JPPIPA 11(8) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Planning a Waste Management System by Utilizing Geographic Information Systems

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Received: June 15, 2025
Revised: August 5, 2025
Accepted: August 25, 2025
Published: August 31, 2025

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DOI: 10.29303/jppipa.v11i8.12171

Abstract: This research aims to increase the reach of waste management system services in Pariaman City by utilizing geographic information systems. This research is descriptive. The data collection technique used observation. The sampling technique used was total sampling. The data analysis technique used Interpretative Structural Modeling and Geographic Information Systems. The planning results include the proposal of 9 new temporary waste storage locations and the optimization of waste transportation services. This proposed system significantly increases the coverage of waste management services in Pariaman City: from 51.41% (640.66 hectares) of the total residential area of 1,245.47 hectares, to 81.67% (1,017 hectares) served.

Keywords: Geographic information system; Planning; Waste management system

Introduction

The purpose of waste management regulations as stipulated in Law Number 18 of 2008 states that waste management is an effort to maintain environmental sustainability and quality, and improve public health. Waste management is an essential part of public health. Waste that is not managed properly can create conditions that can negatively impact public health and the environment (Towansiba et al., 2024). Waste is the residue of daily human activities and or natural processes. Waste is material or objects that are no longer functional or unusable, whether originating from households or from industrial waste (Aulia & Mahmud, 2025). All waste produced by human and animal activities, whether in solid, sludge, liquid, or gaseous form, is discarded as unnecessary or unwanted. Although considered useless and unwanted, these materials can sometimes be recycled and used as raw materials.

Management encompasses a wide range of issues, from ineffective recycling systems and infrastructure to unregulated waste disposal that pollutes air, water, and soil (Sharma et al., 2021). Waste management includes activities such as storage, collection, transportation, processing, and disposal. Waste management activities are tailored to regional conditions and the environmental carrying capacity of the area. Good operational waste management techniques address waste from source to final disposal. The main components of sustainable waste management are production, collection, transportation, and disposal. Waste generation is a crucial step in implementing waste reduction strategies at source. However, for effective management, there is growing interest in minimizing waste through reuse and recycling, which requires the integration of waste sorting into the waste management process (Kihila et al., 2021). Management Waste management encompasses the activities of storage, collection, transportation, processing, and disposal. Waste management activities are tailored to regional conditions and the environmental carrying capacity of the area. Waste management is expected to serve all residential areas.

Waste management is crucial, especially for temporary waste storage and the waste collection

How to Cite:
Bahari, P. R., Antomi, Y., Dewata, I., & Syah, N. (2025). Planning a Waste Management System by Utilizing Geographic Information Systems. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 867–878. https://doi.org/10.29303/jppipa.v11i8.12171

process. Temporary waste storage has several environmental advantages, as its use reduces the number of waste collection vehicles, resulting in reduced traffic and air pollution. Waste management can begin with household waste. Household waste can be managed independently or disposed of directly at temporary waste storage locations (Pangesti et al., 2024). Furthermore, temporary waste storage reduces illegal dumping and facilitates the designation of waste disposal sites in remote locations, thus avoiding the environmental impacts of waste disposal. The primary function of temporary waste storage is to temporarily collect waste before it is transported to a processing facility or final disposal site (Aulia & Mahmud, 2025). Therefore, temporary waste storage facilities play a crucial role in the waste management system. The purpose of temporary storage facilities is to serve residential areas in disposing of waste.

The increasing population growth has caused the Pariaman city government to face a waste problem. Rapid population growth and increasing living standards have led to an increase in the production of municipal waste (Sharma et al., 2021). The annual increase in population directly increases daily consumption, resulting in solid waste generation (Afkar et al., 2025). This waste problem is reflected in the estimated daily waste generation data for Pariaman City in 2021, which reached 61.95 m^3 (Central Statistics Agency of West Sumatra Province, 2021). The mounting piles of waste undoubtedly negatively impact environmental sustainability. Furthermore, the waste problem also has implications for public health. Waste pollution can occur through air, water, soil, or contact with other organisms, causing diseases that harm public health (Sumampouw & Pi, 2021). Waste collection also affects waste services, with low frequency of solid waste collection leading to public dissatisfaction, which leads to increased demand for more frequent services. In addition, the main reasons for household dissatisfaction and demands for more frequent waste collection include waste accumulation, poor collection schedules, and increased risk of disease outbreaks (Roman et al., 2025).

Based on the results of the initial research conducted, it can be seen that of the total residential land area of 1245.48 Ha, only 640.66 Ha of settlements are served by the Pariaman City waste service system. This means that only 51.41 % of Pariaman City settlements are served by the waste management system. This is caused by the uneven location of the temporary shelters in reaching settlements, the inadequate number of temporary shelters causes the capacity of the temporary shelters to be small. In terms of waste transportation, it does not reach settlements and its transportation capacity is small. In addition, there is 1 temporary shelter located in the river body area which does not comply with applicable regulations. The service area for pedicab drivers in collecting waste is divided in each area, but all pedicabs collect their waste only at 1 temporary shelter with varying distances between pedicabs. This also causes queues for loading and unloading waste and delays in work time due to the queues for loading and unloading and the distance between the service area and the temporary shelter. At the final disposal site (TPA), waste disposal is carried out openly without any waste processing, which would be beneficial for waste management and waste volume reduction. This is due to the fact that the waste processing facilities already available at the final disposal site (TPA) are not yet operational.

The increase in waste volume is inversely proportional to the availability of Temporary Shelters. The increasing volume of waste causes the capacity of Temporary Shelters to exceed capacity. Efforts to manage the waste generated by entering Temporary Shelters can be done through a waste management approach that is oriented towards waste management from the source.

Interpretive structural modeling GIS in waste management can provide spatial and non-spatial information regarding the distribution of TPS points, TPS capacity, TPS service radius, TPS technical feasibility, and TPS facility requirements (Ramadhan et al., 2025). Geographic Information Systems (GIS) enable visual mapping and depiction of geographic data related to waste disposal locations. Data regarding names, addresses, coordinates, and waste collection schedules can be collected through this system. The application of geographic information systems in surveys of the distribution and condition of waste disposal sites provides benefits for many parties, such as the government, in monitoring the distribution and condition of waste disposal sites, scheduling waste collection, and planning accurate and safe waste disposal sites (Novriansyah et al., 2023).

