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Healthy and Waste-Free Area: Integrated Waste Management, Regional Resilience through Sustainable Development in Deli Serdang Regency, Indonesia

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Abstract

Integrated waste management is a serious challenge in Deli Serdang, which has a direct impact on environmental health and the quality of life of the community due to rapid population growth and urbanization. Waste that is not managed properly has an impact on environmental degradation, public health risks and the resilience of areas vulnerable to climate change. The purpose of this study is to analyze integrated waste management strategies in realizing healthy and waste-free areas in order to strengthen regional resilience through sustainable development. The method used is a mixed-method, and in-depth interviews, surveys and documentation analysis were carried out in data collection. The data analysis used is thematic analysis for qualitative and SEM PLS for quantitative. The results of the study indicate that the application of a circular economy-based waste management model, environmentally friendly technology, and community participation and inclusive government policies can increase the effectiveness of waste management. In addition, the integration of the zero-waste concept with climate change adaptation strategies can reduce greenhouse gas emissions and improve environmental quality and public health. This study also emphasizes that the success of integrated waste management depends on the synergy between local governments, the private sector, and the community in building a sustainable ecosystem. Therefore, more adaptive policies and investment in innovative waste processing technologies are needed to achieve healthy and waste-free areas in Deli Serdang. These findings contribute to regional development planning that is more resilient to environmental challenges, while also providing a model for other regions in Indonesia in implementing sustainable waste management systems.

Keywords: *Integrated Waste Management, Regional Resilience, Sustainable Development, Healthy Area.*

Introduction

Waste management is one of the biggest challenges faced by many countries around the world, especially in urban areas. According to data from World Bank [1], Global waste production was estimated at 2.01 billion tons in 2016, and is predicted to increase to 3.4 billion tons by 2050 without significant intervention. Developing countries, including Indonesia, contribute a significant proportion of this waste, which is often a complex problem involving environmental, public health, and economic development issues. [2] In Indonesia, waste management is a pressing issue, where it is estimated that each person produces around 0.7 kg of waste per day. Total waste production in Indonesia is estimated to reach more than 67 million tons per year, and only around 60% of the total waste is transported and managed formally. However, a bigger challenge arises from the fact that many areas, including Deli Serdang, still rely on final disposal

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sites (TPA) as the main solution for waste management. This not only threatens environmental health but also the quality of life of the surrounding community.

A healthy and sustainable environmental condition is one of the important pillars in resilient regional development. In Deli Serdang Regency, the challenges in waste management are becoming increasingly apparent along with rapid population growth and economic development. Deli Serdang, as one of the regencies in North Sumatra, has its own challenges in terms of waste management. Based on data from the Central Statistics Agency (BPS) of Deli Serdang in 2022, the population in this district reached more than 1.7 million people. This rapid population growth has a direct impact on increasing waste production. With a population that continues to increase, it causes a significant increase in the volume of waste produced. It is estimated that the total waste production reaches around 1,200 tons per day, but only around 30% of that amount is managed properly. This is because the lack of a good waste management system creates serious problems such as environmental pollution, impacts on public health, and decreased quality of life.

This situation shows a crisis in waste management that can threaten public health and environmental sustainability. Waste that is not managed properly not only contributes to land and water source pollution, but can also become a breeding ground for disease. This shows that effective waste management is a must to create a healthy and waste-free area which in turn supports regional resilience. [3], [4] that shows that groundwater pollution due to waste can cause various health problems, including gastrointestinal diseases. This emphasizes the need for a more sustainable approach to waste management. Ineffective waste management can have a direct impact on people's quality of life, trigger various health problems, and damage ecosystems. Piles of waste not only create visual pollution, but also pollute groundwater, damage crops, and become a breeding ground for disease. Environmentally-based diseases, such as diarrhea and respiratory infections, often increase in areas with poor waste management. Thus, regional resilience is very important in integrated waste management. [5] Regional resilience is not only related to the economic and infrastructure capacity to face challenges, but also to social and environmental resilience. In facing the environmental crisis caused by waste management problems, a sustainable and integrated approach becomes very relevant.

Regional resilience is measured by the ability of a region to adapt, recover, and face change. Deli Serdang Regency, as a strategic area, requires a waste management model that is able to build social and environmental resilience. [6] Adopting an integrated waste management system involving reduction, reuse, and recycling is a progressive solution that can improve regional resilience. With these steps, it is hoped that communities can be more independent in managing the waste they produce, and contribute to creating healthier and more waste-free areas. Meanwhile, sustainable development is an approach that reflects a commitment to maintaining a balance between economic growth, environmental protection, and social welfare, According to the United Nations Development Programme (UNDP) [7], sustainable development must include efforts to align economic growth with wise management of natural resources. In the context of Deli Serdang, managing waste wisely is an integral part of sustainable development efforts that will create a healthy and harmonious environment. To achieve this goal, it is important to educate the public about environmentally friendly lifestyles and the importance of active participation in waste management.

An integrated waste management approach provides a solution that can help address this

problem. [8], [9] The concept of integrated waste management in supporting sustainable regional resilience includes various strategies and practices aimed at creating healthy and waste-free areas. A study by [10] emphasizes that integrated waste management can reduce the volume of waste ending up in landfills, increase recycling capacity, and ultimately contribute to sustainable development in an area. [6], [11] In the context of sustainable development, good waste management not only aims to reduce negative impacts on the environment but also contributes to the quality of life of the community by creating new jobs and encouraging local economic development. Sustainable development, as outlined in the United Nations 2030 Agenda for Sustainable Development, emphasizes the importance of social, economic and environmental stability. Integrated waste management in Deli Serdang is expected to be a model for other areas with similar challenges.

