Integrated Information System Design of Municipal Solid Waste Data in Indonesia (Study Case: South Tangerang City)

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Abstract

Municipal solid waste management (MSW) is still a common problem in Indonesia. The treatment for municipal solid waste in Indonesia is majority 60% depends on open dumping facilities and now facing an overcapacity. Government and some researchers have difficulties in study MSW caused lack in quality and quantity of the data. This research designs information system for city's MSW management in Indonesia. Design was followed the object – oriented method design and use UML standards diagram. This study provides information system design that consists of use case diagrams, ERD, class diagrams, and activity diagrams for software. The output of the research can help government to develop information system for MSW management in their city. Information system implementation expected to improve the quality and lacks data in MSW management. Based on the analysis, Information system implementation can also reduce staffing costs and consultant costs in the future.

Keywords
Information System, Municipal Solid Waste Management, Data Collection, Object – Oriented Design, UML.

1. Introduction

Indonesia is still facing problems of municipal solid waste. Indonesia is very dependent on landfilling or open dumping for waste management, around 60-70% of waste was transported to temporary landfills in 2006 (Damanhuri et al. 2013). This waste treatment caused Indonesia some problems such as overcapacity in some landfill sites, one of them is in the city named South Tangerang. The government must improve their strategy and continue to look for solutions to reduce waste in Indonesia and look for other alternative waste processing.

According to the Ministry of Public Works and Public Housing, waste data in Indonesia is still difficult to get. In fact, to form an optimal strategy, complete, accurate and real-time waste data is needed. Support of information technology is a key of successful improvement in BPR methods (Arovah and Dachyar 2020). In Indonesia, waste national data can be accessed in the SIPSN (National Waste Management Information System) created by the Ministry of Environment and Forestry for transparency of waste data for public in a national scale. In the region itself, the waste reports provided are still in the form of predictions, less accurate and not integrated. Therefore, the information system of a waste data should not only be applied on a national scale, but also be applied on a smaller scale such as a city/province, to facilitate data collection and analysis conducted by the local city/province.

Information systems are including computers, databases, and communication systems participation (Xaverius and Dachyar 2020). For information system implementation, there are 3 steps according to Dachyar and Dewi (2015). First, pre – implementation, then implementation and last is post – implementation. Application of an integrated information system can also facilitate the implementation of IoT in the future, information system can support the development of smart city in Indonesia. Smart city is a topic that is often discussed lately. Historically, the smart city concept has emerged in the early 2000s. At the initial concept, as the name suggests, the smart city focuses on the application of the latest technology as a solution.

In its development, the focus of smart cities is not only on the application of technology, but also community participation (Zakharova and Fedorova 2020). According to (Anthopoulos et al. 2016) information and technology of communication is important in smart city concept, to improve people's quality of life and life efficiency. One of the steps that can be taken to implement a smart city is digitalization. According to a Deloitte report (2020), technologies such as 5G, then the application of the Internet of Things (IoT), the use of cloud computing and big data analysis are technologies with great potential for developing smart cities. Therefore, the data collection information system and waste data processing can help facilitate the development of smart cities in the waste management sector. Information system implementation also have an impact to increase competitiveness and effectiveness in several fields, one of the proven works is in university sector (Dachyar and Dewi 2015).

1.1 Objectives

The purpose of this research is to design an integrated waste information system in South Tangerang City.

2. Literature Review

2.1 Waste Management in South Tangerang

Indonesia is depending on 2 ways of waste management, namely open dumping, and sanitary landfill (Priatna et al. 2019). In South Tangerang, only applies the open dumping method to process waste, the open dumping site is named TPST Cipeucang. Open dumping is a method of processing waste by piling waste in open ground without further landfill processing (Priatna et al. 2019). As a result of the open dumping system, the current state of the TPST Cipeucang is already overcapacity, and there has even been a garbage landslide that caused river pollution near the TPST Cipeucang. Due to the condition of the TPST Cipeucang which has exceeded its capacity, the provincial government helps by transporting the waste in the TPST Cipeucang to the open dumping sites in Serang, Banten. Now, TPST Cipeucang is only used as a transit place for waste in South Tangerang, then the waste will be transported to Serang, Banten. There are several waste treatment facilities in South Tangerang others than TPST Cipeucang.