A Geographic Information System (GIS) is software used to input, process, and analyze data, resulting in complex data in the form of a map. A Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, organize, and display all types of geographic data. Geographic Information Systems (GIS) enable the visual mapping and depiction of geographic data related to waste disposal sites. Data on names, addresses, coordinates, and waste collection schedules can be collected through these systems. With accurate and up-to-date information on waste disposal sites, local governments can better evaluate and plan for future waste management. GIS also enables public participation in waste disposal site monitoring.

Meanwhile, Structural Interpretation modeling is a way of analyzing system elements and solving them in graphical form based on direct relationships between elements and hierarchical levels. Structural Interpretation Modeling analyzes system elements and solves them in graphical form from direct relationships between elements and hierarchical levels. Elements can be policy objectives, organizational targets, assessment factors, and others. Direct relationships can be in various contexts. This ISM technique can be used to conduct program analysis in accordance with the vision and mission. ISM transforms unstructured relationships between variables into a structured and hierarchical model, which allows decision-makers to prioritize key factors (Minz et al., 2025). Broadly speaking, the ISM technique is divided into two parts: element classification and hierarchical arrangement. These elements can be policy objectives, organizational targets, assessment factors, and others.

Therefore, based on the above problems, it is appropriate to develop a research project entitled "Planning a Waste Management System Using a Geographic Information System." This research aims to improve the reach of waste management services in Priaman City.

Method

This research is a descriptive research. Method descriptive is a search for facts with appropriate interpretation (Syahrizal & Jailani, 2023). The objects of this study were all temporary waste storage sites and waste transportation facilities. Sample In this study, all temporary waste storage sites and waste transportation facilities were used. The data collection technique in this study used the observation To obtain data on the number, capacity, and coverage of services , as well as the coordinates of temporary waste storage locations using GPS. Once the data is obtained, it will be used as a consideration regarding the number of temporary waste storage locations needed and will be strengthened by decision analysis using ISM analysis, which aims to determine the direction of planning in the waste management system in Pariaman City, where the ISM results suggest that Increasing the need for optimal TPS. The results of the existing conditions can be used to calculate the need for waste facilities and determine the number of additional TPS that can serve the community. (Firdausy & Prayoga, 2024). Several technical parameters such as container volume, compaction factor (Fp), and collection tool circulation (Rk) were also considered in this analysis. (Ramadhan et al., 2025). How to measure the need for temporary waste storage with the following equation:

$$CP = \frac{\text{Persentase layanan} \times \text{Jumlah Ts}}{\text{Kapasitas TPS} \times \text{Fp} \times \text{Rk}} \quad (1)$$

After determining the required storage and transportation needs, a geographic information system (GIS) plays a role in distributing new temporary waste storage locations based on location criteria. After obtaining the distribution of storage locations Meanwhile, a search for new waste transportation routes was conducted using a geographic information system . Using the proposed GIS model for the location of temporary waste storage sites, the model includes planning the location of waste disposal sites, vehicles, and optimal routes. Collection routes were planned using GIS, with network analysis tools from ArcGIS software, in this way the shortest or minimum path through the infrastructure network was calculated (Neto et al., 2024). For more details, see the following diagram.

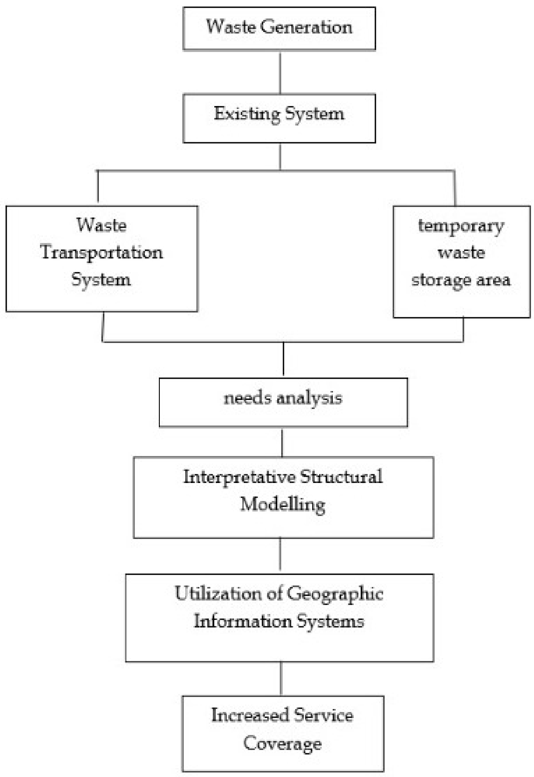

Figure 1. Research diagram

Result and Discussion

One crucial step in waste management is having adequate infrastructure for waste collection, sorting, and processing. This system involves organized waste disposal, effective recycling facilities, and environmentally friendly waste management methods. (Aqilla et al., 2023). Therefore, planning must consider sustainability. Planning a sustainable waste management system is a crucial part of achieving the

Sustainable Development Goals. (Harahap et al., 2024). Planning also ensures ecosystem preservation by integrating ecosystem values into land-use planning, thereby promoting environmental sustainability (Al-Thani, 2025).

This study begins with the use of ISM analysis which aims to plan by determining the direction of planning in the waste management system in Pariaman City. ISM transforms unstructured relationships between variables into a structured and hierarchical model, which allows decision makers to prioritize key factors (Minz et al., 2025). Planning means considering environmental, social, and economic aspects in order to achieve order in planning the development of the entire region and achieving the right scale that allows the process to be permanent. Environmental planning includes sustainable resource use in land, transportation, and development, and aims to reduce adverse impacts on the environment and promote biodiversity conservation (Al-Thani, 2025).

This method begins by identifying waste management problems in Pariaman City, which are described in the following table.

Table 1. ISM Problem Identification

Problem	Code
There is no waste processing because there are no officers	E1
The waste processing plant is not functioning, causing waste to pile up in the landfill.	E2
The location of polling stations (TPS) that do not reach residential areas results in less than optimal service distribution.	E3
The lack of temporary waste storage places causes waste to pile up in several temporary waste storage places.	E4
The small capacity of the temporary waste storage area creates additional complications in emptying.	E5
The small number of vehicles causes additional irritation.	E6
Garbage truck routes are not optimal in transporting garbage in commercial areas.	E7
Small transport capacity results in the need for additional trips.	E8

Source: Department of Housing, Settlements and Environment, Pariaman City, 2024

After identifying the problems to be analyzed to obtain decision direction, a comparison is made between each problem element to obtain the driver power value and dependency value as described in the following table.

