Terbit *online* pada laman web jurnal : https://jes-tm.org/index.php/jestm/index

Journal of Engineering Science and Technology Management

| ISSN (Online) 2828 -7886 |

Article

Analysis of Waste Transportation Needs for Service Optimization in Bangkinang City District

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DOI: 10.31004/jestm.v5i2.332

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ARTICLE INFORMATION

Volume 5 Issue 2
Received: 17 December 2025
Accepted: 25 June 2025
Publish *Online*: 28 September 2025
Online: at https:JESTM.org/

Keywords

Garbage
Garbage Transportation
HCS
SCS

A B S T R A C T

Waste transportation is a waste sub-system that aims to bring waste from the location of the transfer of the waste source directly to the Final Disposal Site (TPA). The purpose of this study is to find out the transportation system and waste collection patterns, analyze the transportation needs of waste transportation, and analyze the transportation needs of waste transportation in 2025. The methods used to analyze the transportation needs of waste transportation are the Hauled Container System (HCS) and Stationary Container System (SCS) methods. The data used are regional topographic data, the number of waste transportation equipment, the travel time of waste transportation, and the number of residents in Bangkinang Kota District. The need for garbage carts/pedicabs in 2023 is 61 units and garbage transport vehicles needed for a waste volume of 4.105 tons/day from the Temporary Disposal Site (TPS) to the Final Disposal Site (TPA) consisting of 10 units of tipper trucks measuring 6m³ for 1 trip/day and 1 unit of armroll truck measuring 6m³ with 10 container tubs for 1 trip/day. The need for garbage carts/pedicabs in 2025 is 65 units and garbage transport vehicles in 2025 with a predicted waste volume of 4.105 tons/day is 10 units of tipper trucks measuring 6m³ for 1 ration/day and 1 unit of armroll truck measuring 6m³ for 1 ration/day with 10 container tubs.

1. Introduction

Geographically, Bangkinang Kota District is located in the central part of Kampar Regency, Riau Province, with an area of 177.18 Km². The population according to the Kampar Regency Central Statistics Agency in 2024 is 40,451 people. As an urban area with high population density and dominant non-agricultural activities such as trade and services, waste production increases along with consumptive living patterns.

Waste transportation is a waste sub-system that allows waste to be transported directly to the final disposal site from the waste source. However, waste management in Bangkinang Kota District is still considered inadequate because there is still waste that is not fully transported from the waste source to the TPA. Based on field observations, there are still many illegal dumping sites (TPS liar) in Bangkinang Kota, which aesthetically disturbs the surrounding community.

The purpose of this study is to determine the transportation system and collection patterns using Hauled Container System (HCS) and Stationary Container System (SCS) methods, analyze the needs for waste transportation, and predict the needs for 2025.

2. Literature Riview

2.1 Definition of trash

Law Number 18 of 2008 defines waste as the solid residue of human activities and natural processes. Kodoatie (2005) also explains that waste is solid or semi-solid waste that arises as a byproduct of urban activities. Furthermore, according to Nugroho (2013), waste is any item considered unusable but can still be reused if managed properly. This demonstrates that waste is not always useless but can have value if handled properly.

Meanwhile, Kristiana (2016) stated that waste generally originates from human activities or certain natural processes that produce residual materials that have lost their primary function. SNI 19-2454-2002 defines waste as solid waste consisting of organic and inorganic materials that must be managed to prevent harm to the environment or development. Based on these various definitions, waste can be understood as residual material that requires management to prevent negative impacts and still has the potential for reuse.

2.2 Waste Classification

According to Nugroho (2013), waste is essentially any item considered unusable but still reusable if properly managed. Kristiana (2016) adds that waste is residual material that has lost its primary function and generally originates from human activity. SNI 19-2454-2002 also emphasizes that waste consists of organic and inorganic materials that need to be managed to prevent environmental damage and maintain sustainable development.

Based on its source, waste can originate from natural processes, human activities, daily consumption, and industrial activities. Natural waste, such as dry leaves, is generally biodegradable, but in residential areas it can cause problems if not managed properly. Human waste, such as feces and urine, has the potential to spread disease if not handled with adequate sanitation. Meanwhile, consumer waste originates from the daily use of goods by the community, and industrial waste is the residue from production processes that, in large quantities, can become waste requiring special handling.

Based on its form, waste is divided into solid, liquid, and gaseous waste. Furthermore, waste is also classified based on its nature into organic and inorganic waste. Organic waste includes leaves, food scraps, and other natural materials that are easily decomposed by microorganisms. Conversely, inorganic waste such as plastic, metal, and glass cannot decompose naturally and can cause long-term pollution if not managed properly. Understanding this classification is essential as a basis for planning an effective waste management system.