South Tangerang have a facility for waste recycling named Waste Bank. Waste Bank is a facility that allowed people to deposit their recycle waste and will be processed by the third parties and will be paid for deposited the waste. Waste Bank is one of the most popular waste treatment facilities in Indonesia, and South Tangerang City. Another treatment facilities in South Tangerang are TPS 3R (Recycle, Reuse, Reduce) and Integrated Treatment Facility (ITF). These two facilities have a same concept. They will collect the waste from nearest community, the waste that stored will be separate by the staff. Waste that can be recycle and still have a value of money will be sell to the third parties. The organic waste will through composting process. The difference between ITF and TPS 3R is, the residual waste treatment. In ITF, residual waste will be burnt in incinerator, but in TPS 3R the residual waste will be transferred to TPST Cipeucang.

2.2 System Development Life Cycle

The System Development Life Cycle (SDLC) is a stepwise approach to analysis and design that holds that systems are best developed by specific cycles of analyst and user activity (Kendall and Kendall 2014). In general, there are 7 phases in the SDLC approach, first, problem identification, purpose, and goals, defining user requirement, analyze system requirement, design the system, software documentation and development, test, and Maintain the System, last, implementation and evaluation of the system

2.3 Object Oriented Methodology

The object-oriented approach is an approach to facilitate the development of systems that must change rapidly in response to a dynamic situation (Kendall and Kendall 2014). This approach is suitable when performing continuous maintenance, system adaptation and system redesign. This approach also focused on system and data design (Dennis et al. 2012). The object-oriented approach follows an industry standard design called UML (Unified Modeling Language). UML is a diagram standardization to break down the system into a smaller part.

2.4 Business Process Automation (BPA)

Business Process Automation is a requirements analysis technique that does not change the basic process, but only improves the process efficiency. The advantages of BPA are that the project is relatively fast, the culture changes are not significant and can also reduce human error. However, there are some lacks using BPA. BPA only changes efficiency slightly and can automate non-value-added processes (Dennis et al. 2012).

2.5 Use Case Diagram

The use case diagram is one of the models used in the object-oriented approach. The use case diagram can show interaction of actors with the system. In use case diagram visualize three things: the actor that initiates an event, the event that triggers the use case, and the use case that performs the action triggered by the event (Kendall and Kendall 2014). In the use case diagram, there are no specific details and guidelines for its diagram, but there are 3 most important elements that are most often used in the use case model, there are actors, use case or activities and relations.

2.6 Entity Relationship Diagram (ERD)

Entity Relationship Diagram (ERD) is a tool that is often used to design a relational entity in database, this approach is less confusing and can give a visual mapping for software developer to figured out the network of databases (Chilton 2015). Based on Chilton (2015) there are 3 main steps to build an ERD. First, determining the data requirement, then grouping the data into entity, last, relating the entities with notation.

Relation between the entities can be figured by crow's foot notation and can figured the minimum and maximum of cardinality (Chilton 2015).

2.7 Class diagram

Class diagrams are static diagrams that describe classes, attributes, methods, and the relationships between classes in a system (Kendall and Kendall 2014). Class diagrams also describe the data stored and the processing of that data, this diagram is an extension of the ERD. In the class diagram there are several elements, namely classes, attributes, methods, visibility, and the relationship between classes. Classes represent actors or objects that must be captured by the system (Dennis et al. 2012). A class can also be described as an object on a system. The class is described by a square shape and the title is italicized, later in the class there will be attributes and methods. Attributes are information contained in a class, which will later be described according to the visibility of the attribute. Then at the end of the class there is a method, namely the method used in each class which will later be described also based on the visibility or type of the method. There are several types of visibility, namely: Public (+), Private (-), Protected (#), Package (~), Derived (/), Static (underlined).

2.8 Activity Diagram

Activity diagram is one of the diagrams from Unified Modeling Language which is useful for software development and design. Activity diagram is a diagram that describes the sequence of activities in a process, which generally describes the process of a system and can represent various scenarios (Kendall and Kendall 2014). There are 3 main symbols that usually used in activity diagram: start and end process (Circle), activity (Rounded rectangle), fork and join (Line), relationship (Line), decision making (rhombus).

