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Original Article

Performance Intelligence of Sustainable Waste Management through SWOT Analysis at the 3R Waste Management Site in Subang Antapani, Bandung

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ABSTRACT
The city government, in its efforts to reduce waste being thrown into landfills, has attempted to build several 3R TPSs. On the other hand, 3R is still found not to be implemented optimally and there is still the practice of collecting, transporting, throwing away. From the research conducted, the status of TPS 3R Subang is rated in the poor category. For this reason, intelligence is needed to improve performance to the adequate category or the good category. The aim of this research is to intelligence of improving the performance of TPS 3R Subang from low to medium or good. The analytical method used is a qualitative method with SWOT analysis. SWOT has two internal and external factors and it is necessary to identify internal and external factors from TPS 3R Subang. The results of carrying out this intelligence obtained coordinates (0.6; 0.2), namely in quadrant I (SO), meaning that what shall be done to improve performance is to use strength to be able to seize every opportunity, namely optimizing the use of incinerator machines, optimizing terawang stone compost, maggot cultivation, and seize opportunities by selling cultivated in larger volumes.

KEYWORDS
Waste Management; Intelegence; SWOT; TPS 3R

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INTRODUCTION

The growing population and its consumption patterns generate significant amounts of waste (Huda et al., 2023), aligning with statements by Warlina & Listyarini (2022) and Husodo (2020), which highlight that increasing population correlates with rising waste production annually. Improper waste management can lead to severe environmental issues, such as environmental pollution and the proliferation of diseases (Huda et al., 2023; Soumokil & Rochmaedah, 2022).

Waste-related challenges in urban areas necessitate vast land availability, yet such land is scarce in major cities (Prasetiyadi et al., 2018). Waste management is a persistent global issue that remains unresolved (Suhendar, 2021). The habit of burning waste

uncontrollably can have detrimental effects on the environment, especially air quality, by releasing greenhouse gases and other toxic pollutants (Permana & Iqbal, 2019; Firmansyah et al., 2021). Many communities still perceive waste as mere residual, valueless material. Waste management practices predominantly rely on the "end-of-pipe" approach, involving collection, transport, and disposal at final waste processing sites.

Law No. 18 of 2008 states that the accumulation of large waste volumes at final processing sites has the potential to release methane gas (CH4), thereby increasing greenhouse gas emissions and contributing to global warming. Greenhouse gases (GHGs) are the primary drivers of global warming's environmental impact (Lupiyanto et al., 2023). Every stage of waste management, from storage, collection, transportation, recycling, to final disposal, contributes to greenhouse gas emissions (Novia & Mulyani, 2022).

Reducing greenhouse gas emissions is a global commitment outlined in the Paris Agreement to limit the rise in average global temperatures. Indonesia has set targets in its Nationally Determined Contribution (NDC): a 29% reduction in emissions through independent efforts (unconditional) and a 41% reduction through international cooperation (conditional) by 2030 (Marsudi, 2022).

According to Bandung City Sanitation Office data from 2022, the daily waste volume in Bandung reached 1,594.18 m^3, primarily from household waste. The composition includes 44.52% food and leaf waste, 16.70% plastic, 13.12% paper, 4.75% fabric, 3.98% wood and branches, 2.38% rubber and leather, 1.82% hazardous waste, 0.90% metal, and 11.83% other materials. The Sarimukti final processing site (TPA) is already overloaded. In response, the Bandung City Government has launched 3R-based programs (Reduce, Reuse, Recycle) by establishing 3R Waste Transfer Stations (TPS 3R), such as TPS 3R Subang, to limit waste generation and reduce the amount transported to TPAs.

The implementation of 3R principles proposed by the government is an economically valuable, simple, and cost-effective waste management solution that can be adopted by all communities (Permana, 2020). Sustainable waste management requires integrated solutions to address environmental issues and provide socio-economic benefits (Yazdanparast et al., 2019). This requires integrating social, economic, and environmental factors (Elsaid & Aghezzaf, 2015). In addition to the 3R program, waste reduction can be achieved through incinerators capable of reducing waste volume by up to 65%. Incinerators, operating at approximately 800˚C, are efficient, environmentally safe, and straightforward to use. They comply with SNI ISO 8423: 2017 standards (Soumokil & Rochmaedah, 2022) and offer hygienic, economical, and energy-producing waste management (Koçak & İkizoğlu, 2020).

Sustainable waste management employs environmentally friendly methods and techniques that do not harm public health or the environment, ensuring benefits for current and future generations (Indonesia, 2008; Law No. 18 of 2008). Periodic analyses, conducted every six months, are crucial for effective urban waste management aligned with sustainability principles. Enhancing TPS 3R performance requires intelligent strategies to optimize processes, providing valuable input for proper, accurate, and efficient waste management (Rahmawati et al., 2021).

Previous studies, such as Hoang & Fogarassy (2020), explored sustainable urban waste management systems in Hanoi, Vietnam, using the “Waste-to-Energy” concept and a national strategy to manage non-household and household waste by 2025. Hannan et al. (2020) studied urban waste collection and cost optimization in Latin America and the Caribbean. Koçak & İkizoğlu (2020) reviewed waste types and disposal practices in Turkey, noting that while sustainable waste management has improved, employment in this sector remains suboptimal.

