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Law Enforcement and Governance Policy as an Implementation of Waste Management in Urban Areas of Padang City, Indonesia

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Abstract: Padang City faces serious waste problems, including a 500-ton increase in daily waste generation to 500 tons and an annual accumulation of 236,296 tons (2023). Waste from the Final Processing Site is predicted to exceed its maximum limit by 2026; waste composition mainly comprises organic materials (62.53%) and plastics (13.6%), which have not been sufficiently managed through the Reduce, Reuse, and Recycle (3R) paradigm. This study analyzes the institutional, technical, regulatory, financial, and participatory barriers to waste management in Padang, as well as the policy implications from collaborative governance and circular economy perspectives. Using qualitative-descriptive methodology, with document analysis and policy evaluation, this study offers a unique contribution by combining polycentric governance defined as multi-level coordination and activity among government, private sector, and community actors with responsive regulation that situates punitive enforcement in the context of observed social behaviour and institutional capacity. The results indicate that institution fragmentation, under-enforcement of established laws, unsustainable funding mechanisms, and low community participation undermine the waste management practices in Padang. Integrated Waste Processing Place 3R and waste banks have, so far, not achieved optimal scale in terms of effectiveness. Contextualizing these outcomes through the lenses of polycentric governance, responsive regulation, circular economy, and community-based social marketing shows the role that cross-sectoral collaboration, participatory mechanisms, and adaptive regulatory tools played in building resilient urban waste systems. Theoretically, this study contributes to environmental governance scholarship by integrating governance design and regulatory innovation in the Global South context, while offering practical recommendations for performance contracts among stakeholders, as well as the adoption of Extended Producer Responsibility (EPR), decentralized technologies for organic waste, and digital-based incentives at the community level. Therefore, this study not only highlights the need for structural reforms but also contributes to establishing inclusive, adaptive, and sustainable waste management systems in Indonesia's urban areas.

Keywords: Law enforcement; Governance policy; Waste management; Urban Area; SDGs 6; SDGs 11; SDGs 16

1 Introduction

The Coordinating Ministry for Human Development and Culture has stated that the issue of waste management in Indonesia is exceedingly multifaceted and encompasses a range of dimensions, including the escalating volume of waste, the insufficient infrastructure for appropriate waste management, and inadequate public awareness of the significance of effective waste management practices. Inefficient waste management has a significant detrimental impact on environmental conditions, public health, and economic stability. A similar scenario is observable in Padang City, which is characterized as an expanding urban locality.

The researchers [1] revealed that the latest data shows the urgency of firmness and strong law enforcement in violations of waste management. Padang City produced 236,296 tons of waste throughout 2023 alone. This number has increased by 9.94% compared to 2022, which reached 234,973 tons. This data shows the extent of the waste problem in Padang City. The development of the waste management system appears stagnant, with no practical solutions to overcome it. This problem seems to be focused on the Regional Government, as the people of Padang

City seem apathetic and do not actively work with the City Government to create a clean environment to address the waste problem.

Data from the National Waste Management Information System, under the auspices of the Ministry of Environment and Forestry, indicates that over the past five years, waste volumes have increased significantly. In 2023 alone, out of the total 25.2 million tons of waste generated, only 66.24 percent, or 16.5 million tons, were managed. The remaining 33.76 percent, or 8.4 million tons, remained unmanaged. Waste generation poses a significant challenge for all jurisdictions in Indonesia, including Padang City. Conversely, the regional secretary, along with the Mayor of Padang City, indicated that the volume of waste generated in their jurisdiction in 2024 is projected to reach approximately 500 tons per day.

His party also has several programs to educate the public in managing waste. First, the *Padang Bagoro* program. This program is carried out simultaneously once a month with families who clean up the trash in front of their homes. The second program is to optimize waste banks by targeting construction in each Citizens Association. Currently, there are 909 Citizens Association in Padang City, and waste banks have been established in 182 Citizens Association. Padang Mamilah is oriented towards helping increase the community's role in reducing waste. Starting from sorting household waste to be processed into compost through biopores and composters. Finally, in terms of policy, to manage waste, the Padang City Government has a major regulation on the procedure for collecting waste levies, divided into two categories: household waste and business waste from industry, private community facilities, and public activities.

1.1 Modern Waste Management

The establishment of a contemporary waste management system is of paramount significance for an expanding urban environment [2–4]. This endeavor is executed in accordance with a robust environmental policy that transcends mere electoral considerations, thereby furnishing stakeholders within the waste management domain with a sustainable strategic orientation [5, 6]. This framework serves as a foundation that fosters collaboration among all parties involved in devising a comprehensive strategy for the waste management sector. The initial action to be undertaken is the creation of an infrastructural framework. This framework predominantly entails the formulation of a legal foundation, followed by the establishment of a governmental entity tasked with its regulation and implementation, then the design of an organization endowed with adequate resources to oversee waste management, and finally, the introduction of these measures through publicly acceptable methodologies, ensuring the capacity to bear the associated costs. The solidification of primary and supplementary legislative measures constitutes the essential pillars for the development of an advanced waste management sector [7–9].

The legal foundation of a policy must be articulated through regulations, directives, regulatory frameworks, and guidelines promulgated by the nation's preeminent legislative institution [10, 11]. Nevertheless, variances in requirements may exist across different regulatory domains, encompassing domestic regulations, commercial products, hazardous waste, construction debris, and recyclable materials [12–14]. In all scenarios, it is imperative to ascertain the entities responsible for waste management, with a particular focus on waste generators and those engaged in the management process [14–16].

1.2 Policy Implementation in Waste Management System

Responsibilities and authorities must be clearly described in the implementation of policies in the waste management system [17–19]. In implementing the process of developing advanced waste management, regulations and their derivatives must be adapted to build a development framework guided by target-setting [20]. This will provide incentives for the private sector, social communities, and regional stakeholders. The design of regulatory arrangements will be easily monitored and enforced if the intended impact as a basis for compliance is clearly and transparently disclosed. The creation of technical aspects with adequate resources, supported by institutions that provide supervision and approval, is a key factor in implementing a sustainable system, including in waste management [21, 22]. Without adequate institutional capacity and authority to maintain legal continuity, all efforts will be in vain, resulting only in lobbying, corruption, and mismanagement in waste management [23, 24].

Law enforcement plays a crucial role by incorporating contributions from the private sector. Commercial entities will find it challenging to thrive in the market if their competitors benefit from cost efficiencies resulting from noncompliance with established standards. This regulatory framework will be enforced uniformly and impartially across both waste management agencies and waste producers. In essence, it is imperative to establish and uphold an equitable and just competitive environment.

1.3 Law Enforcement

The exclusive reliance on local revenues to finance the expenses associated with a waste management system is impractical; consequently, it is imperative to formulate a comprehensive strategy to address the diverse costs that emerge within an advanced system [25–28]. In the absence of a robust policy framework that guarantees cost coverage and of suitable policies, establishing a financially sustainable circular economy will be unfeasible, thereby inhibiting

the private sector's willingness to invest. A significant proportion, exceeding two-thirds, of the overall expenses is attributed to operational costs, which necessitate consistent revenue streams for their financing [29–32].

Imposing specific product levies or fines on waste-intensive products such as packaging is a suitable option to address operating costs. For example, this is implemented in Tunisia, charging up to 80% of the product. The right combination of policies must be based on laws that involve legislative decision-making processes. The proportion of contributions charged must be determined using realistic, publicly tested cost estimates.

The waste management problem in Indonesia, specifically in Padang City, is increasingly complex due to rising waste volumes, limited infrastructure, and limited public awareness. Based on data, in Padang City, waste generation in 2023 is projected to reach 236296 tons, with a daily projection of 500 tons, and the *Aie Dingin* Landfill site is predicted to be full by 2026. This realization has led to the understanding that the end-of-pipe method of waste management is no longer a feasible solution and requires a paradigm shift. The importance of government-community collaboration, waste banks, and the Reduce, Reuse, and Recycle (3R) management principle has been noted in several previous studies. Nonetheless, these studies tend to analyze either technical considerations, local engagement, or regulatory compliance, without exploring in depth how the interplay among governance structures and regulatory design affects implementation effectiveness. Moreover, prior studies fail to illuminate how cross-actor integration can alleviate institutional fragmentation, and how regulations have become more opportunistic in responding to social dynamics and red tape. This study has filled the gap by examining specific aspects of the institutional and regulatory dimensions of sustainability in urban waste management systems in Indonesia.

In response, this study draws on the concepts of polycentric governance and responsive regulation. On the other hand, responsive regulation provides a strategy for law enforcement, using persuasive and coercive instruments that adapt to institutional capacity and actor behavior. This is relevant to both frameworks and highlights how assessing these structural weaknesses, weak law enforcement, and low public participation can be managed through inclusive, adaptive, and multi-layered governance and regulatory design in the Padang City context.

Hence, this study aims to contribute: (i) theoretically by enriching discussions about environmental governance in developing countries through association of polycentric governance and responsive regulation; and (ii) practically with policy guidance for local governments on how to build contracts that enable collaborative, adaptive, and sustainable waste management systems.

2 Literature Review

Kala and Bolia [33] underscored the imperative for a Comprehensive Waste Management Policy (CWMP) that encompasses training, community engagement, and facilitation for the informal sector; however, it does not explicitly address law enforcement and governance frameworks pertinent to the execution of waste management initiatives. Hardi et al. [34] found that the effectiveness of waste management in urban environments requires a collaborative effort between central and local government entities, as specified in Law No. 18/2008 on Waste Management, which articulates the distribution of responsibilities and mandates producers to adopt recycling and waste-reduction methodologies.

Synthesis of study [35] confirmed that law enforcement, including sanctions and monitoring, is crucial for an effective Municipal Solid Waste segregation management policy. Governance policies should integrate clear boundaries and responsibilities among various stakeholders to improve waste management in urban areas. Furthermore, a key contribution of study [36] addressed the lack of enforcement and clarity of responsibilities regarding waste management policies in Chegutu Municipality, emphasizing the need for clear roles among stakeholders and holistic policy development to improve governance and implementation. This is the basis for this study.

Law enforcement and governance policy are crucial for waste management in urban areas, as they establish regulations, promote regional cooperation, and address illegal dumping, ensuring effective collaboration and compliance with environmental standards in the Yangtze River Delta region [37]. Zhang et al. [38] explained that although the government plays a significant role in directing waste management, it struggles to protect the interests of all stakeholders. Effective governance policies and law enforcement are crucial for implementing strategic waste management in urban areas. Therefore, in this study, the government's role in law enforcement and supervision is crucial to the discussion.

The research [39] underscored that municipal corporations and urban local authorities are responsible for waste management, operating under governmental policies such as the Solid Waste Management Rules 2016, which establish a comprehensive framework for effective implementation and governance within urban settings. The research [40] accentuated that the proficient governance of waste in urban environments, exemplified by cities such as New York City and Seoul, necessitates the collaboration of diverse stakeholders, inclusive of public entities and private sectors, thereby underscoring the critical role of civic involvement and stewardship in enhancing outcomes related to waste management and recycling metrics.

