Location of Hospital Waste Disposal Site With FSWARA-GIS-MAIRCA Hybrid Algorithm

Fatemeh Ramila Heydari Pirbasti (f.heydaripirbasti@gmail.com)
Islamic Azad University South Tehran Branch https://orcid.org/0000-0002-8336-3514

Mahmoud Modiri
Islamic Azad University South Tehran Branch

Kiamars Fathi Hafashjani
Islamic Azad University South Tehran Branch

Alireza Rashidi Komijan
Islamic Azad University Firoozkooh Branch

Research

Keywords: Disposal Site, Waste, Hospital, Location, FSWARA, GIS, MAIRCA

Posted Date: February 4th, 2020

DOI: https://doi.org/10.21203/rs.2.22537/v1

Location of Hospital Waste Disposal Site With FSWARA-GIS-MAIRCA Hybrid Algorithm

Fatemeh Heydari Pirbasti[1,*] ,Mahmoud Modiri[1],Kiamars Fathi Hafashjani[1],Alireza Rashidi Komijan[2]

Abstract

Background: One of the major environmental issues facing most societies is the management of waste, industrial, medical and hazardous waste. Locating is an activity that analyzes the capabilities of an area in terms of whether the land is suitable for a particular application. The metrics used in location vary by application type, but they are all aligned to select the right location. Choosing the right burial site for waste is the most important step in waste management. Inappropriate burial selection causes contamination of water, soil and air in the area. The ultimate goal is to find the most suitable location that has the least impact on the environment and natural resources around, and is economically the least costly and engineered.

Results: In this study, we chose south of Tehran as a case study to implement the FSWARA-GIS-MAIRCA Hybrid Algorithm. Selecting inappropriate locations for hospital waste disposal site at the southeast of Tehran province is one of the environmental problems of this region causing damage to the environment and pollution of ground waters. Since waste disposal site is the most economic, accepted, and important method in most areas, the present study aimed to locate the hospital waste disposal site at the southeast of Tehran province. Using fuzzy Delphi method, nine criteria (slope, height, soil type, distance from fault, distance from surface water, depth of ground waters, distance from residential areas, distance from hospitals and distance from road) were finally selected as the final criteria. Then, the desired criteria were weighed using the FSWARA and entered the GIS system as information layers to calculate the final maps for the appropriate zones, which eight locations were selected for waste disposal site.

Conclusions: Finally, using the MAIRCA method, the selected locations were ranked and finally among these eight locations, the fourth point was selected as the final location for hospital waste disposal site at the southeast of Tehran. According to the desired criteria with 34 degree slope, 1008 meters high, 3.4841 meters distance from fault, 8.4428 meters distance from surface water, 12 meters depth of ground waters, 457 meters distance from residential areas, 6.4749 meters distance from hospitals, and 1598 meters distance from road.

Keywords: Disposal Site, Waste, Hospital, Location, FSWARA, GIS, MAIRCA

[1] . Department of Industrial Management, Faculty of management, South Tehran Branch, Islamic Azad University,Tehran,Iran.
[2] . Department of Industrial Engineering, Faculty of Industrial management, Firoozkooh Branch,Tehran,Iran.
*. Corresponding author. E-mail address: f.heydaripirbasti@gmail.com

Background

Following human progress and with the development of human activities, the volume of hazardous waste has increased, which attracted large attention given the risks of transport, filtration, disposal site; and more importantly, their environmental problems. Hazardous waste management has become one of the important subjects for researchers (Makajic-Nikolic & et al, 2016). Healthcare waste management includes the production, storage, collection site, transport, processing, and disposal. Preventing the production of waste and post-care as well as preliminary filtration are among the features of healthcare waste management which has taken into consideration due to the hazardous nature of these substances (zanjirani Farahani & et al, 2015).

Hazardous Waste Management (HWM) includes the collection, transport, filtration, recycling, and disposal of these substances. Selecting the appropriate location for the infectious waste disposal of centers is one of the major issues in waste management. Specifying a location for hospital waste disposal site is one of the most difficult and complicated processes because it requires the combination of social and environmental factors. Interpreting these factors as well as the factors related to cost requiring the appropriate allocation of resources is difficult. In addition, it depends on the consideration of governmental rules which is based on the definite conditions of the case study (Basu & et al, 2015).

The centers located outside the hospitals for urban waste disposal site cannot perform the disposal appropriately. As a result, the construction of new buildings and appropriate facilities for infectious waste disposal site is a growing problem that should be highly regarded. In the past, the inappropriate disposal site of infectious waste caused many problems such as the prevalence of diseases and weakness in public health which were a common problem in many hospitals, because their disposal site was not far from the other disposal sites. For this reason, urban authorities should make policies for considering new hospital waste disposal sites for better effectiveness of waste disposal to achieve integrity in the region (Joghtaei & et al, 2016). New disposal sites should be in accordance with governmental rules including environmental, safety, health, social, economic, geographic, and other rules, which should at the same time reduce the negative environmental, health, social, and economic effects. Thus, urban authorities and municipalities are logically in charge of hospital waste disposal. Thus, the process of selecting the most appropriate locations in this case is one of the most complicated issues of management (Mohseni et.al, 2011).

Environment and urban experts believe that due to its specific problems, waste management indicate the cultural, social, and economic status of a country and require the exact and foresighted design. Locating the hospital waste disposal sites is an important and complicated social problem, because the decisions related to location imposes lots of costs and risks for those using these facilities (Aydi& et al,2013).

Appropriate and principled location is the best option for sustainable development and environmental protection of cities and also one of the most important solutions for hospital waste management. In fact, the appropriate location of waste disposal sites can realize the final goal of hospital waste management requirements due to ecological, economic, and social parameters in the framework of sustainable urban development principles (Wichapa & et al, 2017). Therefore, it is necessary to conduct extensive studies on planning, designing, and locating hospital waste disposal site concerning the effective factors in this regard. The presence of multiple effective factors in the field of appropriate location of waste disposal site guides the decision makers towards using the system which has high precision in terms of speed and ease of use in operations. Location processes are difficult, complicated, and tiresome due to the involvement of many criteria, while traditional methods are very time-consuming, costly, and inaccurate (Donevska et al, 2012). Solving this problem needs a scientific and integrated process to make an appropriate decision based on scientific principles. Such a process requires structuring the problem in a clear form involving all criteria and factors involved indecision making on the one hand and providing the possibility of conscious judgements on the other hand without being confused. Using the multi criteria decision-making methods is one of the solutions used by researchers to overcome such complexities providing the possibility of analysis and making the multi criteria and complicated problem as structured and systematic to provide an appropriate approach to achieve logical results (De Feo&De Gisi,2014). Selecting multiple factors leads to the multiplicity of information layers and the attempts for finding an appropriate solution for analysis on any information layers and achieving correct results lead the decision makers unconsciously toward using a system which is at a high level in terms of speed and ease of use in operations (Chauhan& Singh, 2016).

Shah et al. (2019) used the AHP-GIS to investigate the appropriate location for urban waste disposal site at the east of Karachi and the region considered for waste disposal was 200 meters far from the Malir River according to the road distance criteria, good proportions for the disposal site, road conditions, rivers, etc. (Danesh& et al, 2019). These researchers selected the hazardous waste disposal site using the FANP and GIS techniques. For this purpose, environmental and socio-economic criteria were identified and normalized using the fuzzy method. The weight of parameters was determined using the network analysis process. The results showed that the maximum weight was related to ecological criteria (61.34%) and land use (0.27).