This study builds upon prior research by adopting a qualitative method with SWOT analysis to identify internal and external factors. The findings differ from previous research in terms of location, identified factors, and strategies, emphasizing the significance of context in developing effective waste management solutions. This research aims to provide practical insights for policymakers and other TPS 3R facilities pursuing sustainable waste management.

METHOD

The type of research conducted employs a qualitative method with SWOT analysis. The data used in this study is sourced from primary data. Primary data was collected through questionnaires and in-depth interviews with staff from TPS 3R and the Environmental and Forestry Agency (DLHK). The output includes internal factors (strengths and weaknesses of TPS 3R Subang Antapani Bandung) and external factors (opportunities and threats outside TPS 3R but still correlated).

Respondents included three workers from the TPS

3R at KSM, one representative from DLHK, the neighborhood chief (RW), the village head (Lurah), and their staff. The research aimed to formulate strategies to improve TPS 3R performance using a qualitative approach with SWOT analysis.

The qualitative method in this study was employed to complement the quantitative study by understanding processes, facts, observations, and discussions related to internal and external factors associated with the research. SWOT analysis was applied to identify alternative solutions and formulate strategies based on the interaction between strengths, weaknesses, opportunities, and threats (Salim & Siswanto, 2019).

To operationalize variables for formulating improvement strategies, SWOT analysis was used. Developing the SWOT matrix (as shown in Table 1) required identifying internal factors such as strengths and weaknesses of TPS 3R Subang, and external factors such as opportunities and threats related to TPS 3R Subang.

The definitions of strengths, weaknesses, opportunities, and threats, according to Dkw & Awatara (2018), are as follows:

Strengths: Current situations or conditions that act as the organization's or program's strengths.

Weaknesses: Organizational activities that are not functioning well or resources needed by the organization but are unavailable.

Opportunities: Positive factors from the external environment that provide the organization or program with opportunities to leverage.

Threats: Negative factors from the external environment that hinder the growth or functioning of an organization or program.

This approach aims to create actionable strategies that address both internal and external factors affecting TPS 3R performance.

Table 1. SWOT matrix (implementation of the Subang 3R TPS performance strategy)

IFAS (*Internal Strategic Factors Analysis Summary*) **EFAS (*External Strategic Factors Analysis Summary*)**	***Strenght*(S)** **Determine the factors of internal strengths**	***Weaknesses*(W)** **Determine the factors of internal weaknesses**
Oportunity (O) Determine external opportunity factors	SO Determine a strategy that uses strengths to capitalize on opportunities	WO Determine strategies to minimize weaknesses in order to achieve / take advantage of opportunities
Threats (T) Determining external threatsl	ST Create a strategy that uses force to address threats	WT Create strategies that improve weaknesses and avoid threats

RESULTS AND DISCUSSION

This study is located at the TPS 3R site on Subang Street, Antapani Village, Bandung City, as shown in Map 1 of Bandung City. The availability of educational facilities is assessed Several solutions to waste management problems faced by various countries are outlined in the following studies. Hoang & Fogarassy (2020) conducted research in Hanoi City, where they identified insufficient waste management systems, poor collection and disposal practices, limited financial resources, weak public awareness, ineffective resource use, and the inappropriate application of technology. The researchers employed a comparative method using MCDA-AHP to assess four waste management alternatives. The highest-ranking sustainable urban waste management options were mechanical-biological treatment (MBT), composting, and refuse-derived fuel (RDF) for waste-to-energy applications or incineration. At the same time, sustainable development should aim to continuously reduce the waste-to-energy ratio, incorporating plans for industries to reuse recyclable materials.

A study by Hannan et al. (2020) in Latin America and the Caribbean highlighted problems such as weak legislative frameworks and the lack of an integrated waste management system, institutional issues, insufficient resources, weak policies, inadequate funding, poor financial efficiency, poor financial planning, and ineffective billing systems. These issues hinder sustainability efforts. To address these challenges, the focus was on optimizing solid waste collection (SWC) processes and minimizing costs. Urban management should be carried out in an integrated manner, effectively combining bureaucracy, markets, and networks.

