OPEN ACCESS

JPK

Jurnal Pengembangan Kota (2022)
Volume 10 No. 2 (118–126)
Tersedia online di:
http://ejournal2.undip.ac.id/index.php/jpk
DOI: 10.14710/jpk.10.2.118-126

RIVER DEBRIS TRANSPORT PLANNING FROM SOURCE TO PUTRI CAMPO FINAL PROCESSING PLACE, SURAKARTA CITY

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Abstract. The waste from the river is one of the obstacles in managing the Bengawan Solo River, Surakarta City. River debris is usually collected in tributaries so as not to carry the pollutant load to the watershed, causing flooding, and then transported to the Final Processing Site (TPA). This study aims to analyze the waste transportation system from the source to the landfill. This research was conducted by direct observation and using Multi-Attribute Utility Theory (MAUT) for determination. Alternative waste transportation used are haul container system (HCS) and stationary container system (SCS). The criteria used are the number of ritations, price, ease of transportation, potential damage, maintenance, and type of container. Based on the weighting results on the MAUT analysis, transportation with the SCS method has a higher weight than the HCS method.

Keywords: River Debris; Transport; Surkarta City

[Judul: Perencanaan Pengangkutan Debris Sungai Dari Sumber ke Tempat Pengolahan Akhir Putri Campo Kota Surakarta] Sampah dari sungai menjadi salah satu kendala dalam pengelolaan Sungai Bengawan Solo, Kota Surakata. Sampah sungai biasanya dikumpulkan di anak sungai agar tidak membawa beban pencemar ke daerah aliran sungai yang menyebabkan banjir dan kemudian diangkut ke Tempat Pemrosesan Akhir (TPA). Tujuan dari studi ini adalah untuk melakukan *decision analysis* sistem pengangkutan sampah dari sumber ke TPA. Penelitian ini dilakukan dengan cara observasi langsung dan menggunakan *Multi-Atribut Utility* Teori (MAUT) untuk penentuan. Alternatif pengangkutan sampah yang digunakan adalah *Haul Container System* (HCS) dan *Stationary Container System* (SCS). Kriteria yang digunakan adalah jumlah ritasi, harga, kemudahan pengangkutan, potensi kerusakan, perawatan, dan jenis *container*. Berdasarkan hasil pembobotan pada analisa MAUT pengangkutan dengan metode SCS memiliki bobot yang lebih tinggi dibandingkan dengan metode HCS.

Kata Kunci: Debris Sungai, Pengangkutan; Kota Surakarta

Citation: Sari, Mega Mutiara., Inoue, Takanobu., Harryes, Regil Kentaurus., Yokota, Kuriko., Septiariva, Iva Yenis, Suhardono, Sapta., Kato, Shigeru., Notodarmojo, Suprihanto., Nafisah, Aninda Putri., Suryawan, I Wayan Koko. (2022). River Debris Transport Planning from Source to Putri Campo Final Processing Place, Surakarta City. **Jurnal Pengembangan Kota**. Vol 10 (2): 118-126. DOI: 10.14710/jpk.10.2.118-126

1. INTRODUCTION

Excessive use of environmentally unfriendly products will also impact the surrounding environment (Li & Wang, 2019). The behavior of the Indonesian people who have a habit of littering causes many environmental impacts (Dhahir, 2020). The impact of dumping waste in the river is that it will become a nest of disease for residents who live around the banks of the Bengawan Solo River (Baptiste, Gravitiani, & Eric, 2021). Breeding places for animals that bring sources of disease, such as mosquitoes, rats, and waste that accumulates in rivers, can also block the flow of river water to cause flooding. Disposal of solid waste in water bodies will also damage the habitat of animals and plants in the river and disrupt the flow of water (Raman & Sathiya Narayanan, 2008; Sari et al., 2022). Agricultural irrigation is hampered around the Bengawan Solo River flow due to the blockage of the river flow that leads to the irrigation flow.

