Optimization of waste transportation route at waste transfers point in Lowokwaru District, Malang City

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Abstract. Increasing population led to the emergence of the urban infrastructure services issue including waste problems especially waste transportation system. Data in 2016 shows that the amount of waste in Malang was 659.21 tons / day. The amount of waste transported to landfill only reached 464.74 tons / day. This indicates that not all waste can be transported to the landfill Supiturang because Level of Service (LoS) reached 70.49%. This study aims to determine the effectiveness of waste transportation system and determine the fastest route from waste transfers point in Lowokwaru district to the landfill Supiturang. The data collection method in this research were 1) primary survey by interview officials from the Sanitation and Gardening Agency which questions related to the condition of the waste transportation system in waste transfer point, 2) Secondary survey related to data of waste transportation system in Malang City i.e the amount of waste generation in waste transfer point, number of garbage trucks and other data related to the garbage transportation system. To determine the fastest route analyzed by network analyst using ArcGIS software. The results of network analyst show that not all routes are already using the fastest route to the landfill Supiturang.

1. Introduction
Municipal solid waste collection (MSWC) is a solid waste management process consisting of generation, collection, transfer, treatment and final disposal [1, 2, 3, 4, 5]. The costly aspect of the process municipal solid waste was collection and transportation, because of the massive use of vehicles and labour intensity of the work [6]. About 85 % proportion of total cost for solid waste was waste collection [1, 2, 3].

A large number of population and the diversity of activities in major cities in Indonesia has resulted in problems in terms of urban infrastructure services, such as waste issues. One of the problems in waste management is waste transportation. According to Law No. 18 of 2008, waste transportation is part of waste management [7]. Waste transportation is defined as an activity of carrying waste from source and or from waste transfer point (TPS) to final solid waste disposal site (SWDS) in landfill (TPA).

[8] explain that waste transport activities are one of the important components and require careful calculation where the target is to optimize the transport time required in the system. The process of costs incurred in the transport system. Inefficient routes will cause longer distance, thus higher cost for fuel. In determining the route can affect the required haul time to the landfill. Inefficient route selection can also result in addition; the transportation process will also affect the surrounding environmental conditions, associated with exhaust emissions of waste transporting vehicles. Good domestic waste transport system services with optimal routes will reduce the adverse impacts of these activities on the environment [9]. The most significant reason for implementing network analysis and transport route planning is because businesses are interested in determining the best route to minimize cost and time [10]. Business in waste transportation system considers waste transportation route much since the length of waste transportation route is proportional to the expense of related cost of vehicle fuel and vice versa.
Based on the data from the Department of Hygiene and Gardening Malang City in 2016, the waste generation in Malang was 659.21 tons/day, while the amount of waste transported to the landfill was only 464.74 tons/day. This amount is assumed to be the same for 2017 since there is no significant improvement of waste management in Malang City. The amount indicates that not all waste is transported to final SWDS in Supiturang landfill. The value of level of service (LoS) of waste transportation is 70.49%, below the effective rate which should be 100% where there is no waste remain in waste transfer point. Lowokwaru is a district with a high number of educational facilities, evidenced by the number of universities both public and private, such as Brawijaya University, Malang State University, Muhammadiyah University of Malang, and others. Consequently, the number of the universities leads to positive population growth followed by more the activities. This can result in the amount of volume of waste generated is also greater.

The condition of transfer points in Lowokwaru district, Malang also show problem in waste transportation system. Delay waste pick up, overload truck capacity, and lack of human resources capacity are typical problems exist in transfer points. In addition, waste is still often seen in the waste transfer point at the time of transfer stations must be in a state of free waste. It shows that the level of effectiveness of transportation in waste transfer point Lowokwaru district does not reach 100%. According to [11] target method, source, or process can be used to assess the effectiveness. From target’s point of view, which is transporting waste goal, waste transport can be said to be effective if there is no more waste after the last waste pick up schedule [11].

