

Optimization Model for Hazardous Waste Management System

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ABSTRACT: Industrial and technological advances has made a hazardous waste problem in the world because of the imposed risk directly on the environment and human life. There are two important aspects to reduce negative effects of waste are minimizing waste generate and optimizing utilization of industrial waste. The purpose of this paper is to present a multi-objective optimization model for industrial waste management that includes hazardous waste by focusing on the location and route. The model has the objective of minimize the total cost and total risk. This model can help decision maker to determine the optimal location for each facility and can determine the optimal route strategy.

KEYWORDS: Hazardous Waste Management, Multiobjective Optimization

I. INTRODUCTION

Optimization is a process to determine conditions to achieve the best results. One of the problems related to optimization is hazardous waste management system in the chemical industry. The industrial and technological advances has made a significant hazardous waste management problem because the risks involved are the environment and human life. The constraint of this research is specifically to make an optimization model of industrial waste which belong hazardous waste. Mostly, industrial waste is any substance produced by industrial activities which includes any unusable materials, including hazardous waste which is a type of waste because it cannot be disposed of carelessly. Industrial waste can be considered as hazardous waste if it has one of the following characteristics are ignitability (something that is flammable), corrosivity (something that can rust), reactivity (something that explodes), toxicity (something poisonous).

Hazardous waste handling needs specific transportation and treating to reduce their effect on environment and human health. Presently, hazardous waste must often be stabilized so that can be enter a landfill and must go through different treatments in order to stabilize and dispose of them. This research only focused on transportation to determine locating and routing facilities such as disposal and treatment centers, because of treatment and disposal are two important stages in hazardous waste management. Using total cost and risk as objectives in order to make good decisions on environmental and economic aspects. An effective method of reducing the hazardous waste transportation cost and risk is to select the safest possible routes connecting hazardous waste generation, treatment and disposal sites.

II. RELATED WORK

Many researchers has carried out research to make mathematical models of hazardous waste management in determining locations, transportation routes and transportation risks. In [1] proposed a goal programming model that discusses determination of location and routing for one type of hazardous waste that aims to minimize travel time, risk of transportation, and risk of disposal. In [2] made research on multi-objective location and routing problem so that it aims to minimize total cost including transportation cost and annual fixed costs for treatment technology and disposal facilities, and also minimizing risk that occur. Their model determined locations treatment centers and technologies,

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locations for disposal centers, routing for different types of waste to treatment centers with compatible technologies, and routing for waste residues to disposal centers. In [3] develop research from Alumur and Kara. In contrast to their previous model, the mathematical model developed in this paper additionally aims to help decision makers to decide location of treatment centers using different technologies, various types for hazardous waste routing in compatible treatment, location for recycling centers and hazardous waste routing and waste residues in these centers, and location for disposal centers. This model utilizes a Lexicographic Weight Tchebycheff method to find efficient solutions. While according by Boyer et al. [4] who discussed about hazardous industrial waste locations-routing problems using the biojective mixed integer programming model, which aims to minimize the total costs (including transportation costs, operational costs, initial costs and storage costs of recycling sales waste) and minimize transportation risk.

III. RESULT AND DISCUSSION

This mathematical model aims to treat all hazardous waste generated, routing various types of hazardous waste to compatible center and remove all waste produced in a safe and also cost-effective way. This model used mixed integer programming. The proposed model is to minimize total costs and minimize total risks. There are costs at that time the operation for transportation, treatment and disposal, and there are risks that impact to the environment in transporting hazardous waste. In the model, we assumed that potential locations for treatment and disposal facilities have been identified. Nodes will be connected to each other through transportation routes. Hazardous waste from the source produced must be brought to the appropriate processing facility. sometimes there are types of waste that are not compatible with certain types of processing technology, so the problems in compatibility are also important to consider. The model can be written as follows:

Minimize $f_1(x) = \text{total cost}$
Minimize $f_2(x) = \text{total risk}$

$$\begin{aligned} \text{Min } f_1(x) = & \sum_g \sum_t W_{gt} \times S_{gt} \times C_{gt} \\ & + \sum_t \sum_d W_{td} \times S_{td} \times C_{td} + \sum_g \sum_d W_{gd} \times S_{gd} \times C_{gd} + \sum_t TC_t \times CT_t + \sum_d DC_d \times CD_d \end{aligned} \quad (1)$$

$$\begin{aligned} \text{Min } f_2(x) = & \sum_g \sum_t PR_{gt} \times W_{gt} \times A_{gt} + \sum_t \sum_d PR_{td} \times W_{td} \times A_{td} + \sum_g \sum_d PR_{gd} \times W_{gd} \times A_{gd} \\ & + \sum_t TC_t \times PF_t + \sum_d DC_d \times PF_d + \sum_t TC_t \times AF_t + \sum_d DC_d \times AF_d \end{aligned} \quad (2)$$

Subject to:

$$WT_t \leq WMT_t \times X_t \quad \forall t \in T \quad (3)$$

$$WD_d \leq WMD_d \times X_d \quad \forall d \in D \quad (4)$$

$$TC_t = \sum_t QT_t \times COM_t \quad \forall t \in T \quad (5)$$

$$GN_g = \sum_t W_{gt} + \sum_d W_{gd} \quad \forall g \in G \quad (6)$$

$$\sum_t TC_t \geq MW_t \times f_t \quad \forall t \in T \quad (7)$$

$$\begin{aligned} W_{gt} & \geq 0 & \forall g \in G & \quad \forall t \in T \\ W_{td} & \geq 0 & \forall t \in T & \quad \forall d \in D \\ W_{gd} & \geq 0 & \forall g \in G & \quad \forall d \in D \end{aligned} \quad (8)$$