2.9 Cost and Benefit Analysis

In carrying out a project and investment there are cost and benefit that must be considered. In this research, projects that will be carried out in the future are investments in technology and information systems. In terms of determining the benefits of execute technology projects, there are 2 types of benefits that can be identified, tangible and intangible benefits (Indrajit n.d.). Tangible profits are profits that can be calculated and can be cashed, then intangible benefits are profits that cannot be cashed but the benefits can be felt while implementing the technology.

3. Methods

This research is using the phases of object-oriented methodology, there are planning, analysis and design. At the planning phase, data collection in the form of interviews and collection of reports on waste management facilities is carried out. Then in analysis phase, customer needs analysis and system requirements analysis are carried out with business process automation. At the design phase there are 3 main stages, the system design stage, the database design stage, and the development design stage. Then an analysis of the benefits and costs is carried out to calculate the advantages and costs of implementing a waste information system. The design base is adapted to the UML standard, for database design using ERD with crow's foot notation.

4. Data Collection

Data was collected by interviewing several environmental service's staff in South Tangerang City and collecting documents such as waste bank reports, ITF. TPS 3R and TPST Cipeucang. Details of interview subjects and interview results can be seen in table 1.

Table 1. Interview Subject and Output

Interview Subject	Interview Output
Transportation and Collection Division Staff	Transport and collection process, requirement gathering.
Partnership and community empowerment Division Staff	Process in Waste Bank, TPS 3R and ITF and report in each facility.
Technology Development Division Staff	Process in ITF, ITF monthly report and requirement gathering.
TPST Cipeucang Managing Executive	Garbage truck weighing process and report.
Environmental Services Secretary	Requirement gathering and recommendation.

5. Results and Discussion

5.1 Requirement Analysis

From Rustan and Dachyar (2020), one of the methods that can be used to gathering requirement, needs and specification of user, is voice of customer (VOC) to get the expected output from user. From the results of requirement analysis, the expected output is integrated data storage to integrate data from various facilities and can be accessed by restricted user and a data input system for data collection of waste that has not been routinely recorded or is still recorded manually (TPS 3R, Waste Bank and ITF). Then an analysis is continued to determine the requirements needed by the system. The system in general is expected to have a login identity for each user, can generate reports from daily activities. The system in general is also expected to have personalized access for each user (Table 2).

Table 2. General System Requirement

No	*Functional*	*Non - Functional*
1	User can login with email and password	System can storage big data
2	User can see and access dashboard	
3	Report download is restriction	
4	System can manage user's access	

The design of the input system will focus on TPS 3R, Waste Bank and ITF facilities. In general, the ITF input system and TPS 3R are expected to be able to record incoming waste data, weight of waste sold to collectors and composting weight result. Meanwhile, the Waste Bank system is expected to be able record the waste weight data that deposited by each member and generate report for the recapitulation. For the system requirements in Waste Bank, TPS 3R and ITF can be seen in table 3.

Table 3. System Requirement for Waste Bank, TPS 3R and ITF

No	Waste Bank System Requirement	TPS 3R and ITF System Requirement
1	Waste bank officer can input weight data of waste each member.	ITF/TPS 3R officer can input waste income data
2	Waste bank officer can choose waste category	ITF/TPS 3R officer can input waste sold data
3	Waste bank officer can choose member who deposited the waste.	ITF/TPS 3R officer can input composting timeline data

4	Waste bank officer and Environmental Services Staff can access report	ITF/TPS 3R officer can input composting weight result
5	Waste bank officer can add new member into the system.	ITF/TPS 3R officer can generate report for each module
6	Waste bank officer can add waste price and choose the collector's identity	
7	Admin can add new collector's data into the system.	

5.2 Design Phase

In the design phase, there are 3 stages, system design, database design, development design. In system design, the output is a use case diagram design for the Waste Bank, TPS 3R, and ITF input systems. In the TPS 3R and ITF use case diagrams, there are some main activities such as logging in, collecting incoming waste data, collecting waste data that will be sold to collectors and collecting data composting result. All officers will be registered first with different access. The use case diagram for TPS 3R and ITF can be seen in figure 1 and 2.

