Optimization of waste management in developing countries with spatial approaches (Study case: Depok City and Curitiba City)

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Abstract. Waste management is a challenge for city authorities in developing countries especially due to increase of waste. The burden that is incurred on the city budget as a result of the high costs associated with its management and lack of understanding of the diversity of factors that influence the various stages of management. Comparative and descriptive analysis are utilized in this paper to observe the differences that arise at various levels of the administration so that they can be analysed. Data are collected from journal publications starting in 2013-2019. This paper compares how the handling of waste management has used a spatial approach starting from the Asian, Indonesian, and Depok levels. The purpose of this research is to find out what areas of waste management can be solved by spatial approaches, and recommendations for solutions that can be applied to the Depok City based on success story in other countries or regions. The Depok City already has a community-based approach that runs the trash bank. However, the waste bank is still ineffective, despite the low level of waste collection in Depok City. The optimization of waste management in Depok City can be improved its accuracy using spatial approach.

1. Introduction
Waste management is one of the big problems that faced by many countries in the world [1], thus becoming one of the points is important to the 17 points SDGs. It is because of the poor quality of the waste management affects aspects of environmental, economic, and social well as directly or not directly. Attention specifically focused on the state develops which continues to prioritize the development and growth of the economy due to the generation of waste associated positively with the growth of the economy [2].

Global average rate of collection of waste in the country growing from 50% in the year 1990 be around 65% by the year 2012 [3]. Trash that is not collected has the potential to be burned or dumped into land open and into a body of water [4]. Not only that, the countries growing in the region of Asia, especially Indonesia has a problem other is the lack of segregation at source, the process of collecting the complex, open dumping landfill, and yet the control of emissions of gas and leachate on the location of the landfill [5]. Indonesia's capital city, Jakarta, has a solid waste collection rate of 70% with a door to door solid waste collection system [5], and 66% in 1999 while
Bogor, Tangerang and Bekasi only 23% of total solid waste urban areas produced [6]. The average generation of municipal solid waste in Indonesia consists of 70% of waste, around 2.5-3.0 liters per capita per day, and all of it is transported directly to landfill. On a national scale, only 60% of the waste collected from the population, the rest is burned or disposed of into waterways or open land [4]. This figure is an increase when compared to 1995 which is equal to 40% of waste transported [4]. Collection and transportation of waste imposes collection systems in several housing locations from door to door systems to container systems [7].

2. Materials and Method
Analysis of comparative study of waste management that is used in the paper is to observe how the differences that emerged in the two areas that have similarities in conditions of social and economic (the number of population density of population, wide area geographically, the amount of GDP). The theme of the city that will be the focus in writing this is a town which is classified as the Metropolitan in class number population, and the city satellite of the capital of the country. The town is in accordance with the will be reviewed and in accordance with criteria that are Depok and Curitiba City.

GIS or Geographic Information System is a spatial data processing application using a computerized system by combining graphical data with object attribute data using digital grounded maps. GIS is growing rapidly and is widely implemented in all fields such as education, health, geography, weather, population, piping networks and others. Basically, GIS displays and accelerates the data desired by the user where previously only using the manual method but currently using the digital method (Computerized). The geography approach as a tool to provide a new perspective on waste management has been carried out by several researchers in recent years. These approaches include optimizing waste transportation [8][9][10], increasing the effectiveness of the amount of waste transported and recycled [11], waste transportation model that considers the amount of generation, transportation, and relocation of waste containers [12].

The establishment of GIS modelling to analyse the level of transportation and collection of waste, as well as an evaluation, consists of several stages [13]:
1. Data collection
2. Establish and develop a GIS database
3. Conduct an analysis of the current level of waste collection and transportation
4. Identifying the optimal allocation of polling stations based on the road network, population density, and buffers from existing polling stations.
These stages can be chosen in the form of a flow chart [13].

