

## SERVICE RANGE OF EXISTING TEMPORARY WASTE COLLECTION SITES (TPS) IN MOJOKERTO REGENCY

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**Abstract.** Waste management in Mojokerto Regency still faces spatial service gaps because existing temporary waste collection sites (TPS) do not reach all built-up areas. This study identifies areas that remain outside the service range of existing TPS and proposes priority locations for new facilities. Using a quantitative spatial analysis, waste generation was distributed with binary dasymetric mapping and the service range of existing TPS was analysed with the Huff Gravity Model in a GIS environment. Existing TPS serve 5,303.44 ha of built-up area (5.45% of the regency), whereas 19,209.28 ha (19.73%) remain unserved. Areas with a service probability below 37% are classified as unserved and grouped into four development priorities: 0–10% (Priority 1), 10–20% (Priority 2), 20–30% (Priority 3), and 30–37% (Priority 4). Areas with a probability above 37% are considered adequately served. These findings provide a spatial basis for planning new TPS locations and improving service equity.

**Keywords:** Temporary Waste Collection Site; Service Range; Huff Gravity Model; Dasymetric Mapping; GIS

**[Judul: JANGKAUAN PELAYANAN TEMPAT PENAMPUNGAN SAMPAH SEMENTARA (TPS) EKSISTING DI KABUPATEN MOJOKERTO].** Kabupaten Mojokerto masih menghadapi kesenjangan pelayanan persampahan secara spasial karena Tempat Penampungan Sementara (TPS) eksisting belum menjangkau seluruh kawasan terbangun. Penelitian ini mengidentifikasi area yang berada di luar jangkauan pelayanan TPS eksisting dan menyusun prioritas lokasi fasilitas baru. Penelitian menggunakan pendekatan kuantitatif melalui analisis spasial. Timbulan sampah didistribusikan dengan pemetaan dasimetrik biner, sedangkan jangkauan pelayanan TPS dianalisis menggunakan Huff Gravity Model dalam lingkungan GIS. Hasil menunjukkan TPS eksisting melayani 5.303,44 ha kawasan terbangun, setara 5,45% dari total luas kabupaten. Sebaliknya, 19.209,28 ha kawasan terbangun atau 19,73% dari total luas wilayah belum terlayani. Area dengan probabilitas layanan di bawah 37% dikategorikan belum terlayani dan dibagi menjadi empat prioritas: 0–10% (Prioritas 1), 10–20% (Prioritas 2), 20–30% (Prioritas 3), dan 30–37% (Prioritas 4). Area dengan probabilitas di atas 37% dianggap terlayani memadai. Temuan ini menyediakan dasar spasial untuk menentukan lokasi TPS baru dan meningkatkan pemerataan layanan persampahan.

**Kata Kunci:** Tempat Penampungan Sampah Sementara; Jangkauan Pelayanan; Model Gravitasi Huff; Pemetaan Dasimetrik; SIG

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### 1. INTRODUCTION

Waste-related problems remain a major challenge in rapidly urbanising regions. Studies identify increasing waste generation, inadequate collection infrastructure, financial constraints, and weak coordination as recurring challenges in developing-country cities (Ferronato & Torretta, 2019; Guerrero et al., 2013; Sharholy et al., 2008). Global assessments also emphasize that improving collection and waste handling is

essential as municipal solid waste generation rises (Kaza et al., 2018; United Nations Environment Programme, 2015; United Nations Environment Programme & International Solid Waste Association, 2024). In Indonesia, waste collection and management continue to face operational and infrastructure constraints, including outside large urban centres (Budiarto et al., 2025; Damanhuri et al., 2014). Household and similar household waste management is also addressed in the national regulatory framework, while SIPSN

publishes reported waste-management performance data (Republic of Indonesia, 2024; Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, n.d.).

Previous studies emphasise that the spatial distribution of waste facilities affects the performance of municipal solid waste management. A GIS-based study in Semarang identified uneven waste collection-site density and service gaps in rural and peri-urban areas (Ramadan et al., 2024), while research in Pariaman used GIS to assess service coverage and planning needs (Bahari et al., 2025). Other studies have investigated capacitated collection-site location, household collection-network design, clustering of collection areas, and GIS-based collection-point and route optimisation (Al-Refaie et al., 2021; Blazquez & Paredes-Belmar, 2020; Cheng et al., 2024; Ghiani et al., 2012; Kwikima & Ngole, 2025; Parsons et al., 2023). Recent work further highlights the need to consider facility capacity and land-use or regulatory exclusions when siting collection points. These findings support analysing service gaps before determining new facility locations.