2.3 Sources and Generation of Waste

Waste generation is defined as the amount of waste produced by a community in units of weight or volume over a certain period of time, generally expressed per capita per day. SNI 19-3964-1994 explains that the amount of waste generated is influenced by city classification. In large cities, waste generation ranges from 2–2.5 liters/person/day with a weight of approximately 0.4–0.5 kg/person/day. Meanwhile, medium to small-sized cities produce waste generation of approximately 1.5–2 liters/person/day with a weight of 0.3–0.4 kg/person/day. These data indicate that the level of population activity and

regional characteristics influence the amount of waste generated.

According to Law Number 18 of 2008, waste sources are the origin of the materials that generate the waste. Generally, managed waste is divided into household waste, non-household waste, and specific waste. Understanding these sources is necessary to determine the appropriate management approach. In planning calculations, waste generation is often calculated using a simple formula: the population multiplied by the average per capita generation, for example, 0.4 kg/person/day. This approach helps illustrate the waste management system needs in a given area.

2.4 Factors that influence waste generation

Waste generation in a region is influenced by several key factors. Population size is the most important factor, as a larger population means a greater volume of waste. Furthermore, the socioeconomic status of a community also influences the amount of waste per capita. Communities with higher economic status tend to produce more waste, particularly from consumer goods and packaging.

Another factor is technological advancement. Technological advancements encourage the use of various products made from plastic, metal, or single-use materials, potentially increasing the volume and diversity of waste. Therefore, demographic changes, welfare levels, and technological developments are important aspects to consider when analyzing a region's waste generation.

2.5 Factors that influence waste generation

General description of waste management in Bangkinang City District in waste management, for waste collection in Bangkinang City is carried out as follows:

1. Garbage from residential sources is collected by garbage carts by cleaning staff, then collected at the TPS (garbage bin), then transported to the TPA.
2. Specifically for protocol roads, each sub-district is responsible for their area, swept by cleaning staff, then collected into trash bins/cans, then transported by dump trucks, and also go around collecting the contents of residents' trash bins to be disposed of at the landfill. When cleaning protocol roads, it is recommended to do it before peak traffic hours to avoid obstructing traffic flow.
3. Collecting garbage by placing communal garbage bins in certain locations, but you must also pay attention to the condition of the bin so that the area around the bin remains clean and not dirty and you need to make sure that the garbage bin has a cover.

2. 6 Factors that influence waste generation

Waste transportation, as outlined in the Regulation of the Ministry of Public Works No. 3 of 2013 and Law No. 18 of 2008, refers to the activity of moving waste from its source, temporary storage sites (TPS), or TPS 3R facilities to integrated processing facilities or final disposal sites. This activity includes the transportation process from the last collection point, either through direct collection systems or via transfer points such as transfer depots or TPS. The selection of transportation modes and equipment is strongly influenced by the waste collection system applied in the area.

Waste transportation requires careful planning to optimize travel time and transport capacity, especially when waste volume is large, disposal sites are located far away, or waste flows converge from multiple areas. Factors such as vehicle rotation and traffic conditions also influence the effectiveness of the transportation process. Operationally, the responsibility for waste transfer and transportation lies with municipal or district governments, while its implementation is carried out by local sanitation units, private operators, or partnerships, depending on the organizational structure of the respective region.

2.7 HCS (*Hauled Container System)*

The Hauled Container System (HCS) is a waste collection method in which movable containers are transported directly to the final disposal site. In this system, the collection vehicle lifts the filled container, delivers it to the disposal site, and returns with an empty container to the original location. This method is considered efficient and flexible because it can be applied in various settings and allows for the transport of large volumes of waste.

Calculations in the HCS are used to determine the haul time or the duration required for one complete transportation cycle. The haul time is determined using the THCS formula, which includes the time for collection, loading and unloading, empirical factors, and travel distance. The collection time itself is calculated

from the duration of filling, emptying the container, and the travel time between containers.

The number of daily hauls is then estimated based on the vehicle's working hours, off-route factors, and the travel time to and from the vehicle pool. Haul frequency may also be calculated using the volume of waste collected relative to container capacity. These calculations ensure that the HCS can be planned effectively to meet the waste transport needs of a given area.

2.8 SCS (*Stationary Container System)*

The Stationary Container System (SCS) is a waste collection system in which the containers remain fixed at the collection point, typically in residential areas or public facilities. When the container is full, the waste is transferred into a collection truck, and the full container is replaced with an empty one to maintain continuous service.