The main problems faced by the government related to integrated waste management as regional resilience in Deli Serdang, namely a) There is a low level of community participation in waste management. Although the community is aware of the importance of waste management, their involvement in existing programs is still minimal. This hampers the effectiveness of waste management implementation, because many of them do not fully understand their roles and responsibilities in this system; b) Lack of infrastructure and appropriate technology for waste management. In Deli Serdang, waste management still relies heavily on traditional methods that are inefficient and not environmentally friendly. Inadequate infrastructure and limited application of green technology hinder efforts to recycle and manage waste effectively; c) Waste management policies are also often not integrated with broader sustainable development policies. Furthermore, collaboration between the government, community, and private sector is key to creating an effective waste management system. [12] Local governments need to play an active role in formulating policies and regulations that support integrated waste management. In addition, the involvement of the private sector in waste management technology innovation can be a solution to reduce the amount of waste and increase management efficiency. For example, advanced recycling technology can be used to process waste into new raw materials, thereby reducing the need for natural resources.

In order to strengthen regional resilience through sustainable waste management, an innovative approach is needed that involves various elements of society. [13], [14] Community-based approaches that encourage active participation from the community will strengthen the sense of ownership and responsibility in waste management. In addition, pro-environmental policies and incentives from the government to support community group initiatives can produce sustainable positive impacts. By strengthening regional and community capacity in waste management, it is hoped that Deli Serdang Regency will be able to create a healthy and low-waste area. Sustainable development based on the principle of regional resilience will bring positive changes and improve the quality of life of the community. In the future, sustainable programs that focus on waste reduction, reuse, recycling, and community education must be a priority in regional development plans. This study focuses on how integrated waste management can be a foundation for building regional resilience and supporting sustainable development in Deli Serdang Regency. Through strategic steps that are oriented towards the community and the environment, it is hoped that an area will be created that is not only healthy and free of waste, but also resilient in facing future environmental challenges. Thus, this study is expected to provide a real contribution in efforts to create a better and more sustainable life for all people in Deli Serdang Regency.

Based on the problems explained, it can be concluded that the sustainable development approach has an important role in integrated waste management as regional resilience, resulting in waste management not only being related to waste processing, but also being part of a broad strategy that includes social, economic and ecological aspects. This is also supported by the results of data processing through VOSviewer, namely

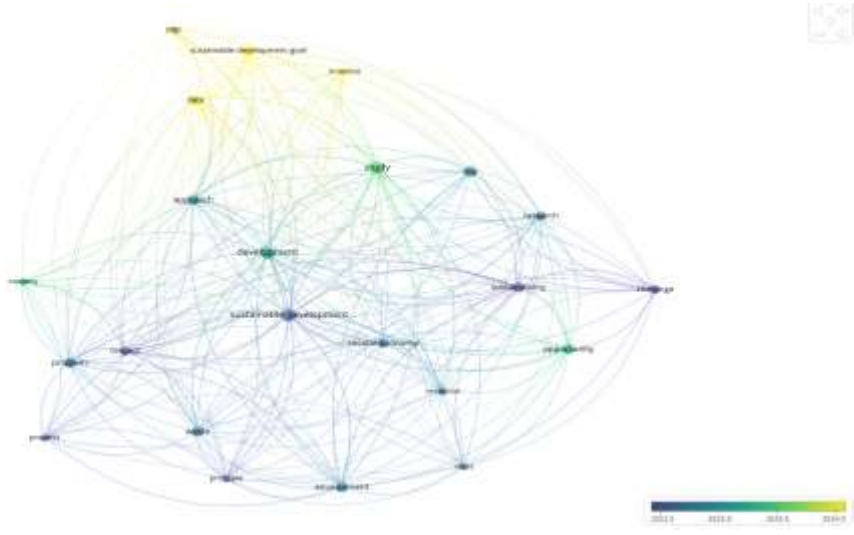

Fig 1. Mapping of Research Data related to Research Themes

Source: vosviewer (processed data)

The analysis of the VOS Viewer results conducted in this study emphasizes the importance of interactions between various concepts in integrated waste management, regional resilience, and sustainable development. By utilizing data and findings from previous studies, Deli Serdang Regency can develop a more effective and sustainable waste management system. Approaching the problem in a holistic manner allows for the discovery of innovative solutions and increased community participation, which in turn will lead to the achievement of a healthy and waste-free area. Steps to strengthen evidence-based policies and empower communities should be a primary focus to ensure long-term success. [15], [16] The concept of sustainable development is at the heart of integrated waste management, which aims to reduce waste, increase resource efficiency, and create a healthier environment. Sustainable development in this context refers to how waste management can be implemented with methods that not only handle waste, but also reduce its negative impacts on the environment and society. [17], [18] One of the main approaches associated with this concept is the circular economy, which emphasizes the reuse and recycling of resources to reduce the amount of waste that ends up in landfills.

A healthy and waste-free area is a concept that focuses on creating a clean and healthy environment through good waste management. The goal is not only to reduce the volume of waste, but also to improve the quality of life of the community. A clean area allows people to live in a healthier environment, increase their productivity, and reduce long-term health costs for the government and the community. Thus, the development of this healthy area is in line with the central and regional government programs that encourage sustainable city development. Through the implementation of appropriate policies and programs, Deli Serdang can be an

example for other regions in terms of waste management and sustainable development. With a sustainable approach, circular economic integration, policy support, and high public awareness, Deli Serdang Regency can become a model for a healthy and waste-free area in the future.