Zhamiyeva et al. [24] asserted that effective waste management in Kazakhstan requires systemic legal reforms and the implementation of international agreements. Governance policies should integrate proactive approaches

to enhance stakeholder participation and accountability, thereby improving urban waste management outcomes. Meanwhile, Davis and Garb [41] discussed a community environmental policing model that advocates government enforcement of e-waste burning, emphasizing an active approach to addressing barriers to environmental governance, which can be applied to improve waste management in urban areas. This serves as the basis for this study, which emphasizes the importance of law enforcement and good governance in waste management policies.

Dewa et al. [42] focused on law enforcement in waste management in Denpasar City, combining preventive and repressive approaches, guided by the principles of Good Environmental Governance. However, its effectiveness is hampered by community violations and low public awareness, so increased government regulation and supervision are needed. And this study [7] explained that law enforcement and governance policies are crucial for implementing waste management in urban areas, establishing sanitation infrastructure, and ensuring compliance with regulations. This is one of the focuses of this research that effective governance encourages cooperation and resource allocation, addressing the challenges of waste management in cities.

Earlier works have underscored the need for integrated waste management policies. Studies show that to ensure effective waste management in urban areas, a clear legal framework and public participation are needed. Other studies highlight the need for both central and regional governments to work together, as well as for producer responsibility to support 3R practices. Research based in cities around the world suggests that poor law enforcement and jurisdictional overlap are key barriers to achieving a well-functioning waste management system.

However, reviews in the literature often assess each aspect in isolation. Most studies emphasize either public participation or regulation, rather than recognizing both within a wider institutional setting. Similarly, numerous studies operate purely within technical descriptions but fail to critically engage with how policy and governance can be designed to be responsive to the particular social dynamics and technological developments at play. This led to a gap because, in reality, waste in urban contexts cannot be addressed without institutional and regulatory frameworks, public behavior, and technological innovations.

The recent international literature shows changing approaches to new waste management structures. A couple of studies identify digital monitoring systems that facilitate near-real-time tracking of waste-generation data for informed decision-making. Moreover, Artificial Intelligence (AI) tools for waste sorting have already been introduced in some cities around the world to enhance inorganic waste processing. Not only does this technology improve sorting accuracy, but it can also deliver long-term operational cost savings.

This study makes a unique contribution to past research by demonstrating how polycentric governance which promotes coordination among actors and responsive regulation by adapting law enforcement approaches in a context of action integrate into the new regime of experimentalistic waste technologies. The result is dealing with waste management not just as a technical or participatory matter, but rather as the interaction between actors and adaptive regulatory frameworks enhanced by opportunities for innovation from digital technology and AI.

Hence, this literature review provides strong evidence of the importance of linking institutional aspects, adaptive regulation, and technological innovation in the context of urban waste management in Indonesia. This area remains an unfilled research gap. The present study seeks to address this gap by synthesising the concepts of polycentric governance and responsive regulation into a more holistic, solution-focused framework.

3 Methodology

As the study led to an in–depth understanding of the dynamics, this research employed a qualitative approach with a descriptive-analytical design. We collected material and data using a variety of mixed-methods approaches: document analysis, policy evaluation, field observations, and semi-structured interviews with key informants.

3.1 Document Analysis

The documents reviewed included:

(a) National laws and regulations related to environmental and waste management (Law No. 18/2008 on Waste Management, Law No. 32/2009 on Environmental Protection and Management, Government Regulation No. 81/2012 on Management of Household Waste and Household-Like Waste).

(b) Regional regulations and Padang Mayoral Regulations related to waste management, levies, and the Padang Bagoro program.

(c) Official reports from the Padang City Environmental Agency regarding waste generation, management infrastructure, and the achievements of the waste bank program.

(d) Data from the Central Bureau of Statistics regarding demographics, population density, and socio-economic indicators relevant to waste generation.

(e) Documents resulting from studies or reports of collaborations with donors/international agencies.

3.2 Policy Evaluation

The evaluation used a content analysis of regulatory and policy documents, as well as a gap analysis to compare

existing legal norms with field practices. Evaluation indicators included: clarity of objectives, consistency between regulations, feasibility of implementation, law enforcement mechanisms, and the level of public and private sector participation.

3.3 Field Observations

Observations were conducted at waste management facilities, including the *Aie Dingin* Landfill Final Processing Site, several 3R Temporary Storage Sites, and waste banks in sub-districts. Observations aimed to understand waste collection, transportation, sorting, and processing practices, as well as the technical challenges encountered.

3.4 Semi-Structured Interviews

Informants were selected purposively, including officials from the Environmental Agency, waste bank managers, community leaders, and academics. Interviews focused on their views on policy effectiveness, coordination among actors, law enforcement mechanisms, and opportunities to adopt new technologies for waste monitoring and sorting.

3.5 Data Analysis Techniques

Data were analyzed through triangulation of methods and sources, with the following steps:
(a) Categorization of institutional, regulatory, participation, and technical issues.
(b) Thematic coding based on the theoretical framework of polycentric governance and responsive regulation.
(c) Preparation of a comparison matrix between field findings and normative regulatory standards.
(d) Inductive drawing of conclusions to identify patterns, challenges, and opportunities for improving waste management governance in Padang.

4 Results and Discussion

4.1 Results

4.1.1 Physical environment

Padang City is situated along the western coastline of Sumatra Island, specifically positioned at coordinates 0°44'00" to 10°08'35" South Latitude and 100°05'05" to 100°34'09" East Longitude. The total land area, following the expansion mandated by Government Regulation Number 17 of 1980, is 694.96 km^2. Five major rivers traverse the city and comprises 19 islands. The administrative demarcations of Padang City are:
(a) North: Padang Pariaman Regency.
(b) East: Solok Regency.
(c) South: Pesisir Selatan Regency and the Indonesian Ocean.
(d) West: Indonesian Ocean.
Padang City consists of 11 sub-districts (municipalities), with a total area of 694.96 km^2. The details can be seen in Table 1.

Table 1. Padang City area data

No.	District	Area (Ha)	Area (%)	Number of Sub-Districts
1	Bungus Teluk Kabung	100.78	14.5	6
2	Lubuk Kilangan	85.99	12.37	7
3	Lubuk Begalung	30.91	4.45	15
4	South Padang	10.03	1.44	12
5	East Padang	8.15	1.17	10
6	West Padang	7.00	1.01	10
7	North Padang	8.08	1.16	7
8	Nanggalo	8.07	1.16	6
9	Kuranji	57.41	8.26	9
10	Pauh	146.29	21.05	9
11	Koto Tangah	232.25	33.42	13
	Total	694.96	100	104

4.1.2 Demography

The phenomenon of population growth within urban centers and districts exhibits a notable annual increase. Consequently, this population increase correlates with higher consumption levels and increased communal activities. It is undeniable that every human endeavor generates waste. If such waste is not managed with due diligence and seriousness, it can lead to a plethora of significant adverse effects. The rise in population density directly contributes

to increased waste production, necessitating that this increase be accompanied by effective management strategies to prevent environmental degradation and deterioration in public health standards.

Projections of population dynamics and public infrastructure are critical components of strategic planning for waste management systems. The objective of these projections is to forecast future waste generation volumes, thereby facilitating long-term strategic planning. In this context, demographic projections were conducted for 11 sub-districts in Padang City served by the Aie Dingin Final Processing Site. The demographic projection analysis spans 25 years, from 2023 to 2047. According to Central Bureau of Statistics data, Padang City's population in 2022 was 919,145, comprising 461,712 males and 457,433 females.

The population of Padang City in 2021 was 954,177. Padang City recorded a 1.26% population increase from the previous year. The disproportionate distribution of the population within Padang City can be attributed to the presence of sub-districts with elevated population density, specifically Padang Timur Sub-district (9,485 individuals/km^2) and Nanggalo Sub-district (7,227 individuals/km^2). The poverty incidence in Padang City in 2021 was 4.94%, up from 4.40% the prior year. The predominant demographic group in Padang City is the Minangkabau, who uphold traditional customs and cultural practices while simultaneously embracing constructive influences from external regions.

The life of the people of Padang City is relatively harmonious with other immigrant communities from ethnic minorities, namely the Mentawai Tribe, transmigrants from Java, Chinese ethnic groups, and others. The majority of Padang City's population is Muslim. Most of its adherents are Minangkabau people. Other religions practiced in this city include Christianity, Buddhism, and Confucianism, mostly by residents who are not from the Minangkabau tribe. Various places of worship are also found in this city. In addition to being dominated by mosques, churches, and Chinese temples, Padang City also has other places of worship. Based on Central Bureau of Statistics data at the end of 2021, the number of Muslims was 890,969, followed by Catholics at 12,529 and Protestants at 6,549.

In the field of Education, according to Central Bureau of Statistics data, the School Participation Rate for Elementary School is 99.61%, for Junior High School it is 96.63%, and for High School it is 94.07%. The High School Participation Rate indicates the high level of education awareness among Padang City residents and their readiness to provide workers.

4.1.3 Urban planning

Padang City, mostly dense forest, has the largest land area of 35,448 hectares. The residential land area in Padang City is approximately 7,182.43 hectares. Padang City also has technically irrigated rice fields totaling 4,942.90 hectares. We can make an observation based on hydrological conditions, as many rivers, both large and small, flow through the city of Padang. In the Padang City area, 21 rivers flow for a total length of 123.9 km. In general, the rivers in the Padang City area are at a height that is not much different from sea level. This condition made many parts of Padang City susceptible to flooding/inundation. Land in Padang City is used for housing, agriculture, plantations, offices, supermalls or malls, public facilities, and other purposes.

4.1.4 Waste management policy

(1) Waste management

As part of its urban development, Padang City is establishing an Integrated Waste Processing Facility. This Integrated Waste Processing Facility is strategically designed to implement the 3R principles. The site designated for the infrastructure development of the Padang City Integrated Waste Processing Facility is located within the *Aie Dingin* Final Processing Site, in Balai Gadang Village, Koto Tangah District, Padang City, West Sumatra (Figure 1).

Figure 1. *Aie Dingin* Landfill

With a planned land area for the construction of the Integrated Waste Processing Place of ±18,370 m^2. There is a fairly wide access road to the planned Integrated Waste Processing Place construction area with a road width of ±5 meters. Location of Integrated Waste Processing Place infrastructure development in Padang City and topographic maps of Balai Gadang Village and Koto Tangah District.

(2) Waste sources

Waste sources can be classified as follows [43]:

• Residential: typically manifested in the form of individual houses or multifamily apartments. The categories of waste produced include organic waste such as food waste, paper products, cardboard, plastic items, textiles, leather goods, horticultural refuse, timber, glass, metal, and discarded household articles, as well as hazardous waste, including used lubricants and plant pesticides.

• Commercial areas: comprising establishments such as retail shops, dining establishments, marketplaces, office complexes, hotels, and similar entities. The categories of waste generated are similar to those observed in the residential sector.

• Institutions: specifically referring to entities such as educational facilities, healthcare institutions, correctional facilities, governmental offices, and others.

