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Integrated waste management based on sustainable approaches, methods and systems in Sinjai regency

Fahsul Falah[1*], Muhammad Hatta Jamil[2], Eymal B Demmallino[1], Ariady Arsal[3], Darmawansyah[4], Darhamsyah[5], Andi Nur Apung Massiseng[6]
[1]Environmental Science Study Program, Graduate School, Hasanuddin University, Makassar 90245, Indonesia; ffahsul@gmail.com (F.F).
[2]Department of Socio-economics of Agriculture, Faculty of Agriculture, Hasanuddin University, Makassar 90245, Indonesia.
[3]Agribusiness Study Program, Graduate School, Hasanuddin University, Makassar 90245, Indonesia.
[4]Public Health Study Program, Faculty of Public Health, Hasanuddin University, Makassar 90245, Indonesia.
[5]Environmental Management Study Program, Postgraduate School, Hasanuddin University, Makassar 90245, Indonesia.
[6]Department of Fishery Agrobusiness, Faculty of Fisheries, Universitas Cokroaminoto Makassar, Makassar 90245, Indonesia.

Abstract: Waste management in Sinjai Regency aligns with Regional Regulation Number 28 of 2018 concerning Policies and Strategies for the Management of Household Waste and Waste Similar to Household Waste. This study aims to analyze the methods, management systems, and recycling efforts in Sinjai Regency, as well as their implications for ecosystem sustainability. The research used a descriptive qualitative and quantitative approach with analysis based on normative standards. A case study method was applied using Delphi analysis, content analysis, and SERVQUAL (Importance Performance Analysis). Sampling was conducted through Stratified Random Sampling. The Delphi analysis results indicate that the waste management system is influenced by service quality, waste removal processes, transportation to landfills, and operational procedures. Meanwhile, analysis based on the Indonesian National Standard (SNI) shows that these standards are important references for ensuring effective waste collection. SERVQUAL analysis further reveals that community satisfaction depends heavily on the punctuality of waste collection according to the promised schedule. Overall, this research confirms that an effective and standardized waste management system plays a significant role in reducing environmental pollution, improving environmental quality, and maintaining ecosystem sustainability.

Keywords: *Community participation, Environmental policy, Recycling, Sustainability, Waste management.*

1. Introduction

A common environmental problem in an area is waste management that has not been optimal in meeting the needs of the community [1-3]. Waste management in Sinjai Regency refers to Law Number 18 of 2008 concerning Waste Management, which emphasizes a systematic, comprehensive, and sustainable approach to waste reduction and handling. In addition, there are other regulations that also regulate waste management, such as Law Number 6 of 2023 concerning Job Creation, Government Regulation Number 22 of 2021 concerning the Implementation and Protection of the Environment, Presidential Regulation Number 97 of 2017 concerning National Policies and Strategies for the Management of Household Waste and Waste Similar to Household Waste (Jakstranas), and Sinjai Regent Regulation Number 28 of 2018 concerning Sinjai Regency Policies and Strategies in the Management of Household Waste and Waste Similar to Household Waste.

Sustainable waste management is one of the important pillars in the implementation of good governance [4-6]. This requires a waste management system that not only meets technical aspects, but

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* Correspondence: ffahsul@gmail.com

also remains based on environmental sustainability and minimizes negative impacts on the ecosystem [7-9]. Waste, which is the residue of human activities, needs to be managed properly so as not to cause environmental pollution, spread of disease, decrease in aesthetics, and ecological disturbances that can affect the balance of biodiversity [10-13]. However, the increasing amount of waste has not been matched by public awareness in maintaining environmental cleanliness, and the government's capacity in waste management still faces various obstacles. As a result, waste continues to accumulate and has the potential to become a serious problem in the future, especially due to population growth, socio-economic development, and technological advances which are expected to further increase waste generation [14, 15].

Effective waste management must consider various aspects, including institutions, regulations, financing, technical-operational, and community participation [16-18]. Sinjai Regency has developed a waste reduction and handling strategy in accordance with Sinjai Regent Regulation No. 28/2018, which includes limiting waste generation, reusing waste, and recycling. This strategy also involves strengthening community involvement through communication, information, education, as well as direct guidance and informal communication [19-21].

To support optimal waste management, Sinjai Regency has provided facilities and infrastructure such as 10 units of six-wheeled vehicles, 21 units of three-wheeled vehicles, 13 units of waste containers, and 1 unit of landfill. In addition, waste reduction facilities include the Reduce, Reuse, Recycle Waste Processing Station (TPS 3R) in Lappa Village, North Sinjai District, which has been active since October 2023 under the management of the Masseddi Beneficiary and Empowerment Group (KPP). However, some facilities such as TPS 3R in Bongki Village, North Sinjai District are not active due to the absence of a management group. Sinjai Regency also has a Parent Waste Bank as well as four other Waste Bank units, namely the Saotengah Village Hope Waste Bank (Central Sinjai District), Tellulimpoe Village Independent Waste Bank, Tongke-Tongke Village Mangrove Waste Bank, and Napast Waste Bank (East Sinjai District). The composting program is also implemented at Rutan and SMKN 1 Sinjai, and involves the informal sector with five waste collectors.

Based on the description above, this study has novelty in examining the role of Sinjai Regency Government policies in determining recycling methods, systems and practices that not only support ecosystem sustainability, but also have the potential to provide economic value to the community. The effectiveness of waste management is highly dependent on the frequency of transportation, the number of personnel, and the availability of adequate facilities and infrastructure so that the system runs efficiently and is able to provide satisfaction for the community as service recipients [22, 23]. Therefore, a comprehensive and integrated solution is needed with support from all levels of society and the strengthening of adaptive policies. Given the importance of these aspects, this study aims to evaluate the quality of waste management in Sinjai Regency to support ecosystem sustainability and community welfare simultaneously.

2. Materials and Methods

This research was conducted at the Department of Environment and Forestry (DEF) of Sinjai Regency, focusing on waste management at Tondong Landfill. Data were collected through two main sources: secondary data from relevant agencies and primary data from respondents through questionnaires. Secondary data were obtained from the Environment and Forestry Agency, the Central Bureau of Statistics, and the Subdistrict Office, while primary data were processed using frequency distribution analysis. The study population was the entire population of Sinjai Regency, with a sample of 100 respondents selected using the Stratified Random Sampling technique [24-26]. This technique divides a heterogeneous population into homogeneous groups to ensure accurate representation. Data analysis was conducted using qualitative and quantitative descriptive analysis techniques, including delphi analysis for technical and institutional aspects, as well as content analysis for waste management

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based on the Indonesian National Standard (SNI). One of the formulas used to determine the sample size is the SLOVIN formula [27-29] which is expressed as:

$$n = \frac{N}{Nd^2 + 1}$$

Where (n) is the sample size, (N) is the population size, and (d) is the degree of accuracy determined at 10%. Using this formula, from a population of 219,323 people, a sample of 100 respondents was obtained. The assessment indicators used in this study refer to the SERVQUAL model [30-32] which consists of five dimensions: reliability, assurance, tangible, empathy, and responsiveness. The diagram used in this study is the Cartesian Diagram for Importance Performance Analysis (IPA) [33, 34] which illustrates the position of each indicator in two dimensions: importance level and performance level (Figure 1). This diagram helps in identifying areas that need improvement and prioritizing actions to be taken to improve community satisfaction.