Waste management, including proper waste transport can improve efficiency and effectiveness. The efficiency of this waste transport can be seen from several factors such as transportation facilities, carrier fleet routes and accessibility. The right transport system and route selection will improve accessibility leading to decrease of cost and time consuming waste transportation. Conditions in some transfer stations in Lowokwaru district, Malang City indicate that transportation performance is not optimal so that the need for evaluation. Therefore, this research is more focused on route optimization, so it could be obtained the shortest and fastest route.

2. Research Methods

The study was conducted on waste transfer point which is located in Lowokwaru District in Malang City. The study area could be seen in Figure 1. The samples of waste transfer point in this research are 12 waste transfer points managed by the Department of Sanitation and Gardening of Malang City (Dinas Kebersihan dan Pertamanan/DKP) and also managed by Market Office (Dinas Pasar) of Malang City.

There were waste transfer point 1) Tunggulwulung, 2) Merjosari, 3) Tlogomas, 4) Dinoyo and Ketawanggede, 5) Sumberari, 6) Menjing, 7) Tunjungsekar, 8) Borobudur, 9) Tawangmangu, 10) TPS Tasikmadu I, 11) TPS Tasikmadu II, and 12) Joyogrand. Scope of material discussed in this research is the process of waste transport system from waste transfer point to landfill. The scope of the study could be seen in figure 2.
Observation is a method of collecting data through direct observation or review conducted carefully and directly in the field or research location. Methodology research implied that the observation is a systematic observation and recording of a symptom that appears on the object of research [12, 13, 14].

Observations in this study were conducted to obtain the required data related to waste transportation system in waste transfer points in Lowokwaru district. Observations include the condition of the waste transfer point, the condition of equipment and means of transporting waste and the condition of roads traversed by waste trucks. Moreover, observation is also done by following the waste truck from waste transfer point to landfill to measure the average speed of the waste truck. The average speed data is used in network analyst calculations for the fastest route determination of waste transfer point in Lowokwaru district to landfill.

Network analyst was developed by Gallardo et al (2015) based on different vehicle speeds of the day. Network Analyst has the ability to calculate the shortest travel time between two locations by determining start time [15]. In 2003, Echols developed GIS application to find out the fastest route between two destinations [16]. Some previous research determined the optimal route of solid waste collection using GIS analysis tools [17, 18].

The use of Network analyst in this research is intended to find out the optimal route can be taken from the existing transfer points in Lowokwaru district to Supiturang landfill. The first step is to fill the road attributes of vehicle speed and also the length of each road segment. Vehicle speed is obtained by following waste truck from waste transfer points in Lowokwaru district to Supiturang landfill. The average speed is calculated afterwards and inserted into the attribute speed in each road segment. The length of road segment can be obtained from the shp file of Malang City. There are two steps to be taken to determine the fastest route which is creating a network file dataset and analysing the fastest route on the network analyst. Network analyst in this research is part of analysis in ArcGIS 10.1 for student.
3. Result and Discussion

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3.1. Fleet routes

Fleet routes are made to facilitate workers and means of transporting waste can be used effectively and efficiently. The assessment of the optimal transport route is done based on the distance and the fastest time from the waste transfer point to Supiturang landfill. The route of waste transportation in Malang City has been determined by the Office of Sanitation and Gardening of Malang City (Dinas Kebersihan dan Pertamanan/DKP). The transportation routes describe the waste transportation from waste transfer point to the final waste disposal site (landfill) through certain streets (St.). The following section shows all routes for waste transportation in the district.

