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# A Facility Location Model for MSW Management Systems under Uncertainty: A Case Study of Nashik City, India

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**Abstract**

In India, a substantial fraction (~ 0.85) of total expenditure on MSW management is spent on collection of waste. Nevertheless, the average waste collection efficiency is about 70 % in Indian urban areas. Waste collection efficiency can be increased by utilising staff and collection vehicles effectively with transfer stations (TSs), though choosing best sites (in an economically optimal manner) for TSs siting is a major task. Also, many parameters (e.g., waste-generation rate, running cost of facilities, transportation cost, revenues etc.) in MSW management system are associated with uncertainties. To study the apportionment of these uncertain input parameters into the results, a comprehensive sensitivity analysis has been performed. Furthermore, the effect of interaction among most sensitive parameters is examined through design of experiment. Also, a facility location two stage stochastic model has been proposed to select the best sites for TSs siting, which is basically a framework of facility location problems involving uncertainty. The developed model is applied on the city of Nashik, Maharashtra, India. The model has 9186 constraints and 8152 variables, which has been written in AMPL (a mathematical programming language). KNITRO 5.2 (nonlinearinterior-point trust region optimizer) have been used to solve the developed model. Sensitivity analysis abduces waste generation as the most sensitive kind of parameter followed by the unit transportation cost of waste from source to TSs. Furthermore, multivariate SA identifies the importance of a facility location framework involving uncertainty.

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## 1. Introduction

MSW management means a series of activities covering all functional elements from waste generation to final disposal (Sasikumar and Sanoop 2009). These functional elements can be categorized as: (1) waste generation; (2) handling, separation, storage, and processing at the source; (3) collection; (4) separation, processing and transformation; and (5) final disposal (Diamadopouloset al.1995). In India, a substantial fraction (0.85 approx.) of total expenditure on MSW management is spent only on the collection of waste (Ghose et al. 2006). Notwithstanding, the average waste collection efficiency is about 70% in Indian urban areas (Sharholy et al. 2008).This collection efficiency can be increased by utilizing staff and collection vehicles effectively with transfer stations(TSs). TSs are intermediate points between final disposal/processing facilities and waste generation sources to increase the efficiency of the MSW management system (Ramachandra and Bachamanda 2007). TSs play an important role in waste management such as: (a) Reduce transportation cost; and (b) Contribute to a reductionin the waste volumes because of the compaction process (Cui et al. 2011). This improvement in the collection system will result in significant saving. Also, modern TSs are fully closed to prevent the entries of animals and flies hence maintain a hygienic condition in the vicinity. However, choosing best sites (in an economically optimal manner) for TSs siting is a major task (Ramachandra 2006). Therefore, finding the appropriate number and location of TSs, similar toother location problems (e.g. fire stations, ambulance), should be well designed (Owen and Daskin 1998). The proposed facility location model for best sites of TSs will help to improve the efficiency while to decrease the costs and pollution.

In MSW management systems, many system parameters (e.g., waste-generation rate, waste treatment cost, etc.), impact factors (e.g., energy price, labor fee, etc.), and their interactions are associated with uncertainties (Huang et al., 1995; Yeomanset al., 2003). Most of these uncertainties should be modelled under a situation of data scarcity for generating probability density function, with only information of maximum variations. If uncertainties are ignored then the problems like insufficient capacity, improper utilization of available funds may be raised. To identify the impact of this uncertainty on model a comprehensive univariate sensitivity analysis (SA) has been performed. Also, to determine combined effect and interaction between distinct input parameters a comprehensive multivariate SA has been performed through design of experiment (DoI). Further, a two stage facility stochastic location model has been proposed to select the best sites for TSs siting under uncertainty.

## 2. Methodology

The developed methodology is consist of three components: (a) facility location model, (b) a comprehensive SA, (c) proposed two stage stochastic model. These components are explained in the subsequent subsection.

### *2.1 Facility Location Model for TSs Siting*

This section presents the facility location model for TSs siting mathematically. TSs siting is limited to some specially chosen sites known as potential sites. These potential sites are generally selected by the municipalities by keeping human health hazards due to insects; nuisance due to bad odor; proximity to high waste generation areas and road accessibility in mind. This facility location model has been used to find best sites among potential sites in an economically optimal manner. This model assume that there is no waste separation at source; city also has facilities for waste processing and disposal; these facilities include derived fuel (RDF) plant, composting plants, pre-sorting units and sanitary landfills. All the costs in this model are calculated as daily cost. The facility location model is developed as follows:

#### *2.1.1 Facility Location Model Variable and Parameters:*

*Indices:*

I = Total number of waste generation point sources
i = Index for point sources (i = 1,2,....,I)