Dasymetric mapping can improve spatial estimates by redistributing aggregated population data using ancillary information such as settlement distribution and land cover, rather than assuming that population is evenly distributed throughout administrative areas (Eicher & Brewer, 2001; Leyk et al., 2019; Mennis, 2009; Nagle et al., 2014; Su et al., 2010). Because waste generation is associated with population size and its spatial distribution, reliable demand estimates are also important for collection planning (Beigl et al., 2008). This is relevant to waste planning because household waste generation is spatially associated with settlements.

Facility planning commonly involves balancing demand, accessibility, capacity, and geographic constraints. Network distance can differ from straight-line distance, and barriers may materially affect estimates of service coverage (Chen et al., 2021; Hong & Murray, 2020). GIS-based multicriteria analysis provides a framework for combining spatial criteria, while location-allocation studies examine how collection facilities

should be positioned in relation to demand points and operational capacity (Ghiani et al., 2012; Malczewski, 2006). This study addresses a related but distinct question by integrating settlement-based waste-generation distribution with the Huff Gravity Model to estimate the probability that each grid cell is served by existing TPS. In addition to distance, the analysis represents facility attractiveness using TPS capacity.

Mojokerto Regency has 18 sub-districts, 299 villages, and five urban villages, with a population of 1,125,522. Local reporting describes persistent illegal dumping and operational constraints in waste collection services, including limited funding for fuel, worker salaries, container maintenance, and transport equipment (Arisal, 2023; Norhadini, 2022). The uneven distribution and limited operation of existing TPS make the regency a relevant case for assessing service gaps.

This study aims to analyse the service range of existing TPS in Mojokerto Regency, identify built-up areas that remain unserved, and classify priority areas for new TPS development. The results are intended to support more targeted and equitable waste-infrastructure planning.

## 2. METHOD

This study uses a quantitative method with a spatial-analysis approach. Binary dasymetric mapping distributes waste generation spatially according to settlement areas, while the Huff Gravity Model estimates the probability that each grid cell is served by an existing TPS. The analysis comprises four main stages (Figure 1):

1. Binary dasymetric mapping to estimate the spatial distribution of waste generation;
2. Road-network distance analysis between grid cells and existing TPS;
3. Huff Gravity Model probability calculation using TPS capacity and network distance; and
4. Classification of service coverage and priority areas for planning recommendations.

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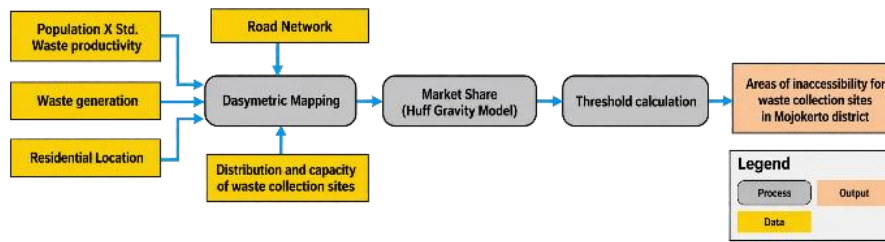


**Figure 1.** Research methodology

## 2.1. Data and Study Area

The study area covers Mojokerto Regency, East Java. The population comprises all residents of the regency, and the analytical units are 150 m × 150 m grid cells. The main datasets include administrative boundaries, village-level population, settlement distribution, road networks, existing TPS locations, and TPS capacity. TPS capacity is classified into two categories: 2,100 kg and 4,200 kg.

## 2.2. Dasymetric Mapping

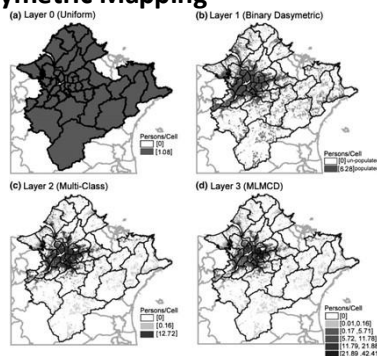


**Figure 2.** Binary Dasymetric Mapping Concept  
Sumber : Su et al. (2010)

Dasymetric mapping redistributes aggregated population data into smaller spatial units using ancillary variables such as land cover and settlement distribution (Eicher & Brewer, 2001; Mennis, 2009; Mennis & Hultgren, 2006; Su et al., 2010). This study applies a two-stage process: uniform distribution of village-level population across each village boundary, followed by binary dasymetric mapping that redistributes population and waste generation only to settlement areas. Non-settlement areas are assigned zero waste generation (Figure 2).

