and the level of resource utilization, but also provide a replicable and popularizable "Shenzhen model" for super-large cities to explore green and low-carbon development.

5. Analysis of Influencing Factors

5.1 Institutional Coordination

Shenzhen's success in building a waste-free city stems primarily from its highly systematic institutional coordination mechanism, which has generated strong policy momentum through top-level design, legal safeguards, and cross-departmental collaboration. The Municipal Party Committee and Municipal Government have identified the development of a "waste-free city" as a core issue in urban modernization governance and established a leading group headed by the Municipal Party Committee Secretary and the Mayor as executive deputy group leader. This high-level coordination mechanism has effectively broken down traditional administrative silos, enabling collaboration among multiple departments, including ecological environment, urban management, housing and construction, and water affairs. A management model characterized by "ledger-based, project-based, digital, and responsibility-based" processes assigns specific tasks to specific responsible units and individuals. Furthermore, Shenzhen, leveraging its legislative power as a special economic zone, has promulgated four local regulations, including the "Regulations on the Classification and Management of Domestic Waste in Shenzhen". Furthermore, 77 policy documents have been issued, incorporating the extended producer responsibility system and mandatory waste sorting measures into the legal framework. An official from the Municipal Ecological Environment Bureau noted, "Legislation not only provides a basis for enforcement but also clarifies the responsibilities of all parties, transforming solid waste management from a soft advocacy model into a rigid constraint.” Furthermore, Shenzhen has innovatively implemented a construction waste emission quota system. Through quantitative control, this system forces construction companies to adopt green processes, reducing waste generation at the source. Implementation mechanisms at the district and subdistrict levels are equally crucial, for example, through Party member vanguard posts to push policy down to the grassroots level and ensure effective system implementation. This multi-tiered system provides a stable organizational foundation and institutional flexibility for developing a waste-free city.

5.2 Technical Assistance

Technological support primarily encompasses digital monitoring platforms, resource-based processing technologies, and the development of a technical standards system. Shenzhen has established a comprehensive innovative solid waste management system. Leveraging technologies such as the Internet of Things, GPS positioning, electronic forms, and video surveillance, it achieves closed-loop oversight of the entire solid waste process, from generation to transportation to disposal. The system connects all waste-generating enterprises and disposal facilities and incorporates intelligent early warning capabilities, automatically alerting users to excessive storage and illegal dumping, reducing enforcement manpower requirements by 80%. A company representative stated, “The smart platform makes solid waste management transparent and traceable, eliminating oversight inherent in traditional manual oversight.” Shenzhen has focused on addressing common technical challenges in resource-based processing, developing and promoting 25 core technologies, including “rapid multi-stage in-situ separation of construction waste” and “synergistic anaerobic digestion of municipal sludge and food waste.” Five technologies have been included in the National Catalogue of Advanced and Applicable Technologies. These technologies have significantly improved resource utilization efficiency. For example, the Youlian Shipyard (Shekou) uses high-pressure water jets instead of steel grit for rust removal, reducing industrial solid waste by 100,000 tons annually. Shenzhen has also formulated 51 local standards and specifications covering waste sorting, treatment facility operations, and resource-based product certification, providing a standardized basis for technology application. Several technical experts emphasized that Shenzhen's technology integration emphasizes advancement and adaptability. For example, the household waste sorting model has been optimized into a “four-category” system based on local waste composition and disposal capacity, which is practical and easy to promote.

5.3 Incentive Mechanism

Shenzhen’s incentive mechanism is key to mobilizing business participation and achieving sustainable solid waste management. It encompasses fiscal subsidies, green finance, market-based trading platforms, and industry cultivation. The city and district governments have collectively invested over 10 billion yuan in subsidies for constructing and operating solid waste disposal facilities, with 5.2 billion yuan allocated for domestic waste collection, transportation, and disposal alone. These subsidies emphasize targeted incentives, such as providing financial grants to households and individuals who achieve significant results in waste sorting, and providing a 66 yuan subsidy for each 240-liter bucket of kitchen waste collected by a residential community. An environmental protection company executive stated, “Financial subsidies reduce our initial investment costs and make recycling economically viable.” Shenzhen has established a green credit system to guide financial institutions in providing preferential loans to solid waste treatment companies and encourage the issuance of green bonds to support related projects. Furthermore, the “Hazardous Waste

Trading Platform" operated by the Shenzhen Emissions Exchange, through public quotation, intelligent matching, and compliance monitoring, has become a "Tmall" for hazardous waste, effectively addressing issues such as price opacity and the weak bargaining power of waste-generating companies. One company leader reported, "The platform has reduced disposal prices by approximately 15%, reducing our operational burden." Furthermore, Shenzhen has actively fostered the local solid waste industry, supporting 131 solid waste utilization and disposal companies. This incentive system has created a favorable market environment, gradually shifting solid waste management from government-led to one driven by both the government and the market.