River debris is usually transported directly to the Final Processing Site (TPA) from the transfer site or the waste source. Waste removed from the river is not sorted due to the wet condition of the waste. It is only collected and taken from the river and then transported using a fleet of waste trucks owned by immediately delivered to the Putri Cempo TPA. After being delivered to the Putri Cempo TPA, managing waste from rivers is carried out in the same way as other waste from household waste. The waste collection process is the most significant contributor to waste management costs (Apaydin & Gonullu, 2018).

Each vehicle assigned to collect and transport waste departs from the same depot to TPS points to transport waste to the vehicle's capacity. The load is emptied at the TPA before returning to the depot or carrying out waste transportation services at the TPS point, which has not been served if it does not exceed the specified time limit (Ambariski & Herumurti, 2016; Mahmudah & Herumurti, 2016).

The transfer and transportation of waste are intended as an operating activity starting from the last collection point of a collection ritation to the TPA or TPST at collection with a direct individual pattern or from a temporary transfer/shelter (TPS, TPS 3R, SPA) or communal shelter to the final processing/disposal site (TPA/TPST). The method of transportation and the equipment to be used depend on the collection pattern used. At the same time, the executor is the manager of cleanliness in an area or region, business entities, and partnerships. Therefore, it depends on the organizational structure in the area concerned. This study aims to select a waste transportation system from the Tanggul River to the Putri Campo TPA, Surakarta City.

In these cases, Multi-Attribute Utility Theory (MAUT) can be useful since it elicits the opinions of knowledgeable practitioners to build a decision model (Keeney, 1992). To help stakeholders make decisions in the face of numerous objectives and ambiguity, the MAUT approach can be developed (Kartini et al., 2023; Sari et al., 2022). Multiple, competing goals, as well as significant uncertainty, characterize a choice to evacuate proactively (Kailiponi, 2010). Each option is ranked based on the MAUT score that was calculated. Options with lower aggregated MAUT scores will be ranked higher based on the minimization objective function. Therefore, the MAUT method is also very appropriate to be used in choosing the transportation of river debris at Putri Campo TPA, Surakarta City.

2. METHOD

This research was conducted in Surakarta City (Figure 1). This research was conducted by direct observation. Observation is a data collection technique carried out through observation, accompanied by notes on the state or behavior of the target object. The observation technique is the systematic observation and recording of the investigated phenomena. In a broad sense, actual

ISSN 2337-7062 © 2022

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Submitted 16 March 2022, accepted 30 December 2022

observation is limited to observations carried out either directly or indirectly.

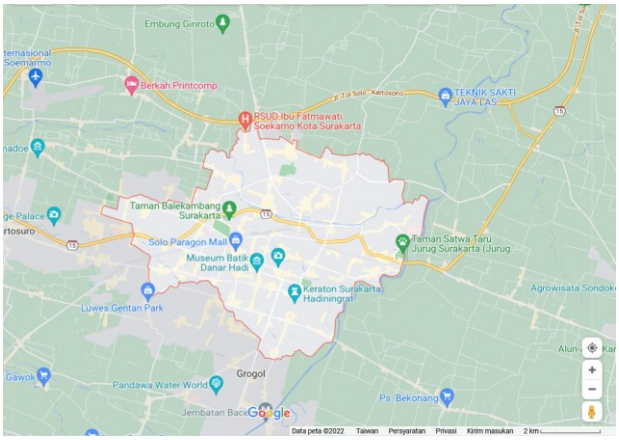

Figure 1. Study Location Map (Google Map, 2021)

Decision Support Systems have several models, such as the Multi-Criteria Decision Making (MCDM) Model. One of the MCDM models that can assist in decision-making is the Multi-Attribute Utility Theory (MAUT) method (Kumar et al., 2017). Several criteria must be considered, having many criteria and alternatives is a technique in the decision-making process using the MAUT method (Pergher & Almeida, 2018). Utility theory evaluates the final value of an object defined as a weight added to a value relevant to its dimension value.