The categories of waste produced are analogous to those found in commercial zones:

• The construction and demolition of edifices encompass new construction endeavors, roadway repairs, and related activities. The categories of waste produced include timber, steel, concrete, and dust, among others. According to Indonesian regulations, building debris is classified as specific waste. It is noteworthy that municipal authorities in Indonesia have not yet recognized this classification as waste requiring management.

• Public amenities encompass entities such as street cleaning, parks, coastal areas, recreational spaces, and similar facilities. The categories of waste produced include refuse, horticultural waste, branches, foliage, and dust.

• Domestic waste processing facilities, including drinking water treatment plants, wastewater treatment facilities, and incineration plants, generate various types of waste. These include sludge resulting from processing, dust, and similar byproducts.

• Industrial zones produce a range of waste types, which include residues from production processes, non-industrial waste, and other related materials.

• In the agricultural sector, the categories of waste produced consist of leaves and unused parts of plants.

The Padang City Temporary Waste Shelter has an average of 3470.852 kg per day (695.146 tons) to be practical, tons/day, with a volume of 501m in the first quarter, and is still trending down! The waste composition in Padang City indicates that easily degradable waste accounts for an average of 62.530%, while inorganic waste accounts for 37.470%. Plastic waste accounts for the largest share of inorganic waste at 13.606%. Padang city, based on data from the Environmental Service, also has a waste generation rate of 0.696 kilograms per capita per day. Therefore, the calculations can be used to predict that waste generation in Padang City for the year 2041 is expected to reach 721,827.79 kg/day or equal to 721.83 tons/day.

4.1.5 Waste management operational pattern

(1) Collection

The process of waste collection is conducted by the administrators of residential zones, commercial sectors, industrial regions, designated areas, public amenities, social institutions, and various other facilities, in conjunction with the district or municipal authorities, through the implementation of Temporary Waste Shelters, Temporary Waste Shelters adhering to the 3R principles, and designated collection apparatus for segregated waste. Temporary Waste Shelters and/or Temporary Waste Shelters compliant with the 3R principles are mandated to fulfill specific criteria, which include the provision of facilities for the categorization of waste into a minimum of five distinct types, possess an adequately sized location and capacity commensurate with requirements, ensure accessibility to the site while preventing environmental pollution, and establish a systematic schedule for collection and transportation.

Waste collection constitutes a systematic approach to managing refuse by aggregating materials from various waste-generating sources, facilitating their conveyance to a designated Temporary Waste Shelter or to processing facilities at a regional level, or transporting them directly to a Final Processing Site without an intermediary transfer phase. The operational modalities for waste collection and transportation from the initial waste source to the Final Processing Site can be implemented via two principal methodologies: direct collection or indirect collection via a Temporary Waste Shelter [43], which will be elaborated upon in the subsequent discussion.

• Directly (door to door): In this system, the waste collection and transportation process is carried out simultaneously. Waste from each source will be collected and transported directly to the processing site or the final disposal site.

• Indirectly (communal): In this framework, before being conveyed to the processing facility or the ultimate processing destination, refuse from each origin is initially gathered by collection apparatuses, such as hand carts, and subsequently transported to the Temporary Waste Shelter. The presence of this Temporary Waste Shelter renders the waste collection procedure indirect. In this context, the Temporary Waste Shelter can also serve as a regional processing site to reduce the volume of waste that requires transportation to the final processing location. Within

this communal framework, refuse from each source is initially collected in a handcart or a comparable device and conveyed to the Temporary Waste Shelter. Hand carts represent the most rudimentary waste transportation implements frequently encountered in urban areas of Indonesia and possess the following stipulations. First, they are lightweight and suited to the road conditions they travel on. Second, easy to load and unload. And third, it should have a lid.

A temporary shelter is a building or place used to move waste from hand carts to platforms, containers, or directly to garbage trucks [43].

(2) Transfer station I/transfer depot

Usually consisting of:

• Building for office space.
• Building for storing/loading waste.
• Parking lot.
• Equipment storage area.

For a transfer depot location or in Indonesia, a Temporary Shelter as above requires a minimum land area of 200 m^2. If this location also serves as a regional-scale waste-processing site, additional land will be needed, depending on the activities to be carried out. Placed on the side of the road and does not interfere with traffic. A permanent foundation of around 2550 m^2 is needed to place the container. In many places in Indonesian cities, these platforms are not provided, and containers are placed on available land. The placement of these facilities is also problematic because it is difficult to obtain land, and it is unclear whether people living near them are willing to accept them.

(3) Communal bins that are built permanently and located on the side of the road

Collection time and frequency must be considered. When community activities are not so dense, for example, from morning to afternoon, it is the best time for waste collection. The frequency of waste collection also determines the quantity of waste that can be collected and transported in a day. The higher the frequency of waste collection, the larger the total amount of waste collected per service and per capita. Note: if the collection system is integrated with recycling, you can determine how often waste will be collected and segregate it accordingly. In such scenarios, dry waste can be collected less frequently. To keep these streets clean, a street-sweeping program needs to be implemented. Typically, street sweeping waste consists of dry leaves, branches/twigs, and road dust. Street sweeping should be done by street sweepers at once: to clean the street litter, collect it into a container, and then transport it with a hand cart to a temporary shelter. To maintain the area's cleanliness and for supervision, street sweeping is done in groups.

4.1.6 Waste collection pattern

In conjunction with container activities, waste collection constitutes the preliminary phase of the continuum of waste management processes. Numerous significant factors that warrant consideration [43] include:

(a) Waste collection must pay attention to:

• Balance of task loading.
• Optimization of the use of tools, time, and officers.
• Minimization of operating distance.

(b) Factors that influence waste collection patterns:

• Amount of waste transported.
• Population.
• Area of operation.
• Population density and level of house distribution.
• Length and width of roads.
• Condition of connecting facilities (roads, alleys).
• Distance of the collection point from the location.

4.1.7 Direct individual pattern

In this pattern, waste is collected from house to house with a collection and transportation tool such as a garbage truck, known as door-to-door service. The collected waste is then transported directly to processing or the Final Processing Site. The individual pattern is directly carried out by a collection truck to processing. Road conditions must be wide enough, and operations must not interfere with other road users. This pattern is usually used when the amount of waste generated is >0.3 m^3/day. Usually, the service areas are shops, elite areas, and protocol roads.

4.1.8 Direct communal pattern

In this pattern, the collector-transporter officers will not enter the alley of leisure visitors; they will only signal if those who have this means of transportation are prohibited, for example, by making noises. Each waste producer transports waste from the source to the collection point (normally, the road mouth). In this way, garbage trucks are waiting at that point at that time. The truck then resumes its route to the next location.

4.1.9 Indirect individual pattern

Garbage will be collected from each source and transported to Indonesia via a translated garbage cart/garbage motorbike. The garbage is then collected by a collection vehicle and taken to the Temporary Waste Shelter. The waste is then transferred at the Temporary Waste Shelter into a collection truck that conveys it for processing or to the Final Processing Site. There is a need for a waste collection management organization with a control system.

4.1.10 Indirect communal pattern

In this operational framework, the waste collection officer refrains from entering the alleyway due to potential accessibility issues for a cart or alternative waste collection vehicles. The waste collection officer will signal their arrival or adhere to an agreed-upon schedule. Subsequently, the waste collection vehicle transports the refuse to the Temporary Waste Shelter. At this Temporary Waste Shelter, the refuse is transferred to a dedicated collection truck for transport to either processing facilities or the Final Processing Site. In this context, the Temporary Waste Shelter may also serve a dual purpose as a regional-scale processing facility to mitigate the volume of waste requiring transport to the Final Processing Site.

The Padang City Cleaning and Parks Service is obligated to transport waste from the Temporary Waste Shelter to the Final Processing Site. The responsibility for waste collection from the point of origin to the Temporary Waste Shelter rests with the community, executed both independently and collectively. Presently, waste collection in Padang City operates under two distinct methodologies: direct and indirect collection patterns. Direct collection is conducted by officers serving commercial establishments, marketplaces, healthcare facilities, educational institutions, governmental offices, thoroughfares, recreational areas, and residential properties situated alongside the primary roadways, where waste containers are readily accessible to trucks.

4.1.11 Waste transfer

Waste transfer is a stage in which collected waste is moved into a transport vehicle for transport to a processing location or for final processing. The waste transfer location should make it easy for waste collection and transportation facilities to enter and exit, and should be located close to the waste source. Waste processing or sorting can be done at this location, enabling this facility to function as a regional processing facility. Waste transfer is carried out by cleaning staff, who can do it manually, mechanically, or a combination of both. For example, the collection officer manually fills the container, while the container is mechanically transported onto the truck (load-haul). Based on the guidelines from the Ministry of Settlement and Regional Infrastructure, then:

(a) Communal point criteria for collection locations (1 m^3, 6 m^3, 10 m^3):

• Empty every day at least once.

• To maximize the cleanliness of the transfer location, there needs to be a filling and emptying schedule.

• Easy to reach, does not interfere with traffic flow or pedestrian comfort.

• Isolated and kept clean.

• Dismantling of transfer points should pay attention to the rules of pollution isolation and be scheduled so as not to interfere with the comfort and health of the surrounding community.

(b) Criteria for the type of temporary storage area:

• Walled equipment: The length and width are made in such a way as to facilitate entry, exit, and loading of trucks. If loading is not done directly from the cart, a special place for temporary waste storage must be provided. The walls are high enough to serve as insulators against the surrounding area. Isolation aims to eliminate the dirty impression of the transfer work.

• Load-hauled container: In the form of a container that generally has a volume of 6–10 m^3. The cart immediately dumps its load into this container. Once full, this container will be taken to the final processing location. This method incurs a significant capital cost because it requires a specialized type of truck.

Waste transfer in Padang City is carried out according to the type of Temporary Waste Shelter. Waste transfer from the brick building is handled manually by waste collectors. In contrast, the transfer of the container Temporary Waste Shelter is done directly by arm roll truck machines. Padang City has a transfer depot in the *Pegambiran* area, which serves as a transfer point for waste from motorized rickshaws and transport trucks. The transfer system is carried out manually, namely, waste from the bento is unloaded and collected at the Temporary Waste Shelter.

4.1.12 Waste transportation

General waste transportation. Waste transportation constitutes a specialized subsystem designed to facilitate the movement of waste from a designated transfer location or directly from the waste generation source to the Final Processing Site [43]. This component of waste management holds substantial significance and necessitates meticulous calculations to optimize the time required for transportation within the system, particularly in instances where:

(a) There exist waste transfer facilities of considerable scale that are tasked with the management of waste.

(b) The geographical distance to the waste destination is relatively extensive.

(c) The transfer facility serves as a convergence point for waste entering from multiple regions.

(d) Rationing requirements must be evaluated with precision.
(e) Challenges related to traffic along the route to the waste destination point.
The requirements for waste transportation equipment include [43]:
(a) Waste transportation equipment must be equipped with a waste cover, at least with a net,
(b) Maximum body height of 1.6 m,
(c) There should be a lifting device,
(d) Capacity is adjusted to the condition/class of the road to be passed.
(e) The truck body/container base should be equipped with wastewater protection.

