Mazandaran University of Science and Technology

Available online at www.iiec2017.com

13th International Conference on Industrial Engineering (IIEC 2017)

Iran Institute of Industrial Engineering

Solid waste location and routing mathematical models: a survey

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Abstract

Today, Waste management is more important than in the past, because with the growing population and large-scale production in factories, consumption patterns have been changed and higher waste is produced. This paper provides a comprehensive review on papers that including of mathematical modeling in the field of urban waste. Mathematical models in peer-reviewed articles, is including of location the recycling and disposal centers, location the transfer stations and routing of vehicles for garbage collection. There are several objectives such as social, economic and environmental. Finally, by discovering unexplored areas of research, suggestions are presented for the future research.

Keywords:
Waste collection, Municipal solid waste management, Landfill location, Location-routing problem, Review

Introduction

According to increasing the changes in the municipal and industrial modern world, municipal solid waste management (MSWM) has become more important. In the past, wastes were decomposed easier and in less time, but in present age, wastes have become to hazardous materials which is recycled and decomposed in a long time, it is noted that these wastes are dangerous for the environment. Today, a large percentage of wastes are materials, which cannot return to nature, or may remain there for hundreds of years. This season will be discussed on the waste management concepts in the literature, categories of waste and disposal methods.

Belien and et al, believe that the waste management is more than just collecting waste. In fact, it is including of collection, transportation, recycling, and disposal and monitoring of waste. Several factors, including environmental, economical, logistical, technical and political issues to be considered and should be taken several important decisions. Among these decisions, firstly, the opening of a new facility or expand an existing facility for waste disposal is the most important decisions. Secondly, allocation of some vehicles such as trucks and trailers to transport waste to the disposal centers and thirdly, the development of efficient routes for vehicles, are important. After much research, researchers concluded that, due to the high labor intensity, extensive use of the vehicles is the most important and most costly aspect in this cycle in the process of gathering [1].

MSWM modeling has been studied extensively in the past few decades, MSWM has been only considered certain aspects such as vehicles routing or location of the transfer station and ignored some aspects such as recycling centers and were considered only one type of waste [2].

Municipal solid waste (MSW) is introduced as a general term that includes all wastes, except hazardous and liquid waste and greenhouse gases. Solid waste can be divided into two categories, general residential waste and commercial waste [3].

"MSWM is one of the challenging issues in cities that due to the various interrelated factors such as operational costs and environmental concerns. Cost, as one of the most significant constraints of municipal solid waste management can be effectively economized by efficient planning approaches"[4].

In addition, each integrated MSWM system, requires to the various processes of utilization and different disposal centers. For example, hazardous waste disposal facilities, are different from the other facilities to have more control (for example, the leachate during use) [5].

Belien and et al, have classified the garbage in four categories, by using of literature review. They concluded that types of waste are Garbage, Skips/containers, Hazardous materials, Recyclables and Others/not mentioned. From another perspective, the types of waste are municipal, industrial, hazardous and hospital [1].

It can be said that with regard to the nature of the wastes, there are several disposal methods. The most typical disposal methods include: Landfill, compost (production of fertilizer from waste), burning and biogas (gas production

from waste). In this paper, we've categorizes related publications on the three parts: location disposal sites problem, vehicle routing problem for waste collection and location-routing problem that locate facilities and find better routes for vehicles at the same time.
Finally, by using the advantages and disadvantages in these papers, we have found gaps and presented the future research trends.

Literature Review

In this section, we have reviewed some papers related to location of disposal centers, vehicle routing and location-routing problems.Then, all of these papers are classified within the table 1 in terms of the subject problem, objective functions, constraint, solution method, uncertainty and use of case study to test the solution method. It should be noted that the papers were reviewed, are in the period of 1997 to 2016. There are various publications in this review, the most frequently journal are:

- European Journal of Operational Research
- Australasian Journal of Information Systems
- Procedia - Social and Behavioral Sciences
- Computers & Operations Research

Figure 1 shows that lots of papers have been about the vehicles routing for collecting waste to disposal facilities and recycling centers, from 1997 until 2016.

