Geographic Information System for Waste Management for the Development of Smart City Governance

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Abstract. The Era of the Industrial Revolution 4.0 has been able to change the paradigm of government towards the contribution of Information Technology in providing fast, precise and accurate services to the public for better information service needs. Trends in Smart City Governance will also increase public and government participation in utilizing application data so that they can provide suggestions and criticisms quickly, easily and accurately. Makassar has a population of 1,469,601 people and is the highest compared to other regions in South Sulawesi. Makassar has produced around 1,200 tons of waste per day that goes to Tamanagappa landfills. Waste generated by each district is different from other districts, so it is necessary to do integrated waste management. To overcome this problem, Makassar City Government applies the Smart City concept that focuses on Smart Environment. This concept aims to reduce and utilize waste and create better energy sources. The research objective is to develop a system that can provide information to the public so that the performance of the Makassar City Sanitation Office becomes effective and integrated. Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, organize and display all types of geographic data. GIS components consist of data, software, hardware, users, and applications. Research using the Spiral method with tools or applications used by implementing ArcView, ArcGis, and Map Info. GIS tools used are based on Open Source such as Google Maps by providing various types of libraries that can be directly used. The results showed 90% of respondents agreed that this application could be used.

Keywords: governance, smart city, GIS

1. Background
The Industrial Revolution Era 4.0 has been able to change the paradigm of government towards the contribution of Information Technology to provide fast, appropriate and accurate services to the public. Nowadays people need better and more useful information services. Smart City governance can increase public and government participation in utilizing application data so that it will provide suggestions and criticisms quickly, easily and accurately.

Makassar has a population of 1,469,601 people. This number is relatively large compared to other cities in South Sulawesi such as Bone which only has a population of 746,973 inhabitants followed by Gowa 735,493 inhabitants. With the large number of residents in Makassar, it is directly proportional to the amount of waste generated per day and has the potential for flooding. Total waste entering Tamanagappa landfill is around 1,200 tons per day.
Of all the garbage that enters the Tamanagappa landfill each day, it must originate from a different sub-district as well as the volume of waste produced. The rubbish produced by each sub-district is different from one sub-district. The presence of waste is influenced by the population, geographical factors, community habits, and the collection system that is running. Waste management systems that are running must be able to work optimally and efficiently. To overcome this problem, Makassar City government began in 2014 started to implement the Smart City concept. Therefore in 2017 the Makassar City has been designated as the place to start the Movement Towards 100 Smart City programs in Indonesia by the Ministry of Communication and Information.

Smart City itself is defined as a city that is able to use HR, social capital, and modern telecommunications infrastructure (Information and Communication Technology) to achieve sustainable economic growth and high quality of life, with wise resource management through community participation-based governance.[3]

The concept of smart city can also increase public and government participation in utilizing application data, providing input and criticism easily.[4] In line with the development of smart cities in Indonesia delivered by the Director of Urban and Rural Ministry of PPN / Bappenas in the e-Indonesia Initiative (eII) and Smart Indonesia Initiatives (SII) Forum 1 in Bandung, October 15, 2015, urbanization is happening from village to city from year to year which shows quite significant figures. Based on data from the Central Statistics Agency (BPS) in 2014, the population in 2005: urban 48.39% and rural 51.61%, 2010: urban 54.19% and rural 45.81%, 2015: urban 59.35 % and rural areas 40.65%, and predicted in 2020: urban areas 63.84% and rural areas 36.16%.

One of the missions in the 2015-2045 sustainable city development goals is to build productive, creative and innovative, and efficient competitive economic and community activities in the city. Through the internet, information can be accessed and used for various purposes by anyone, anywhere and anytime. Various types of internet technology can be used. One of which is able to provide quality information in the form of text, images, sounds, and moving images. With this ability, the website becomes very famous and is growing very rapidly. Cities have a growing problem in spatial planning over time. Not infrequently the problems that arise due to the development of the city itself. To be able to prevent this, city management (governance) is needed through a sustainable planning concept approach, which is based on green technology.[5]

Part of the concept of Smart City is Smart Environment which aims to reduce and utilize waste and create better energy sources through the distribution and management of waste[6] so it is necessary to develop smart city governance based on Geographic Information Systems (GIS) of waste management. The lack of information about the area of waste distribution in the city of Makassar causes this waste to be disposed of in various places and in inappropriate times. To be able to maximize the performance of waste transportation in the city of Makassar, it is necessary to use GIS which is an information system with the ability to manage or process information that is bound or has a reference to time, space, or place.[7] GIS works by storing information about the earth as a collection of thematic map layers, all of which can be linked together. This method is expected to make data more flexible and dynamic so that it can be combined according to needs and usage. GIS automatically connects attribute data with maps, so there is a link between the two. The research is useful in providing waste information in every region or sub-district in Makassar so that it can improve the performance of the Makassar municipal government cleanliness department. The research is expected to be able to result in the development of GIS-based smart city governance in waste management so that it can know the area of waste distribution and can maximize waste collection in the city of Makassar.