To enhance the efficacy and efficiency of waste transportation infrastructure, the implementation of container stations or depots is deemed practical. From this centralized container facility, high-capacity trucks can convey containers to either the processing facility or the Final Processing Site, while municipal refuse trucks do not need to transport waste directly to that site; instead, they deliver to the container depot. Consequently, there is potential to increase the frequency of municipal refuse truck rotations. The anticipated operational lifespan is 5–7 years. The waste load volume is projected to range from 6 to 8 cubic meters, or equivalently, 3 to 5 tons. The daily operational frequency of transport trucks can be 4–5 trips for distances less than 20 kilometers and 2–4 trips for distances spanning 20–30 kilometers, which is fundamentally determined by the duration of each trip, contingent on traffic conditions, loading duration, and waste unloading.

4.1.13 Waste transportation methods

In reference to the waste management systems employed in developed nations, waste transportation can be executed through two distinct methodologies [43], namely:

(a) Hauled Container System (HCS) or Transport Container System, defined as a waste collection system in which the collection containers are removed to the final processing site. This HCS is an exclusive transport container system applied mainly in commercial sectors.

(b) In the case of the Stationary Container System (SCS)/Residential Container System, which is described as a fixed collection system, the waste receptacles can be left in one place and are not picked up or moved. They can include portable collection points, also known as non-lift containers. The SCS is a single-container system designed for residential areas.

4.1.14 Waste transportation operations

To obtain an efficient and effective waste transportation system, waste transportation operations should follow the following procedures [43]:

(a) Use the shortest possible transportation route with the fewest possible obstacles.
(b) Using transport vehicles with the maximum possible capacity/carrying capacity.
(c) Using fuel-efficient transport vehicles.
(d) Can utilize working time as much as possible by increasing the number of workloads and/or transportation trips.

4.1.15 Waste transportation pattern

(a) Waste transportation with a direct individual collection system (door to door);
(b) Transfer system at Type 1, Type 2, and Type 3 depots.

4.1.16 Determination of transportation facilities

Equipment and equipment for waste transportation facilities on a city scale are as follows: the requirements are:
(a) Waste must be closed during transportation, so that waste is not scattered on the road.
(b) Maximum bin height 1.6 meters.
(c) There should be a lifting device.
(d) Does not leak, so that leachate does not scatter during transportation.
(e) Adjusted to the condition of the road being passed.
(f) Adjusted to financial capabilities and maintenance techniques.

Waste transportation financing. The cost of moving and transporting waste consists of:
(a) Investment costs: facilities needed for transportation, such as the garbage trucks used.
(b) Operational costs: operation and maintenance of waste transportation.
The steps for calculating transportation costs are:
(a) First, determine based on the local Basic Activity Unit Price.
(b) Calculate the need for transportation equipment and other supporting facilities.
(c) Calculate operations and maintenance as well as labor salaries.

Padang City has waste transportation infrastructure to the Final Processing Site, using motorized vehicles such as dump trucks and arm rolls, which the Padang City Environmental Service oversees. The efficacy of waste transportation activities and the associated efficiency levels depend on the effectiveness of waste collection efforts.

(a) Household: The transfer and transportation of household waste in Padang City uses a direct communal collection pattern system.

(b) Market; market waste is collected directly at the Temporary Waste Shelter container, and the transfer process is carried out directly with the collection process.

(c) Commercial; truck transport officers, door to door or from the Temporary Waste Shelter, carry out transportation from commercial areas in Padang City.

(d) Industry; transportation of domestic waste from industrial areas is carried out by the Padang City Cleaning and Parks Service fleet from the Temporary Waste Shelter provided in the industrial area.

(e) Roads and parks; the transfer and transportation are included or jointly carried out by officers from the Padang City Environmental Service.

(f) Hospitals; transportation of domestic waste is carried out by the Padang City Cleaning and Parks Service, door to door with a fleet of trucks.

4.1.17 Waste processing

Waste processing includes compaction, composting, recycling materials, and converting waste into energy sources. Waste processing is carried out by considering:

(a) Waste characteristics;

(b) Environmentally friendly processing technology;

(c) Work safety;

(d) Social conditions of the community.

Waste processing technology can be:

(a) Physical processing technology in the form of reducing waste size, compaction, magnetic separation, density, and optics;

(b) Chemical processing technology in the form of adding chemicals or other materials to facilitate the next processing process;

(c) Biological processing technology in the form of aerobic and/or anaerobic processing, such as composting and/or biogasification;

(d) Thermal processing technology in the form of incineration, pyrolysis, and/or gasification; and waste processing can also be carried out using other technologies to produce fuel, namely Refused Derived Fuel (RDF);

(e) Waste processing facilities can be in the form of Temporary Waste Shelter 3R, Waste Transfer Station, Final Processing Site, or Integrated Waste Processing Place.

4.1.18 Final processing

The Final Processing Site is the final processing site in the formal waste management cycle. This phase can use various methods from simple to high-tech. In its implementation, there are 3 methods of waste disposal activities, namely:

(1) Open Dumping

Open dumping, or open disposal, is a primitive waste management practice in which waste is spread in an area, left exposed, and abandoned as soon as the area is full. Open dumping, or open disposal, is a simple waste management system in which garbage is spread on the surface of an area, unprotected from the elements, and abandoned as soon as the site fills up. The earlier approach is no longer recommended due to the high number of possible pollutants that this generates, including:

(a) Spreading of disease-carrying organisms, including but not limited to insects like flies and rodents like rats. Degradation of air quality with the release of obnoxious odors and gaseous pollutants.

(b) The massive volume of leachate or liquid waste leading to water pollution.

(c) Decreased environmental aesthetics due to unsightly conditions.

(2) Control Landfill

This approach is superior to open dumping, where collected garbage is regularly covered with a layer of soil to prevent environmental damage. During its operation, the waste is further compacted and leveled to maximise land utilization and surface stability at the Final Processing Site. Within Indonesia, it is recommended that the controlled landfill method be applied in medium- and small-sized cities. To successfully implement this method, several facilities must be established. These include:

(a) Drainage channels to control rainwater flow;

(b) Leachate collection channels;

(c) Reservoirs;

(d) Operational control posts;

(e) Methane gas control facilities;

(f) Heavy equipment.

(3) Sanitary Landfill

This technique is a breakthrough from the mentioned practice of open dumping, as this method is a world-renowned method used across the globe. The waste is thoroughly encapsulated each day, making it difficult to disturb. However, implementing this methodology requires adequate infrastructure and facilities and imposes a significant economic burden, limiting its recommendation so far to large, densely populated metropolitan areas.

4.1.19 Administrative misdemeanor action and law enforcement

Data collection in Padang City identified several behaviors that do not support sustainable waste management. Some forms even cause direct damage to the city's environment, namely:

(a) Storage of scrap goods.

(b) Disposal of expired food and beverage waste. Red cracker and noodle industry.

(c) Tree felling.

(d) Day land clearing for housing development. Disposal of feces: Burning coconut charcoal. Construction of multi-storey buildings.

(e) Coal stockpile.

(f) Waterlogging and drainage.

(g) Waste sludge causes flooding.

(h) Coconut trees growing on sidewalks.

(i) Fish feed manufacturing business.

(j) JCattle/goat maintenance.

(k) C mining.

(l) Cafes and restaurants, Indiscriminate waste disposal.

The Final Report of the Waste Study in Padang City needs a sociological and anthropological study to research deviant behavior. Several behaviors budded out culturally because the establishment of Padang City as an urban area was not planned. Padang City is a place of migration for its surrounding community, with a variety of cultural characteristics.

The development of Padang City continues to promote sustainable development, alongside efforts to meet societal needs and improve welfare. Such development has significant consequences, including increased strain on environmental systems and natural resources. Empirical data show overexploitation of environmental assets and natural resources, which are essential as basic inputs for development efforts. This magnification of pressure in parallel depletes the environment's carrying capacity, leading to numerous environmental issues. Thus, it is important to incorporate environmental dimensions into the developmental activities to establish sustainable development paradigms for present and future generations.

This primary consideration is codified as a key legal principle in Law No. 32/2009 on Environmental Protection and Management, which stipulates that environmental management, in the context of sustainable development, must be grounded in legal values and sensitive to public awareness at all levels. Moreover, consideration must be given to global environmental trends and to all relevant legal instruments governing the environment. This highlights the need for developing holistic environmental programs and policies.

Continuous, coordinated control and monitoring of environmental conditions are key to effectively implementing an environmental management system. Such environmental alarm and oversight, or more often monitoring, requires systematic assessments conducted regularly, measuring certain environmental elements at defined time intervals. All decisions and actions must be documented, as, generally, during the supervisory process, you can see what worked well and what did not. Supervisory practices are a cornerstone of adaptive management frameworks. Such environmental oversight and monitoring of business operations allow for assessing whether impacts expected from a given business or activity actually occur, and to what degree effective environmental management practices can amplify positive outcomes while minimizing negative ones associated with that same business or activity. Hence, through supervision and accountability from all business owners and citizens, environmental quality in Padang City can be maintained, thereby achieving the goals of sustainable development and environmental soundness.

Based on empirical data from Environmental Management Efforts and Environmental Monitoring documents at the Padang City Environmental Service in 2019, it was found that 26 large scale-enterprises/activities have environmental impact analysis documents, owned 641 medium-scale enterprises/activities with approved documentation and as many as 1358 small scales of enterprises/activities own Letter of Statement of Commitment to Environmental Management and Monitoring documentation must be disclosed. The implementation of these environmental management documents must be reported at least once every 6 months to ensure that supervisory and managerial functions related to environmental impacts arising from these business activities are carried out.

The comprehensive element essential for the development of an environmental management system is supervision and monitoring. Monitoring or supervision refers to the periodic measurement of environmentally relevant components or variables over time, enabling systematic evaluation. While executing supervision, all decisions and actions undertaken must be documented so that success and failure may both be evaluated and recorded. We will become the quintessential activity in adaptive management: Supervision and leadership. Supervision and monitoring

are activities that help determine environmental pollution in an area, enabling government authorities to formulate development policies for environmental management in the region. Regular oversight can help minimize potential ecological damage.

The benefits and objectives of testing the quality of liquid waste, receiving water bodies, noise, and vibration levels in activities/businesses that have an environmental impact in Padang City are:

(a) Benefits

• As the main support for environmental impact control efforts.

• As input for the Padang City Government in managing environmental impacts.

• As a reference for the Padang City Government in planning environmental management in the future.

(b) Objectives

• Collecting general data and information that describes the performance or status of a business's compliance with laws and regulations in the field of controlling environmental pollution and environmental damage.

• Monitoring, evaluating, and determining the status of compliance of the person in charge of the business and/or activity with laws and regulations.

• Knowing the effectiveness of the implementation of the Environmental Feasibility Document carried out by activities/businesses that have an environmental impact in Padang City.

(c) Expected Results

The expected results of this Environmental Impact Monitoring Activity/Business are:

• Realization of activities/businesses that comply with environmental laws and regulations.

