Applications of GIS and Expert Systems for Hospital Wastes Site Selection: A Case Study in Mashhad, Iran

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Abstract

Protecting the environment has been long considered as one of the most paramount issues which have a direct impact on the earth landscape and all the living organisms. For that reason, attention must be paid to pollutant factors and destruction of the environment, while appealing to the best strategies to diminish environmental pollution. Among these influential factors is the hospital waste generated in hospitals and medical clinics that are transmitted to the environment. There are several ways to disposal of such waste, like burning, burying, recycling, etc. In line with this, it is substantial to adopt the best methods in order to select the most appropriate waste disposal site and to manage the quantity of the generated waste effectively, which are the objectives of this research. To fulfill this, the data was collected by interviews and field observations which were then analyzed using the Analytical Hierarchy Process (AHP) and the Expert Choice and geospatial modelling application. Although, to this date numerous studies have been carried out on hospital waste as a case study revolving around the quantity of the type of waste generated in hospitals as well as identifying proper landfill sites using a Geographic Information System (GIS), only a few of them have concentrated on determining optimal disposal methods. To fill this gap, the current research was an endeavor to determine the most optimal method for disposal of hospital waste by collecting the data via questionnaires distributed among the individuals in relation to hospital wastes and environmentalists in Mashhad. In this study, using questionnaires, interviews, and field observations, the data was collected and the quantity of each type of waste generated in eight studied hospitals was estimated. The Analytical Hierarchy Process (AHP) has been used to prioritize different methods of waste disposal on the basis of the criteria influential in selecting the optimal method. The results revealed that the waste sorting methods in the studied hospitals dramatically differ from the standards defined by the World Health Organization (WHO). Moreover, it was observed that the most prioritized methods of disposal were recycling and burying the remains, while landfill and burning methods take the second priority rank and compost and RDF production come last. The results show that in addition to less contamination, there are other effective measures to be adopted as the optimal waste disposal method. What is more, based on the quantity of hospital waste generated in the hospitals in Mashhad, the upward trend in the production of such wastes seems to be alarming, being dramatically different from the global standards. It should be noted that by examining the conditions effective in selecting the waste disposal site in the GIS software, it was found that the current waste disposal site located 32 km off Mayamey Road suffers from worth-mentioning defects, which is are environmentally acceptable.

1. Introduction

Hospital wastes are known as a threat to the survival of humans, living organisms, and the environment. Serious concerns have been raised about managing them and about their related problems throughout the past three decades. Along with the growth of the healthcare industry, improvement of health services and the widespread use of disposable medical supplies, hospitals and the institutes providing healthcare care services for the patients have generated hospital wastes over the last few years. Hospital wastes are generally divided into two main categories: hazardous and non-hazardous.

Non-hazardous part waste resembles the domestic waste that contains paper, packaging bags, glass, food residues, and other inert materials whereas their counterparts, i.e. hazardous waste contains toxic, harmful, carcinogenic, and infectious substances. It is of note that inappropriate disposal of these wastes, especially the hazardous types, could lead to serious health consequences caused by environmental damage and contamination. Due to the very high significance of hazardous wastes, they are commonly detoxified, disinfected, or even burned in the hospitals so that when they turn into

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wastes having non-hazardous characteristics, they are transferred to the disposal site like other non-hazardous wastes on which the disposal operations would be carried out using different ways (Torkashvand *et al.*, 2015).

Managing the hospital wastes greatly affects cultural, social, and economic conditions, turning into a serious challenge due to lack of sufficient financial investment, lack of knowledge, and lack of effective control, and lack of medical personnel trained within the framework of waste management. For this reason, it seems inevitable to have correct policies, to enact a legal framework, and to plan for the proper management of the hospital wastes (Bagheri Zenuz and Shahbazi, 2013). The management of hospital wastes can be divided into three main parts, namely determining a proper location of disposal and burial, managing the quantity of the waste generated in the hospital, and using the optimal waste disposal method on the basis of the available facilities. Recently, the proper disposal methods for the hospital waste have been scrutinized in different cities of the world, in which Geographic Information System (GIS) has been generally used to identify suitable burial sites. Such as, Chandrakant and Pate (2015) investigated the current solid waste landfill in a region called Pimpri-Chinchwad in the Indian state of Maharashtra, and compared it with other available sites. They could finally introduce better disposal landfills for the hospital wastes. In another research, Senthil *et al.,* (2012) investigated the optimization of urban landfills in a region in India.

Due to the great similarity of non-hazardous hospital wastes to urban wastes, the final results can be generalized to the urban wastes. Other researchers such as Suman (2012) similarly studied Nabadwip, a city under municipal administration in the Nadia district in West Bengal, India. In addition to investigating the landfills for the hospital wastes, we can refer to a study in relation to disposal methods conducted on the wastes of Qazvin, the largest city and capital of the province of Qazvin in Iran. It was indeed found how much gas will be produced during the burning method (Torkashvand *et al.*, 2015).

Among the areas focusing on waste studies, statistical surveys on the quantity of the generated waste in hospitals could be also taken into account. Also, Dehghani *et al.*, (2008), examined the pharmaceutical waste in the university hospitals of Tehran University of Medical Sciences, Iran, and identified the share of any solid waste for better management. Moreover, numerous studies having such a focus have been also carried out by researchers such as Elhamiyan *et al.*, (2015), dealing with the wastes from Valiasr Hospital, Nourabad, Iran, as well as, Longe and Altori (2006), in Lagos Metropolis, Nigeria. The fact is that the mentioned studies have mostly addressed the percentage of the generated hospital waste for better management; nevertheless, they have not done any specific research on the optimal disposal method. In other words, such studies show the types of waste exceeding the permissible limits as defined by international institutions and emphasize on controlling them. There is a growing body of strict controls being implemented worldwide concerning the storage, transport, and disposal of hospital wastes, which is an inseparable part of hospital management. In order to protect public health and prevent environmental contamination, many countries apply codes and recommendations for storing, transporting, and controlled disposal. In this way, you can only use a code to obtain instructions for all the aspects of storage, transportation, and disposal. Packages for different classes of hospital wastes vary in color, shape, and size. According to the World Health Organization (WHO), wastes produced in health centers and hospitals are classified according to Table 1.