a. Tungguwulung Waste transfer point
   Tungguwulung Waste transfer point -Candi Panggung St.–Soekarno Hatta St.– Mayjen panjaitan St.–Bogor St.–Veteran St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

b. Merjosari Waste transfer point
   Merjosari Waste transfer point–Sigura-gura St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

c. Tlogomas Waste transfer point
   Tlogomas Waste transfer point–Merjosari St.–Sumbersari St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

d. Dinoyo and Ketawanggede Waste transfer point
   Dinoyo and Ketawanggede Waste transfer point–Gajayana St.–MT Haryono St.–Mayjen panjaitan St.–Bogor St.–Veteran St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

e. Sumbersari Waste transfer point
   Sumbersari Waste transfer point-Mayjen panjaitan St.–Bogor St.–Veteran St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

f. Menjing Waste transfer point
   Menjing Waste transfer point–Pisang Kipas St.–Soekarno Hatta St.–Mayjen panjaitan St.–Bogor St.–Veteran St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

g. Tunjungsekar Waste transfer point
   Tunjungsekar Waste transfer point–Ikan Piranha Atas St.–Ikan Tombro St.–Soekarno Hatta St.–Mayjen panjaitan St.–Bogor St.–Veteran St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

h. Borobudur Waste transfer point
   Borobudur Waste transfer point–Soekarno Hatta St.–Mayjen panjaitan St.–(Ijen St.–Jakarta St.–GedeSt.–Wilis St.–Raya Dieng St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

i. Tawangmangu Waste transfer point
   Tawangmangu Waste transfer point–Tawangmangu St.–Sarangan St.–(Letjen Suparman St.–Letjen Sutoyo St.–Buring St.–Ijen St.–Wilis St.–Raya Dieng St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

j. Tasikmadu I Waste transfer point
   Tasikmadu I Waste transfer point–Kyai Yusuf St.–Ikan Gurame St.–Sudimoro St.–Soekarno Hatta St.–Gajayana St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsepp St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.
k. Tasikmadu II Waste transfer point
Tasikmadu II Waste transfer point–Bulutangkis St.–Renang St.–Kyai Yusuf St.–Ikan Gurame St.–Sudimoro St.–Soekarno Hatta St.–Gajayana St.–Bendungan Sutami St.–Galunggung St.–Raya Langsep St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

1. Joyogrand Waste transfer point
Joyogrand Waste transfer point–Merjosari St.–Sumber Sari St.–Bendungan Sutami St.–Galunggung St.–Raya Langsep St.–Mergan St.–Bandulan St.–Mulyorejo St.–Supiturang landfill.

3.2. Transport System Effectiveness
According to [11], there are three approaches that can be used to measure effectiveness: target approach, source approach, and process approach. In this study the researchers used a target approach to determine the effectiveness of waste transport system in Lowokwaru district. The purpose of transporting waste is to transport all the waste from the waste transfer point to the landfill. If there is still waste in the waste transfer point it means that the waste transport is not effective and if the waste is transported all to landfill has the meaning of effective waste transport. Here is the waste condition at Lowokwaru waste transfer point shown in table 1.

| No.  | (1) | (2) | (3) | (4) | (5) | (6) |
|------|-----|-----|-----|-----|-----|-----|
| 1.   | Tunggulwulung | 12  | 12  | 2   | Waste left over | Ineffective |
| 2.   | Merjosari     | 26  | 26  | 3   | Waste left over | Ineffective |
| 3.   | Tlogomas      | 24  | 24  | -   | No Waste        | Effective   |
| 4.   | Dinoyo & Ketawanggede | 28  | 28  | 2   | No Waste        | Effective   |
| 5.   | Sumbersari    | 24  | 24  | -   | No Waste        | Effective   |
| 6.   | Menjing       | 25  | 25  | -   | No Waste        | Effective   |
| 7.   | Tunjungsekar  | 22  | 22  | -   | No Waste        | Effective   |
| 8.   | Borobudur     | 50  | 50  | -   | No Waste        | Effective   |
| 9.   | Tawangmangu   | 30  | 30  | -   | No Waste        | Effective   |
| 10.  | Tasik Madu I  | 12  | 12  | -   | Waste left over | Ineffective |
| 11.  | Tasik Madu II | 6   | 6   | 1   | Waste left over | Ineffective |
| 12.  | Joyogrand     | 16  | 16  | 2   | Waste left over | Ineffective |