• Controlled pollution and environmental damage factors due to activities/businesses in Padang City.

• Realization of a harmonious Padang City environment that meets environmental carrying capacity.

• Creation of an environmentally aware Padang City development climate.

4.1.20 Waste management governance

(1) Government Regulations Related to Waste

Industrial waste is a major environmental issue in many urban areas in Indonesia, but not all regions have successfully provided adequate waste management services. One of the prominent reasons for ineffective waste management services in certain regions has been determined to be the organizational capacity (or capability) of waste management institutions, which is generally minimal compared with their functional responsibilities (qualitatively, based on the amount of treatment [the ratio of waste that processes]). This organizational mismatch serves as a key factor. Waste is clearly an environmental issue. Article 28H, paragraph (1), of the 1945 Constitution of the Republic of Indonesia states that the state guarantees every citizen the right to a good and healthy environment. The principle is then reflected in Law No. 18/2008 on Waste Management. This law imposes an obligation on both the Central Government and the Regional Governments to provide public garbage disposal services.

In Indonesia, waste management performance by both central and regional governments across various regions remains far from optimal. Data from 2013 by the Indonesian Ministry of Health Basic Health Research show that only 24.9% of waste in Indonesia was collected by designated officials. The majority of households dispose of waste by burning (50.1%), followed by landfill disposal (3.9%), composting (0.9%), and aquatic dumping into water bodies such as rivers, ditches, and the ocean (10.4%). In comparison, negligent disposal practices account for about 9.7%.

Traditional methods of waste disposal, as previously remarked, may not be a threat to the environment when population density is low and organic matter content is high. However, as population density increases and consumer behavior changes, the use of traditional and informal waste-disposal methods, such as dumping waste into rivers, ditches, or the ocean, harms the environment.

(2) Padang City Government Policy Regarding Waste

Waste management in Padang City is very complex and requires serious attention from all parties, including the local government, the private sector, and local communities. Following difficulties in cleaning up waste in Padang City, the Padang City Government implemented an emergency response in 2018, using a technology system for riverbank nets spanning multiple sub-districts. After all, does not the Padang City Government continue to work hard to achieve national waste management of 70% or 49.9 million tons per day in 2025, while for Padang City itself in 2019, the waste management target reached an average of 62.6%, equivalent to 360 tons per day?

In the institutional aspect, it discusses waste management from the authority's perspective to the organization's perspective in the Regency/City. 7 key things in the institutional aspect: 1–Waste Management Authority Reference: Law Number 23 of 2014 concerning Regional Government, Article 1 paragraph (6), the meaning of which is the rights, authorities, and obligations of autonomous regions to regulate and administer these elements set out. Regional governments are empowered to manage their own regions. In carrying out this mandate, they are required to provide certain services to the people, including issuing permits to regulate entrepreneurs and/or communities to minimize environmental pollution. Basically, regions ought to operate independently within their permissible limits, except for matters of government administration as provided by law under the jurisdiction of the Central Government.

Consistent with the principle of distribution of authority between the Central Government and Regional Governments in Indonesia, giving the Regional Government with regulatory authority on the formulation of Regional Regulations derived from delegation as well as attribution; that creation must comply with regulations under law or any higher legal products, in addition to Local government also has authority to set up a local head regulation for further realize regional regulation. In addition, the Environmental Protection and Management Law Number 32 of 2009 defines the environment as an integrated unit in a space that includes all elements, whether natural or artificial, including humans and their activities presumed to affect sustainable life and ecosystem services. The authority of local government in waste management is based on the Regional Autonomy Law. In Indonesia, Law Number 18 of 2008 regarding Waste Management states that it is the prerogative of the central authority to establish a national policy and strategy for waste management. However, regional governmental bodies have the right to develop waste management policies and programs for their own administrative areas, provided they are consistent with higher-order policy. Regency/City policies and strategies must refer to Provincial Policies, and Provincial Policies should refer to national policies. This shows that both the central and provincial governments play a significant role in directing district/city governments on waste management. A similar claim is reiterated in PP Number 81 of 2012 regarding the Management of Household Waste and Household-like Waste.

Second, Implementers of Regional Cooperation. The basis for regional cooperation is the assessment of public service efficiency and effectiveness, recognizing that each can benefit from the other. As per Law Number 2 of 2015 concerning the Establishment of Government Regulation instead of Law Number 2 Year 2014 on Amendments to Law Number 23 year 2014 regarding Regional Government, cooperation between regional governments is classified into mandatory cooperation which means cooperation among regions that is done by adjacent Regions for the administration of government affairs: First: having externalities across regions; or Second, provision of public services whose implementation can be more effective if provided together. This may apply to the administration of Government Affairs that fall under the jurisdiction of a Region but are considered more effective and efficient when grouped by bordering or non-ordering Regions for Voluntary cooperation.

In implementing waste management, Government Regulation 81/2012 states that Regency/City Governments can partner with business entities, communities, and/or other Regency/City Governments. These collaborations and partnerships can span the entire waste service lifecycle, including transportation, processing, and final disposal.

(3) Regional Government Cooperation with the Private Sector

Municipal and regency administrations that do have limitations (insufficient budgets to conduct waste management, limited restrictions on the provision of tools and physical infrastructure for waste processing, and limited human resources to manage the task effectively) could engage in partnerships with the private sector. Agreements for regional cooperation with external agents must be in accordance with the agreed principles of cooperation and defined goals. The aim of regional collaboration also covers every element of management that requires action from the autonomous areas, time expenditures, and potential in regions, as well as public services, in accordance with Government Regulation No. 50 of 2007 on the Implementation of Regional Cooperation. Local governments must take into account various factors when executing collaborations with legal entities or third parties, including:

• A local government is unable to deliver public services due to limitations imposed by regional fiscal resources or a lack of specialized knowledge.

• The engagement of legal entities is posited to enhance service quality and/or expedite regional development, as well as augment regional revenue streams in comparison to management solely undertaken by the local government.

• There exists a favorable disposition among consumers/users of public services towards the participation of legal entities.

• The outcomes of public services can be quantitatively assessed, and their respective tariffs can be determined, thereby ensuring that tariff revenues offset the costs associated with delivering these services.

• Certain legal entities have established a commendable "track record" in their collaborative efforts with local governments.

• There is a potential for competitive engagement from alternative legal entities.

• There are no existing regulations that preclude the participation of legal entities in the provision of public services.

(4) Monitoring and Evaluation of Cooperation

Article 36 of Law Number 23 of 2014 also explicitly mentions the oversight and assessment of collaborative efforts. The Governor, as the Central Government, should monitor and evaluate cooperation that can be carried out by Regency/City Regions within a Province. The Minister supervises and evaluates interactions between Regions, both those under their jurisdiction (Provincial Regions) and other District City Areas outside their jurisdiction. Article 369 thereafter states that the government's regulatory provisions shall regulate matters related to cooperation. 4), based on Article 44 of Government regulations Number 28 of 2018 concerning Procedures for the Implementation of Regional Cooperation.

• The guidance and oversight of Regional cooperation, in a general sense, is conducted by and coordinated at a

national level by the Minister.

• The technical guidance and oversight of Regional cooperation is executed by the minister/head of regional institutions and is administered by the regional head.

• The regional head conducts the guidance and oversight of Regional cooperation by the regional apparatus.

Regulatory frameworks governing oversight and direction encompass the assessment and appraisal of regional collaborative efforts. They are executed in alignment with the stipulations established by laws and regulations that oversee the guidance and supervision of regional governmental administration.

(5) Form of Institutional Management

To perform tasks between the territorial government, including subsidiary tasks related to waste management within the region, an authority may also be established for that purpose by means of the respective regional administration. Law No. 2 of 2015 concerning the Deliverance of Government Regulation provides a distinction on the type and classification of agencies, divided into three groups, namely:

• Type A services are instituted to address governmental responsibilities that are within the regional authority, characterized by a substantial workload.

• Type B services are established to manage governmental responsibilities that fall under the regional authority associated with a moderate workload.

• Type C services are instituted to oversee governmental responsibilities that are within the regional authority, characterized by a minimal workload.

Determining the size of the workload is based on:

• Total population.

• An area.

• The amount of each Government Affairs that becomes.

• Regional authorities.

• Regional financial capacity.

Quoted from Article 211, paragraph (1) and paragraph (2) of Law No. 23 of 2014 concerning Regional Government states that: The organization and arrangement of Regional Apparatus will be carried out by the Central government for the provincial area and the Governor as the representative of the Central government for districts/municipal regions. The nomenclature for the Regional Apparatus and its functional units for organizing Government Affairs is created in accordance with directions from the executive management of the ministry or non-ministerial government institution regarding the Inove Committee and the use of donations.

The agency, as a regional apparatus organization, is an implementing element of autonomy with authority over the sub-affairs of waste in the region. The agency acts as an organizer of waste services. It plays a role in developing policies, norms, and standards, and in supervising and controlling the implementation of waste services in the region (as a regulator). The agency that serves as regulator and operator of waste management implementation is perceived as less effective because its workload spans several matters, leading to suboptimal handling of waste services, including funding, which is sometimes insufficient.

(6) Institutional Structure

Management related to waste issues is included in the environmental operations sector, based on the implementation mechanism of government regulation number 1 of 2016 concerning regional officials. This is made more explicit with the enactment of Regulation of the Minister of Environment and Forestry Number P.74//8/2016 on guidelines for the nomenclature of apparatus at provincial and regency/city levels, focusing on the implementation of government affairs in environmental and forestry sectors.

This regulates the Regions that have been given the authority to form their own organizational structures, as required but not limited by applicable law. This rule states that the Provincial and Regency/City Regional Apparatuses, which form part of the government delegation on environmental affairs, should be organized as agencies. In turn, as organizations strive to meet the increased need for efficient waste management within their areas of influence, their offices rise in the hierarchy.

The waste management sector is classified as a separate agency, and all organizational matters relating to waste are handled at the Head of Division level. In some cases, this is delegated to the Head of Section/Sub-Division. The provincial and regency/city regional apparatus as referred to in this regulation are divided into 3 (three) types, namely type A, type B and type C; Type A regional apparatus is a regional apparatus that has a large workload, the type B regional apparatus is a regional apparatus with moderate workload but the practice of power devolutions type B are still charged to pay for non-budget revenue. At the same time, Type C is a low-workload arrangement. The categorization of regional apparatus types is based on an analysis of the burden of government affairs and the degree of supporting activities required to implement environmental and forestry government affairs at both provincial and regency/city levels.

The organizational framework of the Regency/City Regional Apparatus comprises:

(a) The type A district/city Environmental Service consists of: 1 secretariat and a maximum of 4 fields. The Secretariat consists of a maximum of 3 sub-sections, and the Fields, as referred to, consist of a maximum of 3 sections.

(b) The Regency/City Environmental Service type B consists of 1 secretariat and a maximum of 3 fields. The Secretariat, as referred to, consists of a maximum of 2 sub-sections, and the Fields, as referred to, consist of a maximum of 3 sections.