Using the MAUT method, a ranking order of alternative evaluations is generated (Satria, Atina, Simbolon, & Windarto, 2018). The steps of the MAUT method are as follows (Satria et al., 2018):

1. Break a decision into its different dimensions.
2. Determine the alternative weights on each dimension.
3. List all alternatives.
4. Enter the utility for each alternative according to its attributes.
5. Multiply utility by weight to determine the value of each alternative.

3. RESULT AND DISCUSSION

Waste transportation moves the waste from the source or temporary shelter (TPS) (Akili & Odey, 2021; Suryawan, Rahman, Septiariva, Suhardono, & Wijaya, 2021; Zahra et al., 2022) to the final processing site. In the existing condition, all river waste in Surakarta City is immediately taken and disposed of to the Putri Campo TPA by the PUPR Office of the Surakarta City for SDA using a boxcar equipped with hydraulics. The facilities owned by the PUPR Office of Surakarta City in SDA are 4-unit box-type L300 cars, and all car units are used. The number of transportation facilities owned by the PUPR Office of Surakarta City is very minimal. Additional transportation facilities are needed that are focused on the river debris management system on the Embankment River. Several criteria need to be considered in determining the collection pattern based on SNI 19-2454-2002, and Minister of Public Works Regulation No. 3 of 2013 are as follows:

Number of rites

knowing the number of rites of transporting waste from each alternative. Based on the Minister of Public Works Regulation No. 3 of 2013, the number of rites will affect the workload of workers. The existing waste transportation system involves more garbage motorbikes, which reach 1-2 rites per day. There is only one rite for trucks and garbage trucks per day, so the existing transport trucks are not used efficiently (Adam, Mangangka, & Riogilang, 2021). However, before carrying out the countermeasure scenario, it is known that the current off-route time is so significant, which has exceeded. The standard set in Tchobanoglous and Vigil (1993) is necessary to optimize the existing off-route time, and it is known that the off-route time in the first ritation is so large. After optimizing the off-route time than planning for optimal working time in the first ritation can be done, which is intended in terms of working time for one ritation that has not been optimized, off route time that is outside the time to warm up the car while waiting for a helper or driver, queue time at the landfill, queue time at the landfill, after optimizing the time off route to 0.08 hours, the value of off-route has not passed the specified value of<0.15 (Tchobanoglous & Vigil, 1993).

Cost

The price of transportation equipment will affect the Budget Plan for the river debris management system. One of the criteria for transportation equipment is that it must be durable, strong, and with optimum volume to minimize investment costs (Menteri Pekerjaan Umum Republik

Indonesia, 2013). The operational costs of waste transport vehicles have a value based on the volume of waste transported. Therefore, in calculating the operational cost for waste transport vehicles, it is also necessary to pay attention to the cost of fuel used to transport waste. The calculation of the percentage of fuel costs against the cost of transporting waste determines the percentage of fuel costs needed in carrying out waste transportation services (Burhamtoro, 2016).

Ease of transport

Ease of transportation is related to the workload received by workers. The workload on workers has influenced the physical and psychological abilities of the workers concerned. As a result, the time and distance traveled from one place to another. In addition, the ease of transportation is also based on the way of transporting the waste, such as manually, automatically, and automatically (Fatimah, Govindan, Murniningsih, & Setiawan, 2020).

Potential damage

Damage to the transportation equipment will affect operational costs and even investment costs. The higher the level of potential damage to the equipment, the greater the operating costs required. In addition, if there is fatal damage, it will increase the investment cost by buying a new means of transportation.

Maintenance

Complex maintenance will affect operating costs. Vehicle operations and maintenance involve several components, such as fuel, oil, spare parts, tires, mechanic, and driver wages (Burhamtoro, 2016). These components are calculated using specific formulas obtained from previous research (Burhamtoro, 2016).