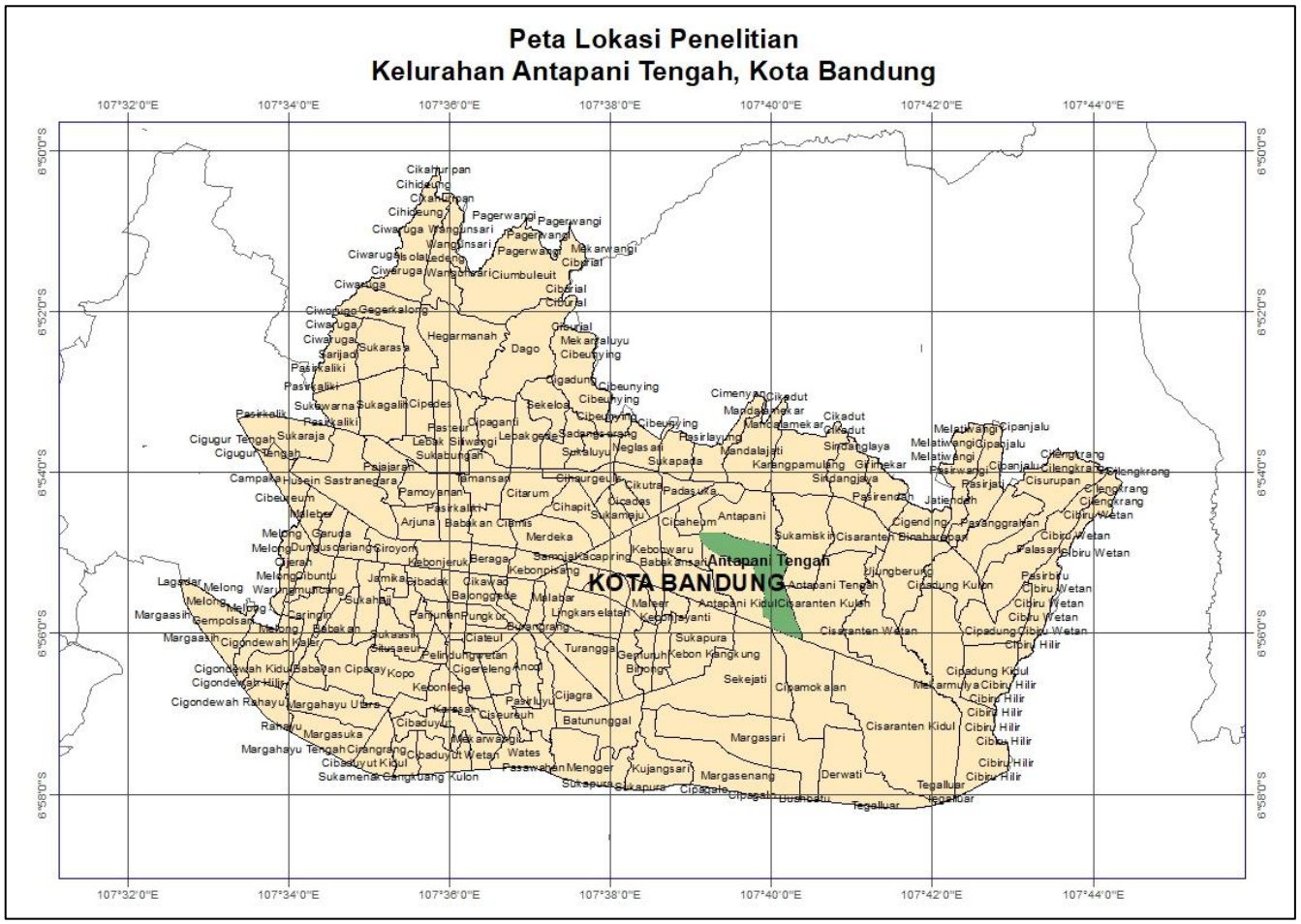

Figure 1. Research Location, Antapani Tengah Village, Bandung City, West Java Province

Kocak & İkizoglu (2020) studied environmental threats in Turkey, including the irresponsible use of natural resources, rapid consumption of raw materials and energy, economic and population growth, and increasing waste production. Their research included three case studies on waste management, waste types, and waste disposal practices to identify improvements in Turkey. Their findings revealed that waste disposal at landfills was unsatisfactory, with unsafe and unhealthy conditions. The waste composition in Turkey included 34% organic waste, 16% paper, 2% plastic, 6% glass, and 1% metal. Composting one ton of waste yielded 200-400 kg of compost. As of 2017, open burning was almost completely eliminated in Turkey.

Heidari et al. (2019) found that a lack of public awareness regarding waste segregation was a significant issue. They proposed the use of a compacting technology-equipped waste sorting unit to enhance storage capacity and ease transportation. A multi-objective approach focusing on the economic, environmental, and social dimensions of sustainability was recommended for the ongoing development of recycling and disposal processes. The research used the Topsis method, revealing that composting was the least effective alternative, while anaerobic digestion and incineration performed better. Initial findings from sensitivity analysis also indicated that the percentage of waste recovery directly impacted the rate of reuse and recycling.

In Cairo, Elsaid & Aghezzaf (2015) identified several issues, including ineffective waste management systems, lack of technology and expertise, urbanization, limited financial resources, weak regulations, and poor oversight. The result was that waste management practices in rapidly growing cities, such as Cairo, failed to meet public cleanliness standards. The lack of efficient solid waste management led to waste accumulation in residential areas and along roadsides, causing environmental, health, and urban image problems. A sustainable waste management system requires the integration and efficient management of three key factors: economic, social, and environmental.

These five studies share common challenges in waste management, including: lack of public awareness

on waste segregation, insufficient resources, poor financial systems, inadequate waste management systems, ineffective resource use, poor policy enforcement, and weak oversight. If waste is not properly reduced and managed, it will have detrimental effects on the environment. The solutions outlined in these studies provide valuable insights and serve as references for evaluating and improving waste management practices, particularly in developing countries.