Table 1: Classification of the waste of the health centers based on the WHO theory (Fled *et al.,* 2015)

Waste Type	Explanation and Example
Infectious wastes	Wastes that are likely to contain Pathogen, such as culture media, wastes of the isolation room, tissue, materials or equipment in contact with infectious patients.
Pathological wastes	Fluids or human tissue like: organs, fetuses, etc.
Sharp particles wastes	Needles, injection equipment, knives.
Medicinal wastes	Wastes containing drugs, expired medicines, things containing drugs.
Genotoxic wastes	Wastes containing chemicals, such as laboratory reagents, disinfectant solvents that are disposed.
Wastes with high heavy metals	Batteries, broken thermometers, blood pressure gauges, etc.
Air Containers	Gas cylinders, Gas cartridges, Aerosol boxes.
Radioactive wastes	Wastes containing radioactive substances, fluids unused in radiology or laboratory investigations, glassware, contaminated packs or papers, urine and feces of the patients under treatment or test with specified or unspecified radionuclides.

Forghani (1998) and Forghani and Kazemi (2016) have provided a detailed methodological framework both theoretical and methodological for building a heuristic natural knowledge elicitation and transfer for developing expert system tools for delivering semi-automated of spatial data leading to an improvement of efficiency of mapping applications.

Different ways of disposal of medical wastes including burning, burying, recycling and etc. were identified and included in this study in order to choose the most appropriate waste disposal site. To fulfill this, the data was collected by interviews and field observations which were then analyzed using the Analytical Hierarchy Process (AHP) and the Expert Choice and geospatial modeling application. These are discussed below sections.

2. Methodology

Research methodology consists of the following sections according to Figure1.

2.1 The Case Study Area

Mashhad is situated in northeastern Iran and is the center of Khorasan Razavi Province. With an area of 351 square kilometers, Mashhad is the second largest city in Iran. Based on the general population census of 2016, the city has a population of 3,001,184 inhabitants is the second most populated city in Iran after Tehran. Mashhad has spread over the Kashafrud area and Mashhad plain between Hezar Masjed and Binaloud Mountains. The maximum altitude of Mashhad is 1150 meters and the least is 950 meters. Due to the presence of hospitals and specialist doctors, this city is considered as a noteworthy medical center of the country and it accepts a considerable number of patients from the neighboring and Arabic-speaking countries for medical treatments in its hospitals. Considering the large number of hospitals and the importance of this city in terms of population, region, and so forth, an appropriate policy has to be adopted for the city's hospital wastes. Figure 2 depicts the geographic location and general map of Mashhad (maps.google.com).

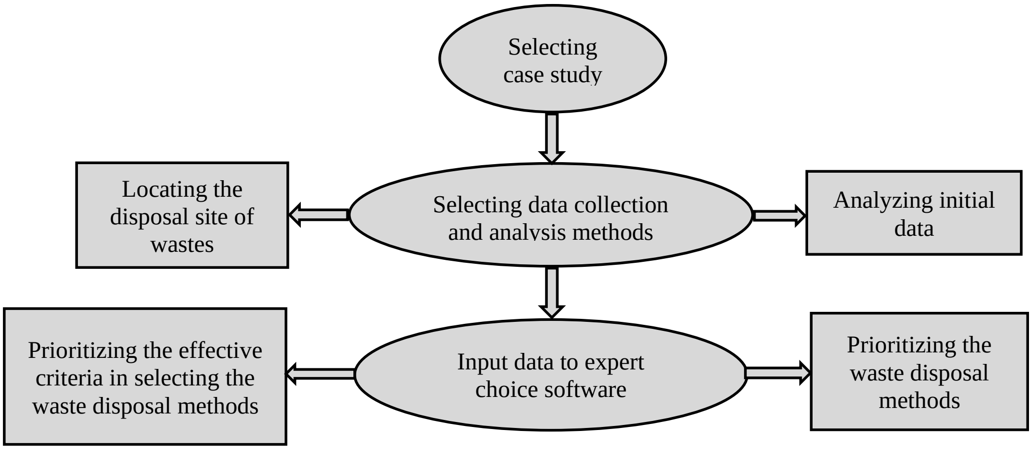

Figure 1: Research methodology

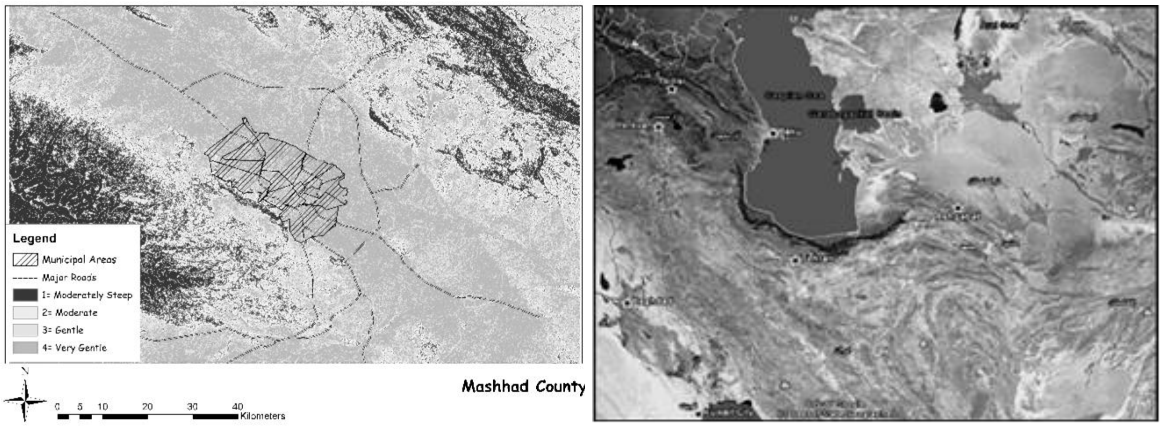

Figure 2: Geographic location and general map of Mashhad

Table 2: The interviewees demographic information

	Occupation and field of work	Education level	Number
1	Garbage collection in the hospital	High School Diploma and below	37
2	Hospital Doctor	Bachelor of Medicine and Surgery	31
3	University professor	PhD.	12
4	Environmental expert	Postgraduate Studies	19
5	Expert on Urban Waste Management	Postgraduate Studies	12
Sum			111