Waste generation is estimated using a coefficient of 0.5 kg per person per day, based on the

Mojokerto Regency Waste Management Master Plan used in this study. For grid cell  $i$ , daily waste generation is calculated as  $W_i = P_i \times 0.5$ , where  $W_i$  is daily waste generation and  $P_i$  is the population assigned to the cell. The output is a settlement-based waste-generation surface on 150 m × 150 m cells.

## 2.3. Huff Gravity Model

The Huff Gravity Model estimates the probability that waste generated in a grid cell will be served by a particular TPS. In the original model, interaction depends on the attractiveness of a destination and the distance or travel time from an origin, relative to competing destinations (Huff, 1964). Here, grid cells represent waste origins and existing TPS represent service destinations. The use of facility capacity as an attractiveness measure aligns with capacitated collection-site location approaches in urban waste-management systems (Ghiani et al., 2012).

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^\lambda}}{\sum_{k=1}^n \frac{S_k}{T_{ik}^\lambda}}$$

In this expression,  $P_{ij}$  is the probability that waste from grid cell  $i$  is served by TPS  $j$ ;  $S_j$  is the capacity or attractiveness of TPS  $j$ ;  $T_{ij}$  is the travel distance or travel time from grid cell  $i$  to TPS  $j$  through the road network;  $\lambda$  is the distance-decay parameter; and  $k$  indexes the  $n$  competing TPS destinations.

The analysis uses ArcGIS 10.8 with the Market Share module. Road-network distance represents accessibility, settlement-based waste generation represents demand, and existing TPS represent supply. The resulting probability value for each grid cell indicates its relative likelihood of being

served by an existing TPS within the model. This interpretation complements facility-location studies that balance service access and capacity constraints (Ghiani et al., 2012).

#### 2.4. Determining Served and Unserved Areas

The probability threshold was determined by comparing the capacity of existing TPS with total waste-generation demand (Table 1). The existing capacity of 117,600 kg represents approximately 21% of the total demand of 559,604 kg, so the remaining 442,004 kg (approximately 79%) cannot be accommodated by existing TPS. The threshold was then set at the probability value at which the share of grid cells classified as served approximates this capacity-to-demand ratio. As shown in Table 2, thresholds of 50%, 40%, and 37% classify 12.39%, 18.98%, and 21.24% of the 10,923 grid cells as served, respectively; the 37% threshold is the closest to the 21% capacity ratio.

**Table 1.** Comparison of Existing TPS Capacity and Waste Generation Demand

| Existing TPS capacity (kg) | Unserved waste (kg) | Total waste generation (kg) (population × 500 g) |
|----------------------------|---------------------|--------------------------------------------------|
| 117,600                    | 442,004             | 559,604                                          |
| 21%                        | 79%                 | 100%                                             |

**Table 2.** Comparison of Service Probability Thresholds

| Grid        | Probability |        |       |        |       |        |
|-------------|-------------|--------|-------|--------|-------|--------|
|             | >50%        |        | >40%  |        | >37%  |        |
| Reachable   | 1,353       | 12.39% | 2,078 | 18.98% | 2,320 | 21.24% |
| Unreachable | 9,570       | 87.61% | 8,845 | 81.02% | 8,603 | 78.76% |
| Total       | 10,923      |        |       |        |       |        |

Grid cells with a service probability above 37% are considered adequately served. Values below 37% are classified as unserved and grouped into four development priorities: 0–10% (Priority 1), 10–20% (Priority 2), 20–30% (Priority 3), and 30–37% (Priority 4). This threshold is the study-specific classification used to interpret the model outputs.

### 3. RESULTS AND DISCUSSION

#### 3.1. Distribution of Waste Generation

Binary dasymetric mapping distributes waste generation according to settlement areas (Figure

3). The resulting pattern shows higher waste generation in densely populated and urbanised settlements, while non-settlement areas are assigned zero generation. The distribution therefore follows settlement patterns rather than treating every part of each village as equally populated.

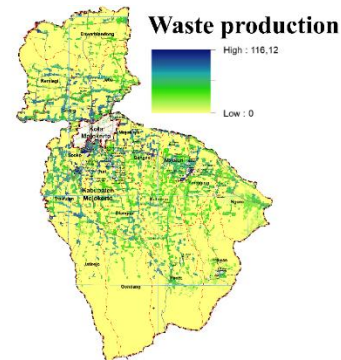


**Figure 3.** Spatial distribution of waste generation

Using settlement distribution as ancillary information reduces the risk of allocating household waste generation to non-settlement areas. Previous research on dasymetric mapping and gridded population data highlights the value of accounting for spatial heterogeneity when transferring aggregate counts to smaller analytical units (Leyk et al., 2019; Su et al., 2010).