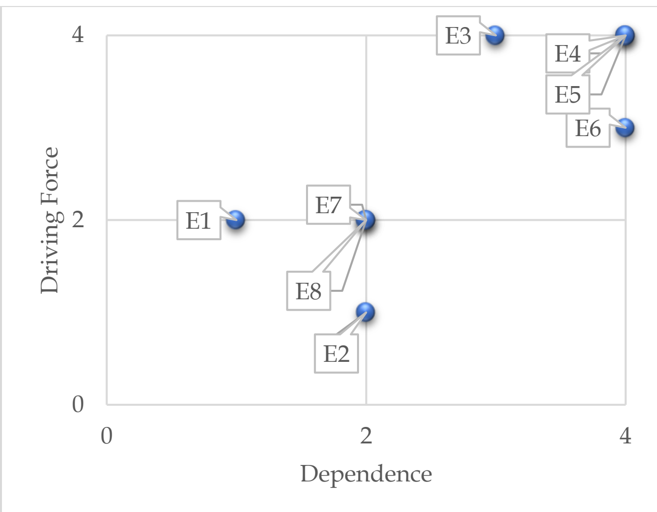

Figure 2. ISM matrix

After obtaining the ISM matrix, it is known that of the 8 problem elements in the waste management system in Pariaman City, there are 4 quadrants with each class, which from the diagram can be interpreted as a level in the decision direction which is explained as in the following level image.

Table 2. Hierarchical Structure

Levels	Hierarchical Structure
Levels 1	E3
Levels 2	E4 E5
Levels 3	E6
Levels 4	E2
Levels 5	E7 E8
Levels 6	E1

Based on the hierarchy table above, it can be seen that there are 6 levels of decision hierarchy from the results of ISM data processing. Level 1 is the priority that must be resolved first, where at level 1 there is a problem element, namely the distribution location (E3) of temporary waste storage that does not reach all settlements. At level 2 there is an element (E4) the number of temporary waste storage places is insufficient causing waste to accumulate in several temporary waste storage places and (E5) the small capacity of temporary waste storage places causes additional iterations in emptying. At level 3 there is an element (E6) the small number of arm rolls causes additional iterations.

Based on the results of the decision analysis, it was found that the distribution of TPS has not been able to provide maximum service and there is still a shortage of adequate numbers and capacities of TPS to accommodate waste generation in Pariaman City. Therefore, this study continued with an analysis of TPS needs so that distribution is even and can reach residential areas. In preparing waste management plans, data is needed regarding the amount of waste generation (Anjani, 2024). The amount of waste generated based on data from the City Cleaning and Parks Service of PerkimLH is 65 m^3. While the storage container capacity is $6m^3$. Capacity evaluation is calculated by comparing waste generation with the volume of existing temporary waste storage sites and then calculating the optimal need for temporary waste storage according to SNI 3242-2008 (BSN, 2008) with the following equation:

$$CP = \frac{\text{Percentage of service} \times \text{Number of Ts}}{\text{TPS Capacity} \times \text{Fp} \times \text{Rk}} \quad (1)$$

$$= \frac{1 \times 65}{6 \times 1.2 \times 1}$$

$$= 9.07$$

$$= 9$$

Based on the results of the analysis above, it can be seen that the number of waste collection devices needed in Pariaman City is 9 units with a capacity of $6m^3$ each. The total volume of waste is $6m^3$. After obtaining the required amount of temporary waste storage, the analysis is continued to determine the location of the temporary waste storage with the help of a geographic information system. This process uses Boolean logic, meaning that Boolean logic only has two decision directions, namely good by giving a value of 1 and bad by giving a value of 0 to the land according to the criteria. The Boolean Algebra method is a method of simplifying logic circuits that is carried out by applying Boolean rules or theorems. This method is faster and easier than using truth tables to simplify a long series of logic functions (Zulsfi et al., 2021). Scoring is the assignment of scores based on the logic of the level of influence of the classes on each important aspect for determining the suitability of a location (Hidayat et al., 2025).

The initial step taken in determining the location is to create a 50 m long road buffer zone so as not to disturb the aesthetics and road users (Lontoc et al., 2023), a 100 m long river body so as not to cause pollution in surface water (Trajković et al., 2024), and a 100 m long residential buffer zone which will have a significant impact on services and not disturb the local spatial planning (Muliarta et al., 2023), which will be done using ArcGIS Pro.

Table 3. Spatial Assessment Criteria (Nahlisa & Artiyani, 2023)

Location Criteria	Information	Category	Code
Land Conditions	Safe from flooding	Good	1
	Flood Prone	Not good	0
Road Conditions	The road can be passed by trucks	Good	1
	The road is impassable by trucks	Not good	0
Distance of settlement	100 m	Good	1
	< 100 m	Not good	0
Distance from Road	50 m	Good	1
	< 50 m	Not good	0
River distance	100 m	Good	1
	< 100 m	Not good	0
Protected Area	No Protected Areas	Good	1
	Protected Area	Not good	0
Based on RTRW	Does not interfere with the RTRW	Good	1
	Disturbing the RTRW	Not good	0

More accurate mapping of urban areas with poorly managed waste can support the provision of targeted waste services and inform environmental modeling of waste (Umar et al., 2023). This procedure follows a GIS framework that eliminates unacceptable locations by considering environmental factors, in addition to political and economic issues, contained in layers of additional information to select potential landfill sites through an overlay process by GIS software. (Rassarandi, 2023). This approach provides a comprehensive overview for selecting suitable and safe land for TPS development, supporting more effective and efficient waste management. (Alfianto et al., 2024).

Based on data verification using imagery, it was discovered that several locations are productive community land. Planned temporary waste storage sites on productive land will be removed, leaving only nine locations, as needed, as depicted in the map below.