Literature Review

Effective waste management is one of the main challenges in sustainable development, especially in areas experiencing rapid population growth and urbanization such as Deli Serdang Regency, Indonesia. Integrated waste management can be one of the main pillars in strengthening regional resilience and achieving sustainable development goals in Deli Serdang in realizing a healthy and waste-free area. Therefore, the concept of integrated waste management is increasingly gaining attention as a strategic solution. A healthy and waste-free area is an area characterized by minimal waste and good management, which has a positive impact on public health, environmental quality, and the sustainability of natural resources. Law No. 18 of 2008 concerning Waste Management, good management must be carried out through a systematic and integrated approach. Integrated waste management is one of the important pillars in creating a waste-free area. A study by [3], [10] shows that integrated management, covering all stages from reduction to final disposal, can reduce negative impacts on the environment and public health.

Research by [19], [20] shows that community involvement not only increases awareness of waste management, but also creates a sense of ownership of the environment. Then, [21] shows that integrated management covers the entire range of management processes, from reduction, selection, collection, to reuse. In the study conducted, they found that areas that implemented integrated management succeeded in reducing waste volume by 30%. Likewise with the results of research from [22] examined the effectiveness of this program in increasing community participation in Medan and found that the Waste Bank encouraged the community to be more active in sorting waste at the source. Furthermore, research by [23] discussed the integrated waste management models that have been successfully implemented in various countries and their impact on increasing recycling rates. They emphasized that well-designed integrated waste management can significantly reduce the amount of waste that ends up in landfills. Therefore, this study provides a basis for initiatives to implement similar models tailored to the unique characteristics of Deli Serdang to achieve optimal results. Thus, an integrated waste management approach is key to achieving a healthy area.

Clear and firm policies from local governments greatly influence the success of waste management programs.[8], [24] shows that the implementation of participatory-based policies in waste management in big cities such as Jakarta and Surabaya has succeeded in reducing waste entering landfills. Their research also states the importance of evaluating regulations to remain relevant to land dynamics and community needs. Then, [25] documenting how the implementation of the Plastic waste reduction task force policy at the national level has been able to provide positive impacts in various regions. In addition, [6], [26] emphasizes the role of policy in supporting sustainable waste management. In their study, they found that strong policies can help local programs achieve success. Thus, local adaptation of policies can encourage the creation of stricter local regulations regarding the reduction of single-use plastic use in Deli Serdang Regency. This study also emphasizes the importance of collaboration between local governments and communities in designing effective management policies as an agenda that needs to be focused on in this study.

Regional resilience [27], [28] is an important concept related to the ability of a community to face, adapt, and recover from various risks and challenges, whether social, economic, environmental, or disaster. In the context of waste management and sustainable development, regional resilience is the key to creating a healthy and waste-free area. Regional resilience can be defined as the ability of a community to manage risks and deal with various forms of stress, including natural disasters, climate change, and social and economic challenges. According to [29] Regional resilience consists of three main components: a) the ability to prepare for and prevent disasters, b) the ability to respond when a disaster occurs, and c) the ability to recover after a disaster. This approach is particularly important in the context of waste management, where resilience can influence the success of a waste management system. As the resilience model developed by Berkes and Ross [23] emphasize the importance of interactions between social and ecological elements. They argue that resilience depends not only on the physical characteristics of an area, but also on the social networks and policies that support it. [7] put forward a more comprehensive resilience model that emphasizes the importance of the relationships between individuals, communities, and biogeophysical systems. In this model, regional resilience is seen as a function of collective intelligence, adaptation, and innovation that can facilitate change and response to environmental stress.

According to [30] Regional resilience can be enhanced through policies that support cross-sectoral collaboration. For example, policies that integrate waste management with sustainable development strategies can produce comprehensive solutions. Thus, in regional resilience, an important element is policy integration that includes alignment between environmental, health, and economic development policies that are aimed at enhancing regional resilience. Regional resilience includes the ability of a community to face and adapt to changes faced, including environmental problems. The relationship between waste management and regional resilience is also explained by [18] which recommends the application of an ecosystem-based approach in regional development planning. By involving various ecosystem elements in waste management, regions can be more resilient to climate change and disaster risks. Therefore, resilience to climate change is also an integral part of regional resilience theory. According to the IPCC (Intergovernmental Panel on Climate Change) [27], Regions that prepare and adapt to the impacts of climate change, such as floods and droughts, show better capacity in resource management. Integrating climate change issues into waste management strategies is an important step to support regional resilience.

The theory of sustainable development is a relevant basis. This theory [31], [32] emphasizes the importance of balance between economic growth, social justice, and environmental protection. Sustainable development encourages the integration of social, economic, and environmental aspects. According to [28] Sustainable Development Goals (SDGs) adopted by the UN, targets related to clean water and sanitation management are part of the main objectives. Research [33] emphasized that waste management that is consistent with the principles of SDGs can encourage sustainable development in the region. Then, [4] underlined the importance of sustainable waste management in achieving the Sustainable Development Goals (SDGs) in various countries, and emphasized that good waste management does not only target the waste produced, but also the consumption patterns of the community which need to be oriented towards sustainability, thus requiring integration between social, economic and environmental issues.

