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Full length article

A bi-level programming approach to joint network design and pricing problem in the municipal solid waste management system: A case study

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ABSTRACT

The fast growth of urbanization and population has held to the increase of waste in cities and caused significant problems in urban management systems. In this study, the design of municipal solid waste management network as well as determination of outsourcing policies is studied from the viewpoint of an organization (e.g. municipality) which collects different types of wastes from all over the city and pays a certain amount of money in exchange. In case of outsourcing, auction will be held and the companies who their business is recycling and composting can participate in by bidding. This process results in the selection of a company or an insourcing alternative. The problem is modelled as a bi-level programming model, which in the first level, municipality decides as the leader on outsourcing, and if outsourcing is agreed upon, a company is selected. In the second level, bidders compete as followers in the auction for receiving more waste from the municipality and offer prices. An exact novel solution method is applied to convert the proposed bi-level programming model into a single-level one that can be solved by commercial solvers. To validate the proposed solution method the relevant results are compared with those obtained by Karush-Kuhn-Tucker (KKT) approach by using data extracted from a real case study. Numerical results show that the proposed method is able to decrease the complexity of the concerned problem and considerable saving in computational time.

1. Introduction

Nowadays, municipal solid waste management is improving in Asian countries (Lee et al., 2016). A waste management network includes the moment of waste collection up to the final step of waste treatment and disposal (Peltola et al., 2016). Protecting the environment and productive resources are among the most important factors of sustainability. Waste and in particular, solid municipal waste has significant damaging effects on the environment. Municipal waste management includes concepts such that recycling, reuse, sustainability, and friendship with the environment (Bocken et al., 2014). This issue not only is a major challenge for the society but also underlies numerous potential job opportunities (Peltola et al., 2016). Municipal waste management includes all the stages of collection and transfer of waste from the production site to recycling, disposal, or any other treatment alternative (Giusti, 2009). The main aim of waste management is the correct collection and disposal of waste such that the system costs and pollutions to environment are minimized (Zhang et al., 2011). The network of waste collection consists of facilities such as waste collection stations, transfer stations, and disposal facilities. The design of this network include identifying optimal locations for different waste management facilities and determining the material flow among them in order to maximize the effectiveness and efficiency of the whole system. Hazardous waste location was first introduced in the location of waste landfill and treatment centers. Location of these centers is usually known as “location of undesirable facilities” in the literature. Erkut and Neuman (1989) has conducted numerous studies and published the most papers in this regard. According to Table 1, waste type is an important issue in the domain of waste management. Waste is generally classified into two types of hazardous and non-hazardous. Any waste that is inflammable, toxic, corrosive, or reactive is considered as hazardous waste (Xie et al., 2012). Planning the waste management system differs based on the type of waste. The planning models of waste management systems differs based on the type of waste. For hazardous waste some extra constrains should be added according to hazard materials’ properties. For example, one of the issues for hazardous waste is the type of vehicle which should be used for transportation; this kind of waste must be transported by special vehicles and the corresponding vehicles should also travel from particular routs and even time windows that the least percentage of people pass through. These requirements increase the cost as well as time of transportation for hazardous waste. Regarding the treatment and disposal of hazardous waste, also some

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Table 1
Classification of the municipal solid waste management literature.

Papers	Problem definition			Decision Variables							Costs			
	network design	collection	landfill	capacity	routing	Inventory	waste collected	treated waste	allocation	location	treatment Cost	collection cost	opera-tional cost	transpor-tation cost
Zhang et al. (2011)	x			x		x	x	x			x	x	x	x
Deng et al. (2011)	x			x	x		x		x	x		x		
Ye et al. (2011)		x							x	x				
Tavares et al. (2011)			x					x		x		x		x
Faccio et al. (2011)		x		x	x		x						x	
Gupta & Sharma (2011)	x	x		x	x		x							x
Das and Chowdhury (2012)	x			x			x	x		x	x	x		x
Buherkal et al. (2012)		x		x	x		x		x			x		x
Achillas et al. (2012)		x		x	x		x		x			x		x
Xie et al. (2012)		x		x	x		x		x	x		x	x	x
Ghiani et al. (2014)		x		x					x	x		x		x
Samanlioglu (2013)	x			x	x		x		x	x				x
Santibañez-Aguilar et al. (2013)	x						x	x			x			x
Zhang et al. (2014)	x			x		x	x	x			x	x	x	x
Eiselt and Marianov (2014)			x	x			x		x	x	x		x	x
Santibañez-Aguilar et al. (2014)	x						x	x			x		x	x
Zhang et al. (2014)	x			x			x						x	x
Vadenbo et al. (2014)	x			x				x						
Vahdani and Naderi-Beni (2014)	x			x			x		x	x				x
Huang et al. (2002)	x			x			x	x	x					x
Ng et al. (2014)	x			x			x		x		x		x	x
Ghiani et al. (2014)	x			x					x	x		x		
Wu et al. (2015)	x							x			x			
Xue et al. (2015)		x		x	x		x		x					x
Mavrotas et al. (2015)	x			x			x	x					x	x
Asefi et al. (2015)	x			x	x		x	x	x	x				x
Tunalıoğlu et al. (2016)	x			x	x		x		x	x	x			x
Yadav et al. (2016)	x			x			x		x	x	x		x	x
Inghels et al. (2016)		x		x	x				x				x	x
Nguyen-Trong et al. (2016)		x		x	x				x					x
This paper	x			x			x		x	x	x	x		

Papers	Modelling						Objective			Solution Method				
	Linear	None-Linear	Multi echelon	Dynamic	Multi Period	Multi waste	Max Profit	Min cost	Min risk	Exact	Heuristic	Meta	commer-cial solver	Others
Zhang et al. (2011)	x		x	x	x	x		x						
Deng et al. (2011)	x		x		x	x		x				x		
Ye et al. (2011)	x								x				x	
Tavares et al. (2011)	x													x

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