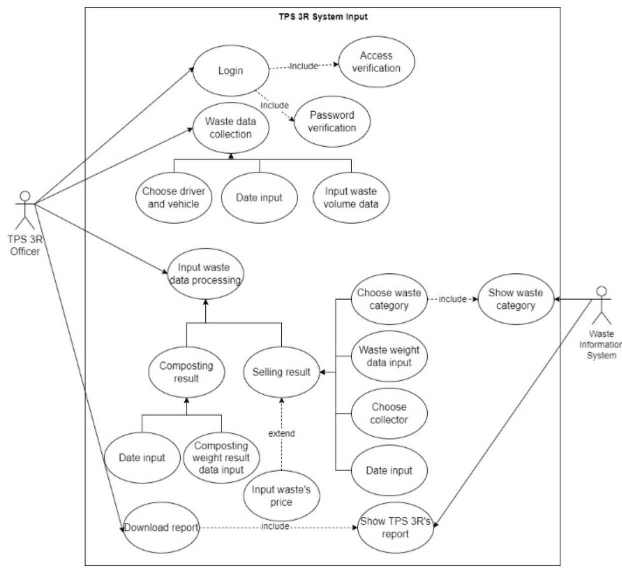

Figure 1. Use Case Diagram for TPS 3R System Input

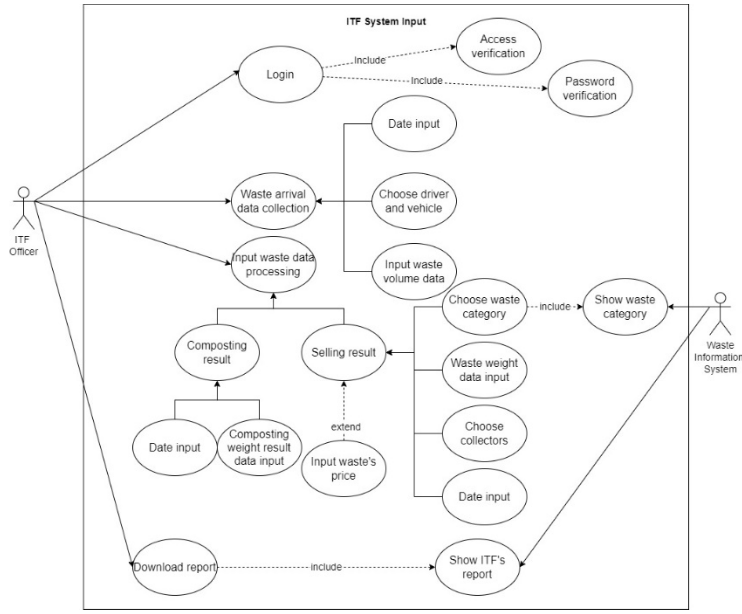

Figure 2. Use Case Diagram for ITF System Input

In the waste bank use case diagram, there are several main activities, which are the same as other officers logging in, then collecting data on the results of weighing waste for each member, add new waste bank members to the system and download reports. The use case diagram of the waste bank can be seen in figure 3.

Figure 3. Use Case Diagram for Waste Bank System Input

For the admin system or the general system, the use case diagram has main activity of downloading reports and changing the master data if needed. The use case diagram for general system can be seen in figure 4.