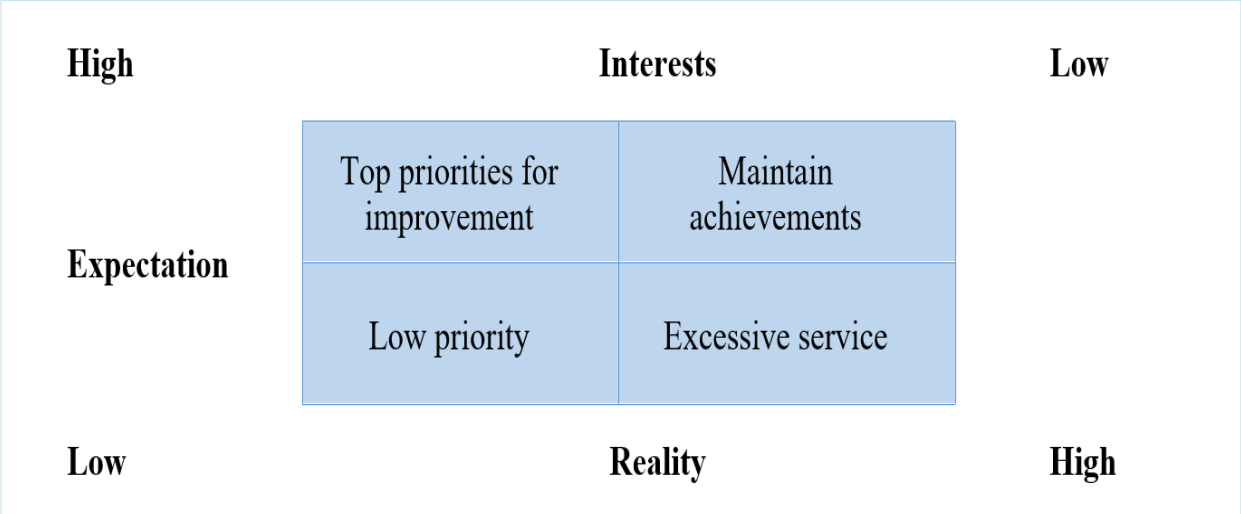

Figure 1.
Cartesian diagram model.

3. Results and Discussion

3.1. Technical and Institutional Analysis of Waste Management (Delphi Analysis)

The urban waste management system is basically seen from the sub-system components that support and interact with each other [35]. These components are technical, institutional, financing, legal and community participation aspects [36, 37]. From this, the good and bad of waste management can be influenced by these five aspects. However, this study only discusses 2 (two) aspects, namely technical aspects and institutional aspects. The method used is the delphi analysis technique [38-40] based on the results of interviews, observations and questionnaires to stakeholders, namely the Environment and Forestry Service of Sinjai Regency.

Sampling respondents as a representation of stakeholder groups based on the level of importance and influence on factors that affect waste management in Sinjai Regency can be seen in Table 1.

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Table 1.
Respondent sampling as representation of stakeholder groups

Key Stakeholders	Stakeholders Interest Group	Interests
Head of Waste Management Division of Cleanliness	Cleaning Division Sinjai Regency Environment and Forestry Service	Responsible for carrying out cleaning activities, transportation of waste and maintenance of cleaning facilities and infrastructure.
Cleaning Staff	Cleaning Division Sinjai Regency Environment and Forestry Service	Responsible for the technical implementation of waste management
Secretary	Related to the main problems in the field and understanding the existing conditions	Related to waste management issues
Head of General and Personnel	Related to the main problems in the field and understanding the existing conditions	Related to waste management issues

Based on the synthesis of theories related to factors affecting waste management, technical and institutional aspects were used. After the descriptive analysis, a Delphi analysis was conducted to explore the factors relevant to the selected stakeholders. The following are the results of the Delphi analysis:

Table 2.
Results of phase I delphi analysis

Factor	R1	R2	R3	R4
Technical Aspects				
Waste service	A	A	A	A
Waste generation	A	A	A	DA
Waste containment	A	A	DA	DA
Waste collection	A	A	DA	DA
Waste transfer	A	A	A	A
Waste transportation to the landfill	A	A	A	A
Institutional Aspects				
Technical work procedures	A	A	A	A

A = Agree
DA = Disagree
= Need iterations
R1 = Head of Waste Management Section of Cleaning
R2 = Cleaning Staff
R3 = Secretary
R4 = Head of General and Personnel

The results of the first stage of Delphi exploration showed respondents' opinions on the factors that influence waste management performance. This Delphi questionnaire covers two aspects, namely technical and institutional. The following is a further explanation:

3.2.1. Waste Service

Four respondents agreed that waste management services influence waste processing performance. Respondent 1, the Head of Waste Management in the Cleanliness Division, stated that good and regular waste services will create a clean and healthy city. Respondent 2, an Executive Staff Member in the Cleanliness Division, added that to keep the city clean, waste services must be provided properly and regularly. Respondent 3, the Secretary, emphasized the importance of special attention to waste and systematic management to maintain environmental cleanliness and health. Meanwhile, Respondent 4,

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the Head of General Affairs and Personnel, asserted that waste services must be carried out to prevent the area from becoming dirty and filled with waste.

3.2.2. Waste Generation

Interviews with several stakeholders revealed that three out of four respondents agreed that waste accumulation is a factor influencing waste processing performance. Respondent 1, the Head of Waste Management in the Cleanliness Division, stated that knowing the amount of waste generated in each location can facilitate the collection process. Respondent 2, an Executive Staff Member in the Cleanliness Division, added that classifying waste accumulation based on population size and community activities in each area can improve waste management services. Meanwhile, Respondent 3, the Secretary, emphasized that understanding high-risk waste accumulation points is crucial for effective management. On the other hand, Respondent 4, the Head of General Affairs and Personnel, disagreed that waste accumulation affects processing performance, arguing that community consumption levels are not always constant, and sudden surges in waste generation can occur at any time.