This system offers advantages in terms of organization and cleanliness because the containers do not need to be moved, reducing the risk of scattered waste and making waste management more orderly. SCS is also efficient for residential areas and allows the use of larger containers, increasing storage capacity.

Operationally, SCS relies on technical calculations such as trip time, the number of containers emptied per trip, and daily trips based on waste volume and container capacity. Formulas such as TSCS and Nd help estimate the required time and trips to ensure that waste transportation runs efficiently.

3. Research Methodology

3.1 Research Design

This research employed qualitative and quantitative methods. The following methods were used:

1. The Waste Transportation Fleet Characteristics Method, used to determine the transportation system and waste collection patterns.
2. The Hauled Container System (HCS) Method, used to analyze the waste transportation fleet.
3. The Stationary Container System (SCS) Method, used to analyze the waste transportation fleet.
4. The Waste Generation Prediction Method, used to predict the volume of waste generated by the population in 2025.

3.2 Data source

a. Primary Data

Primary data collection was as follows:

1. Observation
   In this study, observations were conducted to determine the existing conditions at the waste disposal site (TPS), including analyzing the volume of waste generated, waste utilization, waste composition, and the costs of the TPS.
2. Interviews
   Interviews were conducted with the Kampar Regency Environmental Agency (DLH) to determine the effectiveness of the TPS and TPA in Bangkinang Kota District. Several aspects of operational techniques, financing, organization, community participation in waste management, and the volume of waste received were examined. The number of facilities and operational equipment at the TPS and TPA was also determined.
3. Documentation
   Data collection was conducted through photography to provide an overview of the study area, in the form of photographs and drawings.

b. Secondary Data

Secondary data is data not obtained directly in the field. The sources of secondary data can be seen in the table below:

1. Waste transportation route.
2. Waste volume.
3. Type of waste transportation.
4. Number of waste disposal sites (TPS) and landfills (TPA).

3.3 Research Location

The research location is situated in Bangkinang Kota District, Kampar Regency, Riau Province, Indonesia, with a total area of 177.2 km². Geographically, Bangkinang Kota District has a tropical rainforest climate (Af) characterized by rainfall throughout the year. The average daily temperature ranges from 23°C to 33°C, and rarely falls below 22°C or rises above 34°C. The warm season lasts for approximately 3.4 months, with average daily temperatures exceeding 32°C.

According to data from the Central Bureau of Statistics (Badan Pusat Statistik) of Kampar Regency, the population of Bangkinang Kota District in 2024 was recorded at 40,451

residents. Administratively, the district consists of two urban villages (kelurahan), Langgini and Bangkinang, and two rural villages Kumantan and Ridan Permai.

Figure.1 Research Location

4. Results and Discussion

4.1 Hauled Container System (HCS)

Observations show that the HCS pattern in Bangkinang City operates with arm roll trucks lifting container bins at market points and transporting them to the landfill; the bins are returned to the landfill after being emptied, thus forming an arm roll rotation cycle.

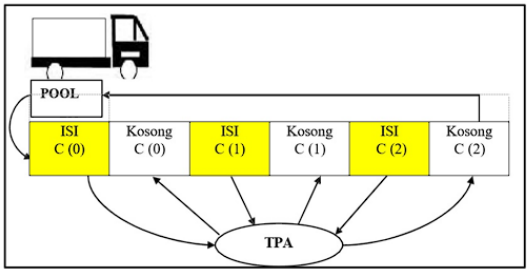

Fig.2 HCS Transport Patterns

The following is a calculation of waste transportation using the HCS method:

$$ND = \frac{7 \times (1\text{-}0{,}25) - (0{,}35 + 0{,}35)}{1{,}332}$$

$$= \frac{7 \times 0{,}75 - 0{,}70}{1{,}332}$$

$$= \frac{5{,}25 - 0{,}70}{1{,}322}$$

$$= 3{,}42 \text{ Minutes/Day}$$

4.2 Stationary Container System (SCS)

In the Bangkinang City District area, the SCS system of waste transportation is implemented using a 6m3 garbage tipper truck with a carrying capacity of 4.2 tons for a fully filled container.

The following is a waste transportation pattern using the Stationary Container System (SCS) pattern.