Sustainable development integrates three main pillars, namely 1) the social pillar related to community welfare, poverty reduction, access to education, and health. According to [23]

sustainable development must prioritize improving the capabilities and welfare of individuals and communities; 2) economic pillars that emphasize sustainable and inclusive economic growth. [13] argues that growth is not only measured from the economic aspect alone, but must also consider income distribution and quality of life; 3) environmental pillars that refer to the protection and maintenance of natural resources and ecosystems. In the report of the World Commission on Environment and Development [34], It is stated that environmental sustainability must be considered so that resources can still be used in the long term. Thus, the theory of sustainable development includes various approaches in planning and implementing development. According to [1], [35], The main thing that distinguishes sustainable development from other concepts is the recognition of the interconnectedness of the various dimensions of development and the importance of addressing the complex challenges faced today. In this context, sustainable management of natural resources becomes an integral part of development strategies. Although much progress has been made, challenges in implementing sustainable development remain. According to [3], [36] resource constraints, unequal distribution of wealth, and climate change are some of the major challenges that must be faced. Therefore, a holistic approach involving all stakeholders is needed to address these issues effectively. The application of sustainable development theory in Deli Serdang Regency can be seen in local programs involving integrated waste management, community education, and strengthening regional capacity. According to research by [11], [28] the implementation of sustainability-based measures in local resource management can bring significant economic and environmental benefits. This study shows that there is an increasing public awareness of the importance of maintaining a clean and healthy environment, which is the basis for achieving a healthy area.

A healthy and waste-free area is one of the important indicators in creating a sustainable and competitive environment. In the context of regional development planning, this concept requires integration of various dimensions, such as social, economic, and environmental. A healthy area is defined as an environment that is not only free from pollution and waste, but also supports a good quality of life for its residents. According to [37] Healthy areas must have adequate infrastructure, access to health services, and green open spaces. Meanwhile, being free of waste involves effective and sustainable waste management and active community participation. According to [38] Policies that pay attention to health in regional planning have been shown to reduce the burden of disease and improve quality of life. This study shows that the existence of good public areas and access to health facilities contribute to the formation of healthy areas. [39] emphasizes the need to pay attention to waste flow paths in the RTRW so that waste management can be carried out efficiently. This approach ensures that residential, commercial, and industrial areas have an integrated management system, so that environmental cleanliness and health are maintained. Thus, in realizing a healthy and waste-free area, the Regional Spatial Plan (RTRW) is very important to integrate waste management into development planning.

Here, waste management becomes an integral part of the development strategy. Lehtonen recommends the application of circular economy principles in regional planning to create a minimum impact on the environment. Environmental policies that encourage sustainable waste management should be part of regional development planning. Research [40] shows that areas that implement waste reduction and recycling policies have a positive impact on environmental quality and public health. Thus, health-based regional planning focuses on creating an environment that supports the physical and mental health of residents, as every development plan must consider waste management aspects to ensure a healthy area.

Framework of Thinking

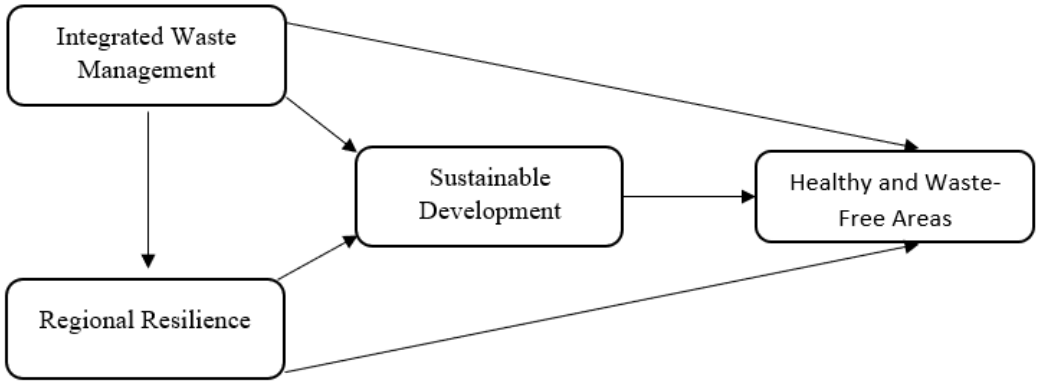

Fig 2 Framework of Thinking

The image explains that the concept of integrated waste management shows that a good waste management system is the basis for the next process in regional resilience. [3] Integrated waste management covers various aspects, such as: a) Reducing waste from its source (reduce); b) Reusing items that are still suitable (reuse); c) Recycling waste for reuse (recycle); d) Processing organic waste into compost or biogas, and; e) Managing remaining waste with environmentally friendly technology. Integrated waste management towards regional resilience shows that a good waste management system can increase the resilience of a region to various environmental and social threats. [41] Some of the positive impacts are a) Environmental resilience can reduce soil, water, and air pollution due to poorly managed waste; b) Economic resilience Creates jobs through waste banks, recycling industries, and waste-based innovations; c) Social resilience can increase public awareness in maintaining environmental cleanliness, reduce health risks due to waste, and strengthen social cohesion through active participation in waste management programs. Regional resilience is very important because it determines how well a region can survive and adapt to various challenges, including environmental disasters that are often associated with waste and climate change.