3.2.3. Waste Containment

Two out of four respondents agreed that waste containment is a factor influencing waste processing performance. Respondent 1, the Head of Waste Management in the Cleanliness Division, stated that waste containment serves as a temporary collection point to prevent waste from scattering. Meanwhile, Respondent 2, an Executive Staff Member in the Cleanliness Division, believed that proper waste containment can encourage community participation in maintaining environmental cleanliness. On the other hand, Respondent 3, the Secretary, disagreed, arguing that the waste containment system has not yet been effectively implemented in the community. Similarly, Respondent 4, the Head of General Affairs and Personnel, also rejected waste containment as a significant factor, reasoning that the presence of too many collection points could lead to waste accumulation, increasing the risk of waste spreading, especially during the rainy season.

3.2.4. Waste Collection

Two out of four respondents agreed that waste collection is a factor influencing waste processing performance. Respondent 1 stated that waste collection helps prevent accumulation and maintains city cleanliness. Respondent 2 added that the process makes it easier for workers to transport waste and ensures that it is more concentrated. Meanwhile, the other two respondents disagreed. Respondent 3 argued that waste collection actually slows down transportation to the landfill and increases the risk of waste accumulation in various locations. Respondent 4 also disagreed, stating that if collected waste is not promptly transported to the Tondong Landfill, it can cause unpleasant odors and disrupt the environment.

3.2.5. Waste Transfer

Based on the interview results, all four respondents agreed that the waste transfer process affects waste processing performance. Respondent 1 emphasized that a smooth transfer process requires adequate facilities and infrastructure. Respondent 2 agreed, stating that proper waste transfer can prevent accumulation and reduce strong odors. Respondent 3 also supported this view, noting that workers must be punctual in transferring waste to prevent buildup at collection points. Meanwhile, Respondent 4 highlighted the importance of a direct household pickup system to speed up waste collection and prevent accumulation in various locations.

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3.2.6. Waste Transportation to the Landfill

All four respondents agreed that waste transportation to the Tondong Landfill is a factor influencing waste processing performance. Respondent 1 emphasized the importance of maintaining facilities and infrastructure to ensure smooth waste transportation. Respondent 2 stated that timely transportation helps create a clean and healthy city. Respondent 3 agreed, noting that selecting a landfill site far from residential areas with easy access would facilitate the transportation process. Meanwhile, Respondent 4 highlighted that optimizing waste transportation to the landfill would help maintain a clean and waste-free environment.

3.2.7. Technical Work Procedures

All respondents agreed that technical work procedures are a factor influencing waste processing performance. Respondent 1 emphasized that having a sufficient and competent workforce facilitates waste management services. Respondent 2 stated that workers must always perform optimally and on time in every service process. Respondent 3 highlighted the importance of having an adequate number of sanitation workers to cover all areas, as well as the availability and maintenance of waste collection fleets to support operations. Meanwhile, Respondent 4 stressed that having enough personnel who perform their duties properly will streamline and improve the waste management process.

3.3. Phase II

The second phase of the Delphi analysis continues from the first iteration, focusing on aspects that have not yet reached a consensus, as presented in Table 3.

Table 3.
Results of delphi phase ii

Factor	R1	R2	R3	R4
Technical Aspects				
Waste service	A	A	A	A
Waste generation	DA	DA	A	DA
Waste containment	DA	DA	DA	DA
Waste collection	DA	DA	DA	DA
Waste transfer	A	A	A	A
Waste transportation to the landfill	A	A	A	A
Institutional Aspects				
Technical work procedures	A	A	A	A

A = Agree
DA = Disagree
= Need iterations
R1 = Head of Waste Management Section of Cleaning
R2 = Cleaning Staff
R3 = Secretary
R4 = Head of General and Personnel

Based on the results of the first iteration, consensus was not reached, necessitating a further iteration. In this phase, the questionnaire was redistributed to relevant stakeholders. The results of the second iteration are as follows:

3.3.1. Waste Service

Four respondents agreed that waste management services are a factor influencing waste processing. They believe that well-organized and consistent services contribute to creating a clean and healthy city.

3.3.2. Waste Generation

In the initial iteration, R1, R2, and R3 agreed that waste accumulation affects waste processing, while R4 disagreed. After the second iteration, R1 and R2 changed their stance to disagreement, while R3 remained in agreement. R1 argued that waste accumulation is not significant due to varying field conditions. R2 reasoned that waste accumulation fluctuates across different areas. R4, who had disagreed from the start, maintained that community consumption is not always stable. Meanwhile, R3 continued to believe that waste accumulation influences waste processing, depending on individual awareness.

3.3.3. Waste Containment

In the second iteration, Respondents 1 and 2 changed their stance to disagree that waste containment affects waste processing performance. Respondent 1 argued that containment depends on public awareness. Respondent 2 stated that containment actually slows down the waste transportation process to the landfill. Respondent 3 remained in disagreement, citing that the containment system is not yet optimal and still requires community education. Similarly, Respondent 4 maintained their disagreement, emphasizing that waste accumulation in containers could still disrupt environmental comfort.

3.3.4. Waste Collection

Based on the results of the repeated iteration, all respondents agreed that waste collection is not a factor affecting waste processing. They argued that waste collection actually slows down the transportation process to the landfill.

3.3.5. Waste Transfer

All respondents agreed that the waste transfer process affects waste management performance. Respondent 1 emphasized the importance of adequate facilities and infrastructure to ensure smooth waste transfer. Respondent 2 agreed, stating that proper transfer prevents waste accumulation and foul odors. Respondent 3 highlighted the importance of timely waste transfer by staff to prevent buildup at collection points. Respondent 4 suggested a proactive "door-to-door" collection method to expedite waste pickup and avoid accumulation.

3.3.6. Waste Transportation to the Landfill

All respondents agreed that transportation to the Tondong Landfill is a key factor influencing waste management. Respondent 1 emphasized the importance of maintaining facilities and infrastructure to ensure smooth transportation. Respondent 2 stated that timely waste transport contributes to a clean and healthy city. Respondent 3 added that a landfill located far from residential areas with good access would facilitate the transport process. Respondent 4 highlighted that optimizing waste transportation would create a cleaner and waste-free environment.

3.3.7. Technical work procedures

All respondents agreed that technical work procedures influence waste management performance. Respondent 1 stated that having sufficient and competent human resources would streamline waste management services. Respondent 2 emphasized the importance of optimization and timeliness in every service process. Respondent 3 highlighted the need for an adequate number of sanitation workers, sufficient fleet capacity, and proper maintenance. Respondent 4 argued that having enough personnel who perform their duties properly would improve waste management efficiency.