(c) The type C district/city Environmental Service consists of 1 secretariat and a maximum of 2 fields. The secretariat, as referred to, consists of 2 subsections, and the fields, as referred to, consist of a maximum of 3 sections.

The allocation of responsibilities and functions of work units and management structures at the Provincial and Regency/City levels is guided by a functional approach within the Environmental Services of Provinces and Regency/City Parks. This regulation provides classification for the creation, structural organization, duties, functions, and working processes of both Provincial and Regency/City Environmental Services, as well as Provincial and Regency/City Forestry Services, that fall under the Regional Head. The duties and functions of work units within the Regency/City Environmental Services, consisting of Type A, Type B, and Type C, based on the Regulation of the Minister of Environment and Forestry Number P.74/2016 concerning Guidelines for Nomenclatures in Provinces as well as Regency/City Regional Apparatuses, are included in the Annex.

(7) Work Procedures

The work procedures should include supervision, reporting, and evaluation forms, as well as procedures for cooperation with related agencies, especially for counseling activities, the collection of levies, the implementation of pioneering projects, and membership in the Urban Waste Management Association. In the Work Procedures of Waste Management Institutions, it is necessary to pay attention to matters related to the Role of Management Institutions, including: First, the Division of Operator and Regulatory Roles. To mitigate potential conflicts of interest and to establish robust checks and balances that guarantee the effective execution of waste management services, Public Work Ministry Regulation about the National Policy and Strategy for the Development of Waste Management Systems articulates the necessity for a delineation of responsibilities between entities functioning as regulators and those operating as service providers. Within the framework of governmental responsibilities, the term regulator refers to an entity tasked with formulating policies, norms, and standards for the administration of public services. Furthermore, the regulator is responsible for exercising supervisory and regulatory functions to ensure that public services are provided in accordance with the established guidelines. Conversely, operators are the entities engaged in the delivery of public services who are responsible for planning and executing activities in alignment with the directives issued by the regulator. The distinct functions of regulators and operators must be explicitly articulated in the delineation of each institution's responsibilities and functions. In regions where the separation of the operator's role into distinct organizational units has not been achieved, the responsibilities associated with waste services (such as street and public facility cleaning, waste transportation, and management of Final Processing Sites) may be integrated into the job structure or positions within the Service, potentially categorized under designations like "Field" or "Section."

Second, the Local Technical Implementation Unit within the Agency shall establish the operator function as a distinct entity, and shall assume responsibility for waste management services. Conversely, the Agency shall serve as a regulatory body. Each regional organization, structured as an agency, may, if deemed necessary, establish a technical unit under its supervision in accordance with relevant regulations. The Agency engaged in environmental management shall be authorized to establish a technical implementation unit for the Regency/City Regional Agency to carry out certain operational technical tasks and/or supporting technical functions.

The technical implementing units of the district/city regional services, as referenced, are categorized into 2 distinct classifications. The technical implementing units of the district/city regional services comprise: first, technical implementing units for class A district/city regional services to accommodate large workloads. And second, technical implementing units for class B district/city regional services to accommodate small workloads. The establishment of technical implementation units in district or city regional offices is determined by the regulation issued by the Regent or Mayor, guided by a written consultation with the Governor as a representative of the Central Government. The cadre of regional apparatus work units is based on a workload analysis of the regional apparatus. In the performance of its duties, the Regent or Mayor consults with the Governor, as the representative of the Government, on the number of work units of local apparatus and, ultimately, presents a recommendation to the relevant people's consultant council of the City.

(8) Institutional Improvement of the Local Technical Implementation Unit to the Local Public Service Agency

The execution of a Local Public Service Agency Financial Management Pattern allows for flexibility in managing financial management under the administration of the Local Technical Implementation Unit, if this is necessary as an effort to improve services with better quality for the community. The Local Public Service Agency Financial Management Pattern provides some degree of flexibility, such that the ability to conduct sound business practice decisions for potential expanded community services as warranted by efficiency, effectiveness, and productivity. The establishment of the Local Public Service Agency in the Local Technical Implementation Unit is subject to the fulfilment of the main substantive, technical, and administrative requirements. The establishment of the Regional

Public Services Agency through the submission mechanism for Local Public Service Agencies includes: first, local Technical Implementation Unit is marked with the 1st institutionalization of District/City Government in the affair of the establishment of an institution, which is then assigned for implementation by a Local Public Service Agency. Second, the technical regulations and instructions regarding the Regional Technical Implementation Unit include the administrative documents required to implement the Regional Public Service Institution which will be carried out through regulations/policies issued by the Regional Head regarding the appointment of the Regional Technical Implementation Unit to ultimately develop the necessary permutations that can lead to the formation of an institution.

(9) Cooperation and Partnership

Law Number 18 of 2008 concerning Waste Management states that local governments may cooperate with other local governments in the field of waste management. This cooperation can take the form of cooperatives or joint local waste management enterprises, whose operational principles are set out in regulations issued by the minister responsible for domestic affairs. One of the most significant applications for cooperation between local governments is in waste management. Individual or combined. Local government entities can partner with waste management enterprises to implement a specific waste management initiative. Such partnerships can be established through an agreement or a draft joint venture agreement between the local government entity and the relevant business entity, with implementation procedures carried out in accordance with applicable laws and regulations. Diligently can be conducted with a third party in accordance with government regulation number 28 of 2018 on the implementation of regional cooperation, which requires the fulfillment of aspects based on the cooperation principle and legislation relating to the subject matter of the cooperation itself, as outlined in article 13, which includes:

(a) In its implementation, the region can be represented by the Governor or Regent/Mayor who acts for and on behalf of the region;

(b) The Governor or Regent/Mayor can authorize officials within the regional apparatus to sign cooperation contracts/agreements;

(c) Officials in the regional apparatus environment carry out their duties based on statutory provisions.

Collaborative relations between local governments and third parties may be carried out according to the provisions in Article 14 of Government Regulation Number 28 of 2018 concerning the Implementation Procedures for Regional Cooperation in the form of individuals, legal entities, and community organizations, whose forms can be both legal entities or non-legal entities, based on statutory regulations. Waste management and the role of government through the creation of a supportive environment will only be judged by how close targets are met and the quality of service provided. For initiatives to meet targets and improve service quality, they must have resources available within local government systems. Locally, in practice, governments are beset by limited resources. The private sector and the community can also help to supplement what is lacking with the government. Thus, the authorities shall explore and utilize potential from the private sector and society [9].

So the use of private and community potential is a systematic action to be carried out by local government agencies that have horizontal relations with territorial functions, through Environmental Service, in synergy with the Waste Management Unit, aims to encourage effective participation of the private sector and the community as partners or prospective partners, and fill operational needs management of waste management units. So, partner support in the management of the Waste Management Unit should be integrated through a legal framework and technical policies that serve as the basis for implementation and supervision. The methods under consideration would help pilot a route towards consolidating the concept of successful community access to waste management services. In this instance, partner support aims to: first, address the constraints on government resources needed to accelerate service coverage and quality improvement. Second. raising awareness of the different actors involved in waste management. Technically, the development and implementation of partnerships is basically the responsibility of the UPT as the operator institution that receives the mandate in waste management; however, the implementation of this partnership requires support from the City Government and the Local Technical Implementation Unit.

4.1.21 Waste financing

Waste management requires funding for investment, operations, maintenance, equipment replacement, and service improvements.

(1) Source of funds

Waste Management Funds in a City: 5%–10% of the Local Revenue and Expenditure Budget Directorate General of Human Settlements. All operations and support are conducted responsibly within the available management costs. Assuming that the city government covers at least 30% of operational costs for cleaning services in public places and roads, and that levies collected from the community and grants can finance 70% of the remaining costs. Funds for municipal waste management come from, first, cleaning service fees. Second, a cleaning fee. Third is the Local Revenue and Expenditure Budget. Collection: 20%–40%, Transportation: 40%–60% Final processing: 10%–30% The cost structure for waste management-service per city/region.

(2) Retribution

This attempts to keep the level of giving over subsidies and avail itself of tariff revisions based on terms and conditions. Tariffs are effectively and responsibly collected to prevent leakage. The collection of the levy is conducted on a legal basis that fulfils the following principles: First, a functional control system is being developed, including common drinking water accounts. Second, divided into billing areas. Third, depending on the target, billing will commence once the service is operating consistently. Fourth, the publication of the tariff structure in the regional regulation.

(3) Gross Regional Domestic Product

The Gross Regional Domestic Product (GRDP) per capita is obtained by dividing the region's total GRDP by its mid-year population to determine its specific contributors. Per capita GRDP at current prices is the value of GRDP for one person. In general, the economic progress of an area is indicated by the GRDP growth rate based on current prices, and Padang City is currently showing a positive trend.

In 2021, economic growth was 3.65%; it increased to 4.31% in 2022, to 4.54% in 2023, and is now at 4.43% (data: Padangkota) for the recent year examined, which is also seen as an urgent need for Indonesia's economic growth. The City of Padang has shown a significant recovery after the decline in economic growth caused by the COVID-19 pandemic in 2020.

(4) Circular Economy

Indonesia has since embraced the idea of a circular economy as part of its Indonesian Vision 2045. In this regard, the government initiated the implementation of circular-economy principles in the construction of the waste-management system. A paradigm of waste management based on the principles of a circular economy assumes that an operational system has been established that minimizes waste and maximizes existing resources. It means that any instances of waste, emission, and energy dissipation are to be avoided wherever possible. This could help prolong the lifecycle of production and consumption, enabling products to be reused while simultaneously recycling their waste into their original form or into new iterations of the product. Hence, following the basic principles of the circular economy in waste management practices is a fundamental step toward reducing waste sent to landfills and natural environments. The Ellen MacArthur Foundation, an organization that aims to accelerate the transition to a circular economy, identifies three core principles.

The first principle of the circular economy is the understanding that waste and pollution are largely the result of products designed for a linear economic model. This specifically refers to products that will eventually have a particular end of life, instead of creating products that can be recovered and reintroduced into the material cycle. According to the Australian Circular Economy Hub, about 80% of environmental impacts are decided at the design stage. This is why: if we make changes to the design, they can have a greater impact on the entire material lifecycle. One simple example of applying this circular economy principle is reducing our reliance on single-use products in our daily lives by redesigning them. Hence, they offer the same value as sustainable alternatives.

The next pillar of the circular economy is based on the very simple reality: resource waste can no longer be tolerated. This claim is based on the recognition that our planet has finite resources. All materials used in most essential products can be reused, repaired, and remanufactured to maximize their lifespan. The most radical feature of the circular economy is its emphasis on creating feedback loops that truly support the regeneration of the natural environment. This principle stems from the inherently cyclical nature of natural processes and represents a zero-waste system. All components, including carbon, oxygen, nitrogen, and water, should be returned to their natural cycles.

The principle is especially relevant to organic materials. In a linear economic model, organic waste ends up in landfills. This process not only wastes the water and energy that went into creating the product, but also increases organic waste that harms nature. On the contrary, valuable nutrients in a circular economy are reintegrated into soil and living systems rather than dumped into landfills. Thus, materials obtained from organic waste can be used to enhance natural resources, as seen in regenerative agriculture.