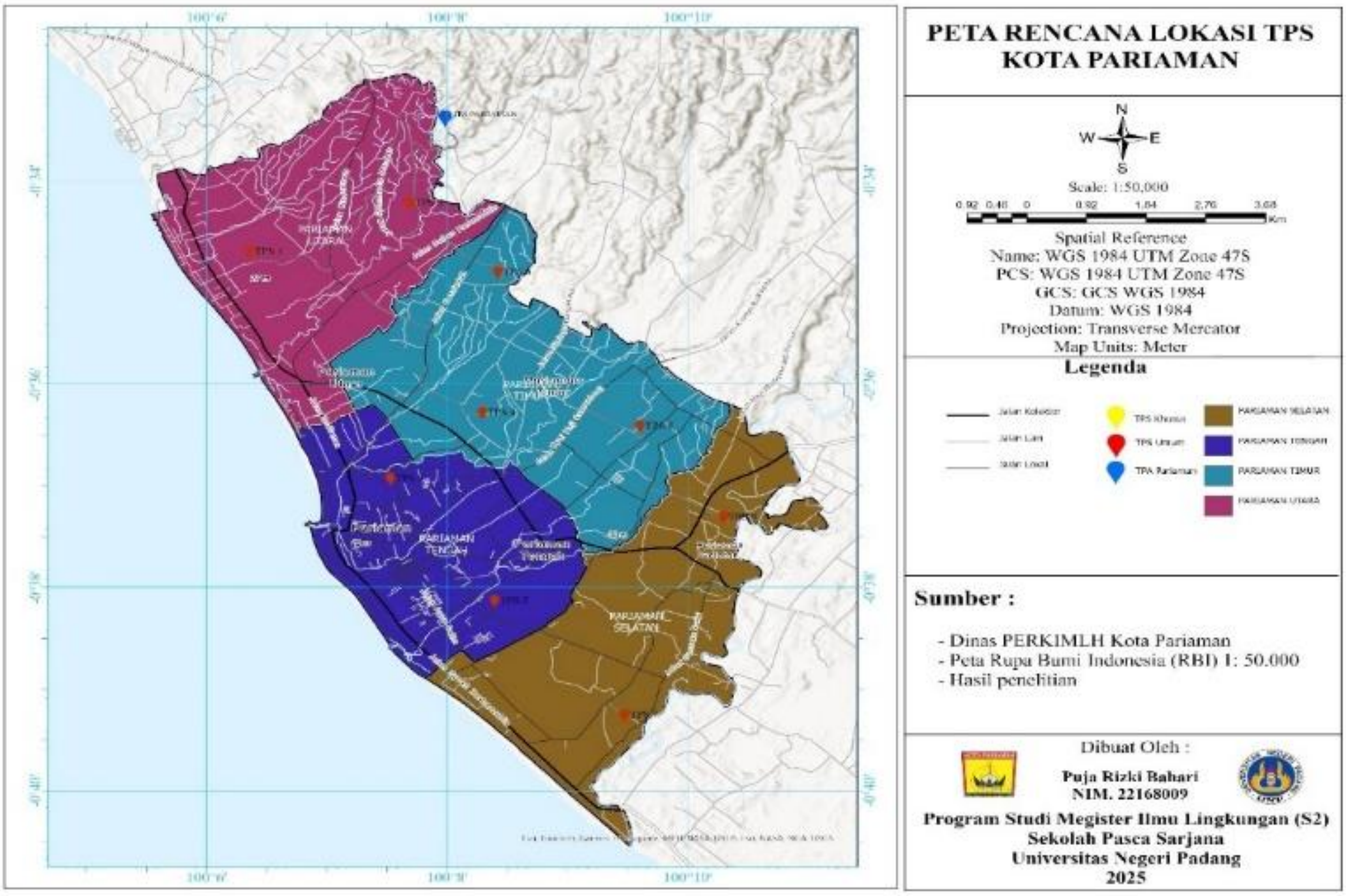

Figure 3. Map of the temporary waste storage location plan (Geographic Information System Analysis, 2025)

Based on the map above, it can be seen that there are 9 temporary waste storage locations which are divided into each sub-district with the following types of bushes and area.

Table 4. Temporary Waste Storage Location Plan Data

Number	Land Use	Area (Ha)
1	Shrubs	3049.355
2	Open Land	4530.865
3	Shrubs	5289.458
4	Shrubs	5876.799
5	Shrubs	5907.219
6	Shrubs	6119.388
7	Shrubs	10082.87
8	Shrubs	21393.44
9	Shrubs	180106.3

Source: Geographic Information System, 2025

The table above shows that the proposed temporary waste storage sites consist of open land and scrubland . Temporary waste storage sites should be built on vacant land because they will not negatively impact land use changes and will not disrupt local community activities. Accessibility Land is like a condition or availability of a connection from one location to another, so that it provides convenience or conditions for moving from one location to another and is safe, comfortable and at normal speed (Novita & Antomi, 2020). During waste collection, temporary waste storage services will be assisted by garbage pedicab services at each waste storage location, as shown in the following table.

Table 5. Pedicab Distribution Plan by Subdistrict

Number	Subdistrict	Number of Pedicabs	Number of polling stations
1	South Pariaman	2	2
2	East Pariaman	4	3
3	Central Pariaman	3	2
4	North Pariaman	2	2
Total		11	9

Source: Geographic Information System, 2025

The data in the garbage rickshaw service table above shows that there are 11 rickshaws operating to transport waste and store it in temporary waste collection sites. These 11 rickshaws are divided into several sub-districts according to their respective needs. The garbage rickshaw service coverage map below shows that the maximum service area provided by the communal system is 1 km from the temporary waste collection site. The number of rickshaws is adjusted according to the number of available rickshaws.

After obtaining the location data for temporary waste storage sites, the next step is to plan dump truck routes to provide waste transportation services in Pariaman City using a geographic information system using network analysis techniques. This analysis uses a geographic information system (GIS) that is adjusted to the location of main roads and waste volumes exceeding 0.3 m3, which are generally found in commercial and service areas. In carrying out network analysis, a software that can be used to support it is ArcGIS. ArcGIS provides various tools related to network analysis, such as tools for identifying routes, determining service areas, finding the nearest facilities, cost matrices, solving vehicle routing problems, and determining optimal locations (Alfianto et al., 2024). Existing transportation routes can be optimized by shortening distance and transportation time. Alternative routes are analyzed using Network Analysis, where this application can find the fastest or shortest route, the nearest facility, and determine the service area (Putri et al., 2023). One of the main aspects of a distribution system is determining the best delivery route (Putra & Munita, 2025). Process Creating a transportation route would be better if it was done with GIS, namely by using ArcGIS as a waste transportation route map (Putri et al., 2023). Optimizing collection routes by implementing strategies such as optimizing collection routes is one of the keys to increasing waste management efficiency. This optimization reduces time, operational costs, and resources, in addition to improving the management of human talent involved (Haro Avalos et al., 2024). The process of collecting and transporting waste on site must be carried out effectively and efficiently by considering several things, such as logical route planning (Khairil et al., 2024).