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3.4. Phase III: Factor Fixation

Table 4.
Results of delphi phase iii.

Factor	R1	R2	R3	R4
Technical Aspects				
Waste service	A	A	A	A
Waste transfer	A	A	A	A
Waste transportation to the landfill	A	A	A	A
Institutional Aspects				
Technical work procedures	A	A	A	A

A = Agree
DA = Disagree
R1 = Head of Waste Management Section of Cleaning
R2 = Cleaning Staff
R3 = Secretary
R4 = Head of General and Personnel

Based on the results of questionnaires 1 and 2, the third-stage questionnaire established respondent consensus on the factors influencing waste management. All respondents agreed that these factors have an impact, with the selected factors including waste services, waste transfer, transportation to the landfill, and work procedures.

3.5. Waste Management Based on SNI

Tondong Landfill is the only final disposal site in Sinjai Regency that applies the sanitary landfill system. Located in East Sinjai District, it is approximately 10 km from Sinjai City center. Its construction began in 2008 with a budget of IDR 300 million for the planning phase. From 2009 to 2010, supporting facilities were built, including sidewalks, wells, leachate ponds, and methane gas collectors.

(a) (b) (c)

Figure 2.
(a) Tondong Landfill zone b (active); (b) Storage tank, well, and leachate pond; (c) Methane gas capture pipe.

Tondong Landfill is equipped with various facilities, including a 4–5meter deep storage pit lined with rubber tarpaulin as a base layer, methane gas disposal and capture pipes, one leachate well, three leachate ponds, a guard post, a shredding machine for waste processing, and a weighbridge. However, waste management in Sinjai Regency remains suboptimal. Of the nine districts, Tondong Landfill services only Sinjai Utara and Sinjai Timur. This is likely due to the higher volume of waste generation in these two districts. Sinjai Utara serves as the city center and administrative hub of Sinjai Regency,

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while Sinjai Timur hosts several key tourist destinations, such as mangrove forests, fish auction sites, and a port.

Waste management services in Sinjai Regency are currently supported by a limited number of facilities and infrastructure, resulting in a heavier operational burden that affects their condition and performance. The available waste management facilities in Sinjai Regency include arm roll trucks, dump trucks, pickup trucks, waste motorcycles, two-wheeled motorcycles, and waste bins.

Table 5.
Number of waste management fleet of the Sanitation Department of Sinjai Regency

No	Type of Fleet	Total (Units)	Transportation Volume
1	*Arm Roll*	9	5 m^3
2	*Dump Truck*	2	6 m^3
3	*Pick Up*	1	2 m^3
4	Garbage Motor	30	-
5	Two-Wheeled Motorcycle	2	-
6	Trash Can	10	-

Population is a crucial factor in waste management planning and administration, as the number and distribution of residents directly influence the volume of waste generated [41]. Population growth is affected by birth rates, mortality rates, and migration [42, 43] which can increase pressure on waste management systems. Therefore, to understand the relationship between population size and the service coverage of Tondong Landfill, demographic data from the Central Bureau of Statistics of Sinjai Regency is utilized. This data includes the population figures of the two districts served by Tondong Landfill from 2020 to 2024, as presented in Table 6. This information serves as a basis for evaluating the effectiveness of the waste management system and planning future improvements in waste management service capacity.

Table 6.
Population of areas covered by Tondong Landfill (2020 – 2024).

Year	District		Total
	North Sinjai	East Sinjai	
2020	43.505	30.421	73.926
2021	46.166	30.317	76.483
2022	46.637	30.550	77.187
2023	47.091	30.772	77.863
2024	47.530	30.989	78.516

To obtain the most accurate population estimate, an approach based on the standard deviation (S) is used as the basis for selecting the projection method. A smaller standard deviation indicates a higher level of accuracy in estimating the population. In this study, the population projection for the Tondong Landfill coverage area is conducted using the Least Square Method [44, 45] as it has the smallest standard deviation of 1,699.683, compared to the Arithmetic Method (1,814.357) and the Geometric Method (1,821.851). The projected population for the Tondong Landfill coverage area is shown in Figure 3.

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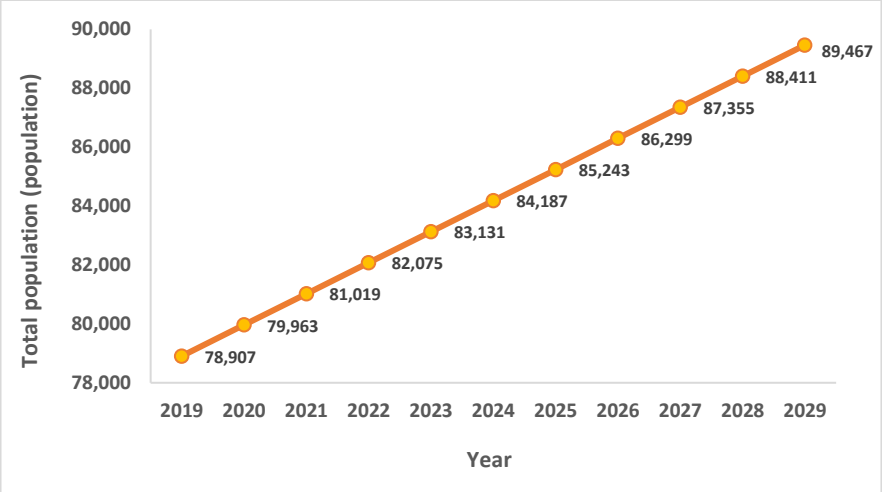

Figure 3.
Projection of the population in the Tondong Landfill coverage area.

Figure 3 shows a trend of increasing population each year, with an initial estimate of 78,907 people in 2019, rising to 89,467 people by 2029. This population growth directly impacts the increase in waste generation within the Tondong Landfill coverage area. According to secondary data from the Sinjai Regency Environmental and Forestry Office in 2023, the daily waste generation entering Tondong Landfill is measured using a weighbridge (Figure 4). This data serves as the basis for assumptions in calculating the waste reduction achieved by residents in the Tondong Landfill coverage area. The waste reduction results act as an indicator of waste management efficiency in Sinjai Regency.