[42] Sustainable development is the middle point that connects integrated waste management and regional resilience with the ultimate goal, namely a healthy and waste-free area. Sustainable development in this context includes various aspects, such as a) Environmental aspects, namely sustainable waste management to maintain ecosystem balance; b) Social aspects, namely education and community involvement in waste management programs; c) Economic aspects, namely encouraging innovation in waste-based industries and creating a circular economy. By applying the principles of sustainable development, waste management does not only focus on waste disposal, but also on long-term benefits for the community and the environment. Sustainable development will lead the region towards a healthy and waste-free area. This reflects the ultimate vision of waste management research and implementation. Indicators of success include a) Increased environmental cleanliness; b) Reduced volume of waste ending up in

landfills; c) Improved public health due to a cleaner environment, and; d) Creation of a circular economy from waste management. With an effective waste management system, the region can be free from waste problems that have a negative impact on the environment and public health. This framework illustrates how integrated waste management is key to increasing regional resilience, which ultimately supports sustainable development to create a healthy and waste-free area. With a systematic approach based on the environment, society and economy, the region can address waste problems sustainably and improve the quality of life of the community.

Hypothesis

Hypothesis [43] is a temporary statement that is submitted to be tested in a study. The hypothesis functions as an initial answer to the research problem that will be confirmed through data collection and analysis. Hypothesis can also be interpreted as a logical prediction or assumption based on existing theories and observations. So, the hypothesis in this study is:

a. Integrated Waste Management Towards Healthy and Waste-Free Areas
b. Regional Resilience to Healthy and Waste-Free Areas
c. Integrated Waste Management to Sustainable Development
d. Regional Resilience to Sustainable Development
e. Integrated Waste Management to Regional Resilience
f. Sustainable Development to Healthy and Waste-Free Areas
g. Integrated Waste Management to Healthy and Waste-Free Areas through Sustainable Development
h. Regional Resilience to Healthy and Waste-Free Areas through Sustainable Development

Methodology

The research method used in this study is a combined research, namely between qualitative and quantitative or what is also called a combined research between the two methods. Mixed-method research, [43] is mixed or combination research is a research approach that combines qualitative research with quantitative research.[44] This approach was chosen to gain a more comprehensive understanding of integrated waste management as regional resilience in Deli Serdang, Indonesia. By utilizing both methods, this study will not only provide measurable numerical data, but also analyze the deeper social and contextual aspects of the problems faced. [45] Data collection conducted in this study was carried out by: a) survey through the distribution of questionnaires. The aim is to determine the level of knowledge, attitudes and behavior of the community towards waste management. The questionnaire will be designed using a Likert scale to measure the perception and level of community participation in the waste management program. b) in-depth interviews conducted with various stakeholders including local government officials, waste program management, and the community. A semi-structured approach will be used to provide flexibility in developing questions and digging deeper into information about their perceptions of waste management and the challenges faced. c) Focus Group Discussion (FGD), which is conducted with community groups who have direct experience in waste management. This discussion aims to explore the community's perspective on existing regulations and how they

contribute to the waste management program. d) documentation studies supported by planning documents, policies on waste management in Deli Serdang will be obtained from relevant government agencies, such as the Environmental Service.

The quantitative analysis used is Smart PLS software which is run using computer media. [46] that PLS (Partial Least Square) is a structural equation analysis (SEM) based on variance that can simultaneously test measurement models and structural models. Measurement models are used for validity and reliability tests, while structural models are used for causality tests (hypothesis testing with prediction models). SEM has been widely known in business research under various names: causal modeling, causal analysis, or confirmatory factor analysis. Furthermore, [47] explains that PLS is a soft modeling analysis method because it does not assume that data must be measured on a certain scale, which means that the number of samples can be small (under 100 samples). There are several reasons why PLS is used in a study. In this study, these reasons are: first, PLS (Partial Least Square) is a data analysis method based on the assumption that the sample does not have to be large, namely that the number of samples less than 100 can be analyzed, and residual distribution. Second, PLS (Partial Least Square) can be used to analyze theories that are still considered weak, because PLS (Partial Least Square) can be used for prediction. Third, PLS (Partial Least Square) allows logarithms using ordinary least square (OLS) series analysis so that logarithm calculation efficiency is obtained. Fourth, in the PLS approach, it is assumed that all variance measures can be used to explain the strengthening of public value.

Next, qualitative analysis is conducted on the results of interviews, observations, and secondary data collection. Furthermore, emphasis is placed on the meaning of data with qualitative descriptive analysis through three related processes as stated by Lan Dey [48] describe the phenomenon, clarify it, and see how the concepts that emerge are related to each other which produces an overall conclusion. To show that the three are related to each other. Then, this qualitative data analysis also uses:

a. Thematic analysis, namely the researcher will identify themes or patterns from interview and focus group data. The data that has been collected will be analyzed qualitatively by classifying information based on relevant categories, such as access to resources, community support, and policy impacts.

b. Data triangulation, namely to increase the validity of research results. This involves comparing information from various data sources (interviews, FGDs, observations, and documents) to find consistency or significant differences.

Results

The results of this study present empirical findings on healthy and waste-free areas: integrated waste management, regional resilience through sustainable development in Deli Serdang Regency. Quantitative analysis was conducted based on data collected through surveys, field measurements, and statistical processing using regression analysis techniques and correlation tests. In this section, the results of data processing are presented that reflect the relationship between integrated waste management variables, regional resilience, and sustainable development in realizing healthy and waste-free areas. The findings of this study not only reveal patterns and trends that occur in the field, but also provide statistical evidence that can be used as a basis for formulating more effective waste management policies at the regional level. The

results of descriptive and inferential analysis will be explained systematically to identify the extent to which the implementation of integrated waste management has an impact on regional resilience and its role in supporting sustainable development in Deli Serdang Regency. The following is a presentation of the research results based on the variables studied.