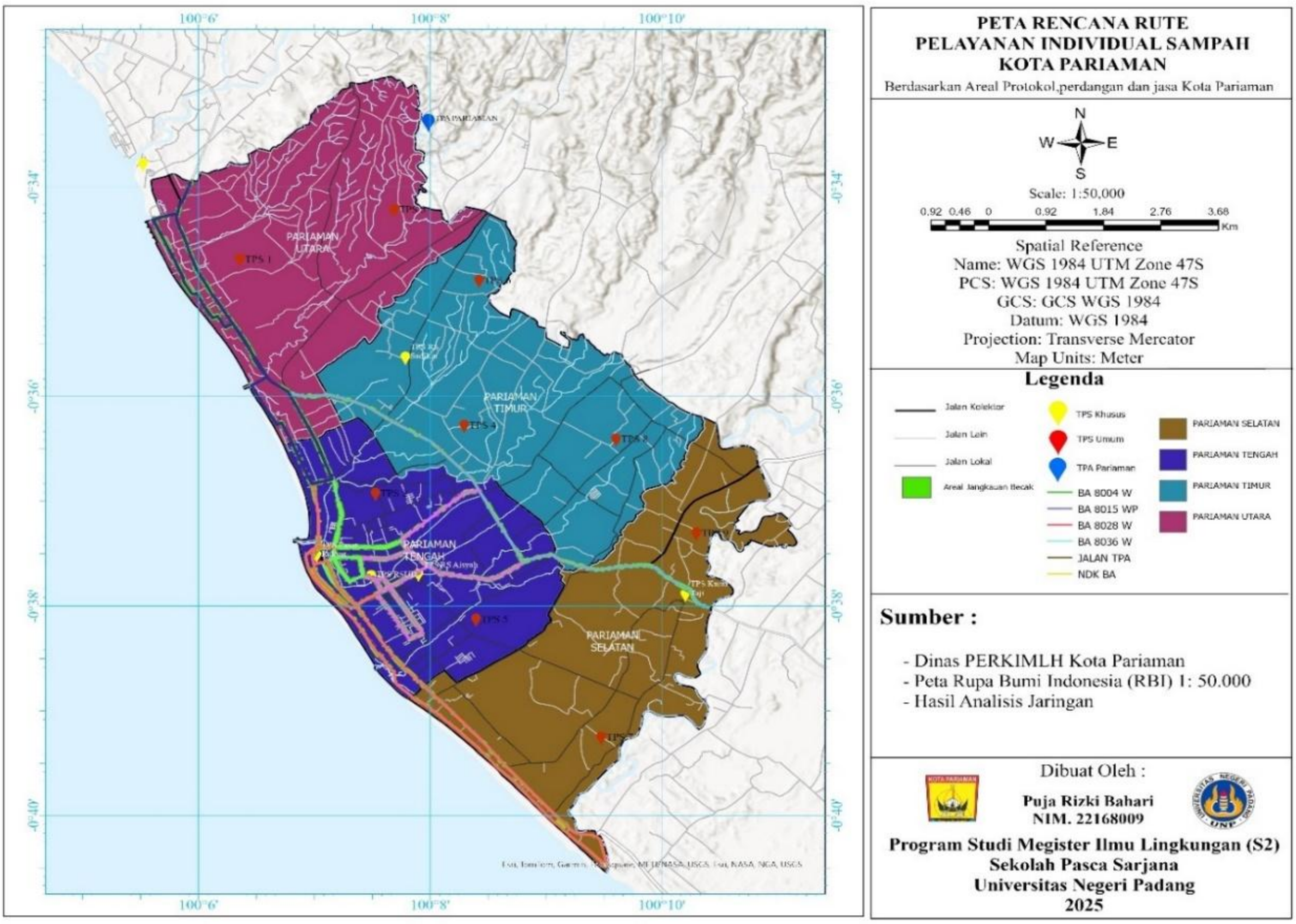

Figure 4. Dump truck route plan map (Geographic Information System Analysis, 2025)

Based on the map image above, it can be seen that there are routes traveled by garbage trucks where these routes will provide direct individual services consisting of 5 fleets that are analyzed using network analysis which produces distance and travel time data which will be described as follows.

Table 6. Garbage Truck Routes

Number	Name	Distance	Time
1	BA 8004 W	8413.951	13 minutes
2	BA 8015 WP	9431.588	15 minutes
3	BA 8028 W	5383.958	9 minutes
4	BA 8036 W	19753.66	30 minutes
5	BA 8814 W	12655.24	19 minutes

Source: Geographic Information System, 2025

Optimizing collection routes through strategies such as optimizing collection routes is key to improving waste management efficiency. This optimization reduces time, operational costs, and resources, while also enhancing human participation (Haro Avalos et al., 2024).

After completing the planning of the location of the temporary waste storage area and obtaining the route for the garbage dump truck, you can see the planned area on the following map.

