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A covering model application on Chinese industrial hazardous waste management based on integer program method

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ABSTRACT

Industrial hazardous waste is a special kind of toxic substance, which poses risks to the environment as well as human health. With the speeding up of industrialization in China, the collecting, recycling, treatment and disposal of industrial hazardous waste gradually become a severe problem to both the environmental protection and the resource management. In this paper, we laid an emphasis on prospective optimization, used integer program method, and selected the optimal locating approach to the collecting and handling of industrial hazardous waste on the basis of covering location model. We also selected an industrial intensive district in Hebei Province in China as an empirical object and examined our model result. Compared to previous results, this one bears the characteristics of immediacy, dynamism and predictability.

1. Introduction

Industrial waste can be characterized as hazardous if they are on the national hazardous waste list or are identified as solid waste with hazardous properties according to national standards and approaches to identifying hazardous waste. It is a special kind of waste, which could be toxic, flammable, explosive, corrosive, chemical reactive, infectious and radioactive. It not only poses risks to the surrounding air, water and soil, but also do harm to the ecological environment and human health through diversified channels. Since the industrial and technical revolution, the increasing amount of industrial hazardous waste had brought extreme pressure to the environment as well as waste and damage to resources. These industrial wastes all bear the characteristics of chronicity, latency, invisibility, non-dilution and sensibility.

This paper firstly analyzed some research approaches to the integrated treatment and disposal of industrial hazardous waste, then introduced in the covering model based on this analysis, and then conducted an empirical research in Hebei Province of China (Hebei Province is a vital industrial area of China and there are some heavy pollution plants in Hebei Province such as chemistry, Auto and paper. Here we selected an industrial intensive district in Hebei Province which could be a typical object for our study and be well applied our model on) and made an analysis of the result on the basis of integer program (KPP-POS), then gave some advices to the local government about the location of industrial hazardous waste treatment and disposal centers, and at last made conclusions and improvements based on the above analysis.

2. Previously relevant researches review

2.1. Review of researches in industrial hazardous waste management

Industrial hazardous waste processing (generation, collection, transportation, storage, integrated utilization and ultimate disposal) is indefinite in both temporal and spatial respects, which makes the pollution control a big problem for environmental management. Developed countries (such as the USA, Japan and some European countries) are the main producers of industrial hazardous waste of the world. Their researches to industrial hazardous management are the most advanced, effective and have the longest history, which are the best references for China. For instance, Samanlioglu (2013) divided the integrated disposal center into collection center, initially processing center, recycling center and ultimate disposal center, and then selected the best route among centers and the optimal disposal approach using multiobjective linear programming model, which minimized the total cost and the transportation risk; he distributed the weights of risk by the importance of each district and selected the most reasonable transportation solution to minimize the total risk (Taha, 1971); in order to solve the connection problem

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between disposal node and generation node (make sure every generation node could connect to at least one disposal node), Gollowitzer and Ljubić (2011) used mixed integer programming model and denoted each node (disposal node and generation node) as a node in a mathematical tree to attain the optimal configuration solution; Church and Arfinkel (Zografos and Samara, 1989) introduced in integrated model, which gave an emphasis on simultaneously enlarging the distance between integrated disposal center and residential area while minimizing transportation cost.

The above studies are all devoted in looking for the balance among high efficiency, low cost, and low risk, and the balance between connectivity and synthesis in transportation, or in other words, to select the best model under the restriction of a fixed environment or a rigid condition. But these studies all neglect the predetermined variable which controls the whole disposal process: the location of integrated disposal center, namely prospective optimization (Taha, 1971; Alidi, 1992). For instance, Ibel Alumer (Alumur and Kara, 2007) selects 13 relatively centric nodes from 92 waste generation nodes as disposal nodes on the basis of geological centrality, but the result is not optimal. If either the rigid condition (location problem of disposal node in this paper) or the mathematical approach of locating is improved, twice the result will be produced with half the effort.