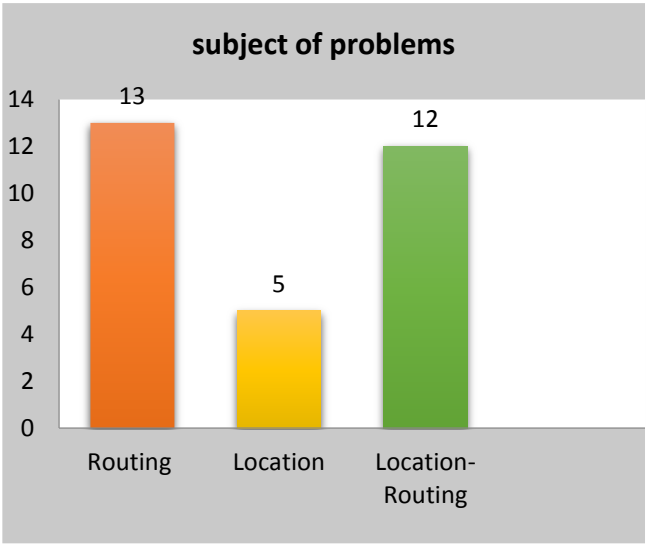

Figure 1 – Subject of problems

These papers have three sustainability goals: economical, environmental and social. Figure 2 visualizes the most attention to the economic aspect and it is peculiar that social approach have been incorporated rarely.

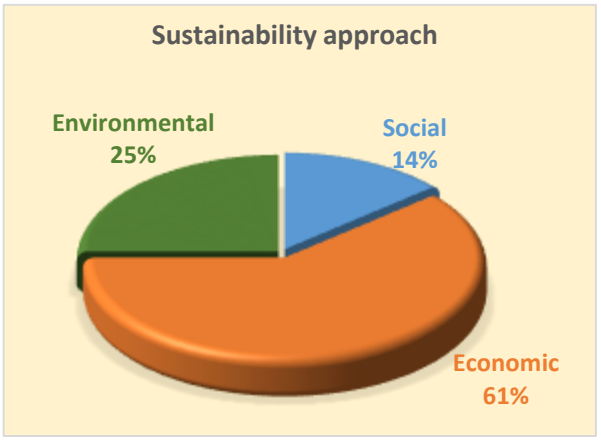

Figure 2 –Publications in terms of sustainability approach

According to these Explanations, there are several objective functions in this field (waste collection).This survey shows that about 70% of the papers are multi-objective and 30% are single-objective.
Figure 3 shows the number of publications in the field of waste management with mathematical modeling in recent years, this graph shows that these publications were highest in 2015 and 2016.

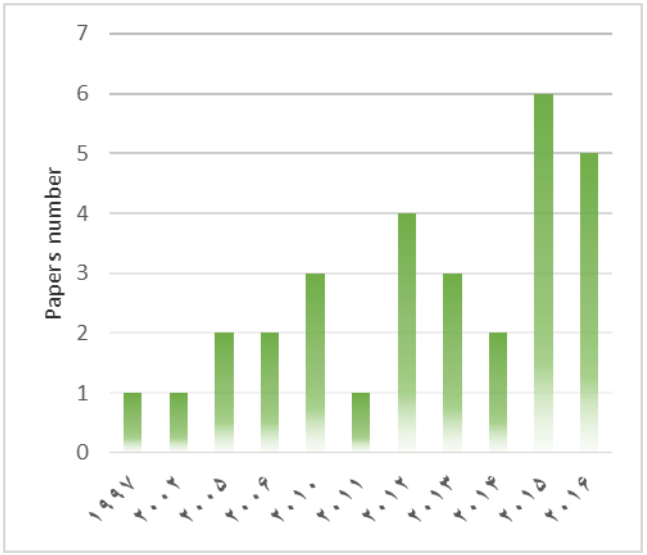

Figure 3- The number of articles in recent years

In the real world, most of the parameters are uncertain, but because of simplicity, most researchers have considered deterministic conditions. Uncertainty is in the form of stochastic or fuzzy. The literature review indicates that only 33% of papers have been considered uncertain parameters.