Tabel 1 Number of Respondents

	18-27	82	82%
	28-37	13	13%
age	38-47	3	3%
	48-57	2	2%
gender	male	38	38%
	female	62	62%
	SMA Sederajat	15	15%
	D3	8	8%
	D4	1	1%
education	S1	75	75%
	S2	1	1%
	S3	0	0%
	5 - 10 year	91	91%
	10 - 15 year	3	3%
years of service	15 - 20 year	4	4%
	25 - 30 year	0	0%
	> 30 year	2	2%
	marry	24	24%
marital status	Not married yet	76	76%
	divorced	0	0%

Source: Data Processing, 2025

Based on the demographic data of the respondents, the majority are in the age range of 18–27 years (82%), female (62%), and have a bachelor's degree (75%). Most respondents have worked for 5–10 years (91%) and are unmarried (76%). This shows that the respondents are dominated by the younger generation who are relatively new to the workforce, highly educated, and the majority do not yet have family responsibilities. Based on the demographic data of the respondents, the majority are in the age range of 18–27 years (82%), female (62%), and have a bachelor's degree (75%). Most respondents have worked for 5–10 years (91%) and are unmarried (76%). This shows that the respondents are dominated by the younger generation who are relatively new to the workforce, highly educated, and the majority do not yet have family responsibilities.

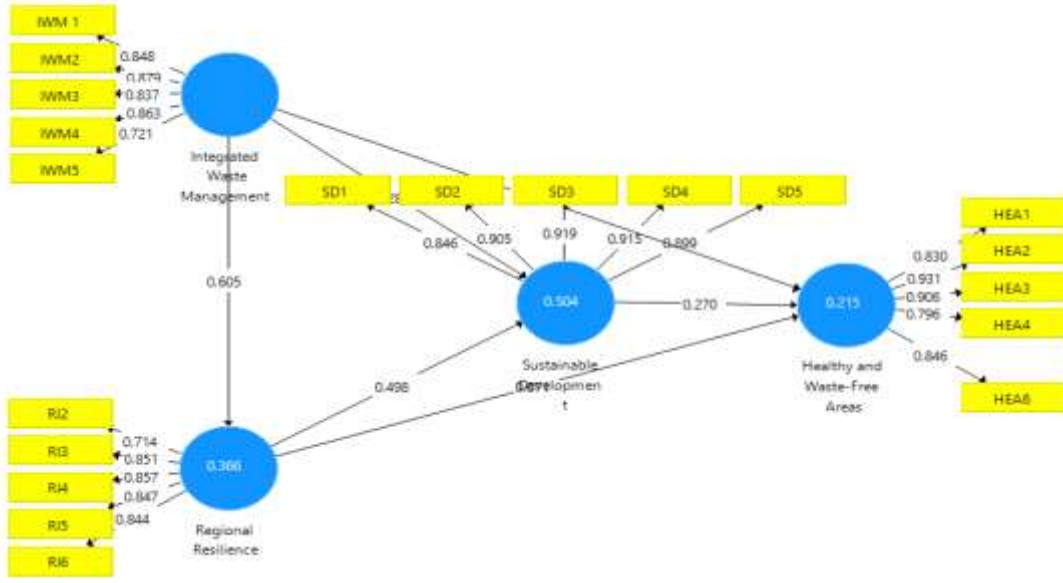

Fig 3 Results of the algorithm

The figure above shows the structural model of the SEM-PLS algorithm results that describe the relationship between latent variables along with the outer loading value and R-square value. Each indicator has an outer loading >0.7, indicating good indicator validity for its respective constructs. The R-square value for the Sustainable Development construct of 0.504 indicates that 50.4% of its variance can be explained by Integrated Waste Management and Regional Resilience. Meanwhile, the Healthy and Waste-Free Areas construct has an R-square of 0.215, meaning that only 21.5% of its variance is explained by other variables in the model. The relationship between constructs such as Integrated Waste Management → Regional Resilience (0.605) and Regional Resilience → Sustainable Development (0.498) shows a strong positive relationship. However, the path from Integrated Waste Management directly to Healthy and Waste-Free Areas shows a negative relationship (-0.390) which requires further attention. This model as a whole provides an illustration that although there is a significant relationship between several constructs, the influence on healthy and waste-free areas is still weak and complex..

Table 2 Author Loading Results

construk	indicator	outer loading	CA	(ro_a)	AVE
	HEA1	**0,830**			
	HEA2	**0,931**			
healthy and waste-free areas	**HEA3**	**0,906**	0,887	0,894	0,692
	HEA4	**0,796**			
	HEA6	**0,846**			
	IWM 1	**0,848**			

	IWM2	**0,879**			
integrated waste management	**IWM3**	**0,837**	**0,883**	**0,903**	**0,680**
	IWM4	**0,863**			
	IWM5	**0,721**			
	RI2	**0,714**			
	RI3	**0,851**			
regional resilience	**RI4**	**0,857**	**0,939**	**0,941**	**0,805**
	RI5	**0,847**			
	RI6	**0,844**			
	SD1	**0,846**			
	SD2	**0,905**			
Sustainable Development	**SD3**	**0,919**	**0,914**	**0,936**	**0,745**
	SD4	**0,915**			
	SD5	**0,899**			

Source: Data Processing, 2025

The outer loading value shows the contribution of the indicator to the construct being measured. In these results, all indicators have values above 0.7, which means they are convergently valid, indicating that each indicator is able to explain its construct well. Values such as HEA2 (0.931), SD3 (0.919), and RI4 (0.857) indicate the very high strength of the indicator in representing its construct. The CA and rho_A values are used to measure the reliability of the construct. All constructs in this model have CA and rho_A values above 0.8, which indicates very good internal consistency. For example, the construct "regional resilience" has a CA of 0.939 and a rho_A of 0.941, indicating that the indicators are very reliable in measuring the construct. AVE measures convergent validity, namely how much of the indicator's variance can be explained by its construct. All constructs have an AVE above the threshold of 0.5, which means they are convergently valid. The highest AVE value is found in the "regional resilience" construct (0.805), indicating that most of the indicator variance is explained by this construct.

