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Utilization of GIS for Determining Ideal Temporary Waste Collection Point (TPS) Locations in Yogyakarta City

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Abstract

Rapid population growth and dynamic urban economic activity directly correlate with an increase in waste generation, a global phenomenon also faced by Yogyakarta City. As a dynamic cultural, educational, and tourism hub, Yogyakarta City confronts significant challenges in formulating and implementing effective and sustainable waste management systems. If not handled optimally, waste accumulation not only degrades the city's aesthetics and creates an uncomfortable environment but also potentially triggers various public health issues, widespread environmental pollution (encompassing soil, water, and air), and significantly diminishes the quality of life for its residents. Within the complex waste management chain, the strategic determination of Temporary Waste Collection Points (TPS) locations constitutes a crucial element. TPS serve as vital transition points where waste is temporarily gathered before being transported to the Final Processing Site (TPA). However, the improper placement of TPS thus far has frequently been a primary source of public complaints due to odor emissions, visual blight, and the risk of disease vector propagation. Conventional approaches to TPS site selection, typically based on practical considerations without comprehensive spatial analysis, tend to overlook various geographical, social, and environmental factors holistically. Objective criteria such as optimal distance from waste generation sources, adequate accessibility for waste transport vehicles, population density in surrounding areas, and the presence of sensitive public facilities (e.g., schools or hospitals) are often neglected. Consequently, instead of providing effective solutions, many TPS have inadvertently created new environmental and social problems. Addressing this challenge, Geographic Information Systems (GIS) emerge as an innovative and effective solution. GIS technology possesses superior capabilities to integrate, store, analyze, and visualize spatial data along with its attributes with high accuracy. Utilizing GIS enables the identification of the most suitable locations for TPS by simultaneously considering various multi-interpretive criteria, a capability difficult to achieve with manual methods. Through careful spatial analysis, GIS can not only assist in mapping waste distribution and modeling efficient transport routes but also allow for land suitability assessment based on specific local regulations and preferences. Therefore, this research aims to explore and implement the utilization of GIS in the process of determining ideal waste TPS locations in Yogyakarta City. Through a systematic GIS-based approach, by applying analysis techniques such as overlay, buffering, and weighted overlay, and by considering comprehensive criteria (i.e., minimum distance from residential areas, road accessibility, safe distance from water sources, stable land conditions, as well as capacity and management aspects), it is expected to identify optimal potential locations. These locations are projected to meet environmental, social, economic, and technical criteria, and align with local regulations such as Yogyakarta City Regional Regulation Number 10 Year 2012 and Number 1 Year 2022 concerning Waste Management (PERDA). Thus, this research aspires to contribute to the creation of a more efficient, sustainable waste management system that minimizes negative environmental impacts and enhances the overall quality of life for the residents of Yogyakarta City.

Keywords: *GIS, TPA, TPS, Public facilities, PERDA*

1. Introduction

Rapid urban population growth and economic activity directly correlate with an increase in waste generation volume. Yogyakarta City, as a dynamic cultural and tourism center, faces significant challenges in effective waste management. Suboptimal waste management systems not only negatively impact urban aesthetics but also potentially trigger public health issues, environmental pollution (soil, water, and air), and a decline in quality of life[1][2]. A crucial element in the complex waste management chain is the strategic determination of Temporary Waste Collection Point (TPS) locations[3][4]. TPS serve as vital transition points before waste is transported to the Final Processing Site (TPA). Inappropriate TPS placement frequently becomes a primary source of public complaints due to odor emissions, visual nuisance, and the potential for disease vector propagation.
Currently, TPS location determination is often based on practical considerations without comprehensive spatial analysis, thereby inadequately considering geographical, social, and environmental factors holistically. This conventional approach tends to disregard objective criteria such as optimal distance from waste generation sources, adequate accessibility for transport vehicles, population density, and the presence of sensitive public facilities like schools or hospitals[5][6]. Consequently, many TPS inadvertently create new environmental and social problems rather than serving as effective solutions.