In Indonesia, research by Khodijah & Pharmawati (2023) addressed problems in Bandung City, where the TPS 3R (Reduce, Reuse, Recycle) system had not yet optimized its capacity to reduce waste at the source and alleviate the burden on the TPA (landfills). The study evaluated two TPS 3R units using aspects such as management, legal frameworks, technical operations, institutional issues, financial constraints, and community participation. The data analysis used a descriptive quantitative method based on the 2021 Technical Guidelines for TPS 3R. The results showed that the TPS 3R Saling Asih II had a good performance score (19.15), while TPS 3R Hikmah had a moderate score (17.75). Some residents of the Saling Asih II area had already started segregating waste, while those in the Hikmah area had not. TPS 3R Saling Asih II served approximately 550 households, exceeding the planned capacity of 400 households, while the number of customers for TPS 3R Hikmah was unknown. The study recommended enhancing staff competency through training and regular monitoring in collaboration with the government as stakeholders. Community participation also needs improvement.

Darmadi & Raharjo (2023) conducted research in Bandung Regency, where improper waste management in the southern part of the region led to flooding. The 3R program had not been implemented effectively, resulting in pollution. The researchers used a mixed-method approach with SWOT analysis and interviews with three key informants (from the village/urban area, neighborhood units, and waste workers). Identified internal factors (strengths and weaknesses) and external factors (opportunities and threats) led to the identification of two to four key factors for each. In this case, the most dominant factors were strengths and opportunities, placing the analysis in quadrant one (I).

Nopriani et al. (2022) identified 13 strategic variables in their research, including regulations, institutions, waste management operators, the volume of waste at operational TPAs, financial matters, training/mentoring, awareness programs, monitoring, waste reduction efficiency, revenue from waste sales, community participation, and cooperation with other stakeholders. They used MICMAC to identify strategic variables and analyze interdependencies among variables. The results revealed that DLH, KSM, DPUPR, PLN, and Pertamina played significant roles in the waste management process. Their research highlighted similarities with other studies, such as the focus on TPS 3R management, financing, regulations, awareness, and community participation.

Herlina & Soviana (2022) evaluated waste management performance in Banda Aceh, identifying community satisfaction and the success of TPS 3R programs. They found that TPS 3R Gampong Lampung received high satisfaction, while TPS 3R Gampong Surien had a moderate satisfaction level. TPS 3R Gampong Lampung was rated as good, while TPS 3R Gampong Surien was rated as moderate. Based on these findings, the researchers formulated strategies to optimize performance and move from moderate to good ratings. However, they did not conduct customer satisfaction surveys.

Lupiyanto et al. (2023) focused on environmental performance in Sleman Regency, Yogyakarta, finding that the TPS 3R Kenanga's performance was rated as moderate. Several factors, including policies, institutions, technical operations, financing, training, awareness, monitoring, waste reduction efficiency, and community participation, significantly impacted performance. The research recommended that efforts to improve performance focus on enhancing these factors.

The TPS 3R Subang in Antapani, Bandung City, was found to be performing poorly according to an evaluation conducted from February to May 2024. The assessment used instruments set forth in the 2017 Technical Guidelines for TPS 3R by the Ministry of Public Works and Public Housing (PUPR). This evaluation revealed that the TPS 3R Subang could only serve 5 RW (1,273 households), while it was designed to serve 10 RW (2,817 households). Issues identified included contamination of compost, high residual waste being sent to TPA Sarimukti (around 80%), poor financial recordkeeping, lack of operational assistance from the government, and insufficient economic benefits for residents participating in waste segregation. To improve performance, strategies need to be developed using SWOT analysis. Internal factors such as strengths and weaknesses and external factors such as opportunities and threats should be identified and assessed in detail.

Identification of Internal and External Factors in Waste Management at the TPS 3R Subang, Antapani Village, Bandung City

IFAS (Internal Strategic Factors Analysis Summary). Internal factors, which include strengths and weaknesses, are the elements that influence the waste management strategy at the TPS 3R Subang in Antapani Village, Bandung City. These factors were derived from discussions with the field manager from the DLHK and three workers from KSM, as well as observations, resulting in nine (9) strength factors and nine (9) weakness factors.

EFAS (External Strategic Factors Analysis Summary). External factors, including opportunities and threats, are elements that can influence the performance of the TPS 3R Subang in Antapani Village, Bandung City, even though they come from outside the TPS 3R Subang environment. However, they are still correlated. These factors were also obtained through discussions with the field manager from the DLHK, three workers from KSM, and observations, producing ten (10) opportunity factors and eleven (11) threat factors.

The weighting and rating values were derived from the results of questionnaires and interviews with the village head, village staff, RW leaders, DLHK, and KSM. The scores were calculated by multiplying the weights by the ratings. The total weight values were obtained from field experts, and the total for each factor must sum to one (1). The rating values were based on respondents' answers using the following scale: 1 = disagree, 2 = acceptable, 3 = agree, 4 = totally agree. The strategies to be used or determined were based on the calculation results of IFAS and EFAS in the SWOT analysis, which helps determine the positioning in which quadrant (X; Y) the strategy should fall, as shown in Figure 4:

Quadrant I: SO — The strategy to be applied is an aggressive strategy, which is the ideal condition, using strengths to seize any available opportunities.