Integrated Waste Management → Healthy and Waste-Free Areas

The results show a significant negative effect with a coefficient value of -0.390 and a p value of 0.001 (<0.05), which means the hypothesis is supported. This shows that integrated waste management actually has a negative relationship to healthy and waste-free areas. This could indicate that the waste management approach implemented is not yet effective or has not been able to encourage the creation of a truly healthy environment.

Integrated Waste Management → Regional Resilience

There is a significant positive effect (0.605; p = 0.000), indicating that integrated waste management is able to strengthen regional resilience. This means that a good waste management strategy contributes to regional resilience in facing environmental and social challenges.

Integrated Waste Management → Sustainable Development

This relationship is also significantly positive (0.589; p = 0.000), indicating that integrated waste management contributes greatly to sustainable development. Efficient and targeted management is the key to achieving environmental, social, and economic sustainability.

Regional Resilience → Healthy and Waste-Free Areas

This relationship is not significant (0.206; p = 0.100), so the hypothesis is not supported. This means that regional resilience is not strong enough to influence the creation of healthy and waste-free areas. This could be due to the fact that aspects of regional resilience have not been integrated with environmental policies or implementations directly..

Regional Resilience → Sustainable Development

There is a positive and significant influence (0.498; p = 0.000), which indicates that a resilient region is able to encourage sustainable development. This reflects that the social, economic, and ecological resilience of a region supports the creation of sustainable development.

Sustainable Development → Healthy and Waste-Free Areas

This relationship is not statistically significant (0.270; p = 0.055), although it is close to the threshold of 0.05. This means that sustainable development has not directly created healthy and waste-free areas, perhaps because the implementation of sustainability aspects is not yet evenly distributed or is still in the early stages.

Integrated Waste Management → Sustainable Development → Healthy and Waste-Free Areas (Indirect)

The insignificant effect (0.078; p = 0.235), indicates that sustainable development does not significantly mediate the relationship between waste management and healthy areas. This could be caused by the suboptimal integration between waste management programs and sustainability goals in the field.

Regional Resilience → Sustainable Development → Healthy and Waste-Free Areas (Indirect)

This relationship is also not significant (0.135; p = 0.072), so it is not supported. Although there is a positive tendency, it is not strong enough to prove that sustainable development mediates the relationship between regional resilience and healthy areas. This could indicate that the contribution of regional resilience to healthy areas has not been consistently supported by sustainable development policies.

Research on integrated waste management and regional resilience through sustainable development in Deli Serdang Regency is essential to achieving the goal of a healthy and waste-free area. By integrating various effective approaches and strategies, Deli Serdang can overcome the challenges of existing waste management and become a role model for other regions in Indonesia. One of the main findings of this study is the varying levels of public awareness regarding the importance of a healthy and waste-free area. Many respondents said that they were aware of the negative impacts of waste accumulation, such as environmental pollution and health problems. However, there are also groups of people who do not understand this concept and its impact on daily life. This indicates the need for more intensive education and socialization

programs to increase public awareness and understanding of the importance of good waste management and its impact on health and the environment. Integrated waste management in Deli Serdang Regency still faces challenges. Many respondents complained about the lack of adequate waste management facilities, such as scattered public waste bins and irregular transportation systems. Although several initiatives, such as the management of Waste Banks, have been implemented, their effectiveness is still limited due to the lack of community participation in waste sorting at the source. The results of the analysis indicate a need to strengthen the integrated management system between the government, community, and private sector, including improving supporting facilities and infrastructure. The results also show that the role of local government is very important in encouraging the creation of healthy and waste-free areas. Respondents expressed the hope that the government would be more active in socializing and implementing policies that support waste management. Initiatives taken by the government, such as cleanliness programs, community trash bins, and waste management training, already exist but need to be improved. The role of supervision is also very much needed to ensure that the policies implemented can run effectively as expected. The level of community involvement in the waste management process varies. Several communities have partnered with the government in waste management through community activities such as "gotong royong" or environmental cleanliness programs. However, there are still many residents who are not actively involved in these activities. Community involvement can be improved through better outreach, where information about the benefits of participating in waste management can be conveyed more clearly. Research shows that when communities feel ownership of their environment, commitment to waste management practices will increase. Innovation and technology are the next important themes in waste management in Deli Serdang. This study found that information technology and mobile-based applications have not been optimally utilized to address waste management issues. The public, especially the younger generation, are potentially vulnerable to various applications that emphasize waste management and sorting at the source. Through applications that provide information and education about waste management, the government can increase public participation and reward those who behave well in waste management.