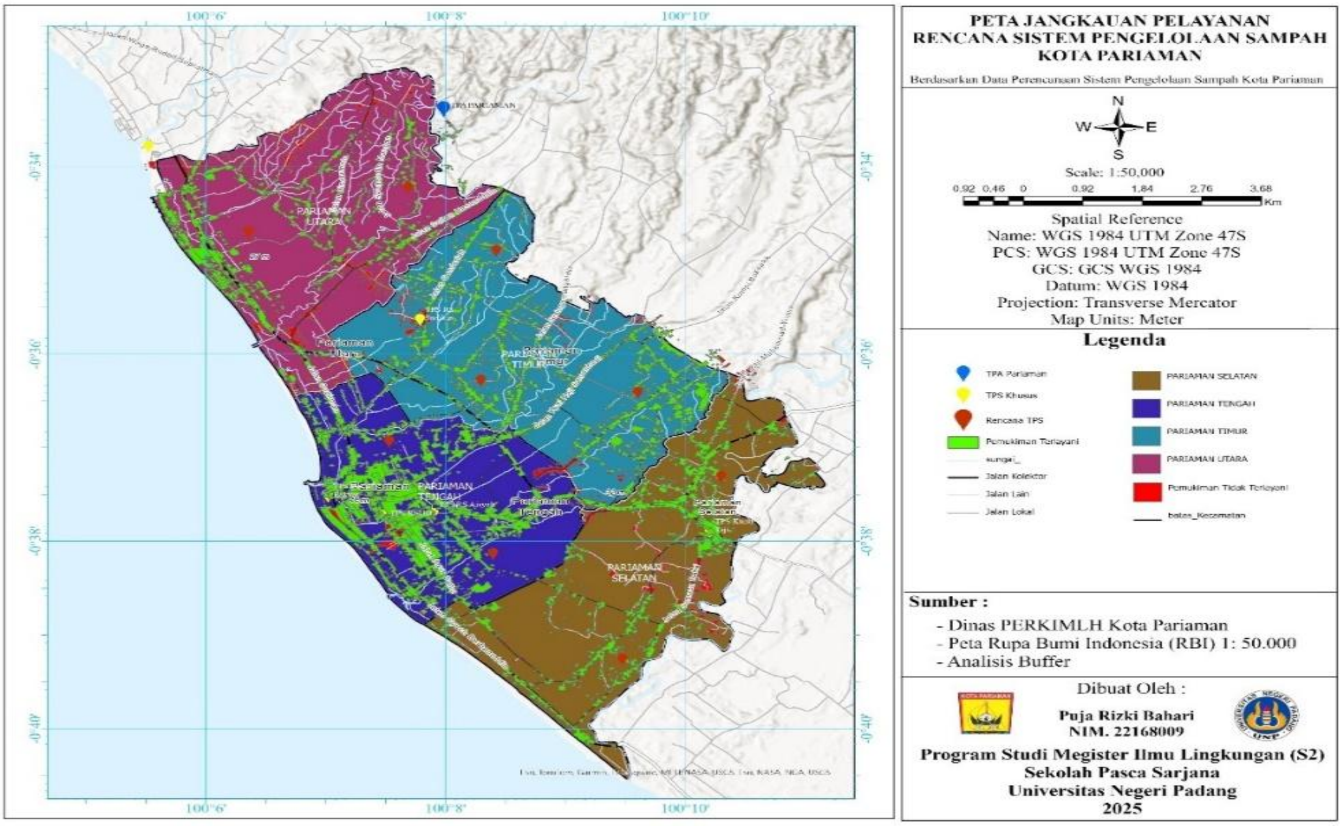

Figure 5. System plan service coverage (Geographic Information System, 2025)

Based on the map above, it is known that the waste management system plan has had a very positive impact on waste services in Pariaman City. Initially, of the total residential area of 1,245.47 Ha, only 640.66 Ha were served by the Pariaman City waste service system, which means 51.4% of the settlements in Pariaman City have been served. Then, with the waste management system plan covering 1,017 Ha of the total residential area of 1,245.47 Ha, only 228.47 Ha of settlements cannot be served by this system plan. This means that 81.6% of settlements can be served by this system plan.

The planning of this waste management system also takes into account the existing system, especially the procurement of equipment and the number of personnel, where in the planned system there is only an addition of equipment in the form of the number of containers. The communal container which was initially 3 became 9, which means that there are 6 communal container units that must be added to improve services to the community and increase environmental awareness. It should be emphasized that environmental awareness encompasses not only an understanding of the importance of maintaining a clean environment but also an awareness of the negative impacts of unsustainable waste management (Fariani et al., 2025). The presence of temporary waste disposal sites will facilitate waste management for the community and government. This process will also improve services and reduce environmental pollution (Fiqra & Antomi, 2023).

In terms of garbage dump truck services, the existing system and the planned system are not much different, only that the planned system optimizes the route according to the criteria provisions adjusted to the location of the main road and the volume of garbage exceeding 0.3 m^3, which is generally found in commercial and service areas.

In terms of waste collection services using communal containers, this presents a significant difference. The initial system only had three temporary waste storage sites accessible to the public. The planned system, however, has nine locations that can be optimized. Geographic Information System (GIS) determines the location of waste generation, knowledge of the distance to the TPS, knowing the collaboration of service facilities with settlements, then the effective route for transporting waste will be known validly so that it can reduce waste generation and save operational costs (Yunus et al., 2022). Spatial data processing or manipulation is one of the capabilities of GIS in producing new information more quickly and efficiently (Hidayat et al., 2025). By selecting the most efficient combination, it is hoped that the total distance traveled by each fleet can be minimized, thereby reducing the time and operational costs required for waste transportation (Chandrahadinata et al., 2025). The strategy that will be developed to reduce food waste at the household level is a defensive strategy, also known as minimizing weaknesses in order to survive threats (Gerda et al., 2023).

Planning the location and route of TPS must also consider the existing land use in Pariaman City, where the obtained location is adjusted to the land use through validation using imagery. In achieving sustainable development from an environmental perspective, an environmentally sound waste management system can contribute to the realization of a sustainable city, because environmentally sound waste management will create a good environment (Widiyanti et al., 2024).

A Temporary Disposal Site (TPS) is a building or area designed to move waste from collection equipment, such as cart or transport vehicle, to in larger containers. The main function of a TPS is as a location for temporarily collecting waste before it is transported further to a processing facility or final disposal site. (Aulia & Mahmud, 2025). Provision of adequate temporary waste storage facilities (TPS) is very necessary for storing waste (Efendi & Littaqwa , 2023). Temporary waste storage is also needed to build a mindset among residents to dispose of waste properly (Iskandar, et al., 2025). Managing solid waste effectively requires a comprehensive strategy that involves all members of the community (Rahmawati & Sapii, 2024). This will reduce the risk of environmental damage and other conflicts, one of which is the emergence of illegal temporary waste disposal sites. The emergence of illegal TPS is due to the lack of legal temporary waste disposal sites accessible to local communities and the lack of special attention from relevant institutions to provide adequate waste disposal facilities (Efendi & Littaqwa, 2023). The impact of the lack of adequate TPS is environmental pollution and disrupts the aesthetics of an area (Fikriyah et al., 2022).

In Pariaman City's waste management system, collected waste is transported to a final disposal site. The landfill serves as a disposal site for waste that cannot be managed (Rahmadani et al., 2025). Landfills remain the best option for solid waste management in Indonesia, as other waste disposal or management options tend to be more expensive (Septianingrum et al., 2023).

Conclusion

Based on the research results, it can be concluded that the waste management system plan has had a very positive impact on waste services in Pariaman City. Initially, of the total residential area of 1,245.47 Ha, only 640.66 Ha were served by the Pariaman City waste service system, which means 51.4% of the settlements in Pariaman City have been served. Then, with the waste management system plan covering 1,017 Ha of the total residential area of 1,245.47 Ha, only 228.47 Ha per settlement cannot be served by this system plan. This means that 81.6% per settlement can be served by this system plan.

Acknowledgments
During the process of writing this article, the author received a lot of support, guidance, direction, and contributions of ideas from various parties. Therefore, on this occasion, the author would like to express his gratitude to the lecturers of the Environmental Science Study Program, Postgraduate School, Padang State University.

Author Contributions
Conceptualization, original draft preparation, results, discussion, methodology, analysis, conclusions, M.M.F.; review and editing, I.U, N.S, E.Y,. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The author declares that there is no conflict of interest regarding the publication of this paper.