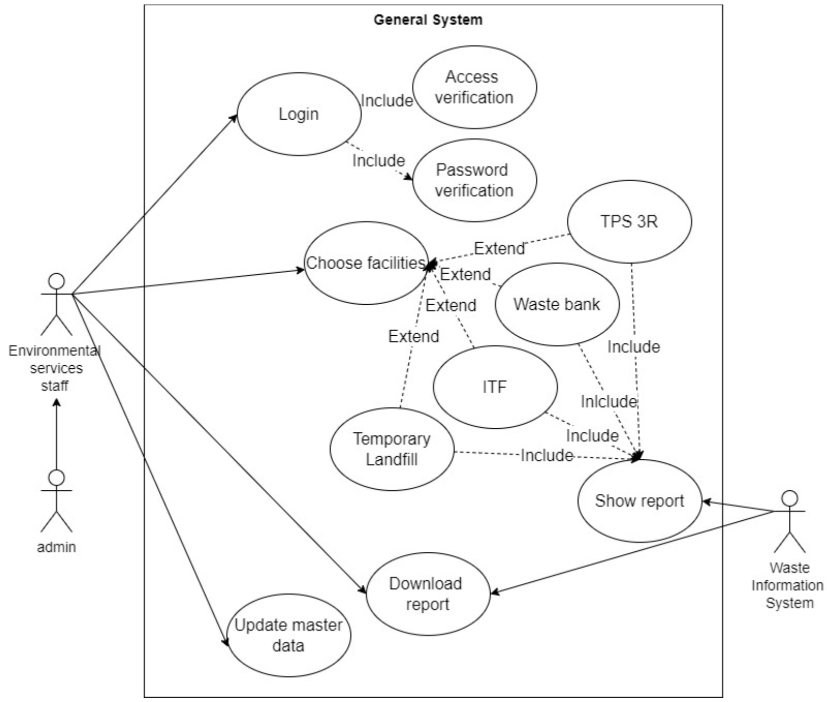

Figure 4. Use Case Diagram for General System

For database design stage, the design format is in the form of a table containing table names, columns, data types, primary and foreign keys, reference tables, reference columns and description. In this research, there are 3 types of tables that will be create in database, there are master tables, transaction tables and report tables. The master table is to store guide data that does not change quickly, the transaction table is to store daily data records that grow and change rapidly, the report table is a table to generate reports. From the database design, there are 18 master tables, 9 transaction tables and 5 report tables, for the detail database design can be seen in table 4.

Table 4. List of Master, Transaction and Report Table

Master Table			Transaction Table	Report Table
Master Users	Master TPS 3R locations	Master ITF Vehicle	Waste bank parent transaction	Waste bank monthly report
Master Roles	Master Module	Master TPS 3R Vehicle	Waste bank transaction detail	Waste bank member report
Master User Roles	Master Waste Bank Member	Master TPS 3R drivers	Transaction input for TPS 3R, ITF and TPA	Waste bank general report
Master District	Master Waste Bank Location	Master ITF Drivers	Waste sold transaction for TPS 3R and ITF	Monthly report for TPS 3R, ITF and TPST
Master Waste Category	Master Vendor	Master Processing Type	Composting transaction for TPS 3R and ITF	General report for TPS 3R, ITF and TPST
Master Collectors	Master TPST Vehicle	Master TPST drivers		

To visualize the relation between tables in databases, this research designed it with entity relationship diagram. ERD is designed to show relationship of each table to other tables using crow's foot notation. Figure 5 show an ERD for documenting waste income in TPS 3R. The transaction table of input TPS 3R related to master vehicle, master drivers, master users and master TPS 3R location.

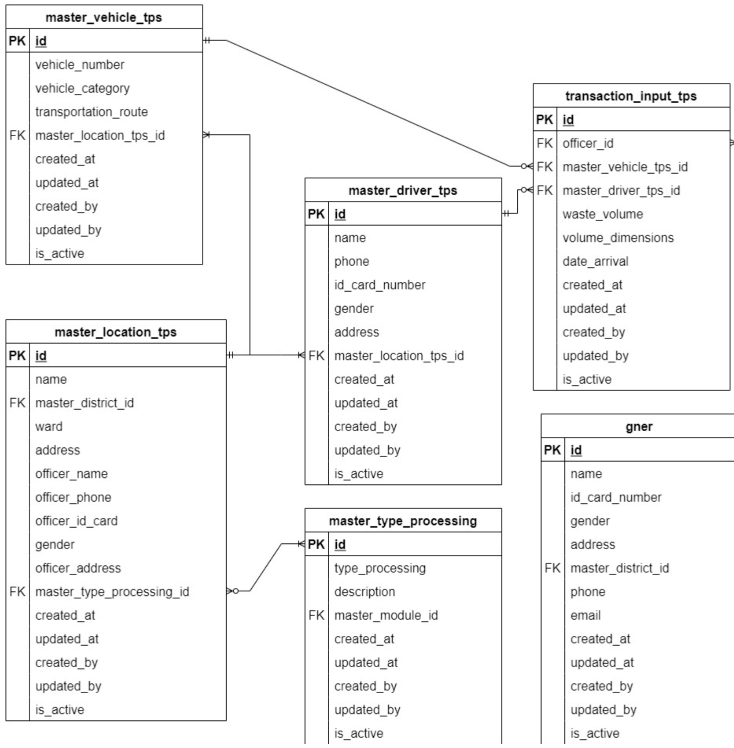

Figure 5. Example of ERD for Waste System Input in TPS 3R

In the development design, class diagrams and activity diagrams are designed. The class diagram is designed for the waste bank input system, TPS 3R and ITF. The class diagram in the waste bank system focuses on the input function of the weighing results of the waste bank members, such as selecting members, choosing the type of waste, as well as input the waste price and the data for collectors. Class diagram for ITF is quite similar with class diagram for TPS 3R, it focusses on input incoming waste data which has the function of selecting driver and vehicle data, as well as input the volume of waste, the function for collecting data on waste that will be sell to collectors is almost the same as the waste bank. For input system in composting, has function to input start and end date of composting process and input the weight of composting results. For an example, the class diagram for TPS 3R can be seen in figure 6.