Using GIS, DEMATEL, and FANP, Feyzi et al (2019) located the disposal site for burning municipal solid waste in Rasht, north of Iran, in the form of environmental, economic, social, and cultural criteria. Alam et al(2019) used the fuzzy logic and Yager's method to examine the weights of environmental, economic and social criteria. In addition, they used the GIS and found appropriate disposal sites in West Bengal, India. Ghazifard and Mortazavi Chamchali (2019) used fuzzy spatial logic through GIS to select appropriate disposal sites. Wadhwa (2018) used GIS and WLC to analyze the criteria such as socio-economic factors for the optimal location of food stores in Minnesota. Abdullah et al(2019) used the DEMATEL and Choquet integal techniques to weigh the municipal solid waste management criteria. Ebadi Torkayesh et al(2019) used the entropy, fuzzy

VIKOR, and ELECTRE techniqu to analzye municipal solid waste in Azerbaijan, Iran. Wichapa & Khokhajaikiat(2018) used Fuzzy AHP and Fuzzy TOPSIS algorithm to determine the weight of selected criteria in the management of hospital infectious waste. Midatana et.al(2018) used the hybrid method of AHP, TOPSIS, and GIS to evalaute and determine the asppropriate location for the construction of industrial centers. Islam et al(2018) used AHP and GIS techniques to determine the disposal municipal solid waste disposal sites in Islamabad and Rawalpindi in Pakistan considering the critera of ground waters, surafe waters, vegetation, soil type, protected areas, roads, slope, residential towns, airports and railways. Mohammed et al (2018) analyzed the appropriate disposal sites for municipal waste using multi-criteria decision-making techniques (weighted liner combination, AHP, and fuzzy logic, and GIS). Saatsaz et.al (2018) used AHP and GIS techniques and regarded 12 criteria for locating appropriate municipal solid waste disposal sites in Zanjan. The results idnicated that approrpaite disposal sites are those which consdiered groundwater depth, climatic conditions, and soil type. Yousefi & et al (2018) studied the criteria scuh asground water depth, distance from ground water, access routes, residential areas, industries, power trasnmission lines, flood, faults, slopes, distance from protected areas, and agricultural lands to determine the approriate municipal waste disposal sites in Salafcheghan using the AHP and GIS techniques. Soroudi & et al (2018) stusied 20 criteria categorized as ecological, social and economic to determine the municipal waste disposal sites in Hassan Abad using fuzzy analytical network processing (FANP) and geographic information system (GIS) models. The results indicated that the prior areas are those where the distance from road, protected areas, and soil type have the maximum weight. Furthemore, in another similar stusdy, Soroudi et al (2018) used the DEMATEL-FANP method as well as GIS algorithmto deremine the approrpaite municipal waste disposal sites in Tehran. The results indicated that soil type had the maximum effect among the selected criteria in determining the appropriate waste disposal site. Nabi Dar et al. (2018) used the weighted liner combination and GIS and considered the road network criteria, agricultural lands, rural areas, slope, river, agricultural land, etc. to determine the waste disposal site in Ladakh. Yildirim et al (2018) determined the municiapal solid waste disposal site using TOPSIS and GIS techniques in Bursa province by considering the economic, social, and environmental factors. Ding & et al (2018) combined the AHP entropy with GIS to select the municapl waste disposal site by consideing the criteria such as distance from surface water, distance from protected areas, agriculturals land, distance from tourist areas, transport costs, land prices, distance from residential areas, etc. in Shenzhen, China. Mohammed et al(2017) proposed a conceptual model for selecting a waste disposal site based on GIS and multi-criteria decision-making methods. Syed Ismail(2017) studied residential areas, surface waters, protected areas, roads, access routes, slope, ground waters criteria to determine approrpiate locations in the ubran area of Selangor, Malaysia using AHP technique and weigted lienar combination (WLC) as well as geographic information system (GIS). Memarbashi et al (2017) analzyed the land suitable for agriultrue in the Sangab plain in the northeast of Iran using AHP and GIS techniques. Guler & Yomralıoglu (2017) studied the land use, residential areas, surface water, population density, airports, protected areas, slope, waste transmission stations, land values, highways criteria to select a location for municipal waste disposal site in Istanbul, Turkey using the AHP and GIS techniques. Chabuk et al (2017) used the AHP and GIS techniques to determine the location of municpal waste disposal site in Al-Hashimiyah Qadhaa, Babylon, Babylon. Hariz & et al. (2017) located the health waste disposal sites based on multi-criteria decision making and GIS by considering the criteria such as distance from rivers, type of land, land use, rural areas and protected areas, road network, etc. in the coastal city of kilifi in Kenya. The analysis idnicated that only 8.2% of the land was suitable for waste disposal, and eight locations were approrpiate for disposal site. Then, sixth location was selected from the eight desired locations using the VIKOR, AHP, PROMETHEE methods. Kharat et al. (2016) used the fuzzy Delphi to screen the criteria and also used the DEMATEL technique to identify the severity of the interactions between the criteria. In addition, they used the fuzzy AHP to weigh the criteria for selecting the municipal disposal site.

Fagbohun & Aladejana (2016) selected the location of municipal disposal site using AHP and GIS techniques and regarded the criteria of land use, vegetation, river, soil, slope and road lines. Chauhan & Singh (2016) considered the criteria of distance from collecting locations to disposal site, land availability for disposal site, transport costs, road conditions, and weather conditions for selecting the location of sustainability at waste disposal facilities using the ISM, FUZZY AHP, FUZZY TOPSIS methods. Among the five selected locations with the help of GIS, the second and third locations were considered more approrpiate for disposal which had the minimum environmental pollution.

According to the studies,some criteria that have been extracted and have the most influence on location process are:Slope,Height,Soil type, Distance from fault, Distance from vegetation, Distance from surface water, Depth of groundwater, Distance from residential areas, Distance from hospitals, Distance from wildlife species, Power transmission lines, Distance from road.So that criteria were defiend and identfieid for selecting the hospital waste disposal site and the Fuzzy-Delphi method and experts' opinions were used for screening. Then, the weight of the criteria was determined using SWARA method. In addition, the MAIRCA method was used to determine the disposal site while the GIS was used for determining the proposed locations.

Materials and Methods

Criteria screening

Fuzzy Delphi method was used to identify the criteria for locating hospital waste disposal sites. For this purpose, the experts' opinions for the importance of each criterion were collected at the first round through the five-point Likert questionnaire and the result of the calculations are presented in Table 1.

Table 1. Results of the first round of the survey with the average opinons of the experts

Row	Linguistic value	Very high	high	average	low	Very low	max	mod	min	The defuzzificated mean
	Numerical value	9	7	5	3	1				

	Sub-criteria - Fuzzy value	(7,9,10)	(5,7,9)	(3,5,7)	(1,3,5)	(0,1,3)				of experts' opinions
1	Slope	16	2	2	0	0	9.60	8.40	6.40	8.27
2	Height	12	8	0	0	0	9.60	8.20	6.20	8.10
3	Soil type	13	5	2	0	0	9.45	8.10	6.10	7.99
4	Distance from fault	12	4	4	0	0	9.20	7.80	5.80	7.70
5	Distance from vegetation	6	4	6	4	0	7.90	6.20	4.20	6.15
6	Distance from surface water	12	7	1	0	0	9.50	8.10	6.10	8.00
7	Depth of groundwater	16	3	1	0	0	9.70	8.50	6.50	8.37
8	Distance from residential areas	11	5	3	1	0	9.05	7.60	5.60	7.51
9	Distance from hospitals	10	6	3	1	0	9.00	7.50	5.50	7.42
10	Distance from wildlife species	0	8	11	1	0	7.70	5.70	3.70	5.70
11	Power transmission lines	8	6	4	2	0	8.60	7.00	5.00	6.93
12	Distance from road	14	4	2	0	0	9.50	8.20	6.20	8.08

- **Survey on second stage**

At this stage, a second questionnaire was prepared and resen to members of the expert group along with the previous opinion of each expert and their differences with the opinions of other experts. At the second stage, the members of the expert group asnwered to the presented questions based on the opinions of other members of the group and the results are presented in Table 2.