References

Afkar, Syah, N., Barlian, E., & Carlo, N. (2025). Domestic Waste Management Strategy in Batang Bayang River, West Pasaman Regency. *Jurnal Penelitian Pendidikan IPA*, *11*(3), 475–483. https://doi.org/10.29303/jppipa.v11i3.10494

Alfianto, R. R., Septiarani, B., Yesiana, R., & Astuti, K. D. (2024). Arahan Penentuan Lokasi Alternatif TPS 3R di Kecamatan Banyumanik. *Jurnal Riptek*, *18*(1), 49–60. https://doi.org/10.35475/riptek.v18i1.250

Al-Thani, M. J. (2025). Empirical insights into governance and planning for zero waste, risk reduction, and sustainability: A case study of the FIFA world cup 2022 in Qatar. *Discover Sustainability*, *6*(1), 660. https://doi.org/10.1007/s43621-025-01115-x

Anjani, A. P. (2024). *Perencanaan Sistem Pengelolaan Sampah di Pasar Sembung, Kecamatan Mengwi, Kabupaten Badung*. *Jurnal Ecocentrism, 5*(1), 31-41. https://doi.org/10.36733/jeco.v5i1.11125

Aqilla, A. R., Razak, A., Barlian, E., Syah, N., & Diliarosta, S. (2023). Pengaruh Sampah Plastik Dalam Pencemaran Air. *Gudang Jurnal Multidisiplin Ilmu, 1*(6), 275-280. https://doi.org/10.59435/gjmi.v1i6.203

Aulia, N. H., & Mahmud, M. (2025). Analisis Pengelolaan Sampah dan Ketersediaan Infrastruktur Tempat Pembuangan Sementara (TPS) di Kota Gorontalo. *Composite Journal, 5*(2), 48-56. https://doi.org/10.37905/cj.v5i2.181

Chandrahadinata, D., Taptajani, D. S., & Fathori, M. Z. (2025). Perancangan Rute Pengangkutan Sampah di Garut Dengan Model Penyelesaian Capacitated Vehicle Routing Problem (CVRP). *Jurnal Kalibrasi*, *23*(1), 117–125. https://doi.org/10.33364/kalibrasi/v.23-1.1897

Efendi, A., & Littaqwa, L. A. A. (2023). Analisis Tempat Pembuangan Sampah Ilegal Menggunakan Sistem Informasi Geografis (SIG). *IJE, 4*, 11–21. Retrieved from https://shorturl.at/pjVCU

Fariani, A., Razak, A., Dewata, I., & Syah, N. (2025). Analysis of Socio-Economic Influences on Household Waste Management in West Sumatra. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 887–894. https://doi.org/10.29303/jppipa.v11i1.9590

Fikriyah, N., Meidiana, C., & Sari, K. E. (2022). Penentuan Sistem Pengumpulan Sampah dan Tempat Penampungan Sementara Desa Sawahmulya, Sangkapura. *Tata Kota dan Daerah*, *14*(1), 35–46. https://doi.org/10.21776/ub.takoda.2022.014.01.5

Fiqra, R., & Antomi, Y. (2023). Environmental Management System for Solid Medical Waste Management In Pariaman City Hospital. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8852–8863. https://doi.org/10.29303/jppipa.v9i10.4954

Firdausy, M. A., & Prayoga, M. I. (2024). Perencanaan Tempat Penampungan Sementara (TPS) dan Sistem Pengangkutan Sampah di Kabupaten Hulu Sungai Tengah dengan Metode Sistem Informasi Geografis (SIG). *Jukung (Jurnal Teknik Lingkungan)*, *10*(1). https://doi.org/10.20527/jukung.v10i1.20672

Gerda, N., Riani, E., & Adji, S. S. (2023). Strategies to Reduce Food Waste at Household Level. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 919–923. https://doi.org/10.29303/jppipa.v9iSpecialIssue.4875

Harahap, M. A. K., Harmain, U., Saragih, J. R., Sinurat, A., Sihombing, B., Purba, I. R., & Saragih, H. (2024). Perencanaan Sistem Cluster Pengelolaan Sampah Dalam Mengurangi Penumpukan Sampah Di Kota Pematang Siantar. *Jurnal Regional Planning*, *6*(2), 69–76. https://doi.org/10.36985/smz44433

Haro Avalos, D. A., Avalos Pérez, M. A., Mantilla Miranda, A. S., & Avalos Pérez, M. C. (2024). Gestión de recolección de residuos alimenticios mediante el método Vehicle Routing Problem: Abordaje en Riobamba, Ecuador. *Revista Venezolana de Gerencia*, *29*(Especial 1), 1099–1111. https://doi.org/10.52080/rvgluz.29.e12.14

Hidayat, M., Ariesmayana, A., & Pangesti, F. S. P. (2025). Kajian Penentuan Lokasi Tempat Pemrosesan Akhir Sampah Kabupaten Serang Menggunakan Analisis Sistem Informasi Geografis. *Jurnal Serambi Engineering, 10*(3). Retrieved from https://jse.serambimekkah.id/index.php/jse/article/view/1015

Iskandar, Y. A., Rachmawati, N. L., Amadea, J., Rahma, D., & Sofyan, F. (2025). Pemilihan Lokasi Pembangunan Tempat Pembuangan Sementara di Desa Sambongrejo, Kabupaten Tuban, Provinsi Jawa Timur dengan Metode MCDM-AHP. *IKRA-ITH Informatika : Jurnal Komputer dan Informatika*, *9*(1). Retrieved from https://journals.upi-yai.ac.id/index.php/ikraith-informatika/article/view/4668

Khairil, D. F., Syah, N., Barlian, E., & Carlo, N. (2024). Evaluation of Solid Medical Waste Management. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 4561–4571. https://doi.org/10.29303/jppipa.v10i8.8494

Kihila, J. M., Wernsted, K., & Kaseva, M. (2021). Waste segregation and potential for recycling -A case study in Dar es Salaam City, Tanzania. *Sustainable Environment*, *7*(1), 1935532. https://doi.org/10.1080/27658511.2021.1935532

Lontoc, G. D., Diola, M. B. L. D., & Peralta, M. H. T. (2023). Multi-criteria evaluation of suitable locations for temporary disaster waste storage sites: The case of Cavite, Philippines. *Journal of Material Cycles and Waste Management*, *25*(5), 2794–2808. https://doi.org/10.1007/s10163-023-01705-9

Minz, N. K., Yadav, M., Prakash, A., & Kain, S. (2025). Analysing the key drivers and barriers for implementing circular economy practices in waste management systems using ISM and MICMAC analysis. *Cleaner Waste Systems*, *12*, 100381. https://doi.org/10.1016/j.clwas.2025.100381

Muliarta, I. N., Hariani, C. Y., Wahyuni, N. M. I., & Rismayanti, A. A. T. (2023). Study of Potential Food Waste in Zero Waste Cities Area- Saridewi, Denpasar-Bali. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 2595–2603. https://doi.org/10.29303/jppipa.v9i5.3019