Container Type

Transport equipment must have aesthetic value by looking beautiful and clean (Menteri Pekerjaan Umum Republik Indonesia, 2013). This can be seen from the aspect of the cover on the tub

There are two methods of transporting the waste: the Hauled Container System (HCS) and the Stationary Container System (SCS) (Sharholy, Ahmad, Vaishya, & Gupta, 2007; Syahputri, Rahmi, Indah, Mangara, & Josua, 2019). HCS is a waste transportation system where the transport containers can be removed and taken to processing or final disposal sites. Trucks with empty containers from the pool go to the TPS 1 location, but the containers they carry then transport them to the TPA. Empty containers from the TPA are returned to another TPS until the last ritation. A transport system in which the collection container is not transported (fixed). The SCS system is intended to serve residential areas. The transportation mechanism starts with the vehicle leaving the pool to the first container, and then the waste is put into the container manually or automatically. The vehicle goes to the next container until the last ritation or the container is full then goes to the TPA for disposal (Figure 2).

Alternative 1: HCS Pattern Using Arm Roll Truck Capacity of 6 m^3

The transportation pattern used in alternative 1 is the Hauled Container System (HCS) or the lifting container system. Vehicles from the poll by bringing empty containers to the first full container to pick up the waste and bring it to the TPS or TPA. Then the vehicle from the emplacement carries the empty container to the location of the water waste source to the final location, and the vehicle returns to the poll. However, in this design, the source of river debris for transportation activities is only on the Tanggul River. The vehicle used for this HCS pattern is an arm roll truck with a capacity of 6 m^3, so to transport waste on the Tanggul River of 5.7 m3 requires 1 ritation/day. The 2021 arm roll truck has a price of Rp. 460,000,000 (Table 1).

Arm roll trucks are equipped with arm rolls that function to move the waste bin from the truck to the location of the waste source or vice versa to ease the burden on workers in transporting waste to the bin. However, according to Tchobanoglous and Vigil (1993), the potential for damage to the arms roll of the truck is higher on the arms roll, so it requires expensive maintenance costs to reduce the potential for damage. In addition, the arms roll truck is equipped with a cover for the entry of waste into the bin.