Quadrant II: ST — The strategy to be used is a differentiation strategy, which utilizes strengths to face or overcome threats.

Quadrant III: WT — The strategy to be used is a defensive strategy, aiming to minimize or address weaknesses to avoid threats.

Quadrant IV: WO — The strategy to be applied is a turnaround strategy, focusing on self-improvement and utilizing opportunities (Agusty, 2020).

Table 2. IFAS dan EFAS SWOT Analysis

Internal Factors	Weight	Rating	Score
Strengths			
1. Competent operators and workers	0.11	4	0.4
2. Possession of an incinerator	0.11	4	0.4
3. Possession of an organic shredder	0.11	4	0.4
4. Possession of an inorganic storage area	0.11	4	0.4
5. Possession of waste management SOPs	0.11	4	0.4
6. Recorded waste management data	0.11	4	0.4
7. Possession of an account at Bank BJB	0.11	4	0.4
8. Possession of a composting system (batatenawang)	0.11	3	0.3
9. Cultivation of maggots (BSF)	0.11	3	0.3
Total	**1**		**3.8**
Weaknesses			
1. Lack of human resources	0.11	3	0.3
2. Limited space	0.11	3	0.3
3. No operational funding from the government	0.11	2	0.2
4. Lack of public awareness about waste sorting	0.11	2	0.2
5. No special operational vehicle for waste transportation	0.11	2	0.2
6. Unable to manage planned waste	0.11	3	0.3
7. Conventional waste management in the same building	0.11	3	0.3
8. Organic waste processing facilities not up to standard, hindering waste management optimization	0.11	3	0.3
9. Restroom nonfunctional or damaged	0.11	3	0.3
Total	**1**		**2.7**

Internal Factors	Weight	Rating	Score
Opportunities			
1. Collaboration with RW-Village-District offices	0.11	4	0.4
2. Partnership with private sector (e.g., maggots, inorganic waste)	0.11	3	0.3
3. Community participation in waste collection from households to the waste bank	0.11	3	0.3
4. The presence of gotong royong (community mutual aid)	0.11	3	0.3
5. All residents of RW 01 to RW 05 understand the importance of environmental conservation and not littering	0.11	4	0.4
6. Almost all residents understand the need for waste management	0.11	3	0.3
7. Almost all residents in RW 01 to RW 05 have been socialized about waste management	0.11	3	0.3
8. All residents in RW 01 to RW 05 understand that waste has economic value	0.07	3	0.3
9. Almost all residents in RW 01 to RW 05 experience waste management services	0.11	3	0.3
10. Almost all residents in RW 01 to RW 05 pay waste collection fees	0.07	3	0.3
Total	**1**		**3.2**
Threats			
1. Community habits of throwing waste into the river	0.09	2	0.2
2. Increasing waste volume due to population growth	0.09	3	0.3
3. Odor from waste near the TPS 3R Subang settlement area	0.09	3	0.3
4. Visible waste on the road near TPS 3R Subang (Jl Subang)	0.09	3	0.3
5. Emissions from the incinerator affecting nearby residents	0.05	3	0.3
6. The location near TPS 3R Subang (Jl Subang) is unsafe (susceptible to theft)	0.09	2	0.2
7. No opportunities to sell organic fertilizer	0.09	3	0.3
8. Some residents still do not understand proper waste management	0.09	3	0.3
9. Many residents do not understand the 3R concept	0.09	3	0.3
10. Waste is only transported to an overburdened landfill	0.14	3	0.3
11. Tipping fees at Legoknangka landfill are 600% more expensive than at Sari Mukti	0.09	3	0.3
Total	**1**		**2.8**

Source: Research findings, 2024

Figure 2 is a pie chart representing the internal factors influencing the performance of the TPS 3R Subang, categorized into **Strengths** and **Weaknesses**, and the external factors that affect the performance of the facility, categorized into **Opportunities** and **Threats**. These factors are classified based on the results of the IFAS and EFAS analysis, showing the internal and external influences on the waste management system at TPS 3R Subang.

Figure 3 shows the values derived from experts in the field, where the internal factors are predominantly influenced by **Strengths**, while the external factors are mainly shaped by **Opportunities**. The results of the SWOT analysis indicate that the positioning is in **Quadrant I**, which suggests a strategy of leveraging **Strengths** to capitalize on **Opportunities**. **Figure 4**. The results of the IFAS calculation were obtained by subtracting the total score of strengths from weaknesses, yielding a value of 0.6. The EFAS calculation was derived by subtracting the opportunity from the threats, resulting in a value of 0.2. Thus, the strategic positioning to improve the performance of the TPS 3R Subang in Antapani Village, Bandung City, is in Quadrant 1 (SO), which involves leveraging strengths to take advantage of opportunities.