In line with advancements in information technology, Geographic Information Systems (GIS) offer an innovative solution to address this issue. GIS possesses the capability to integrate, store, analyze, and visualize spatial data along with its attributes. The utilization of GIS enables the identification of the most suitable locations by simultaneously considering various multi-interpretive criteria[7]. Through meticulous spatial analysis, GIS can assist in mapping waste distribution, modeling transport routes, and assessing land suitability based on regulations and local preferences.

Therefore, this research aims to explore and implement the utilization of GIS in determining ideal waste TPS locations in Yogyakarta City. Through a GIS-based approach, it is expected to identify potential locations that meet environmental, social, economic, and technical criteria, thereby supporting the creation of a more efficient, sustainable waste management system that minimizes negative impacts on the environment and society[8].

2. Research Method

Spatial Data Collection The initial phase of the research involves collecting various relevant spatial data for site analysis. This data will form the foundation for modeling and assessing land suitability. Road Network Map, This data is crucial for analyzing the accessibility of TPS locations. Road quality and width will be considered to ensure smooth operation for waste transport vehicles. Population Density Map: Population density information will be used as an indicator of waste generation sources and to prevent TPS placement in highly dense areas that could cause social disruption.

Land Use Map: This data is essential for identifying current land use classifications, such as residential, industrial areas, green open spaces, and conservation areas. This is important to ensure that TPS locations do not violate land designations or create conflicts with other land functions. Utilization of Geographic Information Systems (GIS) All collected spatial data will be processed and analyzed using GIS software[9][10]. The spatial analysis techniques to be applied include: Overlay, This technique is used to combine multiple spatial data layers into a single new layer, allowing for the simultaneous identification of areas that meet various criteria[11][12]. For example, an overlay between a road network map and a land use map can identify residential areas with good road access.

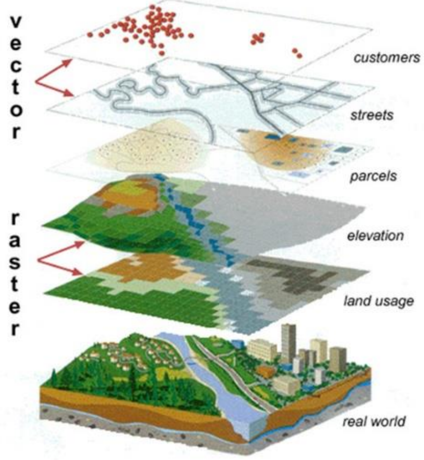

Fig. 1: overlay

Buffering, This operation will be applied to create buffer zones around specific spatial objects. For instance, buffering around residential areas to determine the minimum distance of TPS from residential zones, or buffering around conservation areas to avoid placing TPS in restricted areas.

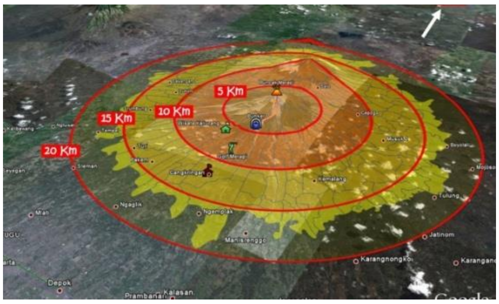

Fig. 2: buffering

Weighted Overlay: This is an advanced spatial analysis technique that allows for the determination of weights (importance values) for each criterion. Each spatial data layer will be assigned a weight based on its significance in determining the TPS location. Thus, locations with the highest total score from all weighted criteria will be considered the most ideal.

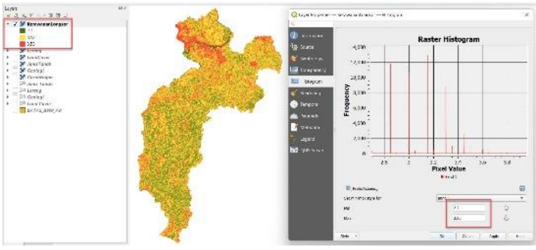

Fig. 3: weighted overlay

Criteria for Ideal TPS Locations in Yogyakarta Based on case studies and existing regulations, the determination of ideal TPS locations considers several key criteria to ensure effectiveness, sustainability, and minimization of environmental impact. Distance Criteria: Distance is one of the most important factors for minimizing negative impacts and ensuring accessibility.Distance from Residential Areas: Ideally, a TPS should be at least 50 meters from residential areas. This aims to minimize disturbances such as odor, flies, and the potential spread of diseases[13][14]. Distance from Roads: TPS locations must be close to main roads to facilitate accessibility for waste transport vehicles. The ideal distance is within a 50-meter buffer from the road network. This ensures efficient waste transfer to transport trucks[15].