Table 2. The results of the second round of the survey with experts' averagve opinions

Row	Linguistic value	Very high	hgih	Average	low	Very low	max	mod	min	The defuzzificated mean of experts' opinions	The difference in the mean of he first and second questionnaires	Result
	Numerical value	9	7	5	3	1						
	Sub-criteria - Fuzzy value	(7,9,10)	(5,7,9)	(3,5,7)	(1,3,5)	(0,1,3)						
1	slope	14	5	1	0	0	9.60	8.30	6.30	8.18	0.08	Accepted
2	Height	15	4	1	0	0	9.65	8.40	6.40	8.28	0.18	Accepted
3	Soil type	13	7	0	0	0	9.65	8.30	6.30	8.19	0.20	Accepted
4	Distance from fault	14	4	2	0	0	9.50	8.20	6.20	8.08	0.38	Next one
5	distance from vegetation	5	5	8	2	0	8.05	6.30	4.30	6.26	0.11	Rejected
6	Distance from surface water	12	8	0	0	0	9.60	8.20	6.20	8.10	0.10	Accepted

7	Depth of groundwater	16	4	0	0	0	9.80	8.60	6.60	8.47	0.10	Accepted
8	Distance from residential areas	12	6	2	1	0	9.65	8.15	6.05	8.05	0.54	Next one
9	Distance from hospitals	12	6	2	0	0	9.40	8.00	6.00	7.90	0.48	Next one
10	distance from wildlife species	0	7	12	1	0	7.60	5.60	3.60	5.60	0.10	Rejected
11	Power transmission lines	8	6	5	1	0	8.70	7.10	5.10	7.03	0.10	Rejected
12	Distance from road	16	4	0	0	0	9.80	8.60	6.60	8.47	0.38	next one

Based on the opinions presented in the first satge and comparing it to the results of this stage, if the difference between the two stages is less than the threshold 0.2, then the survey process will be stopped. As mentioned in the above table, some of the variables of the expert group were agreed upon and the extent of disagreement at the first and second stages was less than the threshold 0.2, thus the survey on the above-mentioned variables was stopped. Among the mentioned variables, the variables with a defuzzificated mean of experts' opinions less than 8 were deleted from the conceptual model of the study. The rest of the survey is codnucted at the third stage.

- **Survey on third stage**

At this stage, while applying the requried changes in the variables, the third questionnaire was prepared and then resent to the experts along with the previous opinion of each expert and the extent of their disagreements, of which its results are given in Table 3.

Table 3. Results of the third round of the survey with the average oponions of the experts

Row	Linguistic value	Very high	high	average	low	Very low	max	mod	min	The defuzzificated mean of experts' opinion	The mean diference of the second and third questionnaires	result
	Numerical value	9	7	5	3	1						
	Sub-criteria - Fuzzy value	(7,9,10)	(5,7,9)	(3,5,7)	(1,3,5)	(0,1,3)						
4	Distance from fault	15	4	1	0	0	9.65	8.40	6.40	8.28	0.19	accepted
8	Distance from residential areas	13	6	1	0	0	9.55	8.20	6.20	8.09	0.04	accepted
9	Distance from hospitals	13	5	2	0	0	9.45	8.10	6.10	7.99	0.09	accepted
12	Distance from road	17	3	0	0	0	9.85	8.70	6.70	8.56	0.09	accepted

As indicated in the table above, the mean difference between the experts' opinions at the second and third stages was less than the threshold 0.2, thus the survey was stopped at this stage.

Thus, 3 out of 12 criteria were deleted from the final research conceptual model during three stages of survey and the final model had nine critertia derived from the present study. The final model was prepared based on the research literature and the results of in,terviews with experts and university professors and then its content validity was confirmed.Table 4 show the final criteria of locating the hospital waste disposal site that extracting by performing Fuzzy-Delphi method.

Table 4. The criteria of locating the hospital waste disposal site

Abbreviations	Factors	References
C_1	Slope	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_2	Height	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_3	Soil type	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_4	Distance from fault	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)

C_5	Distance from surface water	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_6	depth of groundwater	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_7	Distance from residential areas	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_8	Distance from hospitals	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)
C_9	Distance from road	Shah & et al (2019),Danesh & et al (2019),Feyzi & et al (2019),Alam & et al (2019), Ghazifard and Mortazavi Chamchali (2019), Abdullah et al(2019), Ebadi Torkayesh et al(2019), Wadhwa (2018), Wichapa & Khokhajaikiat(2018), Midatana et.al(2018,Islam et al(2018), Mohammed et al (2018), Saatsaz et.al (2018), Yousefi & et al (2018), Soroudi & et al (2018), Soroudi et al (2018), Nabi Dar et al (2018), Yildirim et al (2018), Ding & et al (2018), Mohammed et al(2017), Syed Ismail(2017), Memarbashi et al (2017), Guler & Yomralıoglu (2017), Chabuk et al (2017), Hariz & et al. (2017), Kharat et al. (2016), Fagbohun & Aladejana (2016), Chauhan & Singh (2016)

Stepwise Weight Assessment Ratio Analysis (SWARA)

In this study, the fuzzy SWARA method was used to measure the weights. SWARA method is one the weighting methods where experts have an important role in the calcualtion of weight and final evaluation. For this purpose, the opinions of eight experts from the studied organization were used which the weight of each criterion indicates its importance. This method allows the experts’ opinion to be displayed about the importance of criteria in the logical decision-making process.

This method was proposed by Keršulienė, Zavadskas, & Turskis (2010). Similar to ARAS method, the SWARA method is a new suggested case. However, many actual solutions were used such as a the logical debate on selecting an architect (Kersuliene & Turski, 2011), product design (Zolfani, Zavadaskas & Turskis, 2013), selecting a machine tool (Aghdaie, Zolfani, Zavadskas , 2014), the prioritization of indicatiors for energy sustainability assessment (Zolfani, Saparauskas, 2013), prioritization and inevstment on the approach-based advanced technology (SWARA COPRAS) (Zolfani & Bahrami, 2014), and the development of a new MCDM hybrid approach for selecting the optimal opion of longitudinal mechanical ventilation of tunnel contaminants in car accidents (Zolfani, Esfahani & al, 2013). The process of determining the relative weights of criteria using SWARA method according to Keršulienė, Zavadskas, & Turskis (2010) is as follows:

Step 1: The criteria are categorized in descending order (from big to small) and based on their desired importance (Experts' opinions can be used for determining and classifying the criteria).