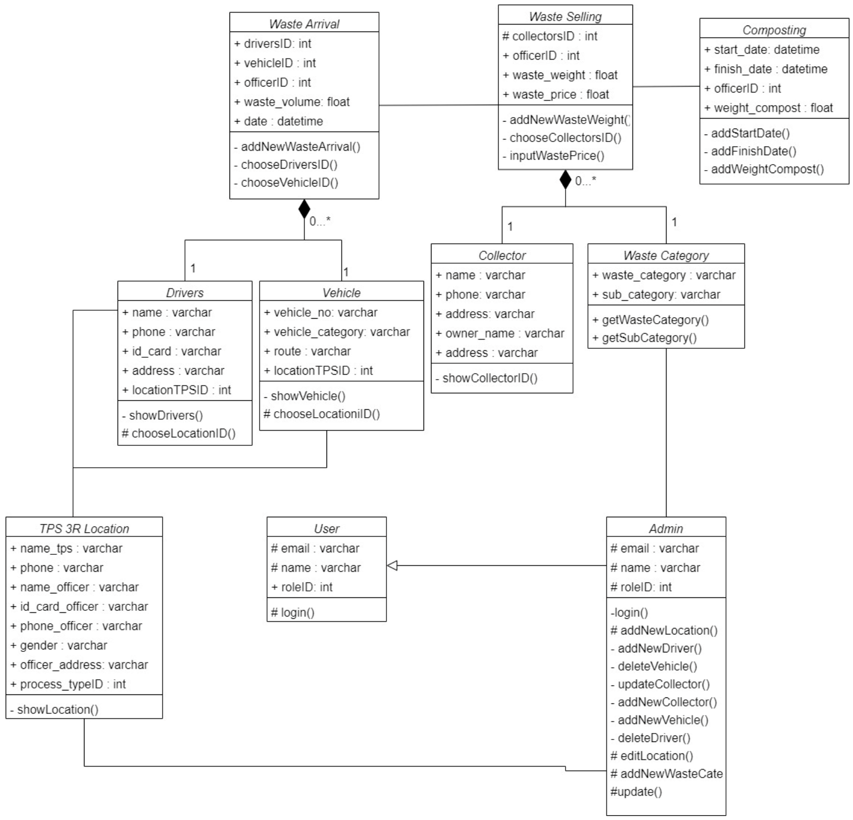

Figure 6. Class Diagram Example for TPS 3R System

Activity diagrams are designed for waste bank facilities, TPS 3R, ITF and general systems. In the system to input waste weight that will be sell to collectors in waste bank, the main process is logging in, then select waste weighing menu, first select members identity, then select the type of waste and input the weight, click save and select another type of waste, if the weighing for everyone has been completed, click submit then enter the waste price and select the identity of the collectors. For the input system in TPS 3R and ITF have a slightly difference from the waste bank. In input system for TPS 3R and ITF did not need to choose the member first, because TPS 3R and ITF are not having members and weighing process is used to do once a day. The activity diagram for weighing waste can be seen in figure 7.