Distance from Rivers/Irrigation Canals: TPS must be outside a 30-meter buffer zone from rivers or irrigation canals. This is crucial to prevent water pollution by leachate from waste, which can damage aquatic ecosystems[16]. Distance from Public Facilities: Based on general criteria for TPA (Final Processing Site), ideal locations should not be near airports (more than 3,000 meters for jet aircraft) and should not be in flood-prone areas with a 25-year return period[17]. Although these criteria are more often applied to TPA, the principle is relevant for TPS to avoid disturbing public facilities and ensure safety from disasters. Land and Soil Condition Criteria: The size and physical condition of the land significantly influence TPS operations. Land Area: According to Permen PU No. 3 Tahun 2013, the ideal TPS land area should be 200 m². However, for TPS 3R (Reduce, Reuse, Recycle), the area can be larger, ranging from 200-500 m² for an RW scale (200 households) and 1,000 m² for new residential areas (serving 2,000 households).

Soil Condition: TPS locations must be on high ground and not prone to flooding. This prevents waste from being carried away by floods and polluting the surrounding environment[18]. Capacity and Management Criteria: An ideal TPS must be able to accommodate waste volume and be well-managed[19]. Capacity: An ideal TPS must have sufficient capacity to accommodate the daily waste volume from its service area. Research indicates waste accumulation at several TPS in Yogyakarta due to imbalanced capacity with incoming waste volume, even though theoretically the TPS volume is sufficient. This points to operational management issues.

Institutional Framework: The presence of a clear managing institution, such as Community Self-Help Groups (KSM) for TPS 3R, is crucial for operational sustainability. Good management also encompasses technical aspects, funding, and community participation. Facilities: An ideal TPS 3R should be equipped with a sorting area, organic waste composting facility, warehouse, and a buffer zone[8]. Yogyakarta City Regional Regulation (Perda) Number 10 Year 2012 concerning Waste Management, subsequently amended by Perda Kota Yogyakarta Number 1 Year 2022, serves as the primary legal basis. Although it does not specifically detail technical TPS location criteria such as distance and land area, this Perda regulates the following: Waste Management Obligation: Every person is obliged to manage household waste in an environmentally sound manner, including waste sorting. Prohibitions: The public is prohibited from mixing waste, managing waste that causes pollution, and openly disposing of waste at the final processing site. Processing at TPS: This Perda encourages waste sorting at the source. If not done at the source, sorting must be performed at TPS 3R or TPST. Yogyakarta Governor Regulation (Pergub) DIY Number 16 Year 2021 and Pergub DIY Number 21 Year 2014 also regulate waste management policies and strategies at the provincial level. The latest Circular Letter (SE) from the Yogyakarta City Government also emphasizes the importance of waste sorting at the source and the schedule for residue delivery to TPS/Depo.

3. Results and Discussion

Limitations of Conventional Approaches in TPS Location Determination The determination of Temporary Waste Collection Point (TPS) locations in Yogyakarta City has traditionally often been based solely on practical considerations, without involving comprehensive spatial analysis. This approach tends to overlook geographical, social, and environmental factors holistically, including optimal distance from waste sources, accessibility for transport vehicles, population density, and the presence of sensitive public facilities like schools or hospitals. Consequently, many TPS inadvertently create new problems, such as unpleasant odors, visual nuisances, and the potential for disease vector propagation, rather than serving as effective solutions for waste management.