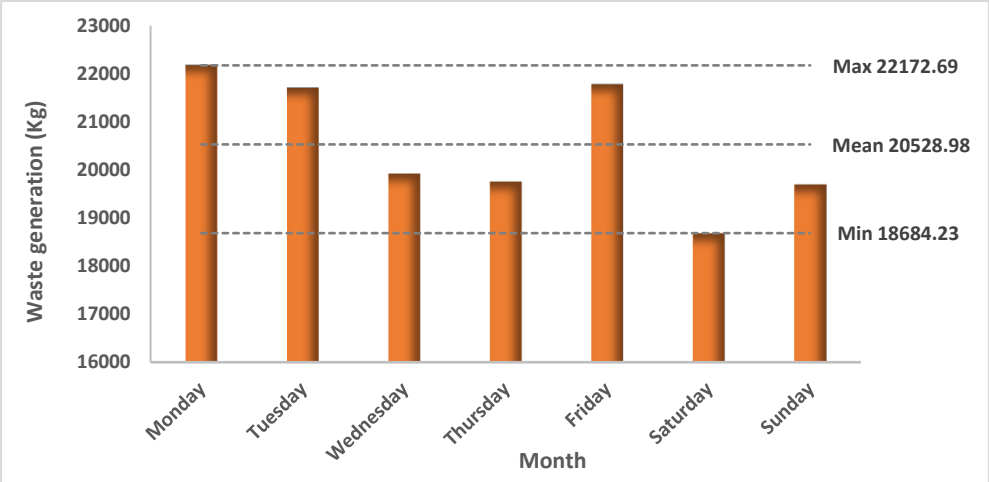

Figure 4.
Daily waste measurement at Tondong Landfill in 2023.

Based on Figure 4, the highest waste generation occurred on Monday, reaching 22,172.69 kg. This increase is likely due to high activity at tourist sites or events held over the weekend. Conversely, the lowest waste generation was recorded on Saturday, at 18,684.23 kg, which may be related to residents' habit of resting on Fridays. The average daily waste generation in 2023 was recorded at 20,528.98 kg. This daily data was then compiled to determine the total monthly waste generation, as shown in Figure 5.

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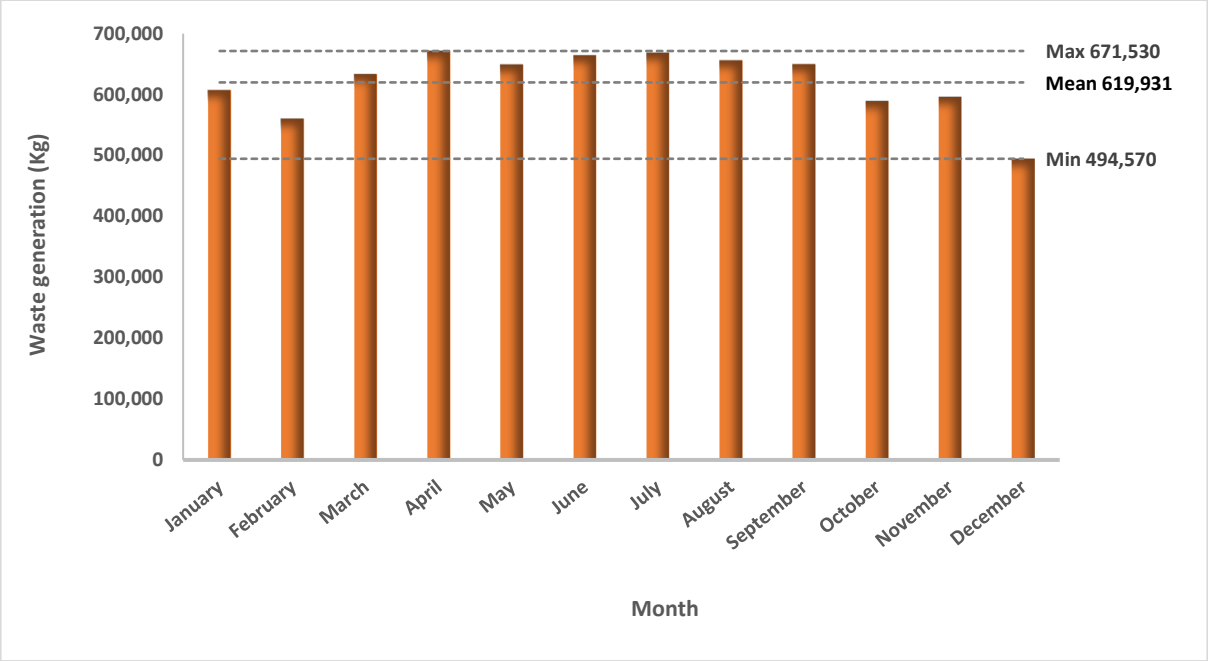

Figure 5.
Waste generation at Tondong Landfill in 2023.

Based on Figure 5, the highest waste generation in 2023 occurred in April, reaching 671,530 kg. This surge was likely influenced by religious celebrations and election activities. Conversely, the lowest waste generation was recorded in December, at 494,570 kg, possibly due to fewer celebrations and a large number of residents traveling out of town for holidays. The total waste generation at Tondong Landfill throughout 2023 amounted to 7,439,170 kg, with a monthly average of 619,930.83 kg.

To predict future waste generation, a population projection for the Tondong Landfill coverage area is required. In 2023, the total waste generation in Sinjai Regency was recorded at 39,939,614 kg per year, with an average daily waste generation of 109,424 kg. With a population of 273,559 in the Tondong Landfill coverage area in 2023, the average waste generation per person per day can be calculated by dividing the total daily waste generation by the population. The annual and daily waste generation data based on population are presented in Figure 6.

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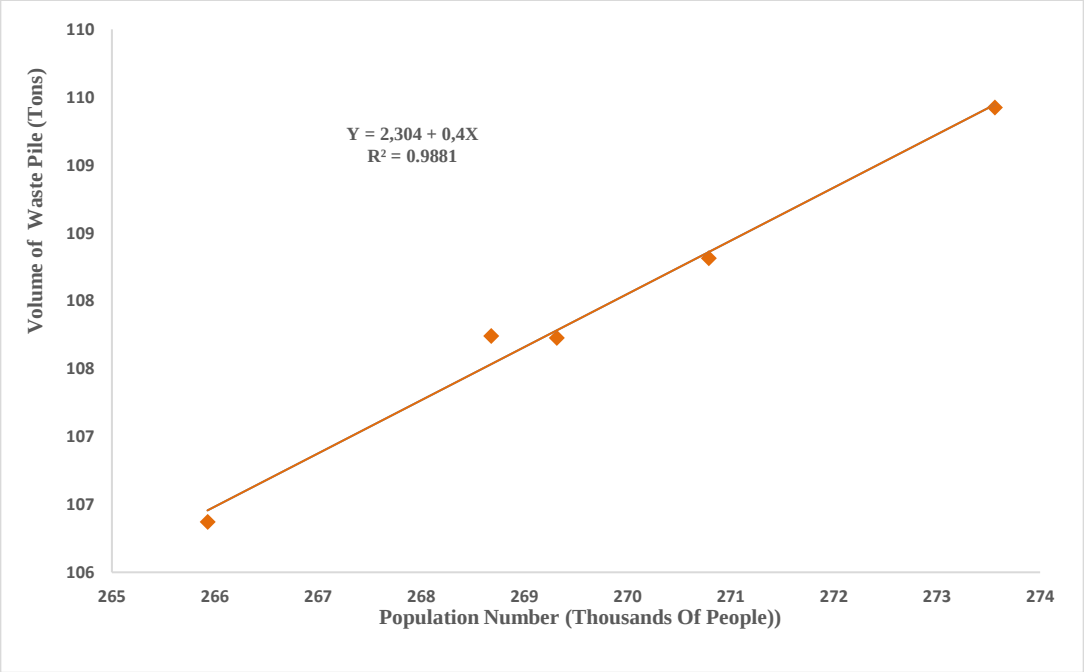