Table 3: General profile of the hospitals under study

	Hospitals	Type of the hospital	Number of active beds
1	Ghaem	Governmental	750
2	Shahid Kamiyab	Governmental	280
3	Bent-ol-Hoda	Governmental	70
4	Hefdah-e-Shahrivar	Governmental	100
5	Jawad-ol-Aemmeh	Governmental	80
6	Farabi	Governmental	200
7	Imam Reza	Governmental	900
8	Hasheminejad	Governmental	300

Because the objectives of this research were evaluating the manufactured hospital wastes, prioritizing common disposal methods, and investigating appropriate disposal sites using the AHP and the ArcGIS spatial analysis, a number of hospitals in Mashhad were selected as the case study, to be investigated via staff interviews and questionnaires. Moreover, a number of experts and university professors who had scientific and practical experiences in the field of environmental protection were requested to complete the relevant questionnaires. In addition, the disposal sites of the waste generated in the hospitals were analyzed.

2.2 Data Collection Method and Analysis

The data was collected in 2017 from 9 major hospitals in Mashhad based on the descriptive cross-sectional method by making use of questionnaires, observations, and interviews from some of the faculty members and environmental activists. Table 2 tabulates the demographic information of the interviewees. Table 3 demonstrates the general profile of the surveyed hospitals.

The Analytical Hierarchy Process (AHP) is a flexible, robust, and simple method used to decide in conditions where Opposite Decision Criteria make it difficult to choose between options. This technique examines complex issues based on their interactions and turns them into a simple way and solves them. A hierarchical analysis process can be used when decision-making is faced with multiple opposing choices and decision criteria. The proposed criteria can be quantitative and qualitative and the basis of this decision making method lies in the decision on pairwise comparisons. The Expert Choice software is a robust tool for multi-criteria decision making based on the Analytical Hierarchy Process (AHP), which was first proposed by Thomas L. Saatchi, one of the founders of the Expert choice at the University of Pennsylvania. The AHP facilitates the decision making process by providing a structure for organizing and evaluating the importance of different criteria and preferences for decision makers. The following steps are identical in both the AHP and Expert Choice:

- Building the hierarchical model
- Enabling the model for group decision-making
- Comparing the criteria and sub-criteria pairwise to determine their importance in decision making.
- Synthesis and integration to determine the best options
- Performing the sensitivity analysis

The objective of the current research was to compare different options based on the importance which have an appropriate compliance with the feature of the pairwise comparison in the hierarchical analysis and Expert Choice software. Therefore, Expert Choice software was used to prioritize deficiencies and fulfill the research objective. The hierarchical analysis method divides the first stage of the analysis of the complex problems into three parts, namely the objectives, criteria, and alternatives so that the problems could be analyzed in a simple way. By forming the matrix related to the criteria (Equation 1) and multiplying the values in the assigned weight in the pairwise comparison (Equation 2), this method yields a final weight for the criteria, doing the prioritization based on them (Orangi *et al.*, 2018).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ji} = \frac{1}{a_{ij}}, a_{ij} \neq 0$$

Equation 1

$$A\omega = \lambda_{max}.\omega$$

Equation 2

In the AHP, we obtain a score for each of the choices, and the choices are ranked according to the score they earned. Unquestionably, the choice with the highest score is the best for selection. The method used in the AHP to calculate the scores is based on the pairwise comparisons. In this process, the elements of each level are compared in relation to their respective element at a higher level in a pairwise way and their weights are calculated. These weights are considered as relative weights. Then, by combining these weights, the final weight of each choice is determined (Orangi *et al.*, 2018) (Figure 3). The AHP analysis method was used in this research to prioritize various types of disposal methods for hospital wastes based on effective criteria. Moreover, the GIS was used to locate and investigate the waste disposal sites. In fact, it is a modern database, being considered to be distinguished in comparison with the other usual databases owing to its being comprehensive and relatively smart. It is comprehensive because the graphical data (spatial) and non-graphical (descriptive-quantitative) data related to different fields are pooled together and it is smart as it is able to select, integrate, and analyze data. In other words, the GIS is a set of visual data (maps) and descriptive and digital data related to earth's incidences, and more importantly these two groups of information have a coherent relationship with each other; it is indeed a simple model of reality. The four fundamentals of that are: measurement, mapping, monitoring, and modeling.

2.3 Analyzing the Amount of Waste Generation

Sorting the waste and determining the quantity of the waste generated by studied hospitals revealed that the average per capita production of these hospitals per bed was about 3.1 kg, as displayed separately in Figure 4. According to the field studies and interviews, it was found that unfortunately about 65% of the hospitals do not pay enough attention to waste collection systems, health regulations, and environmental standards, and it was found that those being employed for waste collection lack adequate training in 45% of the hospitals. Another finding was that although the importance of separating infectious and non-infectious wastes and the use of bags and containers for the storage of wastes has been highlighted and the Ministry of Health and Medical Education (MHME) has emphasized implementation of the enacted guidelines, these instructions are not executed, implying the ignorance of the hospital authorities and inadequate supervision.