Role of Geographic Information Systems (GIS) in Optimizing TPS Location Determination Advancements in information technology, particularly Geographic Information Systems (GIS), offer an innovative solution to overcome the limitations of conventional approaches. GIS possesses the capability to integrate, store, analyze, and visualize spatial data along with its attributes. The utilization of GIS enables the identification of the most suitable locations by simultaneously considering various multi-interpretive criteria. Through meticulous spatial analysis, GIS can support waste distribution mapping, transport route modeling, and land suitability assessment based on regulations and local preferences. This research specifically applies GIS techniques such as Overlay (Superimposition) to combine multiple spatial data layers; Buffering (Buffer Zone) to determine minimum or maximum distances from spatial objects; and Weighted Overlay (Weighted Superimposition) to assign importance values to each criterion, so that locations with the highest total score will be considered most ideal. Implementation of Ideal TPS Location Criteria in GIS Analysis The implementation of GIS in determining ideal TPS locations in Yogyakarta City is carried out by referring to a series of criteria identified from case studies and existing regulations. These criteria are grouped into distance, land and soil condition, and capacity and management criteria.

Distance Criteria Distance criteria are highly important for minimizing negative impacts and ensuring accessibility. Distance from Residential Areas: An ideal TPS should be at least 50 meters from residential areas to minimize disturbances such as odor, flies, and the potential spread of diseases. In GIS analysis, this is translated into a 50-meter buffer zone from residential areas that become restricted areas.

Distance from Roads, TPS locations must be within a 50-meter buffer from the road network to facilitate accessibility for waste transport vehicles. Road quality and width data will be considered to ensure smooth vehicle operations. Distance from Rivers/Irrigation Canals: TPS must be outside a 30-meter buffer zone from rivers or irrigation canals to prevent water pollution by leachate from waste.

Distance from Public Facilities: Referring to general criteria for TPA (Final Processing Site), ideal locations should not be near airports (more than 3,000 meters for jet aircraft) and not be in flood-prone areas with a 25-year return period. Although these criteria are primarily for TPA, the principle is relevant for TPS to avoid disturbing public facilities and ensure safety from disasters.

Land and Soil Condition Criteria, Land Area: According to Permen PU No. 3 Tahun 2013, the ideal TPS land area should be 200 m², and for TPS 3R (Reduce, Reuse, Recycle) it can be 200-500 m² (RW scale) or 1,000 m² (new residential areas). Soil Condition: TPS locations must be on high ground and not prone to flooding to prevent waste from being carried away by floods and polluting the environment. Capacity and Management Criteria, Capacity: An ideal TPS must have sufficient capacity to accommodate the daily waste volume, given the existing waste accumulation at some TPS due to capacity imbalance and waste volume

Institutional Framework: The presence of a clear managing institution, such as Community Self-Help Groups (KSM) for TPS 3R, is crucial for operational sustainability, encompassing technical aspects, funding, and community participation. Facilities: An ideal TPS 3R should be equipped with a sorting area, composting facility for organic waste, a warehouse, and a buffer zone (Source: Jurnal Kriteria Perencanaan TPS 3R from Scribd). Integration of Yogyakarta City Regional Regulations The GIS analysis in this research will be integrated with Yogyakarta City Regional Regulation (Perda) Number 10 Year 2012 concerning Waste Management, subsequently amended by Perda Kota Yogyakarta Number 1 Year 2022. Although this Perda does not specifically detail technical TPS location criteria such as distance and land area, it provides the legal framework and principles for waste management that must be adhered to. Key points from the Perda include: Waste Management Obligation: Every individual is obliged to manage household waste in an environmentally sound manner, including waste sorting. This supports the need for TPS that facilitate sorting.

Prohibitions: The public is prohibited from mixing waste, managing waste that causes pollution, and openly disposing of waste at the final processing site. This prohibition indirectly supports the placement of TPS in locations that minimize pollution risk. Processing at TPS: The Perda encourages waste sorting at the source, or if not done at the source, sorting must be performed at TPS 3R or TPST. This indicates that ideal TPS should have a sorting function or at least support further sorting processes. The interpretation of distance and land criteria from scientific journals will complement the more general substance of the Perda, providing the necessary technical guidance for practical implementation in the field.

4. Conclusion

This research underscores the urgency of strategically determining Temporary Waste Collection Point (TPS) locations in Yogyakarta City, given the negative impacts of suboptimal waste management systems on the environment and society. Conventional approaches to TPS site selection, which are less comprehensive, have proven to create new problems. Therefore, the utilization of Geographic Information Systems (GIS) emerges as an essential and innovative solution.

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