Figure 6.
Relationship between population growth and waste generation.

The Sinjai Regency Environmental and Forestry Agency assumes that the average waste generation per capita is 0.4 kg per day. Meanwhile, according to the Indonesian National Standard (SNI) 10-3983-1995, waste generation for a medium-sized city (100,000–500,000 inhabitants) is estimated at 0.7 kg per person per day. Waste management efficiency can be measured by the reduction rate of waste before disposal at Tondong Landfill, including processing through Waste Banks and TPS 3R. The waste reduction results from management in Sinjai Regency are presented in Table 7.

Table 7.
Waste management efficiency in Sinjai Regency.

Source	Waste Generation			Waste Reduction (kg)	Efficiency
	(kg/person/day)	(kg/ year)	(kg/person/day)		
DEF Sinjai Regency	0.4	1,152,042.2	7.439.170	408,125.2	35.43%
SNI 10-3985-1995	0.7	20,160,738.5		12,721,568.5	63.10%

Waste management in the service area of Tondong Landfill in Sinjai Regency is considered fairly effective in reducing waste generation. Based on the waste generation assumption from the Sinjai Regency Environmental and Forestry Office of 0.4 kg per person per day, the waste reduction efficiency reaches 35.43%. Meanwhile, according to the assumption from the Indonesian National Standard (SNI) 10-3985-1995 of 0.7 kg per person per day, the reduction efficiency reaches 63.10%.

To evaluate the waste management performance in Sinjai Regency, a transportation analysis was conducted by considering the field waste volume (Table 8), travel distance and vehicle speed (Table 9), and the number of vehicle trips per day (Table 10). The calculation of transportation facility requirements was also determined based on the planned service volume. Several assumptions used in this analysis include an armroll truck capacity of 4 trips per day, a safety factor of 1.5, a loose waste

density of 200 kg/m³, a compacted waste density in containers/trucks of 250 kg/m³, and a volume capacity of 7 m³ for both armroll and dump trucks.

Table 8.
Transportation analysis of waste volume in the field.

Waste Volume (tons)	Transported Waste Volume (tons/m³)	Container Requirement (units)
670	100	5

Table 8 presents an analysis of waste transportation volume in the field, highlighting the gap between the amount of waste generated and its transport capacity. The data shows that the total waste volume reaches 670 tons, while only 100 tons/m³ can be transported. With this capacity, five container units are required to accommodate and transport the waste. This indicates that the current waste transportation system still has limitations in handling the entire waste volume produced. In terms of waste management, this data suggests that transportation efficiency needs improvement to prevent waste accumulation, which could potentially pollute the environment and impact public health. The limitations in transport capacity also indicate the need for an evaluation of the number of vehicles, containers, and more effective transportation strategies. One possible solution is to increase transportation infrastructure capacity, optimize waste collection routes, and implement sorting and recycling systems to reduce the transportation burden. These measures can enhance the efficiency and sustainability of waste management.

Table 9.
Travel distance and vehicle speed.

Vehicle Type	Trip	Average Transportation Distance (km/trip)	Total Distance Traveled Per Day (km/day)	Total Daily Travel Distance (km/day) per Container
Vehicle 1	2	21.15	21.95	23.30
Vehicle 2	2	15.58	16.53	21.39
Vehicle 3	2	23.18	29.03	26.80
Vehicle 4	2	22.41	23.29	22.80
Vehicle 5	2	20.53	21.15	27.57
Rata-Rata		20.57	22.39	24.372

Based on the data from Table 9, each vehicle completes two waste transportation trips with varying travel distances, ranging from 15.58 km to 23.18 km per trip, with an average transportation distance per trip of 20.57 km. Overall, the average total daily travel distance per vehicle reaches 22.39 km, while based on containers, the average travel distance is 24.372 km per day. In the waste management system, this data is crucial for assessing waste transportation efficiency and designing optimal operational strategies. The variation in travel distances may indicate differences in transportation routes, road conditions, or vehicle capacity. Evaluating travel distances can aid in more efficient planning, such as optimizing travel routes to prevent vehicles from making excessively long or inefficient trips.

The calculation of the trip time for a dump truck used for waste transportation can be performed using the following equation:

$T_{scs} = P_{scs} + a + bx + s$

$P_{scs} = P_{scs}\,(TPS) + P_{scs\,(door\ to\ door)}$

Where:

T_{scs} = time per trip (hour/trip)

P_{scs} = waste loading time from the first location to the last location (hour)

$P_{scs\,(TPS)}$ = time required to load waste in all landfills

$P_{scs\,(door\ to\ door)}$ = time required to load waste door to door

x = average distance (km/trip)

s = unloading time at FPS (hour/trip)

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W = (off route) unproductive time
For the off-route time (W) of the vehicle, an average value of 0.16 was obtained based on observations over a full workday. The calculation results can be seen in Table 10.

Table 10.
Calculation of the number of trips per day per vehicle.