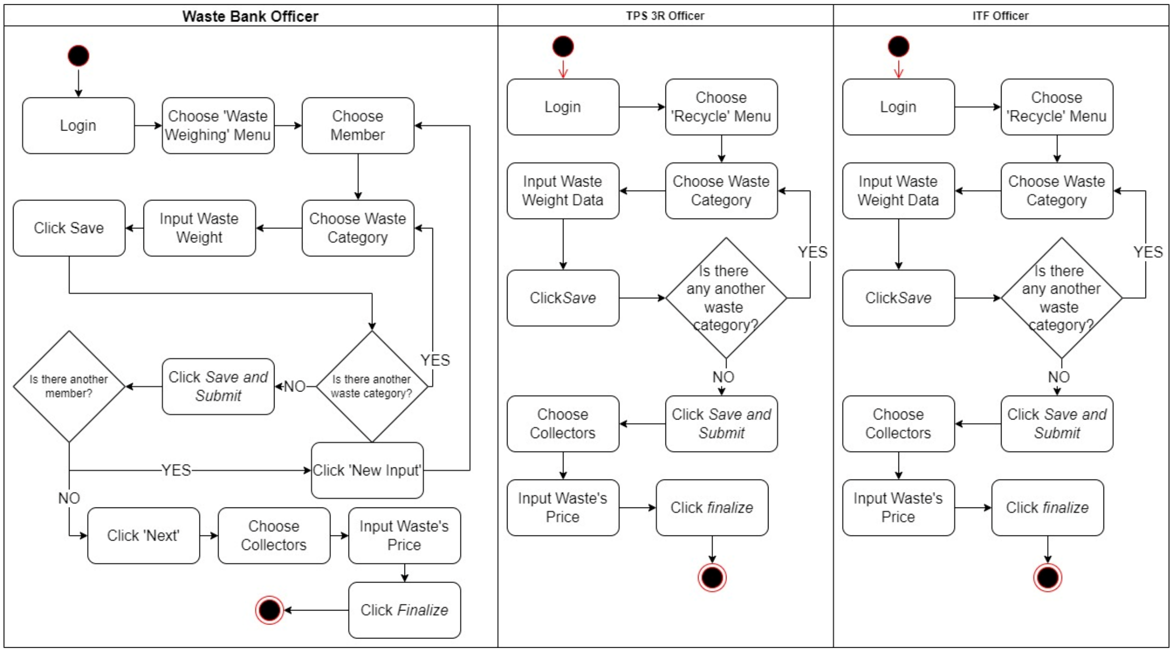

Figure 7. Recycle Data Input Activity Diagram for Waste Bank, TPS 3R and ITF Facilities

In input system for waste arrival data, select the waste arrival menu, then select the identity of the vehicle and driver, then input the volume of waste and submit. Input system for waste arrival data in TPS 3R and ITF have a same process. Activity diagram of waste arrival data collection in TPS 3R and ITF can be seen in figure 8.

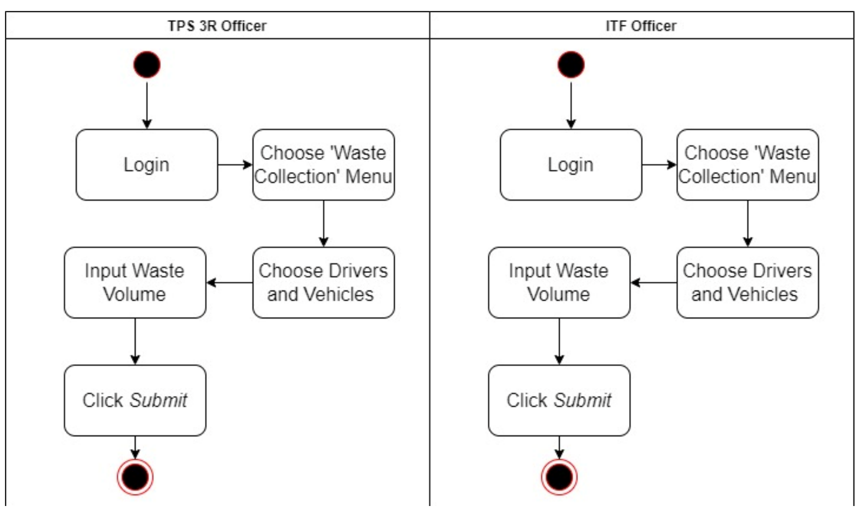

Figure 8. Waste Data Input Activity Diagram for TPS 3R and ITF Facilities

For composting data collection process begins by inputting the start date, then save, when the compost is finished, click edit then input the completion date and the weight of the compost result. Composting data collection system in TPS 3R and ITF are the same. The composting activity diagram can be seen in figure 9.