4.1.22 Community and stakeholder participation

(1) Community Participation

In waste management, the community plays a significant role, contributing to waste generation and helping reduce waste volume at its source by sorting or using simple technologies (such as composting) at the household level and beyond. One notable initiative was the creation of a waste collection group within the community, tasked with organizing actions to achieve environmental cleanliness. This effort involves the establishment of multiple stakeholders, as described in the Integrated Waste Management Action Plan for Padang City 2023–2030, specifically:

- Department of Environment Service;
- Local government;
- Women's Association;
- Community Institutions;
- Environmental Cadres and Facilitators;
- NGOs, Universities, and Experts;
- Environmental Cadres and Facilitators;

• Private (plastic manufacturers, manufacturers using plastic packaging, retailers, importers, etc.);
• Waste Recovery Operator

All parties play their respective roles. The government as regulator and law enforcer, the private sector with corporate social responsibility, universities and NGOs through studies and advocacy, as well as others.

(2) Private Sector Participation

Regarding waste management, the private sector can play a major role. The lack of incentives, as seen in the case of government-provided drinking water, has led to high operational costs for waste management, according to [25, 33, 44–46]. Thus, both direct and joint participation by the private sector are needed. Environmental Law identifies different penalties, commensurate to the seriousness of offences committed, to enable more efficient execution of the relevant law, specifically: first, administrative sanction in the form of a written warning. Second, administrative sanctions imposed by the government. Third, administrative sanction of freezing of permits. And fourth, administrative sanction of dismissal by the government. Thus, Indonesian law emphasizes establishing systems, regulations, and structures, and strengthening governance and law enforcement in the field. However, no less important is awareness and consistency in implementing policies on real cases [47–50].

4.2 Discussions

The waste crisis has hit Padang City can be interpreted of three major indicators: (1) in 2023 it will produce as much as 236,296 tons an increase of 9.94% since the previous year and if it continues like this, the *Aie Dingin* Landfill will be full on in 2026. (2) by an average 4 of 500 tons/day in 2024. (3) The condition shows that there is still easily biodegradable waste, with a composition of about 62.530% plastic waste, which is difficult to manage, and around 13.606%. In fact, only 66.24% of waste has been managed at the national level; thus, local levels mirror a larger governance shortcoming in society.

Polycentric environmental governance holds that the effectiveness of public services increases when authority is distributed but interlinked through common (or at least similar) rules [51–53]. In Padang, the regulatory function is held by the Environmental Service, while the Local Public Service Agency of the Integrated Waste Processing Place holds the operational function. However, most of the partnership frameworks with the private sector–community have been established ad hoc. This lack of a clear chain of command indicates poor coordination, such that decisions regarding the management of Temporary Waste Shelter, tariffs, and 3R innovation are, in many cases, compromised. Ostrom's theory [54] reaffirms the need for shared decision-making spaces, with socially equal actors negotiating targets and incentives as well as through Local Public Service Agency performance contracts or private forums, which determine regionally based reduction quotas.

One finding in relation to enforcement is that despite the government's acknowledgment of a waste emergency, there are no sanctions for illegal dumping and open burning. Responsive regulation conceptualizes compliance as a continuum; regulators should move up the hierarchy of sanctions from education and administrative penalties to criminal punishment while offering incentives to actors who step up their game [55–57]. Padang City, which already has a Mayoral Regulation on waste tariffs without progressive fines, is contextually relevant for this approach.

Economically, 5%–10% of the Local Revenue and Expenditure Budget is still being spent on maintenance, up to 70% levy should cover, but is below that (40%–60%) due to transportation. Extended Producer Responsibility (EPR) is the principle that determines who should be responsible for managing e-waste; the role rests on all parties that need to implement EPR, while taking into consideration the polluter-pays principles as a basis for balancing externality costs through Local Revenue and Expenditure Budget via packaging levies [58]. Afterward, the Mayoral Regulation on service rates should also be expanded into this EPR Regional Regulation so that plastic producers are financed for MRF or RDF in each local area, and the 3R funding gap is closed.

The last node is public participation. The embryo of behavioral change can be seen, e.g., in monthly community service programs, household composting, and 182 active waste banks out of a target of 909 Citizens Associations. But having 20% of Citizens Associations is not progressive enough. Community-Based Social Marketing pushes for a blend of public commitment, visual feedback, and simple incentives to increase participation and it works very well at altering waste behavior [59–61].

To achieve the research objectives, evidence must be provided that their conclusions address the challenges posed by the claims. Since the crisis in Padang City is not only a technical issue but also involves governance failures, law enforcement issues, and financing issues, by integrating polycentric governance, responsive regulation, EPR-circular economy, and the Community Based Social Marketing (CBSM) framework, a complementary policy mix, clear coordination, balanced incentives and sanctions, cost sharing, and citizen behavior change are provided. By positioning the City Government as a meta-regulator [62, 63], the Regional Public Service Agency as a professional operator of Integrated Waste Management, and the engaged producer community as service producers, Padang City can transform this waste emergency into a laboratory for the urban circular economy in Indonesia. In detail, the analysis and discussion of the findings of this study can be seen in Table 2.

Table 2. Dimensions, analysis findings, concepts, and research implications

Dimensions	Analysis of Findings	Relevant Concepts/Theories & Implications
Governance & institutions	Fragmentation of authority (Environmental Service, Local Technical Implementation Unit, Local Public Service Agency) reveals the weakness of polycentric governance: each actor operates independently, making accountability unclear.	Polycentric Environmental Governance Theory (Study [54] emphasized the division of regulator-operator roles, which is not yet clear in Padang. Institutional redesign, including service-level agreements between units and performance-based budgeting, can clarify the hierarchy and encourage innovation.
Law enforcement & behavior	Data shows 15+ forms of violations (fecal disposal, red cracker industry, tree felling, etc.). Administrative sanctions (SATT–SACI) have been regulated, but implementation is weak.	Study [64] proposed a pyramid of sanctions–from education → fines → criminal. Padang can integrate community-based monitoring and digital whistle-blowing to accelerate enforcement.
Circular economy & 3R technical	The high organic waste creates opportunities for composting, biodigesters, and refuse-derived fuel, and 13.6% of plastic requires material recovery facilities.	The three principles of the Circular Economy—zero-waste design, material circulation, and natural system regeneration—guide the focus of interventions. The combination of collective composting + EPR for plastics will close the resource loop.
Financing & economic instruments	The current levy does not cover the costs; the city government uses the Local Revenue and Expenditure Budget, but transportation costs remain dominant.	Extended Producer Responsibility (EPR) & Polluter-Pays Principle shift the burden from the Local Revenue and Expenditure Budget to producers and consumers. The instruments mentioned (product levy, recovery bonus, electricity tariff) need to be adopted through Perda to ensure legal certainty and stable funding.
Community participation	The new waste bank program has reached only 20% of Citizens Association; the culture of littering remains high.	The Community-Based Social Marketing Study [65] emphasized public commitment, visual feedback, and social norms to change behavior. Padang can utilize smart waste applications and digital point incentives to increase participation.

If these problems are not handled sooner, waste management in Padang will have a synergistic impact on the worsening environmental crisis and public services. From an institutional standpoint, waste management operational functions from the Environmental Service, Local Technical Implementation Unit, and Local Public Service Agency are fragmented in terms of roles and authorities. Currently, there is no clear, measurable coordination framework, and each institution operates in a silo. This highlights the lack of a cohesive governance framework, as advocated by polycentric governance theory [54], which calls for multiple decision-making bodies that engage and cooperate in managing common resources such as waste. Management cannot plan efficiently and responsibly without space for negotiation among competing actors [66–68].

Next is the technical challenge of still being an end-of-pipe or final-disposal facility at the *Aie Dingin* Landfill Final Processing Site, which has almost no capacity left and will collapse in 2026. In fact, the waste composition data shows that more than 60% of Padang's waste is organic, and we can process it locally through home composting or community biodigesters. Dependence on a final disposal system indicates that the circular economy-oriented waste management paradigm has not been integrated into waste management policies and planning. These practices are also at the heart of the circular economy, which aims to return resources derived from our consumption activities to production through zero-waste industrial design principles, material reuse, and the regeneration of natural systems [69, 70]. If organic and plastic fractions are addressed in this manner, no bag would have to go to a landfill.

Regulation: The main barrier is poor enforcement of waste management regulations [34, 71, 72]. Research has reported violations ranging from illegal dumping by residents to the use of business actors, but administration sanctions are not enforced. Murphy argues, however, that the lack of civil penalties reflects exactly the opposite in line with Braithwaite's "responsive regulation"—that is, we should build up citizen compliance through a ladder of increasing sanctions: education and warnings, then administrative fines as well as criminal threats. Such a method also lays heavy stress on community involvement, with supervisors using kwan application-based reporting channels or citizen complaint-based systems.

The first major problem is financial. However, the existing funding arrangement is heavily reliant on Local

Revenue and Expenditure Budget, which contributes no more than 5%–10% of management needs, with the major cost center being transport (about 60%). Waste levies do not correlate with the burden of waste generated or the quality of services provided. To solve this problem, Padang City should adopt the polluter-pays principle and implement an EPR policy, requiring producers to contribute to the waste collection and processing system. This would also relieve the government of having to cover the entire budget while making producers accountable for their products throughout their life cycles.

Last but not least, a critical challenge exists in the social aspects, including a lack of community involvement and awareness. Despite launching several initiatives, including monthly community service activities, household composting, and market waste banks across many Citizens Associations, only about 20 percent of the administrative area has adopted these initiatives. This poor participation shows that this species of behavioural change has not occurred, as the approach is still based on normative, top-down education. One approach relevant in this context is CBSM [12]. CBSM focuses on using social psychology-based strategies, such as visual feedback, community rewards, and the establishment of new norms, to encourage voluntary waste sorting and reduce overall waste generation.

Unfortunately, the rapid increase in waste generation is not equaled by the capacity of systemic, institutional, and even cultural forms available to Padang City at this time. In summary, without breakthroughs in governance, financial support systems, law enforcement, and behavioral device approaches, Padang will continue to face waste management challenges that threaten environmental quality and public health. Thus, actions need to be taken that are not only technical but also explore new theoretical and policy approaches related to community participation and sustainability [73, 74].

Waste management in Padang City currently faces serious systemic and multidimensional problems. Waste generation has increased to an average of 500 tons per day in 2024 (based on the total annual accumulation of 236,296 tons in 2023), which is high-pressure on the Site Aie Dingin Landfill Final Processing and, based on the schedule, will reach maximum capacity in no more than 6 years. This is the result of an end-of-pipe management system that focuses solely on disposal rather than on strengthening source reduction and recycling systems. The composition of waste, which is mostly organic (over 60%) and plastic (about 13.6%), demonstrates that the potential to develop a management model based on the key principles of the circular economy has not been fully utilized. Organic waste can be converted into compost or energy through biogas production, and plastic waste can be recycled directly or used as refuse-derived fuel.