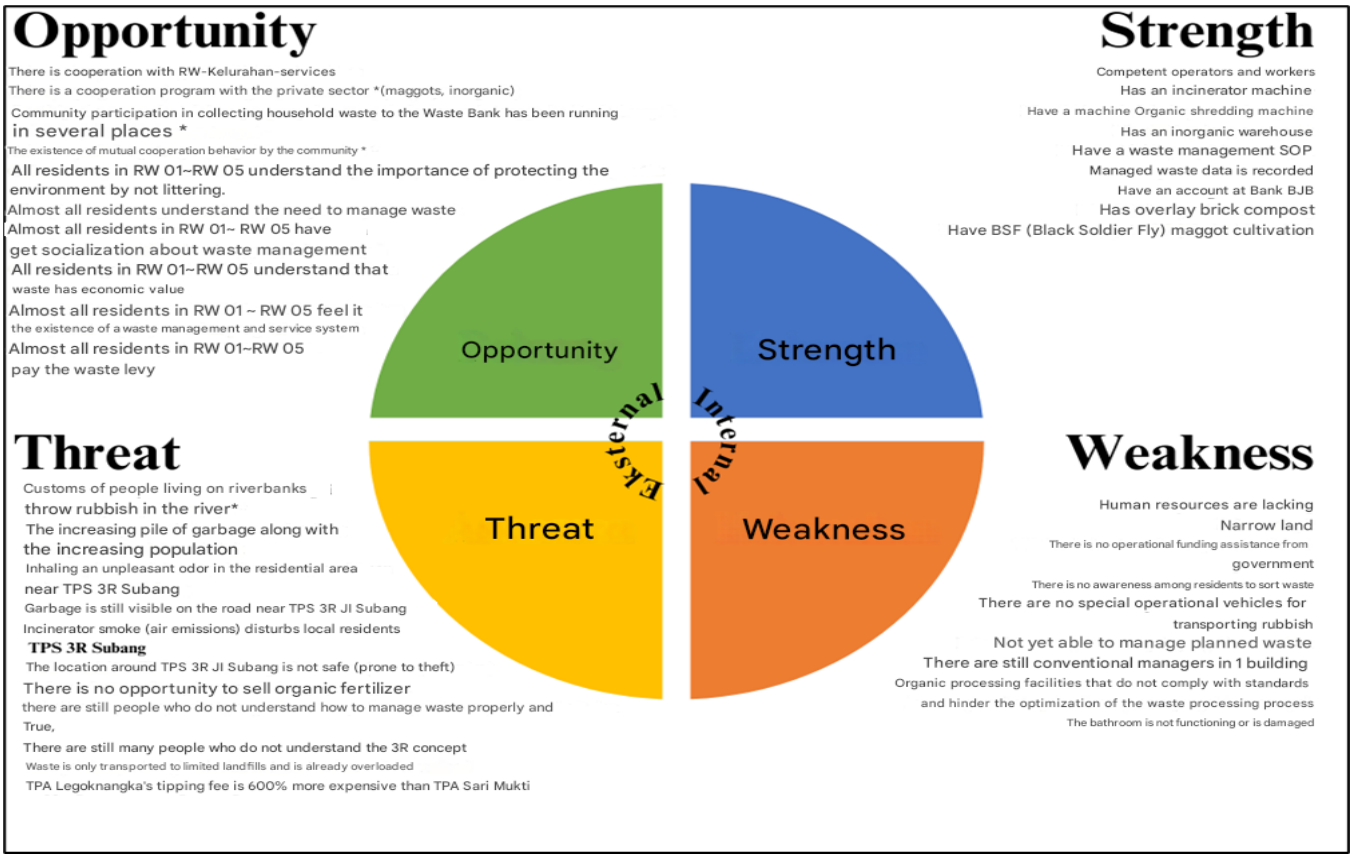

Figure 2. External and internal factors

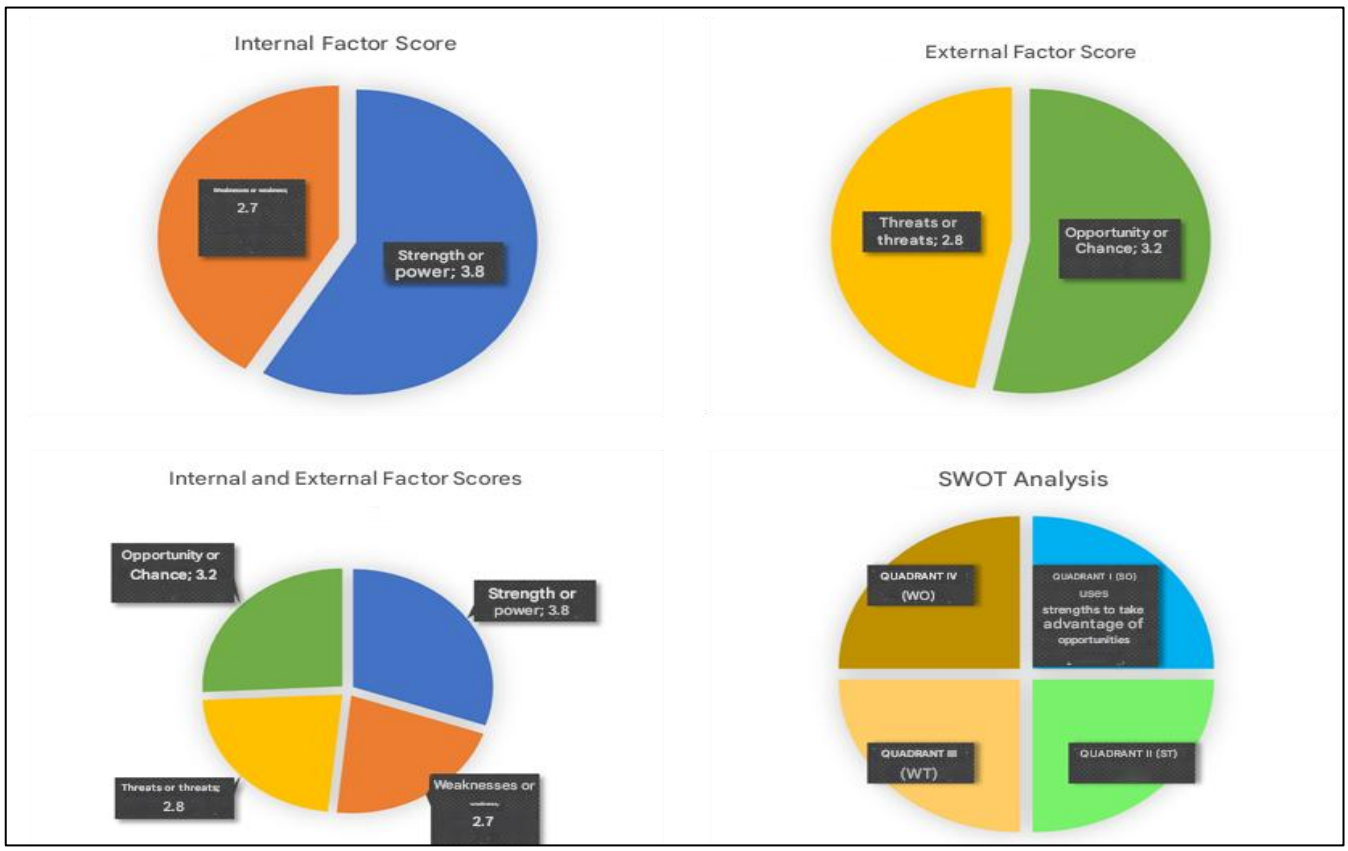

Figure 3. Pie Chart SWOT

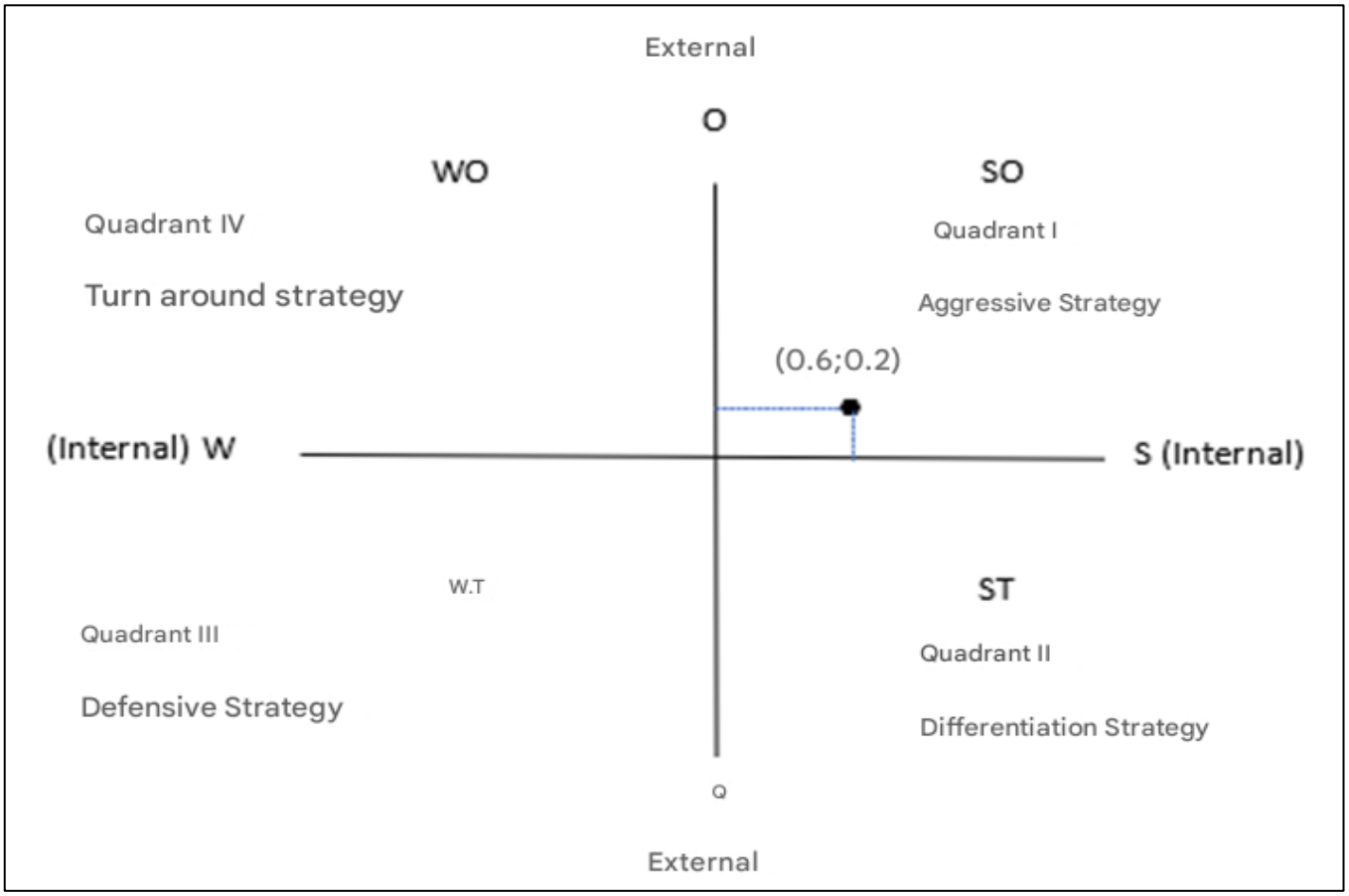

Figure 4. Cartesian diagram of the strategic positioning for improving the performance of the TPS 3R Subang in Antapani Village, Bandung City

As quoted from the literature titled "SWOT Analysis Using the Questionnaire Method" by Salim & Siswanto (2019), the purpose of SWOT analysis is to examine both internal and external factors. It functions to analyze and review the strengths and weaknesses in relation to the current conditions, as well as the external conditions, such as opportunities and threats. The benefit is in the form of strategies that determine the current or future directions concerning both internal and external quality.

Based on **Table 2** of the SWOT Analysis, the results of the IFAS calculation for strengths yielded a total score of 3.8. For weaknesses, the total score was 2.7. Therefore, on the X-axis, the strength minus weakness is divided by two, which results in the coordinate:

$$(3.8/2) - (2.7/2) = 0.6$$

For the EFAS calculation, the total score for opportunities was 3.2, and for threats, it was 2.8. Therefore, on the Y-axis, the opportunity minus threat is divided by two, resulting in the coordinate:

$$(3.2/2) - (2.8/2) = 0.2$$

The SWOT analysis coordinates were calculated as (X; Y) = (0.6; 0.2), which places the strategy in **Quadrant I (SO)**. This indicates that strengths and opportunities are more dominant, and the strategy to apply is an **aggressive strategy**, using strengths to seize every available opportunity.