Vehicle	Pscs	s (hour)	x (hour)	r	h = x/r (hour)	Tscs = Pscs + s + h (hour)	t1 (hour)	t2 (hour)	Nd = ((1-W)H-(t1+t2))/Tscs(tr)	Nd actual
Vehicle 1	0.98	0.06	21.15	23.30	0.91	2.20	0.05	0.33	2.08	2
Vehicle 2	0.94	0.05	15.18	21.39	0.73	1.85	0.07	0.36	3.79	2
Vehicle 3	0.81	0.04	23.18	26.80	0.86	2.13	0.17	0.37	3.25	2
Vehicle 4	1.50	0.07	22.91	22.80	0.98	2.83	0.19	0.45	2.47	2
Vehicle 5	1.66	0.06	20.53	27.57	0.75	2.85	0.12	0.34	2.43	2

Table 10 presents the calculation of the number of trips per day for each arm roll truck used for transporting waste containers in two districts of Sinjai Regency. The results show that each vehicle has a theoretical number of trips (Nd) ranging from 2.08 to 3.79 trips per day. However, in practice, all vehicles only complete 2 trips per day, as indicated in the Nd actual column. This suggests that operationally, the vehicles meet the minimum transportation target of 2 trips per day. Nevertheless, some vehicles, such as Vehicle 2 and Vehicle 3, are theoretically capable of making more than 2 trips per day. The discrepancy between theoretical and actual values indicates limiting factors affecting transportation efficiency, such as container loading and unloading times, traffic conditions and travel routes, as well as other operational constraints like queuing at the final disposal site or driver rest periods.

To improve operational efficiency, vehicles with higher trip potential can be optimized by adjusting operational schedules and reducing idle time—periods when the vehicle is not productively operating despite being ready for use. With this strategy, the daily transportation capacity can be increased without the need to add more vehicles. Overall, the analysis results indicate that the waste transportation system in these two districts operates in accordance with the minimum established standards. However, there is still room for optimization to enhance transportation capacity without increasing the number of operating vehicles.

3.6. Comprehensive Analysis

Comprehensive analysis of waste management performance includes an overall assessment that links the analytical results with theoretical frameworks. The methods applied are SERVQUAL analysis and Importance-Performance Analysis (IPA) to measure public satisfaction in East Sinjai District regarding services provided by the Department of Environment and Forestry. Community responses were obtained through the average scores of each SERVQUAL variable in both perception and expectation groups, referring to the theory [46] which includes:

a. Persepsi < Harapan = Tidak Puas
b. Harapan = Persepsi = Puas
c. Persepsi > Harapan= Sangat Puas

The IPA analysis in this study can be seen in Table 13 as follows.

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Table 11.
IPA analysis for each SERVQUAL item.

SERVQUAL Dimensions	Item	GAP Data		Difference	Category
		Expectation	Statement		
Tangible	Tangible1	3.61	4.25	0.64	Very Satisfied
	Tangible2	3.31	4.46	1.15	Very Satisfied
	Tangible3	3.12	4.52	1.40	Very Satisfied
	Tangible4	3.22	4.47	1.25	Very Satisfied
Empathy	Emphaty1	4.48	3.71	-0.77	Dissatisfied
	Emphaty2	4.40	3.64	-0.76	Dissatisfied
	Emphaty3	4.45	3.05	-1.40	Dissatisfied
	Emphaty4	4.23	3.48	-0.75	Dissatisfied
Responsiveness	Responsiveness1	3.42	3.90	0.48	Very Satisfied
	Responsiveness2	4.25	4.16	-0.09	Dissatisfied
	Responsiveness3	4.06	4.06	0.00	Satisfied
	Responsiveness4	4.13	4.13	0.00	Satisfied
Reliability	Reliability1	4.39	3.59	-0.80	Dissatisfied
	Reliability2	4.26	3.43	-0.83	Dissatisfied
	Reliability3	4.06	3.09	-0.97	Dissatisfied
	Reliability4	4.52	3.08	-1.44	Dissatisfied
Assurance	Assurance1	4.69	3.69	-1.00	Dissatisfied
	Assurance2	3.92	3.62	-0.30	Dissatisfied
	Assurance3	4.04	3.72	-0.32	Dissatisfied
	Assurance4	4.61	2.85	-1.76	Dissatisfied
Average		4.06	3.75	1.40	

Table 11 indicates that the SERVQUAL attributes in waste management in Sinjai Regency with a negative IPA (Importance Performance Analysis) value fall under the Responsiveness dimension. This suggests a low level of public satisfaction, where expectations for related agency services are very high. Survey results show that the average response for each SERVQUAL attribute item is above 4, meaning public expectations are extremely high. However, in practice, responsiveness—especially regarding the timeliness of waste collection—is still considered inadequate. Additionally, all indicators under the Empathy, Reliability, and Assurance dimensions are also perceived as lacking by the public.

Thus, waste management by the Environmental and Forestry Agency of Sinjai Regency still requires improvement. Management needs to enhance service quality, particularly in the Responsiveness dimension, by ensuring timely waste collection. In the Empathy dimension, improvements should focus on staff attitudes when collecting waste, handling complaints, and providing information to the public. The Reliability dimension also requires enhancement, especially in ensuring that staff collect waste as promised, are dependable in waste management, maintain proper administrative records, and possess adequate work skills. Meanwhile, in the Assurance dimension, improvements are needed in aspects such as public safety when staff enter residential areas and collect fees, trust in the agency and its personnel, and consistency in staff politeness.

Table 12.
IPA analysis per SERVQUAL attribute.

Servqual Elements	GAP Data		Result
	Reality (R)	Expectation (E)	
Tangible	4.43	3.80	Very Satisfied
Empathy	3.47	4.39	Dissatisfied
Responsiveness	4.06	3.97	Very Satisfied
Reliability	3.30	4.31	Dissatisfied
Assurance	3.47	4.32	Dissatisfied

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To gain a clearer understanding of the SERVQUAL attribute classification in the Environmental and Forestry Agency, which includes Tangible, Empathy, Responsiveness, Reliability, and Assurance, refer to the IPA (Importance Performance Analysis) graph below (Figure 7). This graph illustrates how well each attribute meets public expectations and highlights areas requiring improvement to enhance the quality of waste management services.