2.2. Location model

Location model problem began in 1909. Alfred Weberk considered about how to select the location of a warehouse to minimize the total distance from customers; on the ground of that, Hakimi (1964) explored where to set up contact and help centers in the highway system to minimize the total distance between people and the nearest center. After him, the selection approach about static center location is classified into three models: median model, covering location model (Church and Velle, 1974) and center model (Owen and Daskin, 1998).

2.2.1. Median model

Using multiobjective program or linear objective integer program to set up P disposal nodes in order to minimize the total distance between demands and disposal nodes, *e.g.*, Church and Velle (1974) proposed that the efficiency of a disposal node is determined by the average distance from the demand to this very node; ReVelle refined the P-center model to either maximize the number of customers a disposal node could handle or maximize profits. This model is applicable to integer program or moderate-scaled locating cases.

2.2.2. Covering location model

This model could be mainly divided into two directions: (1) when it is guaranteed that the given demand range is covered, how to configure the location and number of disposal nodes to minimize the cost (Schilling et al., 1993; White and Case, 1974); (2) when the resource is limited, how to configure the given number of disposal nodes to maximize the demand range (White and Case, 1974; Li et al., 2013).

2.2.3. Center location model

On the basis of covering location model, in the condition of limited resource and uncertainty of distance that can be handled, how to locate to cover all the demand range and simultaneously minimize the total distance.

2.3. The applicability of covering model in industrial hazardous waste disposal

When it comes to public source and environmental management, what people care about is not the most applicable solution but the most desirable one, and the solution is measured by people's desirability. Therefore, covering location model is often applied on public facility location problem, such as the location of firefighting point, emergency evacuation center, service center, public school, police office, library, hospital, and public buildings (Francis et al., 1974). In fact, when we construct an integrated industrial hazardous waste disposal center, what people care most is that all the hazardous waste in a given distance could be disposed immediately and meet their basic demand. Next, is looking for the optimal solution that minimize the distance and cost (Schilling et al., 1993). In addition, covering location model is more applicable to large-scaled, complex and dynamical location problems (Owen and Daskin, 1998; Schilling et al., 1993).

All in all, this paper used the covering location model for industrial hazardous waste management because it is the best when applied on public facility location problem and can better measure people's desirability when compared to other models mentioned above.

3. A covering model based on integer program (KPP-POS)

Before we introduce the integer programming method used to construct the covering model, we must firstly introduce the spirit of KPP-POS, which is the base of our integer programming mathematical model.

3.1. Principles of KPP-POS method

Regard collection nodes as a network and identify the positional relationship among generation nodes by their connective relationship and geological positions. To measure the importance of the nodes is to identify their centrality. Centrality is a way to measure the relevant importance of a vertex in a network. Common centrality includes: Degree Centrality (Hakimi, 1964), Betweenness Centrality (Freeman, 1977), Closeness Centrality (Stephenson and Zelen, 1989), Eigenvector Centrality (Bonacich, 1972), Katz Centrality (Katz, 1953; Bonacich and Lloyd, 2001) and Pagerank Centrality (Page et al., 1998). However, these centralities are all measures of importance for nodes while the importance for node groups (Group Centrality) are somehow neglected.

Realized the limitations of nodes centrality, Everett and Borgatti (1999) developed a new measure to group centrality for individuals, groups and classes by extending the standard network centrality measures. On the basis of the measures to the group centrality for the above objects, we can conclude two measures to the importance for node groups. In addition, Borgatti (2003) defined two new group measures for the identification of key players: Key Player Problem/Negative (KPP-NEG) and Key Player Problem/Positive (KPP-POS), which are used to measure the contribution of a node set in two different respects. KPP-POS could be defined as: given a node network, find out a set of n key players which are maximally connected to other nodes outside the set. This measure could be used to optimize the collection of waste by selecting the key players as seeds. While KPP-NEG on the contrary, removes the selected key nodes in a network to disrupt or fragment the network, and finally identifies and verifies the key players (Wen, 2012).

In this paper, we will focus on the positive key problem. The figure below is an example of KPP-POS problem, which is totally inconsistent to intuition. If we select two nodes as a set to maximize