![Figure 1. Example of Model GIS on Waste Management](image)

3. Result and Discussion
3.1 Social and Economy Condition
The cities used as comparisons are Depok City and Curitiba City. Curitiba City is a city from a
developing country that has become a model for urban planning [14][15]. The city has become the seventh most populous city in Brazil and is included as a metropolitan city, with a population of 1.8 million divided into eight districts [14][16]. The main sector that supports the economy of the City of Curitiba is the service sector [17].

Depok City is a satellite city, including in the same urban population category, Metropolitan City, and also has connecting access between the Capital of the State and the City through arterial roads and railway lines.

In Figure 2 it can be seen that Depok City is located south of DKI Jakarta. Direct side by side and grow as the rapid impact of the growth of DKI Jakarta, making Depok City a satellite city. Depok City has an astronomical position between 6° 19’ to 6° 28’ South Latitude and between 106° 43’ to 106° 55’ East Longitude. Depok City has a geographical position in the southern part of West Java Province which is side by side with DKI Jakarta Province. Depok city is a part of the metropolitan area called JABODETABEK [18]. The population in Depok City is 2,254,513 people (BPS, 2018) so that it falls into the Metropolitan City category [18]. The population growth rate of Depok City is 3.48 percent and population density reached 11,256 people / km². This growth rate is quite high because it exceeds the national growth rate of 1.38 percent.
The population density of Depok City is concentrated in the city center, and a little in the southern part. In accordance with the explanation in the previous sub-chapter, the western and eastern regions of Depok City are less attractive because the slope of the slope is still very diverse in the two regions. The density of the population gathered in the middle of the city is caused by the Education Area and the Service Trade Area along the Margonda Road. The main economic contributor in Depok City is the service sector. In more detail, accommodation, food, information, financial services and education services.

3.2 Landfill
Indonesia still has poor waste management, it is recorded that 69% of the waste is stockpiled and transported directly to the landfill, buried (10%), composted and recycled (7%), burned (5%), and not managed (7%), for the landfill 90% of the regions in Indonesia still use open dumping technology or even burned [19]. In 2013 to 2014 there was a decrease in the percentage of waste that had been sorted which was originally 23.69% to 18.84%. Depok City in 2016 has carried out the process of sorting waste and composting by 57.2% of the total waste, then the residue is disposed of to landfill [19]. Depok City has one TPA unit with a location in Cipayung District with an area of 11.2 ha [19]. The TPA location is functioning safely 30 years and the capacity has reached its maximum limit [19]. The height of the waste pile has reached more than 30 meters and continues to increase [19]. Based on the calculation of the environmental risk index Cipayung Landfill in 2016 has been included in the medium hazard evaluation category, which means that it requires immediate rehabilitation to be controlled under control [19]. Curitiba City has a landfill condition that is not much different from Depok City which is already full, but also does not have the cost to build incinerator facilities [17].

The Curitiba City Government, which does not yet have the income to build new and expensive waste management facilities, is looking for unique innovations to slow the rate of growth of waste generation [17]. The innovations made have succeeded in reducing the rate of waste generation, but the poor
population has the opportunity to work [17]. This innovation has made Curitiba City awarded as an Ecological City through two programs, namely Garbage That Is Not Garbage and Green Exchange [15].

3.3 Legislation on Waste Management
The responsibility for waste management in Depok City is currently technically carried out by the Department of Environment and Hygiene. The head of Department is making technical waste management efforts, but the service level achieved in 2016 was 56.22% [19]. The generation of waste that is not managed by Department will be processed by the community independently and by collectors carried out sorting [19].

3.4 Waste Generation, Composition, and Waste Collection
The amount of waste generated in Depok City still exceeds the capacity of transported waste [7][19][20]. The amount is estimated at 140,603 liters/year. This amount still cannot be transported, only 594 million liters/year of waste that can be transported in Depok City [20]. This low level of transportation makes the accumulation of waste at several locations in Depok City.