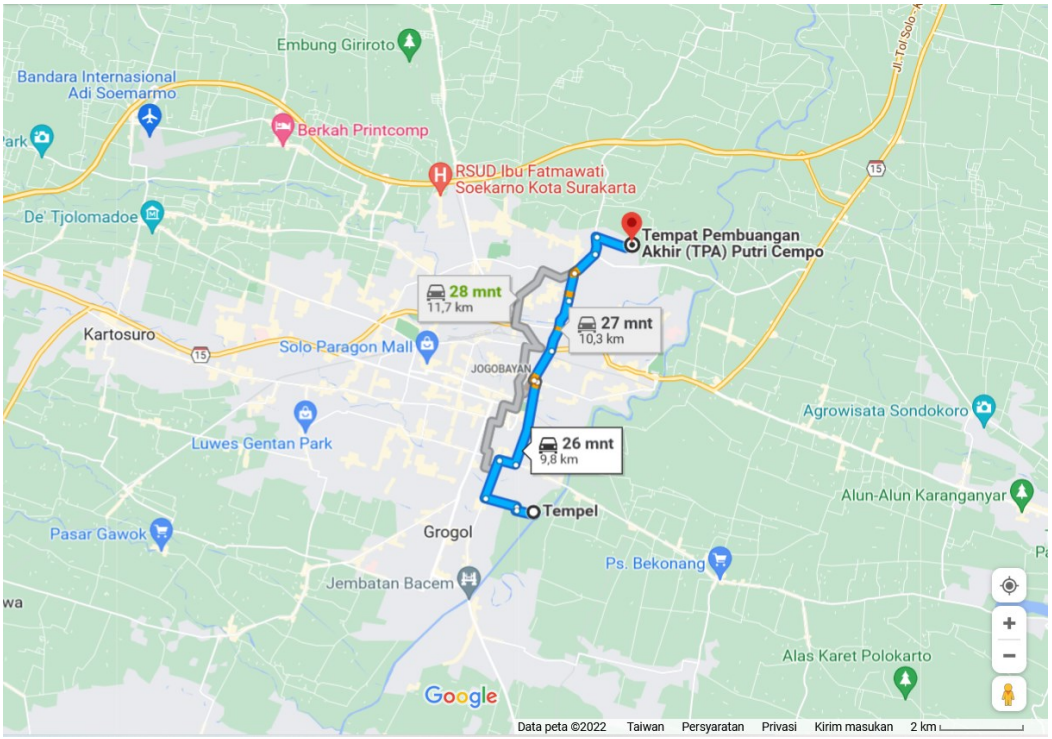

Figure 2. Schematic Transportation from Tanggul River to Putri Campo TPA

Alternative 2: SCS Pattern Using Dump Truck Capacity 6 m^3

The transportation pattern used in alternative 1 is the Stationary Container System (SCS) or a fixed container system. Vehicles from the poll to the source of the waste container transport the waste without moving the container from the truck. Then, the truck goes to the location of the next waste source to the last waste source and then carries the waste to the TPS or TPA. However, in this design, the source of river debris for transportation activities is only on the Tanggul River. The vehicle used for this SCS pattern is a dump truck with a capacity of 6 m^3, so to transport waste on the Tanggul River of 5.7 m^3 requires 1 ritation/day. The 2021 dump truck has a price of Rp. 339,400,000 (Table 1).

Unlike arm roll trucks with arm rolls, dump trucks are equipped with hydraulics that tilts the tub to lower the waste lifted and the water content in river debris. However, it is not possible to transfer the tub from the truck to the location of the waste source or vice versa. This affects the burden of workers in transporting the gate to the tub manually. Furthermore, according to Tchobanoglous and Vigil (1993), the potential for damage to the dump truck is lower on the hydraulic side, so additional maintenance costs are needed for applying oil to the hydraulics. In addition, the dump truck body is not equipped with a cover at the top entry of the body.

Table 1. Recapitulation and Assessment of each Alternative

Parameter	Alternative 1	Alternative 2	Weight
Number of rites	1 rite/day	1 rite/day	3
Cost	Rp. 460,000,000	Rp. 339,400,000	3
Ease of transport	currently	difficult	3
Potential damage	tall	low	2
Maintenance	tall	currently	2
Container Type	closed	open	1

Table 2. Assessment of Numbers and Determination of Values

Parameter	Alternative 1	Alternative 2	Worst Value	Best Value
Number of rites	1	1	2	1
Cost	Rp. 460,000,000	Rp. 339,400,000	Rp. 460,000,000	Rp. 339,400,000
Ease of transport	2	1	1	3
Potential damage	1	3	1	3
Maintenance	1	2	1	3
Container Type	3	1	1	3

Table 3. Alternative Assessment Using Utility Theory

Parameter	Alternative 1	Alternative 2	Weight	Standard weights
Number of rites	1	1	3	0.214
Cost	0	1	3	0.214
Ease of transport	0.5	0	3	0.214
Potential damage	0	1	2	0.143
Maintenance	0	0.5	2	0.143
Container Type	1	0	1	0.071
Total			14	1.0
Utility Value	0.393	0.643		
Ranking	2	**1**		

From the assessment results and weighting using the utility theory method, the alternative with the highest ranking is alternative 2, namely dump trucks. In both alternatives, each alternative has 1 ritation/day by adjusting the capacity of the transport truck to the volume of marine waste. However, in terms of price, alternative 1 has a higher price than alternative 2. This truck price parameter is an important factor because it affects the amount of budget plan issued. Therefore, this preference is given a weight of 3 (Table 2).