Step 2: Starting from the second criterion, the respondent determines the relative importance of the jth criterion with regard to the previous criterion (j -1) for each criterion. According to Keršulienė, Zavadskas, & Turskis (2010), this ratio is called "comparative importance." From the mean$\boldsymbol{s_j}$. this ratio $\boldsymbol{s_j}$ is the mean which is called the comparative importance.

Step 3: Coefficient $\boldsymbol{k_j}$ is determined as follows:

Equaion 1: $$k_j = \begin{cases} 1 & j=1 \\ s_j + 1 & j > 1 \end{cases}$$

Step 4: The remeasured weight $\boldsymbol{q_j}$ is determined as follows:

Equation 2: $$q_j = \begin{cases} 1 & j=1 \\ \dfrac{q_j - 1}{k_j} & j > 1 \end{cases}$$

Step 5: The relative weitghts of the jth criterion are determined as follows:

Equation 3: $\boldsymbol{w_j} = \frac{\boldsymbol{q_j}}{\sum_{k=1}^{n} \boldsymbol{q_k}}$

In this equqation, $\boldsymbol{w_j}$ represnets the rlative weitght of the j^th^ criterion and n repersnets the number of criteria.

Where $\widetilde{\boldsymbol{W}}_{\boldsymbol{j}} = (\boldsymbol{w}_{\boldsymbol{j}}^{\boldsymbol{l}} . \boldsymbol{w}_{\boldsymbol{j}}^{\boldsymbol{m}} . \boldsymbol{w}_{\boldsymbol{j}}^{\boldsymbol{u}})$ is the relative fuzzy weight of the j^{th} criterion and n represents the number of evaluated criteria.

Figure 1 indicates an algorithm for determining the weight of the criteria:

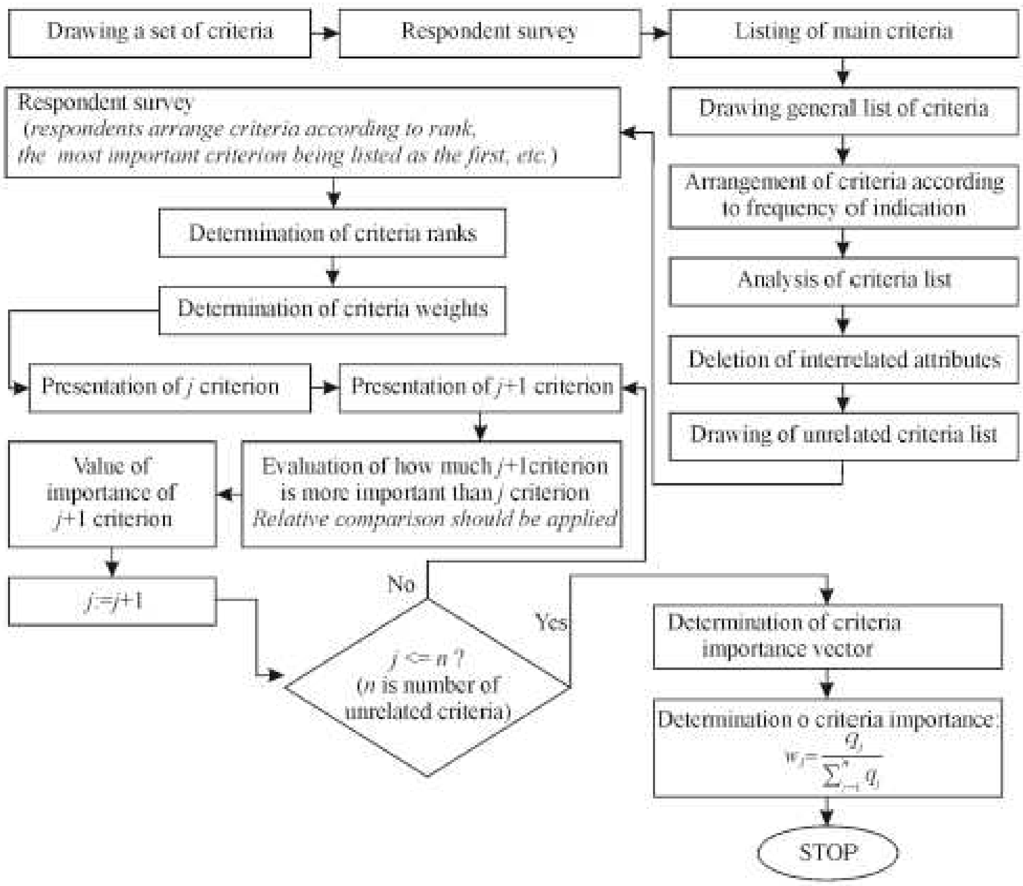

Figure 1: Determining the weight of criteria based on SWARA algorithm (Source: Kersuliene & Turskis, 2011)

The calculations related to the weight and importance of each studied criterion were conducetd using EXCEL software. Such calculations are shown in Table 5 and the criteria can be prioritized based on the weights of last column of criteria:

Table 5. Final calculations related to the weight and importance of the main criteria

	$\tilde{s}_j$			$\tilde{k}_j = \tilde{s}_j + 1$			$\tilde{q}_j = \frac{\tilde{x}_{j-1}}{\tilde{k}_j}$			$\tilde{w}_j = \frac{\tilde{q}_j}{\sum_{k=1}^{n} \tilde{q}_k}$		
C1	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	0.279	0.300	0.329
C2	0.311	0.369	0.455	1.311	1.369	1.455	0.688	0.731	0.763	0.192	0.219	0.251
C3	0.274	0.319	0.384	1.274	1.319	1.384	0.497	0.554	0.599	0.139	0.166	0.197
C4	0.274	0.319	0.384	1.274	1.319	1.384	0.359	0.420	0.470	0.100	0.126	0.155

C5	0.612	0.648	0.695	1.612	1.648	1.695	0.212	0.255	0.291	0.059	0.076	0.096
C6	0.434	0.475	0.530	1.434	1.475	1.530	0.138	0.173	0.203	0.039	0.052	0.067
C7	0.756	0.841	0.951	1.756	1.841	1.951	0.071	0.094	0.116	0.020	0.028	0.038
C8	0.399	0.459	0.535	1.399	1.459	1.535	0.046	0.064	0.083	0.013	0.019	0.027
C9	0.446	0.586	0.795	1.446	1.586	1.795	0.026	0.041	0.057	0.007	0.012	0.019

Finally, the final fuzzy weight of the criteria was obtained and deffuzificated using the center of gravity method, the results of which are presented in Table 6.

For deffuzificatation (i.e. calcualting the individual weights of each criterion), the centrality method was used to calculate BNP value. In other words, the normal fuzzy perfomance should be changed to the classic (definitive) performance value. Best non-fuzzy performance (BNP) can be calculated by different methods. In this stduy, the centrality method was used to measure the BNP value:

Equation 4: AS $\hat{y}_i = (\boldsymbol{y_i^l . y_i^m . y_i^u})$

Equation 5: BN$\boldsymbol{P}_i(\boldsymbol{y}_i) = \frac{(y_i^u - y_i^l) + (y_i^m + y_i^l)}{\mathbf{3}} + \boldsymbol{y_i^l}$

Table 6. The final weight and final rank of subcriteria for selecting hospital waste disposal site

Code	The relative fuzzy weight of sub criteria				Code
C1	0.329	0.300	0.279	0.303	1
C2	0.226	0.219	0.213	0.220	2
C3	0.164	0.166	0.167	0.166	3
C4	0.118	0.126	0.131	0.125	4
C5	0.070	0.076	0.081	0.076	5
C6	0.046	0.052	0.057	0.051	6
C7	0.023	0.028	0.032	0.028	7
C8	0.015	0.019	0.023	0.019	8
C9	0.008	0.012	0.016	0.012	9

Based on Table 6, “slope” with the weight of 0.303 has the most importance for locating hospital waste disposal site. “Height” with the weight of 0.22 has the second priority. Furthermore, “distance from road” witht the weight of 0.122 and “distance from hospitals” with the weight of 0.019 has the least importance. Figure 2 shows the weight and priority chart of the criteria.