![Figure 4. Waste Collected of Depok City](image_url)
Table 1. Percentage of Collected Waste in Depok City

| Subdistrict   | Household | Household with collected waste | Percentage | Quality |
|---------------|-----------|--------------------------------|------------|---------|
| Sawangan      | 29.900    | 21.243                         | 71%        | Bad     |
| Bojongsari    | 14.951    | 10.622                         | 71%        | Bad     |
| Pancoran Mas  | 44.916    | 30.800                         | 69%        | Bad     |
| Cipayung      | 22.458    | 15.400                         | 69%        | Bad     |
| Sukmajaya     | 23.356    | 11.002                         | 47%        | Bad     |
| Cilodong      | 46.710    | 22.003                         | 47%        | Bad     |
| Tapos         | 63.987    | 47.846                         | 75%        | Bad     |
| Beji          | 31.994    | 23.924                         | 75%        | Bad     |
| Limo          | 37.848    | 26.311                         | 70%        | Bad     |

This un-transported rubbish can have an impact on Depok City itself, because residents tend to dump the waste into rivers and into vacant land [20]. This can have an impact on river water pollution, air, and soil pollution. Depok City’s waste has the composition of the dominant element in the form of organic waste by 55%, as well as the composition of other developing country waste [19].

Figure 5. Non-Organic Waste Generation of Depok City
In addition to organic waste, other compositions consist of inorganic waste which has the potential to be carried out as much as 20% recycling process, both textile and textile by 8%, rubber and leather by 2%, and other waste as much as 15%[19]. However, inorganic waste that has this potential still cannot be managed optimally so that it always ends up buried in the landfill [19].

3.5 Waste Management Program
The Depok City Government made efforts to reduce waste generation and carry out community-based recycling processes at the subdistrict level [19]. Organic waste is collected into buckets which are then taken to the Waste Management Unit (WMU) and for nonorganic material such as paper, plastic, metal and glass, is deposited at the waste bank at the local community level [19]. Local community response this program positively and has succeeded in reducing waste generation, but the carrying capacity of WMU and waste bank facilities is far below than the waste generation [19]. In 2016 Depok City need 163 more unit of WMU and 2089 more unit for waste banks to cover all waste [19].

Curitiba City government focuses on slums and areas that are not served by waste collection vehicles [17]. This effort is aided by portrayal from a geographic point of view using GIS technology which is generally used as an effort to optimize waste management [8][9]. Determination of the shortest optimal route for the waste transportation stage using a GIS application in the form of network analysis and Dijkstra's algorithm [7]. The Garbage That Is Not Garbage program encourages residents to separate waste into two major groups, namely easy recycling and difficult [17]. In terms of implementation, a waste transport car has been carried out, and the efforts to increase public awareness are carried out at educational institutions [17] and also interactive games [17][21].

The sorted waste recycling program is considered a success because 1,200 trees are saved every day [17]. Health benefits can also be seen from the number of people with dengue fever decreased due to reduced inundation which becomes a den of mosquitoes from old tires that have been taken for recycling [17]. The people of Curitiba City are already 70% active in this activity, and 13% of the waste is recyclable [17]. Curitiba City has The Green Exchange program which accommodates slums that are not served by waste collection vehicles [17]. Help for the poor to buy bus and vegetable tickets with disaggregated waste, students buy school equipment and toys with disaggregated waste, and buy vegetables that are not sold out from farmers are some of the program’s technical efforts [17]. Indirectly, the government has tried to take out the waste without the need to provide a waste transport vehicle [17].

4. Conclusions
The Curitiba City Government, which does not yet have the budget to build new and expensive waste management facilities make innovation that involve people. The innovations made have succeeded in reducing the rate of waste generation, but the poor population has the opportunity to work. The innovation was successful because the policies carried out were based on data and also the analysis of the exact location. Identify areas that are not served by the transportation of rubbish and are slums to make a big impact. Waste collection in the area provides three concurrent benefits: providing employment to the poor, reducing waste dumped on the riverbank, and improving the health of the poor with a clean environment. This accuracy is supported by the spatial approach. Depok city already has a community-based approach that runs the trash bank. However, a number of research results indicate that the waste bank is still ineffective, despite the low level of waste collection in Depok City. The optimization of waste management in Depok City needs to be improved its accuracy with the help of a spatial approach, one of which is with GIS technology.

6. Preferences
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