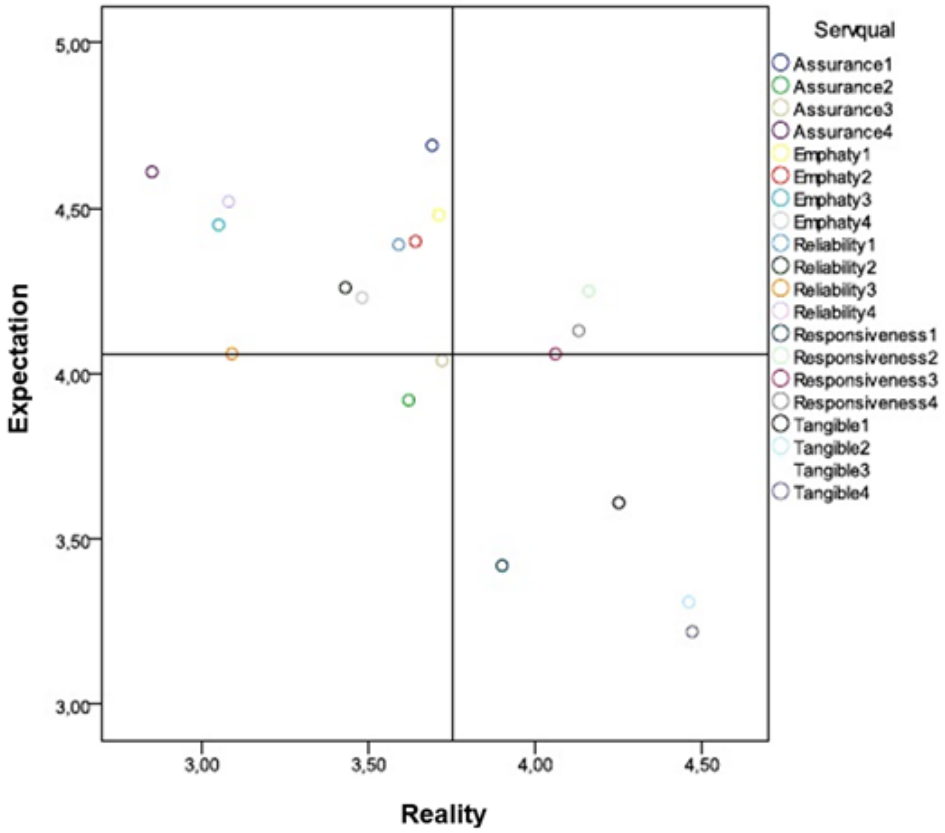

Figure 7.
IPA (Importance Performance Analysis) graph.

Based on Figure 7, the position of SERVQUAL attribute items for the Environmental and Forestry Agency of Sinjai Regency is analyzed by comparing public expectations and actual experiences. This analysis uses the mean of overall public expectations (4.06) and the mean of actual experiences (3.75) as the coordinate axes in the Cartesian diagram. From the diagram, the analysis can be summarized as follows:

3.6.1. Quadrant I

Quadrant I includes factors that are considered important by the community but have not been met according to expectations, resulting in very low satisfaction levels. The attributes in this quadrant include aspects of empathy, reliability, and assurance, such as the attitude of personnel in providing services, the reliability of the department in waste collection, and the sense of security felt by the community.

Based on this classification, the Department of Environment and Forestry of Sinjai Regency needs to implement continuous improvements, especially in the empathy dimension. This includes the attitude

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of personnel when collecting waste, providing assistance, handling complaints, and responding to questions and requests for information. Additionally, improvements in the reliability dimension are necessary to ensure a consistent waste collection schedule, dependability in waste management, proper administrative record-keeping, and adequate staff skills in carrying out their duties. Enhancements are also needed in the assurance dimension, particularly in maintaining the community's sense of security when personnel enter residential areas and ensuring that staff consistently exhibit polite behavior.

3.6.2. Quadrant II

Quadrant II includes factors that are considered important by the community and have met their expectations, resulting in relatively high satisfaction levels.

The attributes in this quadrant focus on the responsiveness dimension, particularly regarding the timeliness of waste collection, the department's readiness to respond to complaints, and its willingness to assist the community with administrative matters, information, and consultations related to waste management.

Based on this classification, the Department of Environment and Forestry of Sinjai Regency needs to maintain performance in the responsiveness aspect by ensuring that the waste collection schedule remains consistent, improving responsiveness to public complaints, and continuing to provide adequate administrative services and consultations for residents.

3.6.3. Quadrant III

Quadrant III includes factors that are considered less important by the community but are perceived as being overemphasized.

The attributes in this quadrant include tangible aspects, such as the condition of waste collection vehicles, transportation equipment, staff uniforms, and safety and health tools. Additionally, one aspect of responsiveness, namely providing information about the waste collection schedule, is also included in this quadrant.

Based on this classification, the Department of Environment and Forestry of Sinjai Regency can optimize resource efficiency by reducing excessive attention to tangible and responsiveness aspects that do not significantly impact public satisfaction. This can be achieved by adjusting budget allocations and service priorities to focus more on factors that are truly needed by the community.

3.6.4. Quadrant IV

Quadrant IV includes factors that are considered less important by the community and whose performance is also not very prominent. The attributes in this quadrant include the sense of security when paying monthly fees and the level of public trust in the department and its staff.

Based on this classification, the Department of Environment and Forestry of Sinjai Regency can reevaluate its focus on the assurance dimension, particularly in terms of transparency and public trust in the services provided.

To optimize the Importance Performance Analysis (IPA) in assessing waste management in Sinjai Regency, the following steps can be implemented:

Responsiveness: Improve the timeliness of waste collection.

Empathy: Enhance staff attitudes in waste collection, assisting residents, handling complaints, and providing information.

Reliability: Ensure waste collection services meet commitments, improve dependability in waste handling, refine administrative records, and enhance staff skills.

Assurance: Increase the public's sense of security when staff enter their homes and pay monthly fees, strengthen trust in the department and its personnel, and maintain consistent courtesy in service delivery.

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By improving these aspects, the quality of waste management services in Sinjai Regency can be further optimized and better aligned with community expectations.

4. Conclusion

The results of the Delphi analysis show that the waste management system is determined by the services implemented, waste transfer, waste transportation to FPS and work procedures. Waste management based on SNI that has been carried out shows that normative standards are standards used as references to achieve the expected results of waste collection activities, including the amount of waste transported, the area served and the number of residents served supported by adequate facilities and infrastructure. Furthermore, a comprehensive analysis of waste management was carried out using the SERVQUAL analysis technique or what is commonly called IPA (Importance Performance Analysis) analysis, showing that the public's desires regarding waste management are determined by the timeliness of waste collection as promised, the skills and attitudes of officers in serving and receiving complaints and answering and providing information in terms of service to the public, so that the public can feel comfortable and with good and regular waste services will make the residential area clean and healthy. Waste management in Sinjai Regency shows progress in several aspects, such as composting and waste bank initiatives, but still faces major challenges in terms of infrastructure, technology and public awareness. For methods, landfilling and composting are the most widely applied, but their efficiency needs to be improved. In the system, collection and transportation are still constrained by limited resources. For recycling, community participation is the main key to success, which needs to be supported by education and wider access to recycling facilities. With an integrated approach, involving the government, community, and private sector, Sinjai Regency can improve the sustainability and effectiveness of its waste management.

Institutional Review Board Statement:

The research presented in this study was conducted in accordance with ethical standards and has been approved by the University Ethics Committee. This ensures that the research complies with all necessary ethical guidelines to protect the rights of participants throughout the study.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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