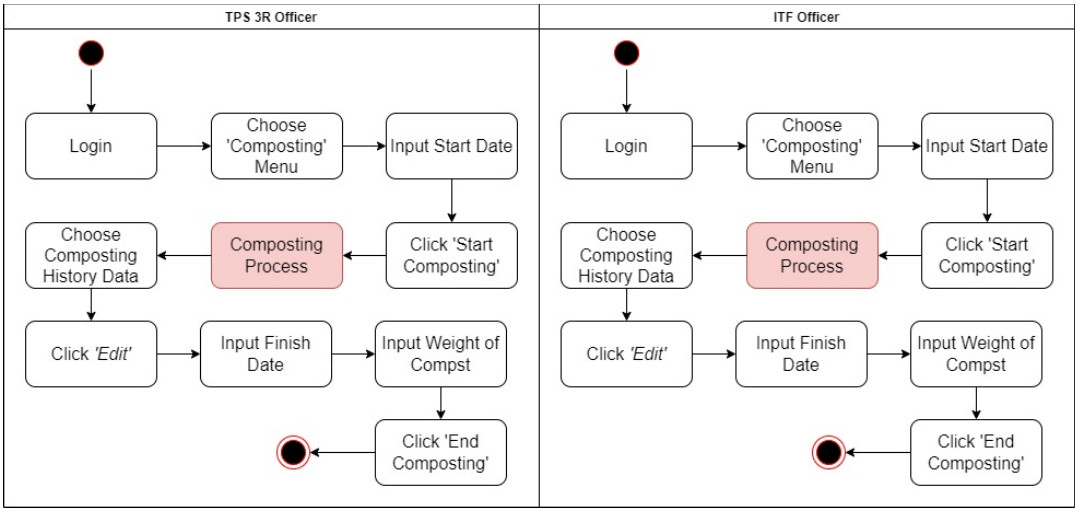

Figure 9. Composting Data Input Activity Diagram for ITF and TPS 3R Facilities

In the admin system, admin or staff of environmental services can download reports for each waste processing facilities, admin or staff can change some master data through the website, some master that can be changed on the website are master identity of drivers, vehicles, collectors, user roles, types of waste, waste bank locations and TPS 3R locations.

5.3 Benefit Cost Analysis

The implementation of waste information system in South Tangerang city will be beneficial for local environmental services. There are several tangible benefits that can be calculated. The first is the reduction of manpower of waste bank supervisors. Currently, there are 12 waste bank supervisors who are in charge with recapitulation of waste bank data and assisting several waste banks. The results of the recapitulation will be reported to the South Tangerang city environmental services. With the implementation of the waste information system, there is no need a supervisor to do recapitulation of waste bank, the supervisor's costs can be reduced. Second, currently South Tangerang City environmental services is using consultant services to predict the overall weight waste. With complete waste data, consultant services can be reduced because environmental services can have high quality and complete data.

For cost analysis, the implementation of the South Tangerang city waste information system requires costs for system development, database subscription if needed and additional staff for admin positions. The current benefit and cost analysis does not include maintenance costs, and the analysis carried out is within a period of 1 year. Details of the costs and benefits are described in table 5.

Table 5. Benefit CAnalysis

Benefit					
Category	Benefit	Qty per year	Quantity	Cost	Total Cost
Tangible	Supervisor Reduction	12	12	$ 194	$ 27,994
Tangible	Consultant Services Reduction Fees	1	1	$ 3,471	$ 3,741
Intangible	Accelerate communication flow for data recapitulation to national government				
Intangible	Immediately data extraction if the staff needed				
					$ 31,735

Cost					
Category	Cost	Qty per year	Quantity	Cost	Total Cost
Tangible	Software Development	1	1	$ 3,741	$ 3,741
Tangible	Subscription Database Fee	1	1	$ 1,944	$ 1,944
Tangible	Admin wages	12	2	$ 347	$ 8,331
					$ 14,061

6. Conclusion

This research purposed design of a waste information system in South Tangerang. From the results of the analysis, the input system is designed for 3 waste facilities in South Tangerang, TPS 3R, Waste Bank and ITF. Data integration system for all waste processing facilities are also needed. This research provides design of use case diagrams for system design, database design and relations between tables in database network, activity diagrams and class diagrams to visualize methods for each class and process in the system. This system design is designed to collect waste data at TPS 3R, waste bank, ITF and integrate waste data from all facilities includes TPST Cipeucang.

The method used to design South Tangerang waste information system is object-oriented design with UML standards for diagram. This South Tangerang waste information system is a beneficial investment because can reduce costs of waste consultants and costs of waste bank supervisors. The costs needed to implement the South Tangerang waste information system are costs of developing applications, database subscription fees and admin salary.

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