Nahlisa, A., & Artiyani, A. (2023). *Penentuan Lokasi TPS 3R Menggunakan Sistem Informasi Geografis (SIG) di Kecamatan Tidore, Kota Tidore Kepulauan*. Retrieved from http://eprints.itn.ac.id/id/eprint/13295

Neto, A. B. P. S., Simões, C. L., & Simoes, R. (2024). Optimization of municipal solid waste collection system: Systematic review with bibliometric literature analysis. *Journal of Material Cycles and Waste Management*, *26*(4), 1906–1917. https://doi.org/10.1007/s10163-024-01966-y

Novita, Y., & Antomi, Y. (2020). Penentuan Potensi Lokasi ATM (Automatic Teller Machine) Bank Nagari Menggunakan Sistem Informasi Geografis (SiIG) di Kota Padang. *Jurnal Buana, 4*(5). https://doi.org/10.24036/buana.v4i5.1183

Novriansyah, M. A., Simatupang, D. S., & Sujjada, A. (2023). Sistem Informasi Geografis Pemetaan Lokasi Tempat Pembuangan Sampah Legal di Sukabumi. *G-Tech: Jurnal Teknologi Terapan*, *7*(3), 1194–1206. https://doi.org/10.33379/gtech.v7i3.2869

Pangesti, D. T., Syah, N., Dewata, I., Arlian, E., & Sholichin, M. (2024). The Influence of Family Leadership Style in Encouraging Awareness and Action on Household Waste Management. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 166–172. https://doi.org/10.29303/jppipa.v10iSpecialIssue.7622

Putra, H., & Munita, A. A. (2025). Optimasi rute pengangkutan sampah menggunakan metode VRPTW dan Nearest Insertion Heuristic di Kecamatan Jatisampurna. *JENIUS: Jurnal Terapan Teknik Industri,* *6*(2), 165-176. https://doi.org/10.37373/jenius.v6i2.1652

Putri, I. A., Rini, I. D. W. S., & Hayati, R. N. (2023). Studi Optimalisasi Rute Pengangkutan Sampah Stationary Container System Berbasis Sistem Informasi Geospasial (SIG) di Kecamatan Balikpapan Timur. *Jurnal Pengendalian Pencemaran Lingkungan (JPPL)*, *5*(2), 168–176. https://doi.org/10.35970/jppl.v5i2.2007

Rahmadani, L. Y., Efani, A., Wahyudi, S. T., & Atikawati, D. (2025). Study of Waste Reduction through Climate Village Program (Proklim) in Malang City. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 966–977. https://doi.org/10.29303/jppipa.v11i1.10203

Rahmawati, F. K., & Sapii, I. (2024). Kajian Pengolahan Limbah Padat: Pemanfaatan Limbah Anorganik Kering Untuk Pembuatan Produk Ecobrick. *Journal of Environmental Engineering Research, 2*(1), 22-26. Retrieved from https://jurnal.unugo.ac.id/jeer/index.php/jeer/article/view/58

Ramadhan, M. A., Rahayu, D. E., & Widarti, B. N. (2025). Analisis Sebaran dan Cakupan Pelayanan Tempat Penampungan Sementara (TPS) di Kota Samarinda menggunakan Sistem Informasi Geografis (SIG). *Jurnal Teknologi Lingkungan*, *9*(1). http://dx.doi.org/10.30872/jtlunmul.v9i1.18810

Rassarandi, F. D. (2023). Optimalisasi Sistem Angkutan Sampah di Kelurahan Pulau Setokok dengan Pemanfaatan Sistem Informasi Geografis (SIG). *Journal of Science and Applicative Technology*, *7*(2), 91. https://doi.org/10.35472/jsat.v7i2.748

Roman, A., Mwalilino, J. K., & Mtoni, P. E. (2025). Municipal solid waste generation and management in Morogoro Municipality. *Sustainable Environment*, *11*(1), 2510723. https://doi.org/10.1080/27658511.2025.2510723

Septianingrum, D., Mizuno, K., & Herdiansyah, H. (2023). Extended Producer Responsibility for Waste Management Policy. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 2686–2692. https://doi.org/10.29303/jppipa.v9i5.3469

Sharma, H. B., Vanapalli, K. R., Samal, B., Cheela, V. R. S., Dubey, B. K., & Bhattacharya, J. (2021). Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery. *Science of the Total Environment*, *800*, 149605. https://doi.org/10.1016/j.scitotenv.2021.149605

Syahrizal, H., & Jailani, M. S. (2023). Jenis-Jenis Penelitian Dalam Penelitian Kuantitatif dan Kualitatif. *Jurnal QOSIM Jurnal Pendidikan Sosial & Humaniora*, *1*(1), 13–23. https://doi.org/10.61104/jq.v1i1.49

Towansiba, S., Martanto, E. A., & Mangallo, B. (2024). Management of Solid Medical Waste at Regional Public Hospital of West Papua Province. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5710–5717. https://doi.org/10.29303/jppipa.v10i8.7834

Umar, F., Amoah, J., Asamoah, M., Dzodzomenyo, M., Igwenagu, C., Okotto, L.-G., Okotto-Okotto, J., Shaw, P., & Wright, J. (2023). On the potential of Google Street View for environmental waste quantification in urban Africa: An assessment of bias in spatial coverage. *Sustainable Environment*, *9*(1), 2251799. https://doi.org/10.1080/27658511.2023.2251799

Widiyanti, F., Astirin, O. P., & Gravitiani, E. (2024). Stakeholder Relationship Model in Waste Bank

Management in Madiun City. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3185–3192. https://doi.org/10.29303/jppipa.v10i6.7499

Yunus, M. Y., Alimuddin, I., & Nasution, A. (2022). Implementasi Sistem Pengelolaan Persampahan Berbasis Sistem Informasi Geografis (SIG): Studi Kasus Kecamatan Watang Sawitto. *Urban and Regional Studies Journal*, *4*(2), 84–89. https://doi.org/10.35965/ursj.v4i2.1397

Zulsfi, A., Simanjuntak, N. B. P., Sari, V. A., & Rahmi, F. (2021). Penerapan Analisis Geospasial Berbasis Sistem Informasi Geografis Untuk Pemetaan Tingkat Ancaman Bencana di Kabupaten Padang Pariaman, Sumatera Barat. *Jurnal Geosains dan Remote Sensing*, *2*(2), 82–91. https://doi.org/10.23960/jgrs.2021.v2i2.50