2. Methods

2.1. Types of Research
Applied research is carried out with regard to practical realities, applications and the development of knowledge produced by basic research in real life. Applied research serves to find solutions about certain problems. The main objective of applied research is problem solving so that research results can be
utilized for the benefit of humans either individually or in groups or for industrial or political purposes and not for scientific insight alone. This research does not focus on developing an idea, theory, or ideas, but rather focuses on the application with a low level of abstraction so that the benefits or impacts can be felt directly by the government, especially the cleaning service and the city community that uses the application. To be able to improve performance and maximize better waste management, it is necessary to support information systems based on GIS in mapping and reporting recycled waste by type in each district and city of Makassar.

2.2. Design of Experiments and How It Works
The design method used in this study is spiral model, which is an evolutionary software model that compiles the iterative nature of the prototype by means of control and systematic aspects of the linear sequential model. The spiral model has the potential to develop additional versions of the software quickly. Based on the spiral model, there are six phase that will be carried out in this study.

![Spiral Model](image)

**Figure 1. Spiral Model**

a. Planning Phase
Planning phase to define resources, accuracy and performance in the form of information about the Makassar municipal waste management system.

b. Requirement and Analysis Phase
The requirement phase is carried out to determine the needs of the government and the community. Analysis will be carried out to trace and search for information on the Makassar City Sanitation Office and collect the necessary data such as the number of janitors in the field, the number of garbage transport vehicles both tricycle and trucks, Makassar city sub-district data and Makassar city daily waste volume data. The data was obtained from interviews from Makassar city Sanitation Office Staff and field surveys.

c. Design Phase
Design or depiction phase, is the phase of developing a system model that will be made based on GIS in an effort to manage waste in the Makassar city district in coordination with the Makassar city Sanitation Office. The design uses context diagrams, tiered, flowchart, ER-Diagrams, and system interfaces.

d. Construction Phase
Construction phase or the construction phase, to build a development of governance through information service distribution and waste processing. The application is created using the PHP programming language, and the MySQL database. Research using the spiral method with tools or applications used by implementing ArcView, ArcGis, and Map Info.
e. Testing Phase
Testing phase or the testing phase is carried out to test the system using the Black Box testing method and look for loopholes whether in the form of coding, design or database. As well as testing the system and is connected with the main system of the City Sanitation Department.

f. Deployment and Acceptance Phase
This phase will try the results of the development of GIS-based governance that is carried out at the construction phase, whether the mapping and waste reporting program that has been made in accordance with what is needed such as features and program user interfaces. This phase uses a web browser.

2.3. Data Collection Methods
The method used for data collection in developing smart city governance consists of:

a. Study of literature
Literature studies are used to collect data and information about the PHP programming language and MySQL database. Both in the form of written documents, electronic documents, scientific journals, video tutorials and websites related to PHP.

b. Interview
Interview is a process in obtaining information about the waste management process that runs in each district of Makassar city involving staff from the Sanitation Office as a resource in research.

c. Documentation
Documentation is a process of recording data obtained from the results of information ranging from writing, description, and important archives. In the documentation it is necessary to record information in the cleaning service needed by the data in the form of garbage transport vehicles, and data originating from districts in the city of Makassar.

2.4. Data Analysis
The data analysis phase uses qualitative techniques by conducting interview methods to find out whether the development of GIS-based smart city governance for waste mapping and management is made so that it can help manage waste in the city of Makassar.

3. Results and Discussion
Development of smart city governance is carried out through the stages of planning, requirements and analysis, design, construction, testing, as well as deployment and acceptance.

3.1. Planning
The Planning Phase uses GIS in Makassar through observation and interviews by looking at the work process from the sub-district to the Environmental Department. To find out the needs of two different agencies, an interview is needed. The results of this system planning are expected to provide information and images that can help the Smart City Makassar program and can provide direct information to the public regarding information about waste management in the city of Makassar.
3.2. Requirement and Analysis
The research obtained data and analyzed some data that had been used to determine the needs in developing GIS-based governance. Where this system displays garbage data that has been previously entered by service officers into the system and then the data is processed for later display. The public can see directly the results of waste processing that takes place in the field in addition to being useful to the community this data can also be reused by the sanitation office to further optimize the performance of officers.