Table 1 - Literature Review

References	Subject problem		Objective functions																Constraint								Solution method						Certainty		Case study
			Economical			Environmental			social			Other			Location				Routing																
	Location	Routing	Investment	Operating cost	Pollution	Transportation risk	Risk of disease	Discontent	Min route / time	Max collection	Min vehicle	Capacity	Various technologies	Time windows	Flow balance	Capacity	Various technologies	Various technologies	Time collection	Flow balance	Meta-heuristic	Heuristic	Robust	Decision techniques	Exact	Certain	Uncertain	Uncertain	Certain	
[6]		*		*										*				*	*	*					*	*			*	*	
[7]	*			*	*			*	*														FAZZY	AHP[1]			*		*	*
[8]	*	*	*	*		*							*		*	*										*		*			
[9]	*	*	*	*		*			*	*			*		*	*									*			*			*
[10]	*	*	*	*					*	*			*			*				*								*			*
[11]	*	*		*		*	*	*					*		*	*				*					*	*			*		*
[12]	*	*	*	*									*		*	*							SAA[2]				*		*		*
[4]	*	*	*	*									*		*	*				*								*			*
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[14]	*	*	*	*																						*		*			*
[15]	*	*																		*						*		*			*
[16]	*	*	*	*	*											*										*		*			*
[17]	*	*	*	*	*											*						*	*						*		*
[18]	*	*	*	*		*										*					*					*		*			
[19]		*									*			*					*			*						*			

[1]Analytical Hierarchy process
[2]sample average approximation

Table 1 - Literature Review

References	Subject problem		Objective functions																Constraint								Solution method						Certainty		Case study
			Economical			Environmental		social		Other									Routing				Location				Meta-heuristic	Heuristic	Robust	Decision techniques	Exact	Certain	Uncertain	
	Location	Routing	Investment	Operating cost	Pollution	Transportation risk	Risk of disease	Discontent	Min route / time	Max collection	Min vehicle	Capacity	Various technologies	Time windows	Flow balance	Capacity	Various technologies	Time collection	Flow balance																
[20]	*		*	*	*																						*					*		*
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[22]	*	*	*																	*		*			*							*		*
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[24]	*	*	*	*		*	*														*		*	*						*		*		*
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[26]	*	*				*			*						*	*					*						*							*	
[27]		*							*					*					*						*						*			
[28]	*	*	*	*											*	*											*					*			
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[32]	*	*	*	*		*		*											*							MOMAP[4]					*				*
[33]	*								*																						*	*			*
[34]	*	*	*						*										*	*													*		*

[3] Ant Colony Optimization

[4] Multi-objective meta-heuristic using An adaptive memory procedure

Waste collection issues have various purposes such as minimizing the costs, environmental risks, social problems and so on. Figure 4 visualizes the number of publications in any kind of objectives.

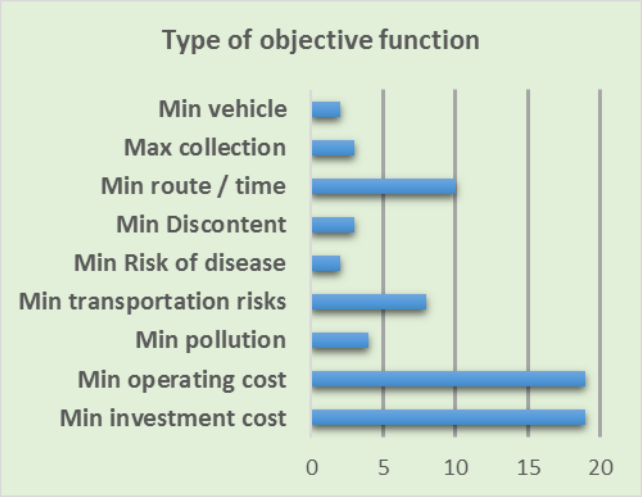

Figure 4–The number of papers used any types of objective functions

Solution methods to solve the waste problems are meta-heuristic methods, heuristic, exact, robust and so on. In these papers, exact methods are used more than meta-heuristic methods. Figure 5 categorizes the solution methods that have been used by researchers.