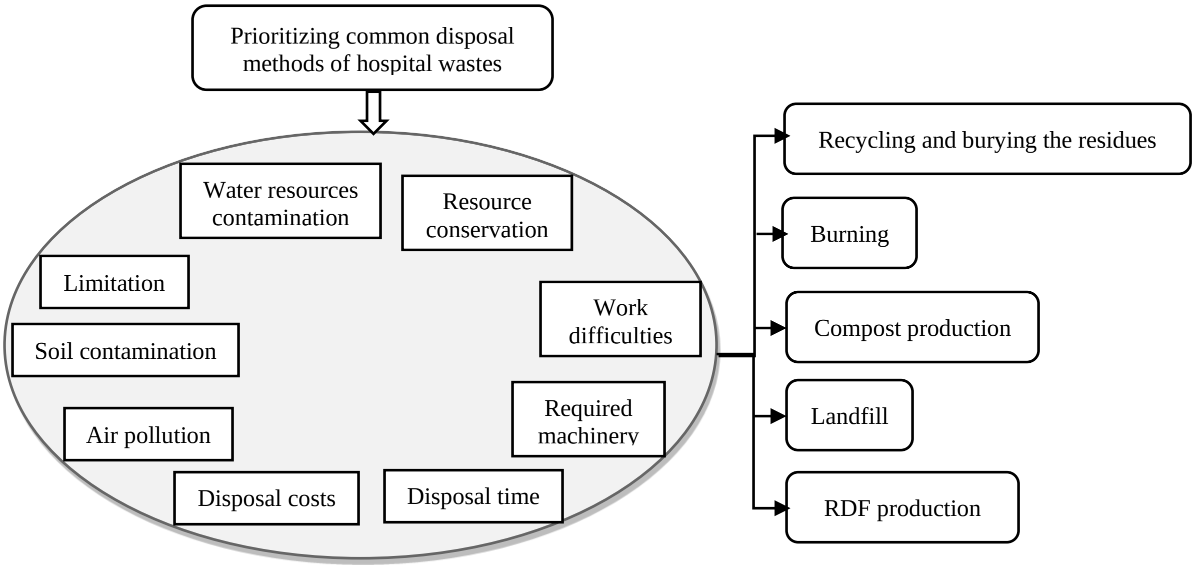

Figure 3: The hierarchical analysis done in the research

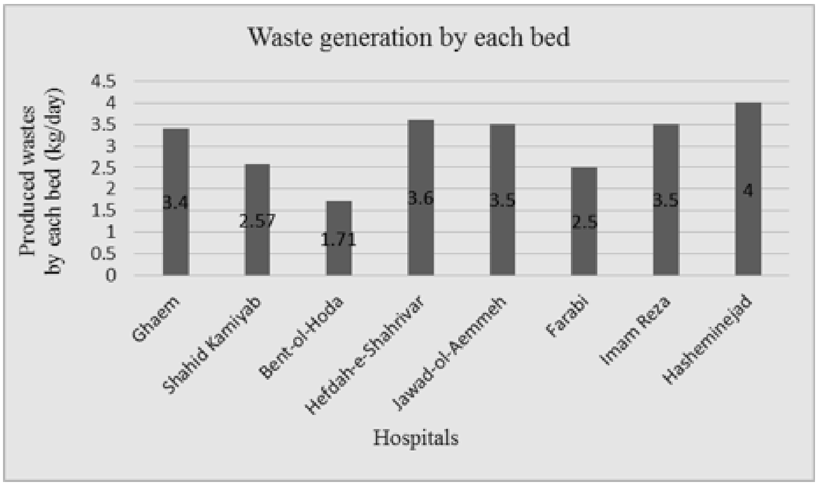

Figure 4: Daily waste generation of each bed per kilogram for the studied hospitals

Table 5: The waste produced in hospitals in different regions of Iran and the world

Researchers	Year	The Region	Waste Per Capita (kg per day)
----	2007	South of Africa	0.6
----	2006	Taiwan	2.7
----	2008	Libya	1.3
----	2002	Turkey	1.92
----	2009	Iran	2.7
----	2008	International statistics	1.1-5
Sepehr Nouri	1990	Semnan Province	0.8-1.8
Omrani	1995	Isfahan Province	2.3
Pirasteh and Pajouhesh	1995	Gilan Province	3.2
Raygan and Shirazi	1996	Fars Province	3.9
Sadeghi	2002	Mashhad	1.67
Firouzmanesh *et al.*,	2005	Sanandaj	2.02
Mirhosseini *et al.*,	2008	Khorramabad	2.7
Amooyi *et al.*,	2009	Babol	2.01
Monavari *et al.*,	2009	Tehran	3.4
Yaghoubi Far and Khamirchi	2009	Sabzevar	2.83
Statistics of the Ministry of Health and Medical Education	2002	Iran	2.71
The current Research	2018	Mashhad	3.1

According to a survey conducted in 2007, 11095 kg of wastes per day were collected from 30 hospitals in Mashhad by the municipality 27.8% of which was infected (Rezaee *et al.*, 2008). In accordance with the standards of the WHO, the maximum amount of infectious wastes should be between 6% and 12% of the hospital waste; indeed, 27.8% of infectious wastes as mentioned above indicate a lack of complete sorting of infectious and pseudo-homemade wastes. Comparison of the eight surveyed hospitals in this study with the statistics reported by Rezaee *et al.*, (2008), shows that the total amount of waste generated in the surveyed hospitals in 2007 was 7370 kg/per day while it was 8880 kg in 2017, showing a rise by 20.48 %. It is projected that the total waste generated by the hospitals in Mashhad will reach 35 tons per day in the next five years, which will be a significant volume to be buried and recycled. In fact, appropriate management needs to be adopted in order to determine the best way to dispose of the hospital wastes. The main methods used in Iran and Mashhad for the disposal of the hospital and non-hospital wastes are: Recycling, burying the remains, landfill, burning, compost and RDF production. Comparison of the hospital waste reported in this paper with the previous studies done in recent years, shows a momentous upsurge in the per capita rate of the hospital waste production, as exhibited in Table 5.

2.4 Locating the Disposal Site of the Hospital Waste

The selection of landfill sites is one of the essential steps in the management of hospital waste. Due to the environmental, economic, and ecological hazards of the landfills, choosing landfill sites should be undertaken with care and in a scientific process. The aim of this part of study is providing a scientific method based on Geographical Information System regarding all sustainable development measures to locate a proper landfill for disposal of hospital wastes (Rezaeimahmoudi *et al.*, 2014).

Therefore, laying emphasis on waste disposal site seems to be of the most paramount issues taken into account when hospital and urban wastes are concerned. This could be achieved by locating with GIS and using the fuzzy logic method. The criteria for locating such as the standards are derived from the environmental directive and the research background (Table 6) and are presented in Table 8. For classification of the layers, the opinions of experts have been used in line with the criteria set by the organizations and using the AHP technique. The classes are given a value ranging from 1 to 4, where 1 represents the most inappropriate while 4 denotes the most appropriate classification (Table 7). It is of note that quantitative methods were used in this research to select the landfill location to reach the final conclusions. Each criterion and parameter required for locating have been evaluated and weighed against each other. After entering the weights obtained in the layers and classifying them, the aggregation and integration of the layers was finally performed in the ArcGIS software. This means, after the initial mapping of each of the criteria, the weights obtained in the way described were multiplied in each of the maps in the GIS software, and finally all the layers in the abovementioned software were overlapping. In Figure 5, a number of effective layers in locating the proper waste disposal site have been shown.