3.3. Design
Based on the results of the interview, the next stage is to design the development of the system created. The design starts by making a context diagram.
Figure 4. Level Diagram

Based on the context diagram, it can be seen that GIS for waste processing consists of 4 entities namely the Office of the Environment, Districts in Makassar city, Sanitation Officers, and Makassar City Communities. Admin comes from the district where inputting data such as subdistrict data and garbage data are stored in the database. Janitors input data such as the number of daily garbage transport reports, the status of the vehicle used to the status of workers in the field.

The Department of Environment and the people of Makassar City can see the results of reports from the two previous entities. The Office of the Environment can directly monitor the performance of officers from each sub-district to the status of the vehicle. The public can see waste information on the city of Makassar. The level diagram in Figure 4 shows the relationships that occur between entities, processes, and data storage needed.

Figure 5. ER-Diagram
Figure 5 shows the ER-Diagram with 13 tables. The subdistrict table is a source of transactions for other tables and thus requires sufficient data support in order to provide accurate information. Figure 6 shows a system flowchart which explains that officials enter District data in the form of landfills, garbage banks, officer details, vehicle details. After that it continues the process of calculating the results of transportation of garbage that has been previously entered by the janitor to count. The process of handling the status by subdistrict officials is in the form of vehicle status and personnel pre-filled by cleaning staff. Then the final filling is the process of making a system report in the form of maintenance, garbage, officer status and vehicle status, as well as waste transportation reports.

3.4. Construction
Based on the results of the interview, the next stage carried out by the author is to design the development of the system created.
Figure 7. The page for the Janitor Admin

Figure 8. Officer Status Report

Figure 7 shows the appearance of the janitor admin page that contains the number of janitors, total vehicles, waste production, and garbage handled. Figure 8 shows the form for filling vehicle status, personnel, and maintenance status as a report.
Figure 9 shows the program script about the officer status report created with the PHP program. Figure 10 shows a list of vehicle and field officer status reports that are useful for knowing the date, time, and name of the officer.
Figure 11 shows the location and list of the District Garbage Disposal Sites in the city of Makassar. The number of sub-districts is 14 and spread in various regions. Figure 12 shows the location and garbage bank located in each district of Makassar city. The location of the waste bank is needed so that the community knows the exact location of the location to facilitate management.
Figure 13. District Details

Figure 13 shows the community who wanted to obtain complete information on names, addresses, transportation schedules for the sub-district, waste production, transport vehicles, and the number of officers in the sub-district.

3.5. Testing
Testing is done by the Black Box method to find out the truth of the GIS by finding fault loopholes whether in the form of coding, design or database. The test focuses on the functional requirements of the system with the aim of trying to find errors of function errors, interface errors, data structure errors, or other performance errors.

Testing input data includes: admin login, district admin system, environmental office admin system, community system. The results showed 90% of respondents agreed that this application could be used.

3.6. Development and Acceptance
This stage will try the results of developing a GIS which will be carried out during the construction phase. Smart city governance development program for mapping and reporting waste that has been made in accordance with what is needed such as features and user interface programs. This stage uses a web browser. A system demonstration was conducted in front of several respondents to get a response back from the respondents. The results of system demonstrations and simulations of respondents indicate that:
1) The system has produced a service system that helps officers and the community.
2) System users are more enthusiastic about the report features, such as reporting waste that has not been handled up to vehicle and officer status reporting.
3) Existing features have been used by respondents and in accordance with the needs of respondents.

4. Conclusion
The development of GIS-based smart city governance can improve the performance of GIS-based services through attention and cooperation in the use of information technology. GIS has been able to assist the community in finding information about the process of managing and distributing waste in the city of Makassar to make people more aware of the ongoing waste management. Through this system the Makassar City Government can monitor the performance of waste management that occurs in each
district of Makassar city so as to maximize the performance of officers and support smart city programs in Makassar based on the respondents' assessment of 90%.

Acknowledgment
Thank you to The Ministry of Research, Technology and Higher Education of Republic of Indonesia for supporting the National Strategic Research (NSR) competition and Makassar City Government in completing the development of smart city governance. The author would like to acknowledge University of Malaya through the research and community service unit as the party that supports financially for this paper to be submitted to i-cosine 2019 in Mallaca, Malaysia.

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