Note: 1=Waste Transfer point 2=Number of Waste Carts 3= Waste Generation (m³) 4=The Rest of The Waste (Waste carts) 5=Waste Conditions at Waste transfer point 6=Effectiveness

Based on table 1, there are seven waste transfer points (Tlogomas, Dinoyo & Ketawanggede, Sumbersari, Menjing, Tunjungsekar, Borobudur, and Tawangmangu) which show how effective it is because in this transfer depo there is no waste. If all waste is transported to landfill, it indicates that waste transport is effective. In the other hand, five waste transfer points that still have the rest of the waste after the last trip of waste transport. The five waste transfer points are Tunggulwulung, Merjosari, Tasik Madu I, Tasik Madu II, and Joyogrand. If there is still waste in the waste transfer point it means that the waste transport is not effective. Therefore, there should be a replacement of vehicles with greater tamping power or by increasing the number of trucks to avoid waste in the waste
3.3. Network analyst

The use of Network analyst in this study is intended to find out the fastest route that can be taken from the existing waste transfer point in Lowokwaru district to Supiturang landfill. The fastest process is obtained from the accumulated travel time of each road segment that can be reached from waste transfer points in Lowokwaru district to Supiturang landfill. While the travel time of each road segment obtained from the division between the lengths of each road segment with the average speed of the vehicle, the average speed of the vehicle obtained from the interview with waste truck drivers.

In this study, in determining a route assisted by Network Analyst ArcGIS 10.1 for students. Network analyst will automatically generate the fastest route that can be passed from the point of the initial location to the point of destination location. The following is the fastest route analysis result done by Network Analyst on ArcGis from each waste transfer point to Supiturang landfill. The fastest routes describe the waste transportation from waste transfer point to the final waste disposal site (landfill) through certain streets (St.). The following section shows all the fastest waste transportation in the district.

a. Tunggulwulung waste transfer point
Tunggulwulung waste transfer point–Arumba St.–Akordion St.–Candi Panggung St.–Soekarno Hatta St.–Mayjen Panjaitan St.–Bogor St.–(Jakarta St.–Gede St.–Simpang Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

b. Merjosari waste transfer point
Merjosari waste transfer point–Bendungan Sigura-gura St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

c. Tlogomas waste transfer point
Tlogomas waste transfer point–Kecubung St.–Tlogo Wulan St.–Tlogo Indah St.–Jojo Utomo St.–Joyo Tambaksari St.–Sumbersari St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

d. Dinoyo and Ketawanggede waste transfer point
Dinoyo and Ketawanggede waste transfer point–Joyo Tambaksari St.–Sumbersari St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

e. Sumbersari waste transfer point
Sumbersari waste transfer point–Sumbersari St.–Bendungan Sutami St.–(Galunggung St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

f. Menjing waste transfer point
Menjing waste transfer point–Pisang Kipas St.–Soekarno Hatta St.–Mayjen Panjaitan St.–Bogor St.–(Jakarta St.–Gede St.–Simpang Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–landfill Supiturang).

g. Tunjungsekar waste transfer point
Tunjungsekar waste transfer point–Ikan Piranha Atas St.–Sudimoro St.–Soekarno Hatta St.–Mayjen Panjaitan St.–Bogor St.–(Jakarta St.–Gede St.–Simpang Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

h. Borobudur waste transfer point
Borobudur waste transfer point–Borobudur St.–Soekarno Hatta St.–Mayjen Panjaitan St.–Bogor St.–(waste transfer point Gede St.–Simpang Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

i. Tawangmangu waste transfer point
Tawangmangu waste transfer point–Sarangan St.–(Letjen Sutoyo St.–Jaksan Agung Suprapto St.–Briegjen slamet Riyadi St.–Bromo St.–Semeru St.–Ijen St.–Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).
j. Tasikmadu I waste transfer point
Tasikmadu I waste transfer point–KH Yusuf St.–Ikan Gurami St.–Sudimoro St.–Soekarno Hatta St.–Mayjen Panjaitan St.–Bogor St.–(Jakarta St.–Gede St.–Simpang Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