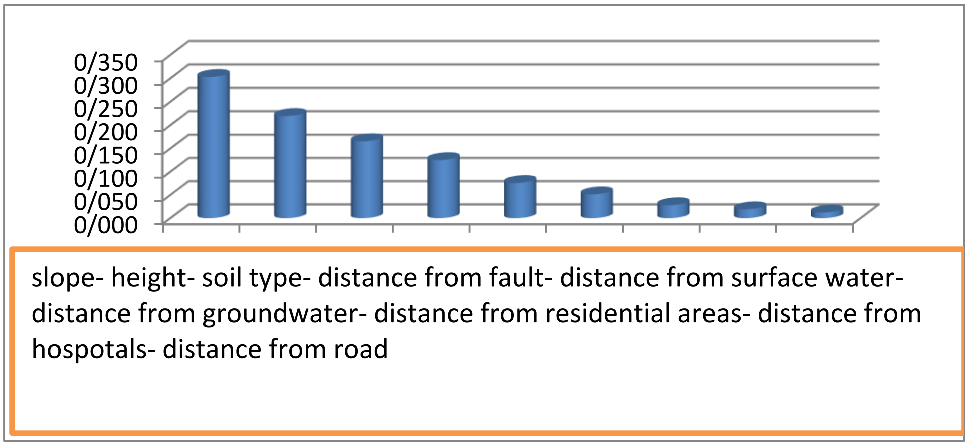

Figure 2. Weight and priority of criteria

The Study Area

The study area is a part of the south of Tehran, including the areas such as Ray, Baqer Shahr, Kahrizak, and Qiyam Dasht (Figure3).

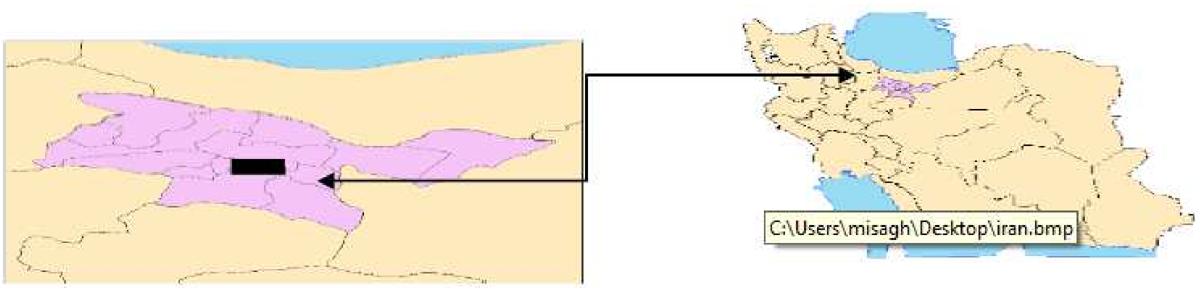

Figure 3: Location of the study area in Iran and Tehran province

ArcGIS 10.2 software was used for spatial preparation and processing of each parameter using the spatial analysis functions (Table 7).

In Figures 4 to 12, the input layers produced with their actual values are indicated.