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$$\begin{array}{ll}
 TC_t \geq 0 & \forall t \in T \\
 DC_d \geq 0 & \forall d \in D \\
 AF_t \in \{0,1\} & \forall t \in T \\
 AF_d \in \{0,1\} & \forall d \in D \\
 A_{gt} \in \{0,1\} & \forall g \in G \quad \forall t \in T \\
 A_{td} \in \{0,1\} & \forall t \in T \quad \forall d \in D \\
 A_{gd} \in \{0,1\} & \forall g \in G \quad \forall d \in D \\
 X_t \in \{0,1\} & \forall t \in T \\
 X_d \in \{0,1\} & \forall d \in D \\
 COM_t \in \{0,1\} & \forall t \in T \\
 f_t \in \{0,1\} & \forall t \in T
 \end{array} \tag{9}$$

Where,

- G = Generation nodes (1,...,g)
- T = Treatment nodes (1,...,t)
- D = Disposal nodes (1,...,d)
- W_{gt} = Amount of hazardous waste transported from generation nodes to treatment center
- W_{td} = Amount of hazardous waste type transported from treatment nodes to disposal center
- W_{gd} = Amount of hazardous waste type transported from generation nodes to disposal center
- S_{gt} = Distance of hazardous waste that transported from generation nodes to treatment center
- S_{td} = Distance of hazardous waste that transported from treatment nodes to disposal center
- S_{gd} = Distance of hazardous waste that transported from generation nodes to disposal center
- C_{gt} = Cost of transportation hazardous waste from generation nodes to treatment center
- C_{td} = Cost of transportation hazardous waste from treatment nodes to disposal center
- C_{gd} = Cost of transportation hazardous waste from generation nodes to disposal center
- TC_t = Amount of hazardous waste treated at treatment center
- CT_t = Operational cost at treatment center
- DC_d = Amount of hazardous waste disposed at disposal center
- CD_d = Operational cost at disposal center
- PR_{gt} = Population along route from generation node and treatment center
- PR_{td} = Population along route from treatment nodes and disposal center
- PR_{gd} = Population along route from generation nodes and disposal center
- A_{gt} = Binary variable where (1) if there is an accident along route from generation node and treatment center, (0) otherwise
- A_{td} = Binary variable where (1) if there is an accident along route from treatment nodes and disposal center, (0) otherwise
- A_{gd} = Binary variable where (1) if there is an accident along route from generation nodes and disposal center, (0) otherwise
- PF_t = Population around the treatment center
- PF_d = Population around the disposal center
- AF_t = Binary variable where (1) if there is an accident from treatment center, (0) otherwise
- AF_d = Binary variable where (1) if there is an accident from disposal center, (0) otherwise
- WT_t = Amount of hazardous waste at treatment center
- WD_d = Amount of hazardous waste at disposal center
- WMT_t = Maximum capacity of treatment center
- WMD_d = Maximum capacity of disposal center

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X_t	= Binary variable where (1) if there is treatment center established to node, (0) otherwise
X_d	= Binary variable where (1) if there is disposal center established to node, (0) otherwise
QT_t	= Capacity from treatment technology at treatment node
COM_t	= Binary variable where (1) if waste of type is compatible with technology, (0) otherwise
GN_g	= Quantity of produced hazardous waste at generation nodes
MW_t	= Minimum amount of hazardous waste needed to establish treatment technology
f_t	= Binary variable: (1) if technology treatment established to node, (0) otherwise

There are two objective functions in the mathematical model above. The first (1) to minimize the total costs, formulated with amount of transportation costs and operating costs for treatment and disposal centers. Transportation costs are calculated by multiplying the amount of waste transported, the distance of each node and the unit transportation costs for each hazardous waste type transported between two nodes. The operating costs is the cost of processing hazardous waste in treatment and disposal center. The second objective function (2) to minimize total risk, which includes transportation risk, population exposure around the treatment center and disposal and the risk of accident on the treatment and disposal facilities. Constraints (3), (4) indicate that the amount of hazardous waste should not exceed the specified capacity. Constraints (5) ensure that the hazardous waste generated is treated only to treatment centers with compatible treatment technology. Constraint (6) shows the flow balance constraint of transported waste from generation nodes to treatment and disposal nodes. Constraint (7) is the minimum amount of hazardous waste needed to establish a treatment and disposal center. Constraints (8) are non-negative constraints and last constraints (9) are state that the binary variables.

IV. CONCLUSION

In this paper, a multiobjective model for the locating and routing of hazardous waste was developed. This model is based on previous literature with some difference and a proposed framework. The framework on this model is location from treatment centers and disposal centers in suitable sites and routing. There are two objectives for the problem of hazardous waste was considered. First, minimization total cost will consist of transportation cost and operation cost. Second objective is minimize total risks that consist of transportation risk, population exposure around the sites and the risk of accident facilities on the site. This paper only makes mathematical model for location-routing hazardous waste, this has not applied to real life. So we hope this model will help in formulating a more effective management model and thus can help in achieving a better solution to be implemented.

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