k. Tasikmadu II waste transfer point
Tasikmadu II waste transfer point–Bulutangkis St.–Atletik St.–KH Yusuf St.–Ikan Gurami St.–Sudimoro St.–Soekarno Hatta St.–Mayjen Panjaitan St.–Bogor St.– (Jakarta St.–Gede St.–Simpang Wilis St.–Raya Dieng St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

l. Joyogrand waste transfer point
Joyogrand waste transfer point–Perum Joyogrand St.–Joyo Sari St.–Joyo Utomo St.–Joyo Tambaksari St.–Sumbersari St.–Bendungun Sutami St.–(Galunggung St.–Raya Langsep St.–Bandulan St.–Raya Mulyorejo St.–Rawisari St.–Supiturang landfill).

3.4. Comparison of existing route with the fastest route
Based on the fastest route from network analyst result there is difference of distance and also travel time between existing routes. Table 2 show the difference between the distance and travel time between the existing route and the fastest route based on network analyst. Network analyst in this study is intended to find out the fastest route that can be taken from the existing waste transfer point in Lowokwaru district to Supiturang landfill. The fastest process is obtained in table 2.

| No | Waste Transfer point | Existing Route (minute) | Fastest route (minute) | Existing Distance (Km) | Fastest Distance (Km) |
|----|----------------------|-------------------------|------------------------|------------------------|------------------------|
| 1  | Tunggulwulung         | 32.8                    | 31.2                   | 14.24                  | 13.82                  |
| 2  | Merjosari             | 23.3                    | 23.3                   | 9.88                   | 9.88                   |
| 3  | Tlogomas              | 26.2                    | 26.2                   | 11.44                  | 11.44                  |
| 4  | Dinoyo and Ketawanggede | 29.9                 | 24.4                   | 12.00                  | 9.10                   |
| 5  | Sumbersari            | 17.2                    | 17.2                   | 7.25                   | 7.25                   |
| 6  | Menjing               | 28.4                    | 26.7                   | 12.04                  | 11.62                  |
| 7  | Tunjungsekar          | 32.7                    | 31.8                   | 13.23                  | 12.81                  |
| 8  | Borobudur             | 29.6                    | 29.1                   | 12.84                  | 12.73                  |
| 9  | Tawangmangu           | 25.4                    | 25.4                   | 11.07                  | 11.0                   |
| 10 | Tasik Madu I          | 34.6                    | 32.4                   | 14.24                  | 13.89                  |
| 11 | Tasik Madu II         | 39.2                    | 37.1                   | 16.31                  | 15.96                  |
| 12 | Joyogrand             | 27.1                    | 27.1                   | 11.74                  | 11.74                  |

Based on table 2 it can be seen the difference of travel time and also the distance between the existing route with the fastest route. There was also the travel time and distance is the same with network analysis, there were Merjosari, Tlogomas, Sumbersari, Tawangmangu and Joyogrand waste transfer point. The difference of travel time and the largest distance is found in Dinoyo and Ketawanggede waste transfer point with the difference of travel time reaches 5.4 minutes and 2.9 km. The difference in travel time and mileage (distance) indicates that the determination of the existing route is still inefficient.

4. Conclusion
The existing transportation route is a route that has been determined by the Department of Hygiene and Gardening of Malang City (Dinas Kebersihan dan Pertamanan) as the responsible of the process of transporting waste Malang City. The value of effectiveness of waste transportation system in waste transfer point in Lowokwaru district is 48% effective. While as many as 52% is still not effective due
to the remaining waste in the waste transfer point. The comparisons between existing route with fastest route based Network Analyst obtained the shortest and fastest route as follows 1): six waste transfer points have the fastest route in travel time (minute) and 2) seven waste transfer points have the fastest route in travel distance (km).

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