Based on the overlapping of different layers with different weights in the ArcGIS software, the primary and final disposal sites are determined which show in Figures 6 and 7. The current new waste disposal site of non-hazardous hospital and urban wastes is located 32km off Mayamey road, where the two proposed sites A and B are far away from the current site; nonetheless, according to Figure 7, a number of primary locations are proposed at nearer intervals. It is of notice that the current location of the landfill suffers from severe disadvantages such as its unpleasant smell in adjacent residential areas and the run offs due to the inappropriate slope of the current waste disposal site. In addition, the long distance of 32km from the city also results in a considerable amount of time wasted for transport as well as the huge cost and amount of fuel consumption. Based on the conducted studies and the research background, the maximum distance of urban landfills should not exceed 20km. In addition, the old landfill site in the southeast of Mashhad is very close to the rural areas, overlooking the city and in the direction of the predominant winds of the area from southeast to northwest; this causes the displacement of the wastes and waste plastic bags into the city causing substantial contamination.

Table 6: The research background related to appropriate sites of the disposal of hospital and urban wastes

	The Authors	**Title of the Paper**
1	Oyinloye (2013)	Application of Geographical Information System GIS for Siting and Management of Solid Waste Disposal in Akur, Nigeria
2	Amini, (2006)	Locating solid municipal solid waste in Sari using various analytical methods in GIS.
3	Majlisi and Damn Afshan (2009)	Locating landfills in Dezful using GIS.
4	Rezaeimahmoudi *et al.*, (2014)	Application of geographical information system in disposal site selection for hazardous wastes
5	Abbasi and Saeidi (2009)	Determining proper location for hazardous waste landfill using GIS techniques and prioritizing the sites in Qazvin Province.
6	Moin-ol-dini ***e****t al.*, (2011)	Locating landfills in Karaj using Fuzzy Topsis method.
7	Chang *et al.*, (2008)	Waste location, multi-criteria decision-making criteria in the GIS environment.
8	Shrivastava and Nathawat, (2003)	Location of water and wastewater treatment plant around Ransh city using GIS and RS.
9	Hendrix and Buckley, (1992)	Use of a Geographic Information System for Selection of Sites for Land Application of Sewage Waste.
10	Lotfi *et al.*, (2007)	Integrating GIS and fuzzy logic for urban solid waste management.

Table 7: Effective criteria in selecting the location for disposal of municipal and hospital waste

Criteria for Disposal of Sanitary Waste							
AHP weight	Value in Arc MAP	low	medium	good	Very good	Rating	Criteria
8	1	■				0-1000	Distance from rivers
	2		■			1000-2500	
	3			■		2500-4000	
	4				■	>4000	
5	1	■				0-400	Distance from faults
	2		■			400-1000	
	3			■		1000-2500	
	4				■	>2500	
	1	■				0-8000	Distance from airports
	2		■			8000-12000	
	3			■		12000-14500	
	4				■	>14500	
17	1	■				0-300	Distance from main roads
	2		■			300-1000	
	4				■	1000-4000	
	2		■			>4000	
35	1	■				0-4500	Distance from urban boundaries
	2		■			4500-10000	
	4				■	10000-15000	
	3			■		>15000	
29	1	■				0-1000	Distance from rural boundaries
	2		■			1000-3500	
	3			■		3500-5500	
	4				■	>5500	
6	4				■	0-5	Slope %
	3			■		5-12.5	
	2		■			12.5-25	
	1	■				>25	

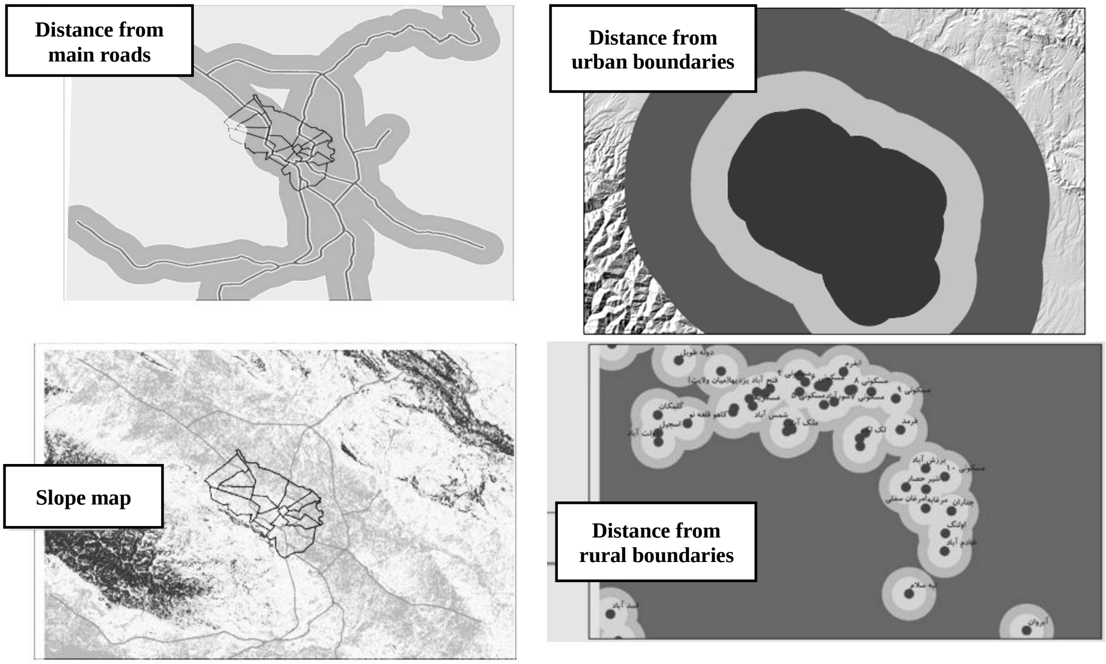

Figure 5: Maps related to the distance from the urban and rural boundaries, slope of the area, and communication paths in the GIS