5.4 Public Participation

The "Waste-free City" resource recycling campaign, launched in 2022, attracted over 4.5 million participants through visits, science education classes, and other activities, significantly enhancing public awareness and commitment. An innovative approach has been implemented at the community level: centralized waste sorting combined with scheduled and designated supervision. 22,000 waste sorting points have been established across the city, and 20,000 waste sorting supervisors have been hired to guide residents on proper sorting on-site. One supervisor explained in an interview, "Residents were initially quite resistant, but through patient explanations and point-based incentives, the rate of active sorting has significantly increased." The creation of "Waste-free City Cells" is another distinctive initiative, with over 1,400 "Waste-free Communities," "Waste-free Schools," and "Waste-free Offices" established, integrating waste reduction into daily life. Furthermore, Shenzhen actively promotes a "technology + public welfare" engagement model. For example, the "Youfu Meijia" mobile internet platform integrates multiple technologies, including mobile internet, cloud computing, and the Internet of Things. Smart recycling bins have been installed in over 300 communities, where residents can earn points to redeem for gifts. This model reduces business operating costs, making public participation more convenient and engaging. Notably, Shenzhen also prioritizes the role of social organizations. For example, the "Linggan Project" initiated by the Duck GAGA Creative Philanthropy Center helps businesses implement workplace waste-fee measures. Interviews revealed that while residents are generally aware of a waste-free city, less than 40% are committed to it. The main reasons are inconvenient facilities, high time costs, and insufficient incentives. Therefore, further efforts are needed to optimize participation convenience and strengthen incentive feedback mechanisms.

6. Discussion

Shenzhen has successfully achieved "zero landfill" of raw municipal solid waste through investment in large-scale, modern incineration facilities, a necessary and efficient measure for a megacity with scarce land resources. However, this high dependence on end-of-pipe energy recovery also poses a potential risk of carbon lock-in. Capital-intensive incineration facilities require a stable and substantial waste feedstock to ensure economic operation. One business executive pointed out, "If the government really pushes for significant source reduction, our return on investment period will be extended, which is commercially contradictory." This mechanism may weaken policy pressure to promote source reduction in practice, creating an inherent conflict with the ultimate principle of a "zero-waste city." Furthermore, while incineration power generation achieves energy recovery, its greenhouse gas (GHG) emission reduction benefits are relatively low compared to the recovery of high-value materials, requiring a critical trade-off between resource substitution benefits and energy output benefits.

The data cited in this study shows that Shenzhen's construction waste recycling rate reaches 99%. However, analysis indicates that this figure reflects more processing capacity and statistical methods than the final market absorption and effective circular economy loop. The lack of stable demand and mandatory procurement mechanisms in downstream markets for high-value products such as recycled aggregates leads to insufficient price competitiveness of recycled products. A government official frankly stated, "We can produce high-quality recycled bricks, but if the market doesn't need them, they end up piling up in warehouses, failing to truly replace virgin materials." Despite significant upfront investment achieving high technology utilization, if recycled products cannot enter the mainstream market, their substitution effect on virgin resource consumption and their substantial contribution to climate adaptation will be greatly diminished. This suggests that when evaluating circular economy indicators, we should focus more on the final market substitution rate rather than simply production capacity or processing volume.

7. Conclusion and Recommendations

This study systematically examined the effectiveness of waste-free city construction in Shenzhen and its impact mechanisms through semi-structured interviews and policy text analysis. The study found that Shenzhen, through the synergy of institutions, technology, the market, and public participation, has successfully established a modern solid waste management system, achieving significant quantitative results: a recycling rate of over 50% for domestic waste, a resource utilization rate of 87.8%, a resource utilization rate of 99% for demolition waste, a comprehensive utilization rate of 91% for general industrial solid waste, and zero landfill for primary domestic waste. At the institutional level, Shenzhen, leveraging the Special Administrative Region's legislative power, has established a multi-tiered system, breaking administrative barriers through high-level coordination and cross-departmental collaboration. At the technical level, an innovative regulatory platform achieves closed-loop management. At the same time, research into resource utilization technologies and standard setting has improved treatment efficiency and adaptability. At the market level, fiscal subsidies, green finance, and trading platform mechanisms have effectively stimulated business participation and promoted the marketization and industrialization of solid waste management. At the public level, initiatives such as the "Dandelion Project," the creation of "Waste-free City Cells," and smart recycling facilities have significantly increased public awareness and facilitated participation. However, the current system still faces challenges, including the relatively low economic viability of some resource-based technologies, insufficient involvement of small and medium-sized enterprises, and the persistent phenomenon of "high awareness but low implementation" among residents. Overall, Shenzhen's efforts in building a waste-free city offer lessons for megacities in achieving a green and low-carbon transition and provide empirical evidence for understanding the complex interactions among diverse actors and multidimensional factors in environmental governance.

Based on the research findings, several policy recommendations are proposed to deepen Shenzhen's efforts to build a waste-free city and promote its experience on a larger scale. First, institutional coordination and regional cooperation should be further strengthened, and an integrated mechanism for solid waste management in the Guangdong-Hong Kong-Macao Greater Bay Area should be explored. This includes unified standards, shared facilities, coordinated supervision, and ecological compensation to address the challenges of cross-regional solid waste transfer and disposal. At the same time, the extended producer responsibility system and green procurement policies should be further improved to promote waste reduction throughout the entire industrial chain. Second, support should be increased for technological innovation and the commercialization of research results. A special fund for the research and development of solid waste resource technologies should be established, focusing on supporting key technologies such as the sorting and utilizing low-value recyclables, coordinated disposal, and low-carbon treatment. Third, public participation should be continuously deepened, the layout and management processes of community sorting facilities should be optimized, and schools, businesses, and social organizations should be encouraged to jointly establish waste-free education and practice bases to promote waste-free culture as an integral part of urban civilization.

This study still has some limitations. The “four-tiered responsibility system” is highly transferable to other centralized governance contexts. The heavy reliance on “green finance” and “technological subsidies” may be difficult to replicate in resource-constrained cities in Western or Central China, where basic collection infrastructure is still the priority. This study relies on self-reported perceptions from stakeholders, which may be subject to social desirability bias, particularly among government officials. Future research could expand to include more urban areas and use quantitative research methods for comparative analysis.

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