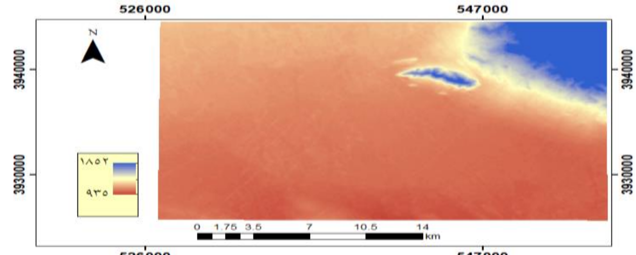

Figure 4. Height

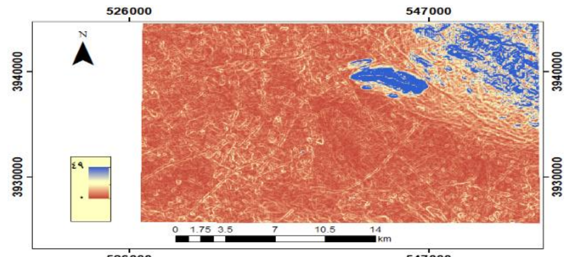

Figure 5. Slope

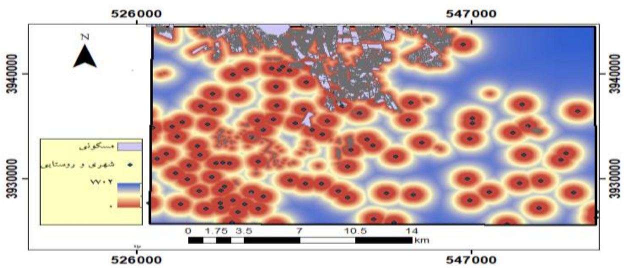

Figure 6. Distance from urban and rural areas

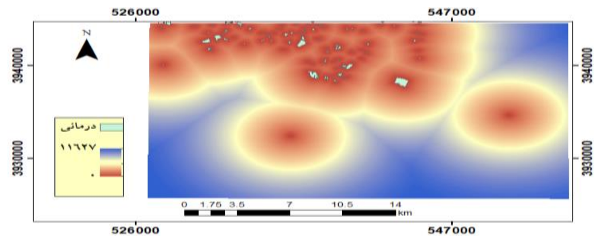

Figure 7. Distance from health and hospital areas in meter

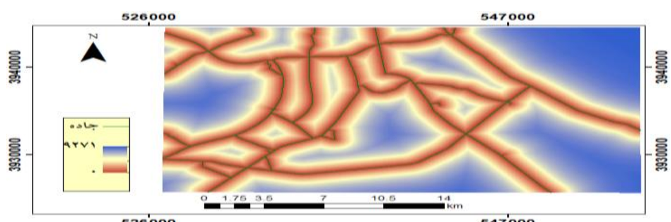

Figure 8. Distance from the communication network and road

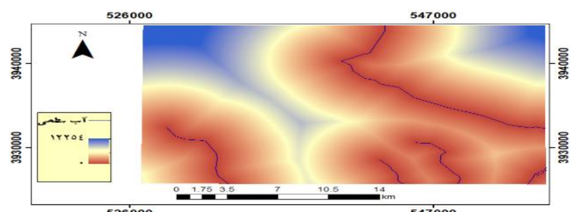

Figure 9. Distance from surface water

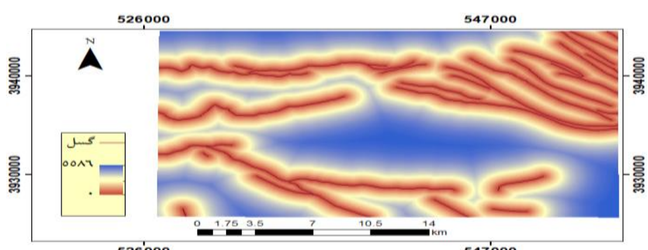

Figure 10. Distance from fault

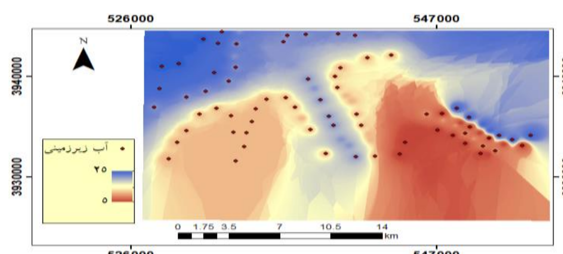

Figure 11. Depth of groundwater with the status of observation wells

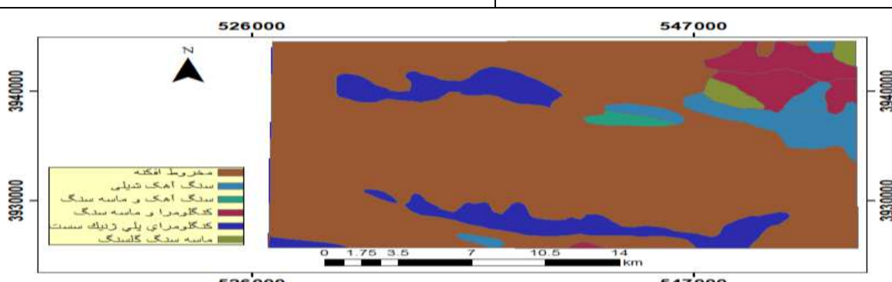

Figure 12. Geological and soil type

Results

Location

For location, the value and spatial relation related to the classes of each layer should be determined. In order to rank the classes of each parameter such as distance from road, it can be divided into ten classes with equal intervals and then reclassify tools can be used to rank each class from 1 to 10. For example, a disposal site is more optimal as it is closer to the road network. Thus, the first class is ranked as 10 and the last and farthest class of access to road is ranked as 1. In Figure 2, the reclassifciation of road access classes was presented. Another method for ranking the classes of a parameter is linar normalization with fuzzy membership function. For example, in road access data, the value of data is between zero and one (Figure 14). Since it is in favorable conditions as being closer to road, thus the reverse linear normalzation is used to assign high values or one to the lower or closer values in road access and zero value is assigned to the higher or further values. The fuzzy membership advantage to the reclassification method is that all data are involved in locating with their actual values and data are not limited to only 10 classes. Figures 13 and 14 indicate the distance map from road by reclassificaiton method and fuzzy membership method.

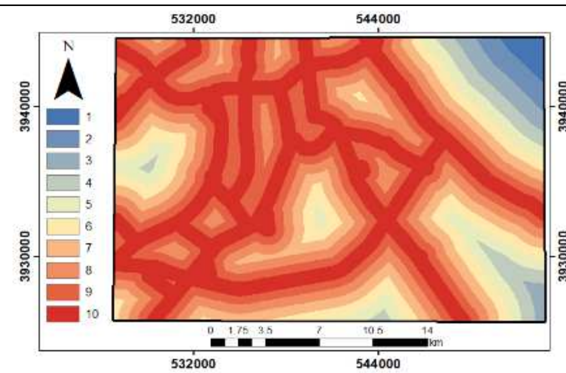

Figure 13. Distance map from road network by reclassificaiton method

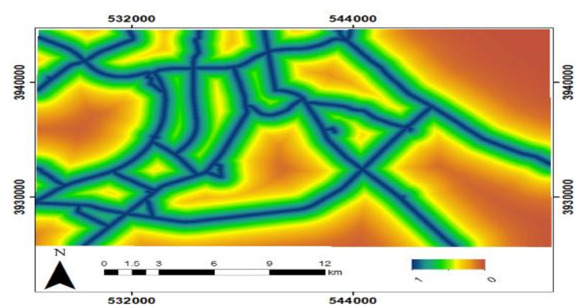

Figure 14. Distance map from road network by fuzzy membership method

Digital elevation model (DEM) with a resolution of 30*30 meters was obtained from the mapping organization and the study area was separated by converting its coordinates to the UTM metric system. Through reverse linear normalization, the belonging values between zero and one were determined. Since the height and slope are lower, it is more suitable for disposal site location. Thus, the lower values of height and slope receive higher belonging values (number one) and the higher values of height and slope receive the lower belonging values (zero). Access and distance closer to the road and hospital accelerate the transport of waste from source to destination. Thus, reverse linear normalization was used for valuation and as the road was closer to hospital, it received higher belonging values. Distance from faults and residential and urban areas also affects the location of disposal site and as the distacne from them becomes more, it will be more favorable. Thus, linear normalization was used and received more belonging value with the increase of distance. Depth of groundwater is also effective in disposal site location and the proximity to groundwater can cause the pollution of waters, and then pollution of the environment, water, and soil resources. For this purpuse, the areas with higher groundwater depths will receive higher belonging value where linear normalization was used. It should be noted that the depth of groundwater in the whole region was determined for preparing the groundwater layer from the sampled wells taken from Tehran's water by IDW interpolation method. Figures 15 to 22 show the desired maps with their degree of belonging between zero and one.

Table 9 indicates the lowest and highest values of each input indicator with their positive and negative effects. For example, slope varies from 0 to 49.35 degrees and as the slope is lower, it will be more desirable for disposal site location and as it is higher, it wil be evaluated as undesirable. As a result, the type of slope effectiveness is negative which means that the higher the slope leads to the negative effect while the fault has a positive effect. The more distance from the fault, the more evaluation as a positive and desirable parameter. Other factors were also presented in Table 9. Since soil type, unlike the other parameters, is a qualitative variable, it is necessary to state the soil type quantitatively in this area. For this reason, the ranking method was used due to the weakness and degree of difficulty. The areas with hard sandstone receive the highest rank of 10, the areas with a high percentage of loose lime receive the lowest rank of 1, and the areas with their combination receive the rank 5 . As a result, the high ranking areas have a positive effect while low ranking areas have a negative effect. Since it is necessary to determine appropriate areas for disposal site to place all the input layers on top of each other and select common areas with high overlap, the values of each layer should be normalzied and standardized between zero and one to make all layers comparable to each other and the layers with high values have no higher effect on location. For this purpose, fuzzy functions or linear and reverse normalization were used. Linear normalization was used for the layers such as distance from faults, residential areas, groundwater depth, surface waters and soil type and reverse normalization was used for the factors such as height, slope, distance from road, and the negative treatment areas with negative effcetiveness. It should be noted that soil type has a positive effect after ranking from 1 to 10 has positive effect and the values with high rank have positive effect while the values with lower rank have negative effect. Before conducting any analyses on the data, they should be standardized and normalized especially when the data are multi-dimensional. Using non-standardized data may have an inappropriate effect on the results obtained from the analysis. Data standardization makes the significance of data non-dependent of their measurement unit. As a result, standardized data are used in multivariate data analysis. Equation 6 was used for linear normalization and equation 7 was used for reverse linear normalization balancing the actual value of data between zero and one. As stated, linear normalization is used for the data such as distance from fault and reverse normalization is used for the data such as proximity to road and hospital, which is more favorable if it becomes closer. Reverse linear normalization is used to assign the value 1 for the areas which are closer and more distant areas will be zero, and the rest of the values are aligned between them.