#### 3.2. Service Range of Existing TPS

The Huff Gravity Model produces a probability value for each grid cell, representing the relative likelihood that waste generated in that cell will be served by an existing TPS. Existing TPS serve 5,303.44 ha of built-up area, equivalent to 5.45% of the regency area. Meanwhile, 19,209.28 ha of built-up area, or 19.73% of the total area, remain unserved (Figure 4).

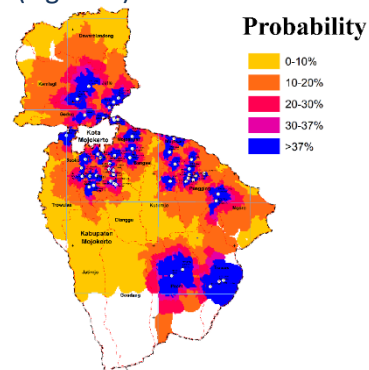


**Figure 4.** Service probability of existing TPS

In the model, the low level of coverage reflects limited TPS capacity and the spatial separation

between waste-generation areas and facilities: because probability declines with network distance, cells farther from TPS or less accessible through the road network have lower service probabilities. This pattern is consistent with GIS-based research showing that facility distribution, network design, accessibility, and capacity affect waste collection coverage and efficiency (Bahari et al., 2025; Blazquez & Paredes-Belmar, 2020; Kwikima & Ngole, 2025; Ramadan et al., 2024).

The Semarang study also reported uneven facility distribution, with rural and peri-urban areas facing service gaps (Ramadan et al., 2024). These findings support planning new TPS based on estimated waste generation, network accessibility, and existing facility capacity rather than allocating facilities only according to administrative boundaries.

### 3.3. Priority Areas for New TPS Development

The four unserved priority classes cover the following areas: Priority 1 (0–10%) covers 29,768.21 ha (35.26% of the analysed area); Priority 2 (10–20%) covers 27,516.52 ha (32.60%); Priority 3 (20–30%) covers 10,301.31 ha (12.12%); and Priority 4 (30–37%) covers 4,026.03 ha (4.77%). Priority 1 warrants the greatest attention because it has the lowest modelled probability of service.

Priority 1 and Priority 2 areas should be considered first for field assessment and new TPS planning. Priority 3 areas can be addressed in a later phase, while Priority 4 areas may first benefit from optimising existing facilities or transport routes. Final siting should also consider field validation, operational TPS status, land availability, environmental sensitivity, and community acceptance.

In addition to the built-up areas, the original coverage tabulation identifies 7,500.25 ha of non-built-up area within the modelled service range (7.70% of the regency area) and 65,364.90 ha of non-built-up area outside the service range (67.13%) (Figure 5). These classes show why the main priority for new TPS should be based on unserved built-up areas and waste-generation demand rather than total unserved land alone.

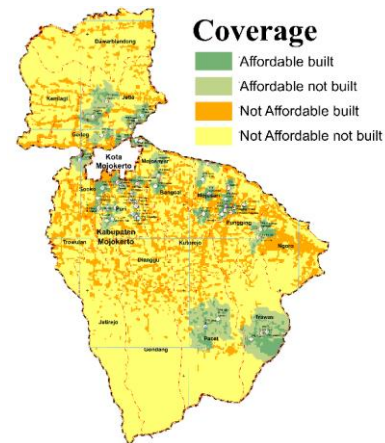


Figure 5. Service coverage of existing TPS

### 3.4. Limitations

The results are model-based and have not been validated against observed service areas or TPS operational records. The probability classes depend on the distance-decay parameter and the 37% threshold, whose sensitivity has not been tested, and TPS capacity is treated as fixed without considering collection frequency or operational status. Future studies should address these points and refine siting through field validation.

## 4. CONCLUSION

This study evaluated the service range of existing temporary waste collection sites (TPS) in Mojokerto Regency by integrating binary dasymetric mapping and the Huff Gravity Model. The analysis indicates that existing TPS serve 5,303.44 ha of built-up area (5.45% of the regency area), while 19,209.28 ha of built-up area (19.73%) remain unserved. Areas with a service probability below 37% are classified as unserved and grouped into four priorities: 0–10% as Priority 1, 10–20% as Priority 2, 20–30% as Priority 3, and 30–37% as Priority 4. Areas with a probability above 37% are considered adequately served under the classification used in this study. Local government should prioritise Priority 1 and Priority 2 areas, particularly built-up locations with high waste generation and limited accessibility to existing facilities. Future siting should be refined through field validation and assessment of operational capacity, road access, land availability, environmental constraints, and community acceptance.

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