The other half of the very big problem is institutional fragmentation and weak cross-sectoral governance. Currently, the Padang City Environmental Service serves as the regulator, and the Local Technical Implementation Unit or Local Public Service Agency handles operational waste transport and processing. Yet, an official coordination mechanism between these institutions and other stakeholders, such as Citizens Association, the private sector, and the community, remains absent. The theory of polycentric environmental governance proposed by the researcher [54] supports this claim, arguing that in a system with several centers of power, an effective mechanism can be created only if there is a structured, fair coordinating mechanism. In the absence of a joint decision-making arena, each actor works in part, and they can even overlap if there is no synergy in waste management programs in Padang.

Moreover, the enforcement of waste management regulations is extremely weak. Researchers noted illegal dumping, open burning, and vegetation destruction around the disposal area, and said community members were also involved. There are appropriate legal regulations concerning administrative sanctions and criminal threats, but these are not always enforced. In this context, the theory of responsive regulation is pertinent [75–77]. This theory introduces a tiered approach at the law enforcement level, reprimands and strict sanctions, and, through digital mechanisms, community involvement as monitors. This is relevant to developing a deterrent impact while fostering contemporary social behaviors that are more eco-conscious [78, 79].

Financing for waste management is another difficulty. The local revenue and expenditure budget, which covers only a small portion of operational needs (5%–10%), indicates that the sustainable financing scheme is weak. The highest costs are in the transportation sector (40%–60% of the total), highlighting that the centralized Final Processing Site system remains the dominant model. Regionally, a circular economy policy that reflects the EPR approach should be adopted as soon as possible, particularly for financing waste collection and processing by producers responsible for single-use plastic packaging. The polluter-pays principle must be applied so that the government and society do not bear the entire financing burden.

For community initiatives and waste banks, yes, this is the first step toward better initiatives; however, this symbolic approach has not yet struck a chord with the entire population. This is because they are only for a limited number of Citizens Association, such as the waste bank program, which has targeted only about 20% of Citizens Association. The city government can adopt a CBSM approach to broaden and increase its impact. This leverages visual feedback and engenders social commitment through incentives like digital points or community awards to change behavior at scale and over time.

Based on these conditions, it can be concluded that waste management in Padang requires not only technical remedies but also policy and institutional transformations. A bridge is needed between collaborative governance based

on polycentric principles, adaptive and participatory regulatory practices, EPR-based financing, and cross-spatial community behavioral interventions. If all these aspects can be designed and implemented synergistically, Padang City will not only avoid a waste crisis but also become a model for sustainable development. Furthermore, the city can also serve as a model for the nation in implementing a sustainable and inclusive municipal waste management system. For details of strategic recommendations and theoretical and practical justifications, see Table 3.

Table 3. Strategic recommendations, theoretical and practical justifications

Area	Strategic Recommendations	Theoretical/Practical Justification
Institutions & Governance	Form a polycentric coordination forum across Environmental Service, Local Public Service Agency, Citizens Association, and the private sector with performance contracts between actors.	Polycentric governance increases service effectiveness when there is a joint decision-making arena [54].
Law Enforcement	Implement the regulatory pyramid: education → warning → fine → criminal, with a digital community reporting system.	Responsive regulation is effective when combined with participation and transparency [80].
Inclusive Financing	Issue Extended Producer Responsibility (EPR) & Volume-Based Retribution Regulations	The Polluter-Pays Principle & EPR are proven to balance costs among society, government, and producers.
Technology & Infrastructure	Accelerate the development of an Integrated Waste Processing Place 3R + biodigester for organics and refuse-derived fuel for plastic.	In accordance with the principles of Circular Economy and waste management hierarchy (Reduce, Reuse, and Recycle (3R) > Final Processing Site)
Community Participation	Increase the coverage of waste banks, digital incentives, and inter-Citizens Association competitions based on waste reduction.	Community-Based Social Marketing (McKenzie-Mohr) encourages behavioral change through social norms and feedback.
Information System & Transparency	Build a smart waste dashboard: Temporary Waste Shelter sensors, violation reporting, and 3R monitoring.	Increasing accountability & accelerating policy response.

Results from earlier studies show that weak law enforcement, limited public participation, and inadequate funding constrain waste management practices in Padang City. These findings are consistent with previous studies conducted in several cities in Indonesia that found similar issues, namely fragmentation of authority among actors and low public awareness. In contrast to previous research that has focused almost exclusively on describing the issues, we argue that polycentric governance and responsive regulation offer a framework for engaging with these challenges.

There are several relevant models compared to global practices. One example is the EPR legislation that the European Union has adopted to ensure producers finance post-consumer management costs for materials like plastics and electronics; this drives both consumer recycling and salvaging & remedial action at end-of-life. 14 In South Korea, an EPR scheme has been evaluated as successful in promoting compliance by industries while alleviating the cost and burden of implementation for local governments through a deposit-refund system. Considering that EPR policy has the potential to play an important role in reducing plastic waste generation and improving the performance of waste management systems, these findings are relevant for Padang City, where EPR policy is poorly implemented.

In addition, community-based incentives already in place in some cities worldwide can offer valuable insights. Programs like Pay-as-You-Throw in Europe incentivize people to sort their trash by charging for the volume of unsorted waste. Digital initiatives, such as point-based waste bank apps, are also emerging in Indonesia but on a limited scale. In the Padang context, this study shows that digital incentive-based programs may emphasize community engagement and information provision, leveraging the *Padang Bagoro* program or a waste bank.

Hence, this study not only reinforces the traditional barriers to urban waste management but also reveals a new nexus in which polycentric governance and responsive regulation could leverage best practices worldwide for EPR and digital-based community incentives. This approach shows that sustainable waste management in Padang City needs integrated structural and behavioral strategies to enable a future, inclusive, adaptive system.

Table 4 shows that the challenges identified in Padang are not unique but share patterns with those in other developing cities. However, global best practices have demonstrated effective solutions through polycentric governance, responsive regulation, EPR, community incentives, and digital/AI-based innovations. By critically comparing local findings with international experiences, this study underscores its contribution by proposing an adaptive governance framework tailored to the Indonesian context that aligns with global standards for sustainable waste management.

Table 4. Comparison of research findings with global best practices

Key Issue	Findings in Padang	Global Practices/Best Practices	Gap & Relevance
Institutional fragmentation	Authority is distributed but lacks coordination among actors.	Polycentric governance in Europe & the US shows that multi-level coordination strengthens policy effectiveness.	Strengthening polycentric governance is needed to reduce overlaps and clarify actors' roles.
Law enforcement	Sanctions exist but are weakly implemented and not adaptive to social conditions.	Responsive regulation in Australia & Canada combines persuasive and coercive instruments.	Responsive regulation should be applied flexibly, aligned with institutional capacity and community behavior.
Financing	Relies on local budget and fees; no producer responsibility mechanism.	Extended Producer Responsibility (EPR) in the EU and South Korea obliges producers to cover post-consumption costs.	Highly relevant to strengthen financing and reduce fiscal burden on the local government.
Community participation	Participation is low; waste bank programs remain suboptimal.	Pay-as-You-Throw schemes in Europe and digital incentive systems in Asian cities have increased community involvement.	Digital/community-based incentives can enhance compliance.
Technology & innovation	Waste management is still manual and limited to Temporary Storage Sites 3R.	Digital monitoring and AI-based waste sorting improve efficiency.	Potential adoption of digital monitoring & AI to track waste generation and support sorting in Padang.

The study identified three major challenges in Padang City's current waste management system. Table 5 shows that the findings are not just descriptive problems but directly relate to weaknesses in governance and regulation. From a polycentric governance perspective, Padang suffers from fragmented institutions and poor coordination among the government, the private sector, and communities. From the responsive regulation perspective, enforcement remains one-dimensional and fails to combine sanctions with persuasive and incentive-based approaches.

Table 5. Key findings and their theoretical relevance

Empirical Findings	Relevance to Polycentric Governance	Relevance to Responsive Regulation
Waste composition dominated by organics (62.53%) and plastics (13.6%)	Lack of coordination among agencies to integrate waste characteristics into policy.	Absence of adaptive rules that encourage producers and communities to handle specific waste streams.
Institutional fragmentation across agencies	Illustrates failure of multi-level coordination; decision centers exist, but do not synergize.	Enforcement is rigid and not adapted to institutional overlap; there is a lack of collaborative compliance mechanisms.
Weak law enforcement	No shared authority between institutions to enforce rules collectively.	Sanctions are punitive and inconsistently applied; persuasive and incentive-based tools are missing.
Low community participation	Community actors are excluded from decision-making processes, contrary to polycentric principles.	No systematic use of positive incentives; regulation does not respond to the behavioral realities of households.
Financial dependency on the regional revenue and expenditure budget	Missed opportunity for multi-actor financing models, such as performance contracts and Extended Producer Responsibility (EPR).	No adaptive regulatory instruments to distribute costs fairly between the government, producers, and consumers.

5 Conclusions

It created several barriers to sustainable waste management in Padang City, including the fragmentation of government institutions, a weak law-enforcement system against waste perpetrators, and limited involvement from surrounding communities and municipalities that heavily rely on local budgets. Using the frameworks of polycentric governance and responsive regulation, we showed that the existing system lacked multi-level coordination and adaptive enforcement mechanisms. For policymakers, some tangible steps are proposed:

Strengthening polycentric governance and existing local institutional structures: Establish multi-level coordination platforms involving local government, private sector, and community-based organizations. Second, adopt EPR to reduce reliance on local budgets and more equitably spread the costs of waste management. Third, embrace responsive regulation that blends punitive measures with incentive-based mechanisms, including a digital reward system for households and businesses. Encourage decentralized technologies for treating organic waste (e.g., community composting and biogas) to reduce the burden on final disposal sites. Fifth, improve community participation through digital-based waste bank systems to be scaled up with financial incentives.

Limitations

This research is limited by its qualitative focus, reliance on document analysis, and a small number of interviews. As such, findings may not capture the full diversity of stakeholder perspectives or the quantitative impact of policy interventions.

Future Research Directions

Further studies could: first. provide comparative perspectives across Indonesian cities to assess differences in governance and regulatory effectiveness. Second, consider how to pair institution-building with digital monitoring systems and AI-based waste sorting. Third, adopt mixed-method approaches that leverage qualitative insights while generating quantitative estimates of impact to strengthen evidence for policy design.

Thus, while the study highlights the urgent need for structural reform in waste governance, it also offers tangible policy interventions and recommendations, along with directions for future innovations that may facilitate the emergence of inclusive, adaptive, and sustainable urban waste management systems.

Author Contributions

Conceptualization, A.K., H.D., and Z.A.; methodology, A.K. and H.D.; validation, A.K. and Z.A.; formal analysis, A.K. and Z.A.; investigation, H.D.; resources, A.K. and Z.A.; data curation, Z.A; writing—original draft preparation, A.K., Z.A., and H.D.; writing—review and editing, A.K., Z.A., and H.D.; visualization, A.K., Z.A., and H.D; supervision, A.K.. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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