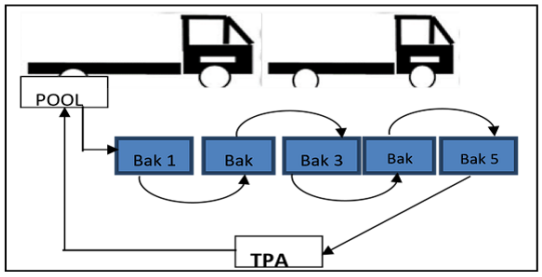

Figure.3 Stationary Container System (SCS)

The following is a calculation of waste transportation using the Stationary Container System (SCS) pattern method:

$$Ct = \frac{6 \times 1}{0{,}5 \times 0{,}5}$$

$$= 24 \text{ container}$$

4.3 Need for Waste Transport Equipment in Bangkinang City District

The solid waste generation in Bangkinang Kota District increased from 3.775 tons/day in 2023 to 4.105 tons/day in 2024. The area applies an indirect individual collection system, where waste is gathered from the source using handcarts and transported to communal collection points (TPS) before being hauled to the final disposal site (TPA). Based on SNI 3242:2008, one 1 m³ handcart can serve up to 640 residents. With a population of 39,085 people, the required number of handcarts is 61 units, which is considered adequate for collection activities. Tipper trucks with a capacity of 6 m³ and a load capacity of 4 tons are assigned to each TPS route, and with 10 units operating two trips per day, their total transport capacity reaches 80 tons per day—significantly exceeding the district's daily waste generation.

The analysis of arm roll truck requirements shows that, although the 2023 waste generation of 3.775 tons/day is already fully accommodated by the tipper trucks' capacity, arm roll trucks remain essential for collecting large containers stationed at TPS locations. There are 138 containers with a capacity of 4 tons each, providing more than sufficient storage for the district's daily waste. Accordingly, only one arm roll truck operating one trip per day is needed to transport these containers to the final disposal

site and maintain smooth operational flow across the TPS network.

4.4 Prediction of Waste Generation in 2025 in Bangkinang District, Kota

The prediction of waste generation in Bangkinang Kota District for the year 2025 is carried out using the geometric method, based on the growth rates of the industrial sector, agricultural sector, per capita income, and population. According to data from BPS Kampar Regency (2024), the industrial sector growth rate is 3.70%, the agricultural sector 1.92%, per capita income growth 1.92%, and population growth 1.55% These values were used to calculate the city growth factor (Cs), which resulted in a value of 1.009%.

Using the geometric projection formula and the baseline waste generation in 2024 of 4.105 tons/day, the predicted waste generation for 2025 is 4.40 tons/day. This increase reflects the influence of economic growth and population expansion on the amount of waste generated in Bangkinang Kota District.

4.5 The Need for Waste Transport Equipment in Bangkinang City District in 2025

The projected waste generation in Bangkinang Kota for 2025 requires an evaluation of transportation equipment capacity to ensure that waste collection and disposal remain effective. Based on population growth of 4.50%, the number of residents in 2025 reaches 40,451 people. Referring to SNI 3242:2008, one handcart with a capacity of 1 m^3 can serve 640 people; therefore, the district requires 65 units of handcarts, an increase of four units from the 2024 requirement. For tipper trucks, each with a capacity of 6 m^3 (4 tons) and capable of conducting two trips per day, the total hauling capacity reaches 80 tons per day, which is far greater than the projected waste generation of 4.40 tons/day. Thus, the existing 10 tipper trucks remain adequate for 2025 without requiring additional units.

The need for arm roll trucks in 2025 also remains unchanged. With one arm roll unit operating at the TPS and supported by 138 containers with a total storage capacity of 552 tons, the system is more than sufficient to accommodate the daily waste load. The calculated waste volume that must be transported by the arm roll truck remains negative after accounting for the capacity already handled by tipper trucks, indicating that the tipper fleet continues to cover the bulk of waste collection. Therefore, only one arm roll truck is required for 2025, maintaining the same number as in the previous year. Overall, the year-to-year comparison shows no increase in truck requirements, with the only notable change being the addition of four handcarts to support population growth and ensure effective waste collection at the source.

5. Conclusion

Based on the analysis of waste generation and transportation needs in Bangkinang Kota District, it can be concluded that the amount of waste continues to increase in line with population growth and expanding economic activity. The projected waste generation for 2025 reaches 4.40 tons per day, showing an upward trend from the previous year. This increase highlights the need to adjust the capacity of waste management services, particularly in the collection and transportation stages, to prevent accumulation at the source and at communal disposal points (TPS).

The evaluation of equipment requirements shows that the existing transportation fleet remains sufficient to support operations in 2025. The number of handcarts needs to be increased to 65 units to match the growing population, while the capacity of tipper trucks and arm roll trucks does not require additional units because their carrying capacity still exceeds daily waste production. This indicates that the current fleet is adequate, provided that trip scheduling and operational timing are well managed to ensure efficient waste transport throughout the district.

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