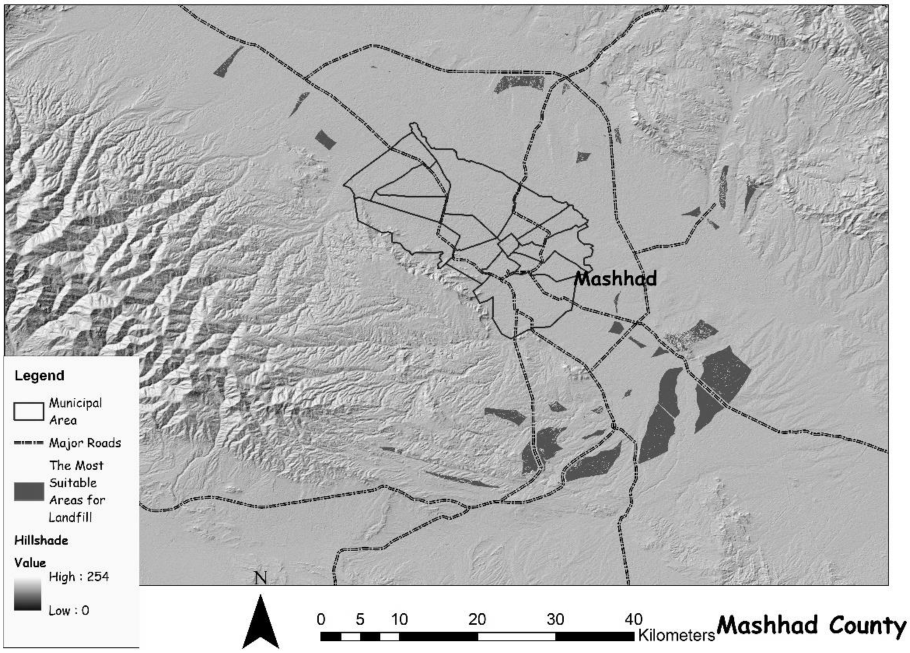

Figure 6: Primary disposal sites of hospital and urban wastes in Mashhad using ArcGIS

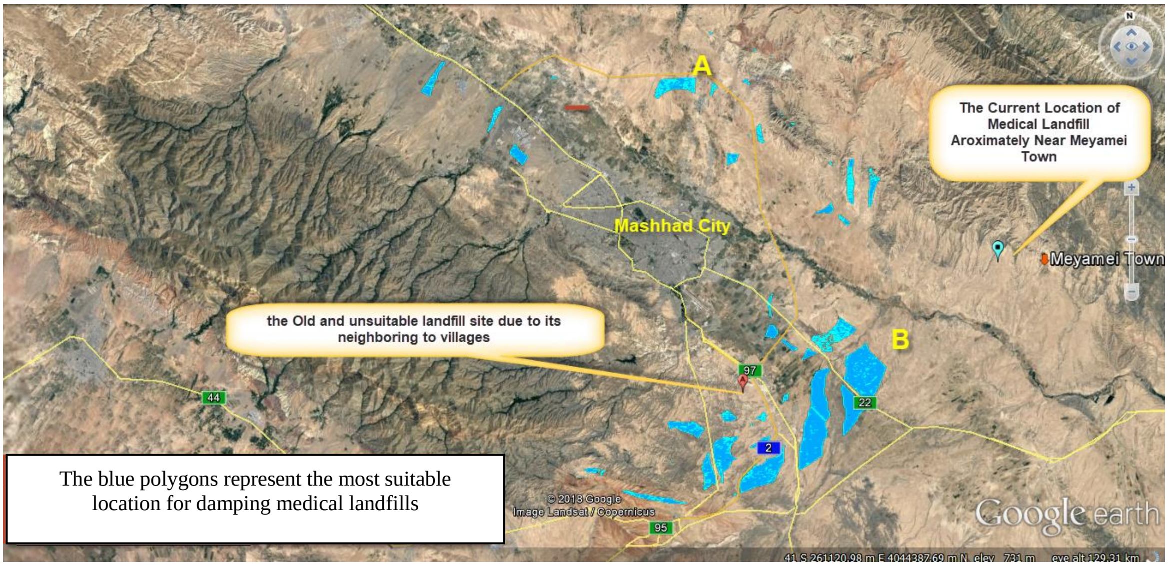

Figure 7: Final proposed sites for hospital and urban waste disposal in Mashhad using ArcGIS modeling

Moreover, this waste is typically disposed of by burning, which pollutes the air not only for the city but also for the farms and animal husbandry, meaning that this is not a suitable place for landfill. Consequently, based on Figure 8 derived from GIS and field studies, Area A is proposed as the most appropriate and comprehensive waste disposal site, considering the field studies and dominant wind direction, making it to be preferred over Area B. The geology of Area B, according to the field study, is a sedimentary type and its bedding is a mixture of sand and clay while its edges are of cracking rocks, being a potential contributing factor in filtering the run offs. It has also a similar position to Area A in terms of its proximity to the seismic fault and the drainage network. It seems Area B could be regarded as the optimal location resultant from the entire natural (environmental) and socio-economic criteria considering its large area and capacity as well as the quantity of waste generated in the region.

2.5 Input Data

The initial data used in the analysis with Expert Choice software was extracted from the questionnaires which were completed by the relevant experts (Table 8). The questionnaires consist of three distinct sections:

- A pairwise comparison of different types of waste disposal methods.
- Investigating the importance of the issues related to waste disposal methods including waste disposal costs, air pollution, soil contamination, and water resources contamination, resource conservation, work difficulty, the required machinery, the disposal time, and the existing limitations.
- Answering a number of questions by interviews and/or verbally.

Expert Choice software has been designed to prioritize waste disposal methods by analyzing two analytic layers where the first layer is related to the mean of the questionnaire data in the study of the importance of the related issues (Table 8) whereas the next layer is the mean of the comparison of different methods of disposal. In order to control the data related to the questionnaires, compatibility, validity, and reliability have a higher importance which are discussed and explained as follows:

- The Cronbach's alpha coefficient can be used to determine the reliability of a questionnaire or a test with an emphasis on internal correlation. If the Cronbach's alpha coefficient is 0.7 or higher, the questionnaire has a good reliability and you can be sure of the internal correlation of the questions. But if the alpha value is less than 0.7, it is better to identify questions that are less correlated with other questions and delete the set of questions to increase the alpha value. However, if the Cronbach's alpha coefficient is between 0.5 to 0.7, the questionnaire would be considered to have an average reliability. If the reliability of the questionnaire is not optimal, it is possible to boost the reliability by identifying the unrelated questions. The SPSS software enables us to check the reliability of each question separately in the set of questions. In this study, it was found that the Cronbach's alpha coefficient of the collected questionnaires using the SPSS was 0.8, implying that the reliability of the initial data is reliable.