Based on the IFAS and EFAS calculations from the SWOT analysis, it was determined that the positioning on the Cartesian diagram (Figure 4) is in Quadrant I, aligning with findings from Urufi & Azzahra (2021). The aggressive strategy can be outlined as follows:

Internal factors using existing strengths include: (1) Utilizing all strength items and seizing opportunities by optimizing the operation of the incinerator, maximizing maggot cultivation, and efficiently processing transparent brick compost with the organic shredder machine. This approach allows the sale of inorganic waste, maggots, and compost to private companies on a more continuous basis, generating income to cover operational costs, including regular maintenance of the incinerator machine. (2) Optimizing the performance of the incinerator to handle its full capacity (2.5 tons per day, 1

shift) to reduce residual waste sent to the landfill (TPA).

Additionally, it is essential to involve the entire community in reviving the existing waste bank by sorting inorganic waste, which would allow for the sale of waste to the environmental department (DLHK). This could provide economic benefits to the community (S2, S3, S8, S9, O1, O2, O3, O4, O5, O6, O8, O9). The waste transported to TPS 3R Subang can be reduced and sorted, making it easier for KSM workers to separate the waste. This will reduce the bottleneck that has caused delays at the TPS 3R Subang, improving the flow and leading to a cleaner, healthier, and tidier environment.

CONCLUSION

The strategy that can be applied to improve the performance of the TPS 3R Subang, based on the IFAS and EFAS calculations from the SWOT analysis, positions the strategy in **Quadrant I (SO)** at coordinates (0.6; 0.2). The appropriate strategy is to enhance the performance of the TPS 3R by leveraging existing strengths to seize every available opportunity. This can be achieved by optimizing the incinerator machine, maggot cultivation, transparent brick compost, and seizing the opportunity for a larger-scale sale of these products and inorganic waste to private companies.

An essential component of this strategy is the active participation of the community in waste segregation at the source, alongside the optimization of waste banks. This would provide economic value to the community members who engage in waste sorting, as they would benefit financially from recycling. Utilizing vacant land to create biopore holes at various points is another key aspect. This method is expected to manage organic kitchen waste more effectively.

Ultimately, this strategy will help reduce the waste bottleneck at TPS 3R Subang, improving waste management efficiency. It will contribute to a cleaner, healthier environment that is sustainable and can be maintained for future generations. Through these efforts, a continuous waste management system can be achieved, ensuring a healthy, clean environment for the community in the long term.

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