In terms of the ease of transporting waste, alternative 1 has a moderate workload because the movable container can reduce the distance from the waste source to the trash bin during the waste transport process. While alternative 2, workers are required to do manual material handling following the truck's location because the tub cannot be moved. The Occupational Safety and Health Administration (OSHA) classifies manual material handling activities as lifting or lowering, pushing or pulling, turning, carrying, and holding (Octavia, 2017). The workload on workers is influenced by the physical and psychological abilities of the workers concerned and the time and distance from one place to another. The distance and travel time should be kept to a minimum because it can cause fatigue and back injury. Therefore, the second alternative has the ease of transportation, which is difficult and directly impacts workers, so this parameter is given a weight of 3 (Table 2).

In terms of potential damage and maintenance, truck arm rolls have a high potential for damage because arm rolls are easily damaged, which results in higher maintenance costs (Tchobanoglous & Vigil, 1993). Maintenance costs include changing the oil on the arms roll and replacing it if it cannot be used due to fatal damage. Therefore, the potential damage and maintenance parameters are given a weight of 2.

In terms of the body, arm roll trucks have a closed body while dump trucks have a hollow body so that some of the waste in the dump truck will be blown away by the wind and pollute the roads it passes. The open body of a dump truck will give the impression of being unhealthy (Tchobanoglous & Vigil, 1993). According to the Minister of Public Works Regulation in 2013, the requirements for

waste transportation facilities must be closed during transportation so that waste is not scattered on the road. The body parameter is given a weight of 1 because an open body on the truck can be overcome by providing a cover in the form of a tarpaulin.

It can be concluded that in carrying out transportation activities, a vehicle in the form of a dump truck with a capacity of 6 m^3 is equipped with a baffle and a tub cover (Table 3). This is a requirement stated in SNI 19-2454-2002 where waste sorted at the source must be kept segregated until the final waste management process. The transportation activity starts from the truck departing from the pool with three workers heading to the Tanggul River to transport the collected river waste and then take it to be processed at the TPS.

A fixed container system is a waste collection system in which waste storage containers are left at the point of collection of existing waste transferred into a garbage truck manually or assisted by mechanical equipment to be transported to the landfill (Burhamtoro, 2016). SCS is used for the collection by stakeholders, and the location network for each type of waste should be considered (Pumpinyo & Nitivattananon, 2014). The system varies depending on the type, the amount handled, and the number of waste collection points. SCS has two main types: systems in which a self-loading compactor is used and systems in which a manually loaded vehicle is used.

With the MAUT approach, it is one of the approaches used by decision makers to identify, measure, and assess several attributes of waste management, especially transportation. MAUT can be used when a decision maker wants to decide on an alternative decision from several alternatives that have been evaluated based on several criteria/attributes needed by stakeholders. The set of feasible solutions can be in a small and limited form or in a large and unlimited form, so that there is uncertainty in decision making. MAUT is based on the main hypothesis which states that every decision maker will try to optimize, consciously or implicitly, using a function that aggregates all the views of that decision maker.

4. CONCLUSION

Waste transportation on the Tanggul River uses a dump truck with a capacity of 6m^3 equipped with a separator tank with 1 ritation per day. Waste processing in the Tanggul River is carried out for organic (wood, twigs, and leaves) and inorganic (plastic) waste. Processing of organic waste is carried out by counting, composting, and sifting which compost uses the hollow brick method as many as 7 units. Meanwhile, for inorganic waste, plastic is enumerated which will then be given to a third party. Final processing on the Tanggul River is the transportation of untreated waste to the Putri Cempo TPA using a 6m^3 dump truck.

5. ACKNOWLEDGEMENT

This research was implemented and fully supported by the Japan Society for The Promotion Science and Indonesia Directorate General of Research, Technology and Higher Education (JSPS/DG-RSTHE), through a Bilateral Joint Research Projects 2019-2022 between Universitas Pertamina, Indonesia, and Toyohashi University of Technology, Japan.

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