- Concerning the questionnaire and the questions related to the current research, another goal was to examine the convergent validity in terms of whether the questions raised would enable us to fulfil the research objectives. This was done by asking the GPS and the respondents while asking some experts specializing in this field to provide guidance and finally the questionnaires were found to have acceptable convergent validity.

- The consistency of the questions was related to two parts namely the internal consistency and repeatability, in which internal consistency is a sign of reliability, but repeatability is done to ensure that the questions are correctly answered and scored so that if the questionnaires are again answered by the former participants after about a week, and compared with the previous responses, the same results would be gained. In this study, about 22 respondents were asked to retake the questionnaires and their responses were checked for the desired compatibility of the responses.

Table 8: Pairwise comparison of the final inputs given to the software for the analysis of the 1st layer

	Cost	Air pollution	Soil contamination	Water resource contamination	Resources conservation	Work difficulty	Required machinery	Disposal time	Limitations
Cost		1/10	1/9	1/9	1/6	2	1/4	1	3
Air pollution			1.5	1.2	2	7	3	7	5
Soil contamination				1	2	6	6	3	2
Water resource contamination					1/4	6	7	5	8
Resources conservation						5	1	3	4
Work difficulty							1/3	1/3	1/10
Required machinery								1/5	1/5
Disposal time									6
Limitations									

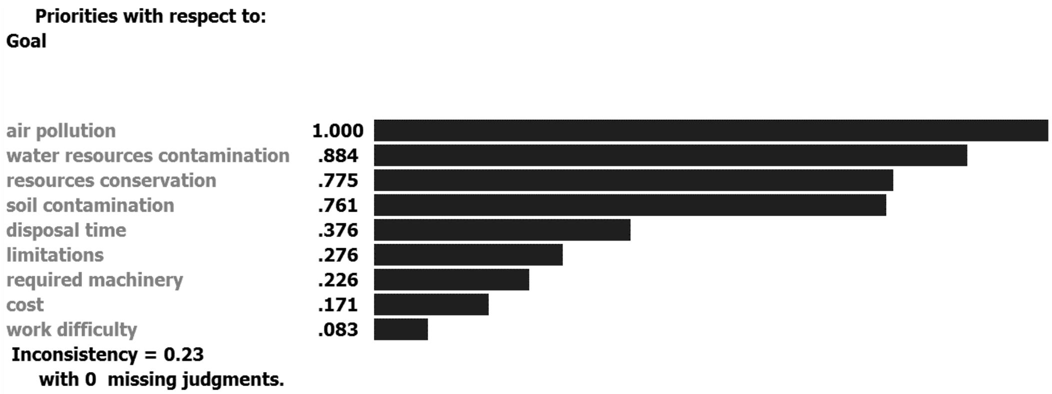

Figure 8: The normalized results related to pairwise comparison of the criteria effective in choosing the waste disposal method

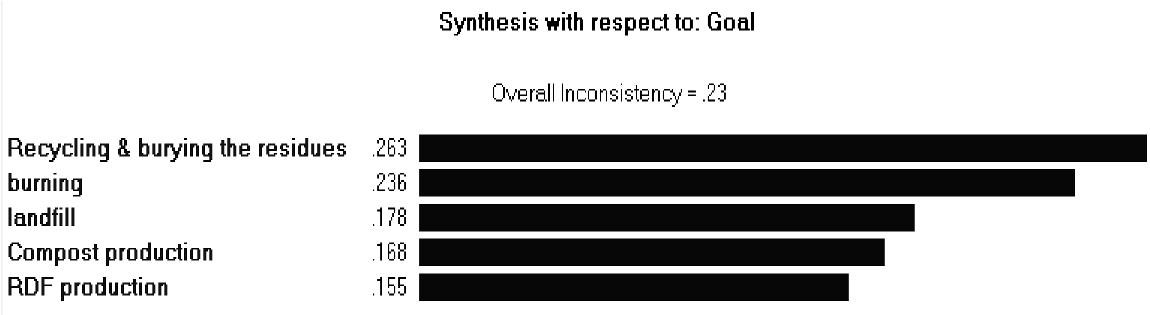

Figure 9: Ultimate prioritization of hospital waste disposal methods

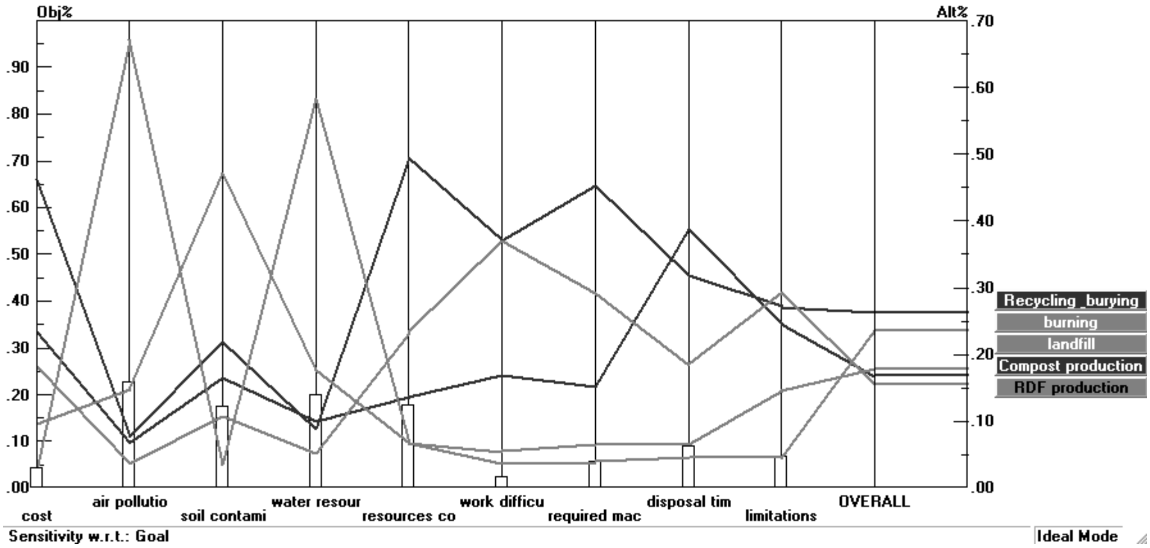

Figure 10: The trend for changes in prioritization of hospital waste disposal methods based on different criteria