Various challenges and obstacles in achieving a healthy and waste-free area in Deli Serdang Regency continue to emerge from the results of thematic analysis. One of them is the lack of adequate budget for the management of waste infrastructure and facilities. In addition, the unclear organizational structure in waste management, as well as cultural challenges in the bad habits of the community in littering, are major obstacles. This shows the need for collaborative efforts between all stakeholders to create a culture of cleanliness and shared responsibility for the environment. The results of the study show that in order to create a healthy and waste-free area, it is important to adopt a sustainable development approach. Respondents said that waste management must be part of a broader development plan, covering social, economic, and environmental aspects. This means that the policies taken must be able to balance economic development with environmental preservation and improving the quality of life of the community. From the results of this study, it can be concluded that there is a lot of potential in creating a healthy and waste-free area in Deli Serdang Regency, but the challenges are also quite significant. For this reason, it is recommended that the local government together with the community actively collaborate in developing more targeted strategies and strengthening integrated waste management based on education and technology. In addition, it is important to strengthen existing regulations and create an incentive system that encourages community

participation in waste management. Through these steps, it is hoped that the vision of achieving Deli Serdang Regency as a healthy and waste-free area can be realized, while supporting regional resilience through sustainable development.

Discussion

Research on integrated waste management in Deli Serdang Regency, which aims to create a healthy and waste-free area, provides significant contributions to understanding the relationship between waste management, regional resilience, and sustainable development. The results of this study are not only locally relevant, but also provide implications for other regions facing similar challenges in waste management. Thus, integrated waste management is an approach that involves various elements in waste management, from reduction, sorting, collection, transportation, to final processing. This approach is very important in the context of Deli Serdang, where the diversity of waste types requires different strategies for handling them. For example, the Waste Reduction at Source (PPS) Program introduced by the Ministry of Environment and Forestry (KLHK) can be adapted in Deli Serdang. This program aims to educate the public about the importance of minimizing the use of single-use plastics and increase public awareness in managing waste at the household level. Furthermore, proper waste sorting can create opportunities for recycling, thereby reducing the burden of waste disposal to the final disposal site (TPA).

Based on KLHK data, only about 10% of total waste is processed into recycled materials. With better management, this figure can increase and provide economic benefits to the community. Integrated waste management in Deli Serdang Regency still faces various challenges, such as low community participation, limited infrastructure, and lack of coordination between stakeholders. This finding is in line with previous research conducted by [49] in West Java, which highlighted that community participation and environmental awareness are key factors in successful waste management. However, the study in Deli Serdang adds a new dimension by emphasizing the importance of integration between waste management and sustainable development to improve regional resilience. In addition, this study also revealed that an integrated approach involving government, private sector, and community can improve the effectiveness of waste management. This is different from previous research by [1] in Yogyakarta, which focuses more on the role of government and technology in waste management. Research in Deli Serdang shows that multi-party collaboration not only increases the efficiency of waste management, but also creates synergy to achieve sustainable development goals. Then, [9], [17] waste management in various countries also faces the challenge of waste management through the implementation of a circular economy, as done by Sweden. This country turns waste into an energy source through the incineration process. Almost 99% of waste in Sweden is recycled or converted into energy, and only 1% ends up in landfills. Sweden even imports waste from other countries to meet their incinerator needs, because waste is used as an energy source. Meanwhile, in Deli Serdang, this potential has not been fully explored. Apart from Sweden, [50] Several European countries also implement the Extended Producer Responsibility (EPR) system, where producers are responsible for waste management from their products, including Germany. The implementation of this system is supported by strict and clear regulations and also a very high level of public awareness, so that integrated waste management can be maximized as regional resilience.

Regional resilience refers to the ability of a region to face various challenges, including

environmental problems caused by poor waste management. Regional resilience includes the ability of a region to face various challenges, whether environmental, social, or economic. The relationship between waste management and regional resilience through a sustainable development approach, supports each other. As the results of research from [21] found that community-based waste management can improve environmental and social resilience. However, the research in Deli Serdang went further by developing a model that is not only community-based, but also involves government and private sector in a sustainable development framework. Then, [17] emphasizes the importance of technology in waste management, such as the use of incinerators and automated recycling systems. Although technology plays an important role, the Deli Serdang study shows that technology must be balanced with community participation and supportive policies. This confirms that there is no one-size-fits-all solution to waste management, and approaches must be tailored to the local context.

This research also contributes to regional development planning, namely 1) the integrated waste management model produced can be a reference for local governments in formulating waste management policies and programs; 2) this study highlights the importance of a holistic approach involving all stakeholders, so that it can be a model for other regions facing similar challenges and also has implications for sustainable development. By integrating waste management into development planning, regions can achieve sustainable development goals (SDGs), especially goals 11 (sustainable cities and communities) and 12 (responsible consumption and production). This study shows that effective waste management can contribute to regional resilience by reducing the risk of environmental disasters, such as flooding and water pollution. Based on the research findings, several policy recommendations can be put forward. 1) local governments need to increase investment in waste management infrastructure, including the construction of TPST and recycling facilities; 2) education and socialization programs must be strengthened to increase public awareness of the importance of waste management; 3) supporting regulations and policies need to be strengthened, including incentives for the community and private sector participating in waste management programs. In addition, it can also provide recommendations related to the integration of waste management into regional development planning. This can be done by including waste management indicators in regional planning documents, such as the Regional Medium-Term Development Plan (RPJMD). Thus, waste management is not only seen as an environmental issue, but also as an integral part of sustainable development. By implementing the recommendations from this study, regions can create healthy and waste-free areas that support sustainable development and regional resilience.

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