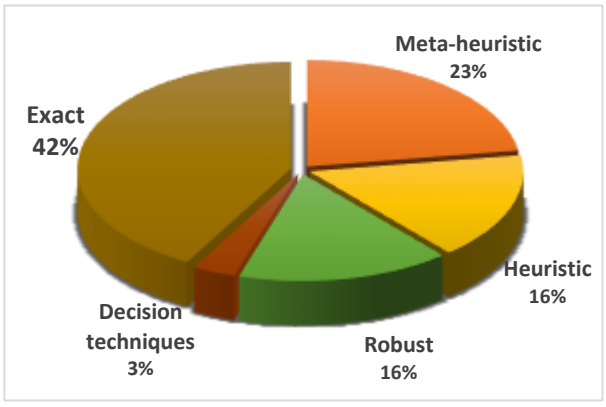

Figure 5- Solution methods that have been used

These papers have two constraints: *i*) Constraints related to the location of disposal and transfer stations, *ii*) Constraints related to the routing of vehicles that collecting wastes.
Figure 6 shows the frequency of using the constraints in the papers. As you can see, both location and routing capacity constraints, have the greatest number and less attention has been paid to the variety of vehicles.

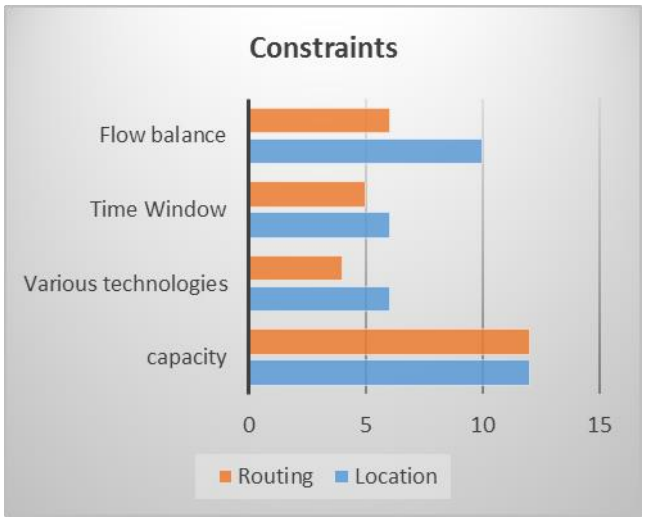

Figure 6- The number of publications in recent years

We found that 73% of papers have used the case study, most of them were in Spain, Turkey, America, Britain, Greece and Chile.

The strengths and weaknesses of the previous works

According to the categorization and assessment of publications in the previous section, three of the most important strengths of earlier work include:

- Increased focus on the economic dimension
- Using of the several objectives simultaneously
- Paying attention to the location and routing at the same time.

And also three of the most important weaknesses in the previous works include:

- Most of papers don't attention to the uncertainty of parameters
- Lack of attention to the social and environmental dimensions
- Lack of attention to the recovery of energy from waste

Future Work

The Suggestions for future research are discussed in this section due to the weaknesses and gaps conducted. You see the number of publications in garbage collection management is growing steadily in recent decades. Increase of computation power of computers and the development of algorithms are effective for solving real complex models. In the cases mentioned that they can be used in future research:
1) Papers that were reviewed in terms of waste collection, often ignored the issue of energy production from waste. Considering the problem of energy production, environmental and social issues simultaneously, can be an opportunity to the future research.
2) It is suggested to validate different methods in future problems in this area. The problem of the maintenance and

repair of machines are an important issues in world of today for waste transportation and the devices in the disposal centers.

3) On the other hand due to the uncertainty of time and failure rate of solid waste shredder, research can be done in the future to consider the reliability of devices based on the recycling and waste incineration. As well as different methods can be used to calculate the reliability of the machines.

4) On the other hand, due to the uncertainty of time and failure rate of solid waste Burning Machines, research can be done in the future to consider the reliability of devices based on the recycling and waste incineration. As well as different methods can be used to calculate the reliability of the machines.

5) One of the other suggestions which can be done in future research, is considering uncertainty in VRP parameters and developing the exact solution methods in solving problems.

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