2.6 Prioritizing the Effective Criteria in Selecting the Waste Disposal Methods

Such criteria as waste disposal costs, air pollution, soil contamination, and water resources contamination, resource conservation, work difficulty, the required machinery, the disposal time, and the existing limitations will all have different priorities in choosing the method of disposal of hospital waste. Consistent with the results provided by the questionnaires as well as the first layer created Expert Choice, we obtained some results presented in Figure 8**.**

By considering the results related to the analysis of the first layer, it is inferred that air pollution with a rate of 22% has the highest importance in choosing the appropriate method for disposal of the hospital waste, followed by water source pollution and source maintenance having a rate of 19.4% and 17% which take the 2nd and 3rd rank of priority. The 4th priority belongs to the soil pollution, suggesting that the respondents generally assume that protecting the environment and preventing environmental pollution have high importance. The reason for their choice is almost obvious, but these four criteria exert a significant impact on the development and transmission of diseases. This is why choosing appropriate methods for the disposal of the hospital waste has to be done by care while considering the cost and work difficulty could be placed at the last level of priority, as shown by the results obtained in our study. Due to the fact that spending the cost for selecting the correct waste disposal method prevents secondary costs, it is quite plausible to allocate budgets and finances, albeit high, to choose appropriate a waste disposal method. It is also interesting to know that the time took the 5th rank of priority, implying a reason to reduce diseases and environmental pollution.

2.7 Prioritization of the Waste Disposal Methods

This research has been undertaken with the aim of determining the best disposal method in Mashhad hospitals in order to minimize the contamination and consequences imposed by waste disposal and to consider the relevant criteria as much as possible. The final results yielded from the second layer are depicted in Figures 9 and 10. Based on Figure 9, it has been finally agreed that the waste recycling method and burial of the additional residues stands higher than the other methods of disposal with a rate of 26.3%. afterwards, the burning method ranks the second with a rate of 23.6%, although it appears to have high levels of contamination, The RDF and compost production might rank the last due to the constraints in terms of required machinery and cost.

By meticulously scrutinizing Figure 10, it is understood that if the burning and burying methods minimize the soil and air pollution and minimize resources elimination, they can be very suitable options for disposal of the hospital waste, reaching to the first priority from the second and third priorities because they appear to be very appropriate in terms of time, cost and work difficulty, and etc.

Moreover, the respondents have also compared the methods of waste disposal and Table 9 indicates the overall mean of the questionnaires. Based on their responses, it can be concluded, recycling and burying the residues takes the first priority, followed by RDF and compost creation. Meanwhile, it is observed that burning and landfills take the last priorities, implying the fact that the respondents are more concerned with the environmental aspect. It is of note that if they had taken into account all the aspects, then different results would be obtained, consistent with the analyses and results obtained in this research based on the Expert Choice software. By comparing these two results, it is possible to infer the advantages of the pairwise comparison of the methods based on the individual criteria. According to Figure 9 and Table **9**, five criteria were used here for different waste disposal methods which were analyzed in a GIS to select best site for waste management of hospitals and medical clinics. The criteria of economic such as land price was out of scope of this study, because the land was allocated by state government on free hold basis.

3. Conclusions and Findings

There are several ways to dispose of hospital waste, such as burning, landfills, recycling, etc. but choosing the best method out of the existing ones, choosing the most appropriate waste disposal site, and managing the quantity of waste generated are of high prominence, and these were indeed the objectives of this research are conducted in Mashhad, Iran. In this research, the initial data was collected using interviews and field observations.

Table 9: Comparison of different waste disposal methods with each other in general

	Burning	Landfill	RDF production	Compost production	Recycling & burying the residues
Burning	1				
Landfill	5	1			
RDF production	6	3	1		
Compost production	7	5	2	1	
Recycling & burying the residues	9	9	5	4	1

The final results and findings were obtained using the Analytical Hierarchy Process as well as Expert Choice, and GIS software, as summarized below:

- In general, the results indicate an increase in the amount of waste generated in Mashhad hospitals, which is about 20% higher than that of 2007, and it is expected that with this speed of waste generation, there will be a generation of around 35 tons of hospital wastes in Mashhad by the next 5 years. This warns us that recycling and disposal of such wastes must be taken into consideration by now. To reduce the rate of per capita waste production, we need to adopt management practices inside the hospital in addition to paying attention to reducing the number of illnesses and the number of hospitalized patients. One of the best and most practical measures to fulfil this is to encourage the individuals to do workouts and reduce air pollution and environment pollution.
- The infectious hospital wastes generated in the studied hospitals in Mashhad are about 2.5 times more than the international standards, which have to be minimized by proper waste management and timely sorting.
- According to the observations, the hospital workers are not adequately trained on sorting and collection of the wastes, implying that the hospital authorities are called for providing proper training on the collection and disposal of different wastes.
- According to the observations and the waste generated in the studied hospitals, the waste sorting methods are far from the WHO standards, being critical indeed.
- By using the Analytical Hierarchy Process in Expert Choice software, it was found that the first ranked methods are recycling and burial of residues for disposal of hospital waste and landfills and burning methods take the second and third priorities. Finally, the compost and RDF production took the final priorities, suggesting the importance of other relevant criteria in choosing the optimal waste disposal method, while the general population merely pay attention to initial observable pollution.
- Burning and landfill methods can be in the first priority for the disposal of hospital wastes in Mashhad in the event of better management and reduction of 50-60% of air and water pollution due to cheaper and available resources.
- Based on the modeling undertaken in GIS which introduce the layers effective in choosing the proper sites for disposal of waste, it was found that the two proposed final sites are different from both the current and the former disposal site.

Based on this study and other appropriate technical recommendations, it was concluded that the current waste disposal site located 32 km off the Mayamey Road, is not appropriate, and government authorities decided to promptly relocate the waste site disposal to another location by utilizing powerful spatial data analytics.

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