Equation6: $(x_i - min(x))/(max(x) - min(x))$

Equation 7: $(x_i - max(x))/(max(x) - min(x))$

Table 7. The lowest and the highest amount of input data in both positive and negative effectivenesses

Factor	Minimum value	Maximum value	Positive and negative aspects
Height (m)	935	1852	negative
Slope (degree)	0	49/35	negative
Distance frm road (m)	0	9270	negative
Distance from fault (m)	0	5585	positive
Distance from residential areas (m)	0	7702	positive
Groundwater depth (m)	5	25	positive
Distance from hospitals (m)	0	11627	negative
Surface water distance (m)	0	12253	positive
Ranking of geology type and soil elements			
Soil type (ranking based on the amount of sandstone and lime)	Sandstone conglomerate	10	positive
	Loose limestone	1	negative
	Limestone and sandstone	3	average
	Sand	5	average

Table 8. Input data by preparation methods and their spatial processing

Factor	Preparation and spatial processing
Height	Creating the DEM, changing the coordinates to UTM, cutting the studied area, reverse linear normalization between zero and one
Slope	Applying the slope function to degree and percent, reverse linear normalization between zero and one
Road	Creating road network layers, applying distance function, reverse linear normalization between zero and one
Fault	Creating fault layers, applying distance function, linear normalization between zero and one
Residential areas	Creating urban and rural residential areas, applying distance function, linear normalization between zero and one
Groundwater	Creating wells points, IDW method interpolation, linear normalization between zero and one
Hospital areas	Creating health and hospital areas, applying distance function, reverse linear normalization between zero and one
Surface waters	Creating a layer of surface water from map 1: 500000, applying distance function, linear normalization between zero and one
Soil type	Classification of soil type to sandstone, limestone and sand, ranking from 1 to 10 from loose to hard elements, linear normalization between zero and one

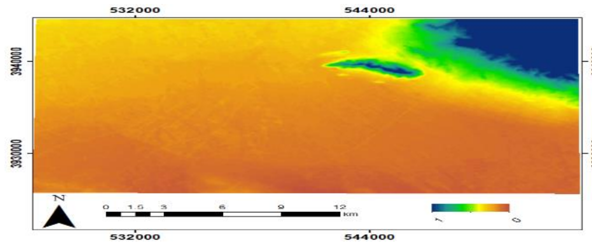

Figure 15. Digital elevation model (DEM) with a resolution of 30*30

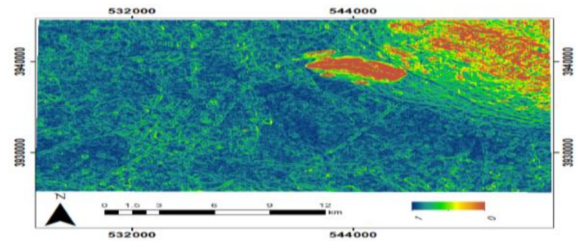

Figure 16. Creating map of the area slope and normalization between zero and one

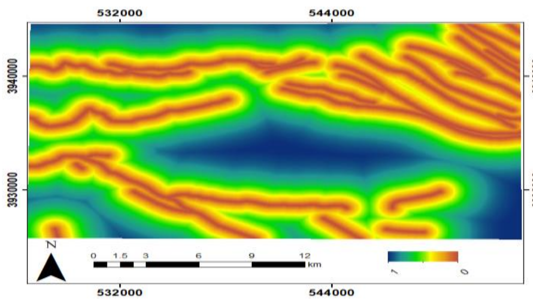

Figure 17.Distance from fault

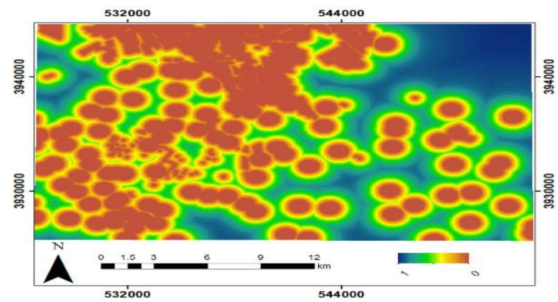

Figure 18. Distance between buildings and rural areas

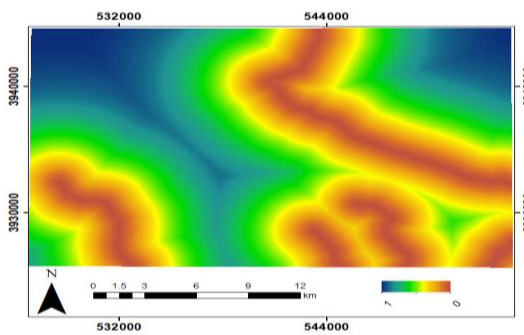

Figure 19.Distance from river

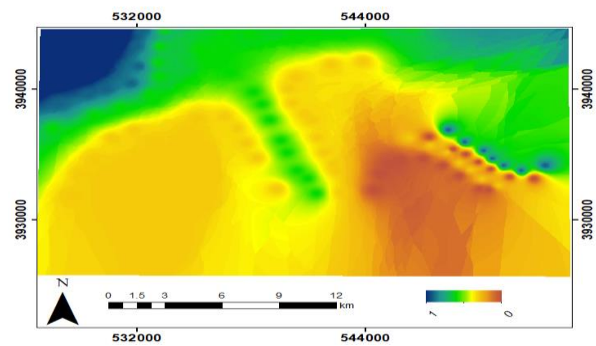

Figure 20. Groundwater depth

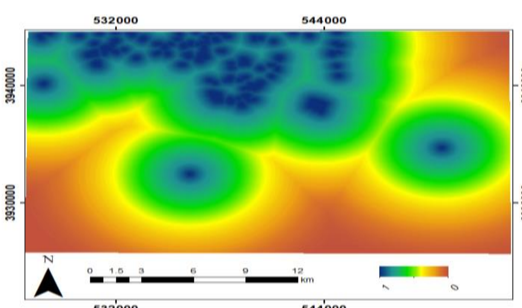

Figure 21. Fuzzy Map of distance from health centers and hospitals

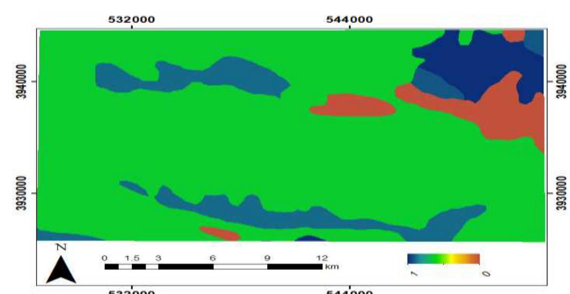

Figure 22. Fuzzy map of soil type rank

Finally, the indicators should be merged together to locate the appropriate disposal site. Weighted linear combination was used to integrate and overlap the layers. Each index is multiplied by the obtained weight and then added to other layers. The map of appropriate and inapproriate locations is shown in Figure 23. Higher values are more appropriate areas. It should be noted that the area which are considered as constraint should be identified and then removed from the final map.

