Designing a Dynamic Model of Waste Management to Get a Sustainable Living Condition

Herman Mawengkang
Department of Mathematics, Universitas Sumatera Utara, Medan, Indonesia

Husain
Universitas Bumigora, Mataram, Indonesia
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Introduction
Introduction

Waste has been a problem to many countries, such as Indonesia. The impacts of these wastes on the economy cannot be ignored and managing them has become a major problem.

Waste management is the collection, transport or disposal, managing and monitoring of waste materials.

Most waste management activities are decided upon and carried out in a public, semi-public area typically involving the waste management organization, one or more regulators and other stakeholders and members of the public.

The environment has a limited capacity for waste assimilation therefore this assimilative capacity of the environment maybe exceeded or put under too much stress to handle the large quantity of waste and this may result in pollution and resource degradation and consequently economic damage.
Introduction

- Uncontrolled urban expansion and the massive increase in urban populations have led to a vast amount of consumption and different types of waste generation over the past years.
Introduction

• In 2012, various cities in the world generated 1.3 billion tons of solid waste, equivalent to 1.2 kg per person per day.

https://www.statista.com
It is expected that annual waste generation rate will reach **2.2 billion tons** by 2025, accordingly.

https://www.statista.com
Introduction
Introduction

- Economical aspects:
  - This amount of waste generation definitely leads to an increase in the necessary funds for collection, transportation, processing and disposal operations, which contains a huge amount of fixed/variable costs (Tirkolaee et al., 2020).
Environmental and health aspects:

- These operational processes must be done within *shortest possible time* to prevent from spread of potential *contamination* and *infections*.
Introduction

- **Social Aspects**
  - The main social aspects include citizen satisfactions and creating job opportunities at recycling facilities
  - Increasing community awareness and participation
Introduction

- Technological Aspects
  - Increase processing efficiency
  - Reducing transportation costs
Landfill (TPA) in Medan
System dynamics model has been used in many areas including global environmental sustainability for pollution control/abatement; waste management challenges and their solutions for safe living of human kind; and environmental management in developing countries. As a modeling method, system dynamics is particularly suited to the simulation of complex systems such as waste generation and its management.
Causal Loop Diagram

- Regional Income
- social life
- Economy
- waste management costs
- garbage retribution
- Births
- Population
- Deaths
- Landfill
- waste management system
- waste management technology
- health
- environment
- organic trash
- non-organic waste
- waste generated
- garbage transport
- collected in the garbage bank
- garbage bank
Interpretation of Causal Loop Diagram

One of the factors of growth / development in a region is the increase in population. As a result of the increase in population, the level of consumption and activity of the population will also increase, so that the resulting waste or waste disposal will also increase. The waste that is produced from the population is of course in the form of organic and inorganic waste so that it will show an increase in the waste generated if the population increases. Garbage transportation will increase if the amount of waste collected at the waste bank increases so that there will be an increase in waste disposal at the TPA.
Interpretation of Causal Loop Diagram

Disposing of waste in the TPA will have a negative effect on health and the environment, so to reduce waste disposal in the TPA, technology is required. With the application of technology in waste management, the benefits obtained are to reduce dependence on landfills, increased processing efficiency, and even increasing the active role of the community in waste management as a partner of the local government so that in general economics can increase local revenue retribution quickly handling waste management and reducing costs. transportation to landfill, Reducing the cost of final disposal, Increasing the added value of recycling (this is called Reverse Logistic) By applying technology, it will have a positive effect on the environment, which of course can reduce waste, can reduce pollution due to open dumping waste processing and save / reduce the need for landfill. So that socially can create employment opportunities, increase public awareness about the benefits of recycling, increase knowledge about technology. And the last health benefit is of course odorless and clean and healthy.
Simulation with Vensim
Result for validation run for waste Management
Interpretation of the validation results for waste management

It can be seen in the simulation that if the population increases, it will result in an increased amount of waste so that conventionally waste management is carried out in a prepared garbage dump site so that the problems that arise will result in health impacts and environmental damage. With the application of technology in waste management in the simulation above, the benefits obtained are of course reduced dependence on landfills, increased processing efficiency, even increasing the active role of the community in waste management as a partner of the local government so that economically it can reduce transportation costs to the landfill, reduce final disposal costs, increase the added value of recycling. From simulations using vensim, if waste disposal is carried out at the TPA, economically, it will cost a lot of money. Benefits to the environment can reduce waste, reduce pollution due to open dumping waste processing and save / reduce the need for landfill. Social benefits, of course, the creation of jobs, increasing public awareness of the benefits of recycling, increasing knowledge about technology. And the last health benefit is odorless and clean and healthy.
The Expectation Result

1. Waste Management System (WMS)
   - Less reliance on landfills
   - Management efficiency has increased.
   - Increase the community's active participation in waste processing as a partner for the local government.

2. The economy
   - Lowering the cost of landfill transportation
   - Lowers final disposal costs
   - Increase the recycling's added value.
The Expectation Result

3. The environment
   - Waste reduction
   - Pollution reduction as a result of open-dumping waste processing
   - Conserve/reduce the need for landfill

4. Technology
   - Reduce transportation cost
   - Increase job opportunity
The Expectation Result

5. Social

- Creating jobs
- Increase public awareness of the advantages of recycling.
- Increase understanding of technology.

6. Health

- There is no odor
- Healthy and clean
The main objectives of the problem are represented as follows:

- Maximizing total amount of income from the reverse logistics in waste management
- Maximizing total job opportunity
- Minimizing transportation cost

Economically and Socially Sustainable Waste Management System
Mathematical model

Constraints

• Allocated to one of the collection facilities

• *Collection facilities* should be allocated to at least one processing/disposal facility

• The number of *permanent* and *temporary facilities* to be established in each region should not exceed their maximum allowable number, respectively

• A *demand node* is covered by the collection facility when it has already been established in the region.
Mathematical Model

Constraints

- A collection facility is allocated to a processing/disposal facility if it has already been established in the region.
- No waste will be collected until the demand node is allocated to its corresponding collection facility.
- No waste is processed/disposed until the collection facility is allocated.
- Capacity constraints of facilities.
- **Total transported waste** from the collection facility to processing/disposal facility does not exceed its capacity.
Conclusion

- Creating a dynamic optimal waste management system leads to an economically, environmentally and socially sustainable waste management.

- Economic, environmental social and technological aspects were studied through the simulation in the budget constraint.

- There would be a trade-off between the total value of the reverse logistics and the job opportunities in the waste management problem.
THANK YOU