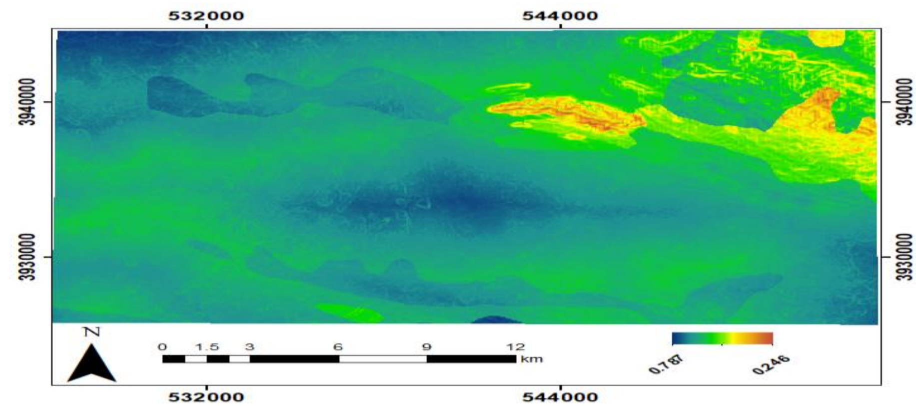

Figure 23. Appropriate map for creating hospital waste disposal site

Preparing constraint maps

In order to prepare the constraint layer of the study area, first all the layers which could create constraint were formed as Boolean. Then, by applying the OR operator among all layers, the constraint layer was obtained and the pixels with a value of zero were considered as non-applicable options. Such constraints are logical and irreversible which should finally be removed from the output map. Table 8 determines the constraints considered in this study. Number one is given to the situations which can be applied while number zero is given to the situations which cannot be applied. In general, information layers can involve landscape layers, specific geological structures, residential areas, etc. Accordingly, if any of these areas is at the studied scope, that part will be removed by applying the initial screening. Figures 25 to 28 indicate the constraints of the study area. Since the changes in the height of the area are from 935 to 1852 meters, thus there is no constraint in terms of height (Figure 24). However, other parameters such as slope, road, urban residential areas, and green space were applied.

Table 9: The constraints regarded for constructing a disposal site location (John, 1999)

Factor	Criterion for drawing a constraint map
Height	More than 2000 m
slope	Slope more than 15%
Road	An area of 1000 m
Protected parks and areas	An area of 2000 m
Urban and rural areas	An area of 5000 m

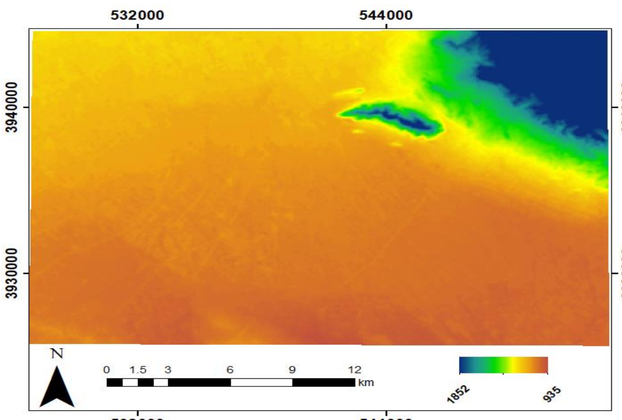

Figure 24. DEM changes in the study area

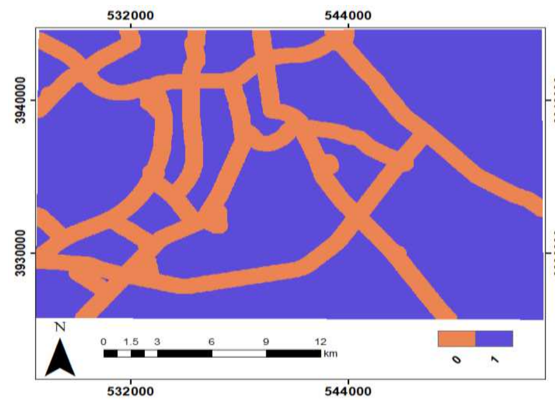

Figure 25. Road constraints in the study area

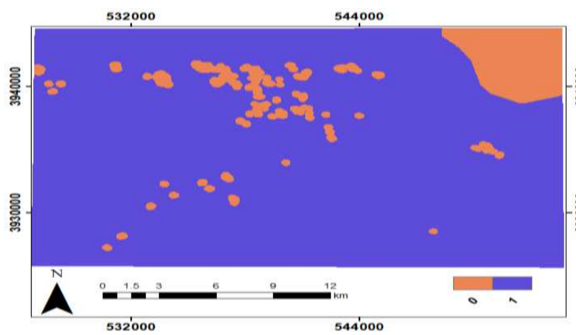

Figure 26. Protected areas constraints in the study area

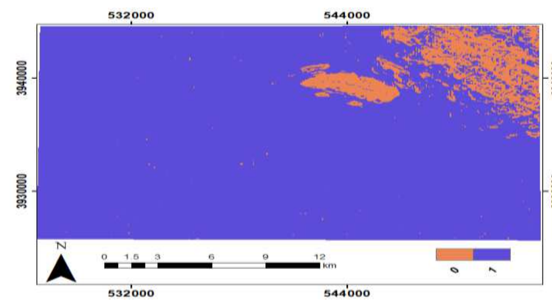

Figure 27. Slope higher than 15% of the study area

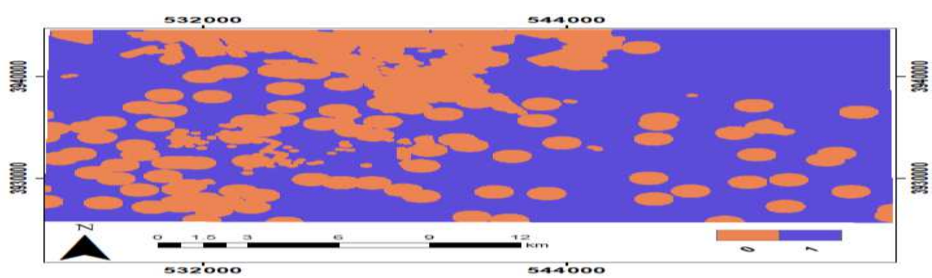

Figure 28. Urban and rural areas of the study area

The final map of hospital waste disposal site location in the south of Tehran is presented by applying the constraint maps in Figure 29. White areas are constrained areas and were removed from the selected locations. The whole area is classified into four classes of weak, average, partially appropriate, and very appropriate. The blue areas or very appropriate areas which are located in three parts of the area. There are the northwest, central, and the southeastern part that the central part can be a better option than the rest due to better access to the whole area. It should be noted that although the northeastern part is closer to Tehran, it is not suggested due to the proximity to residential areas. Based on the obtained information in total eight points as selected locations in the central part, it can be observed in Figure 30 while Table 10 shows the distance between each point to the desired criteria.

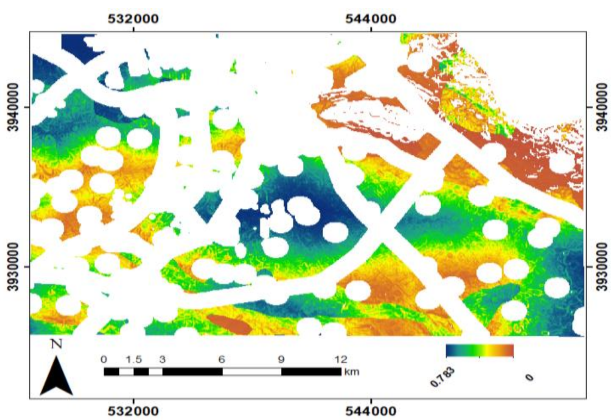

Figure 29. The final map of the locations appropriate for hospital waste disposal site

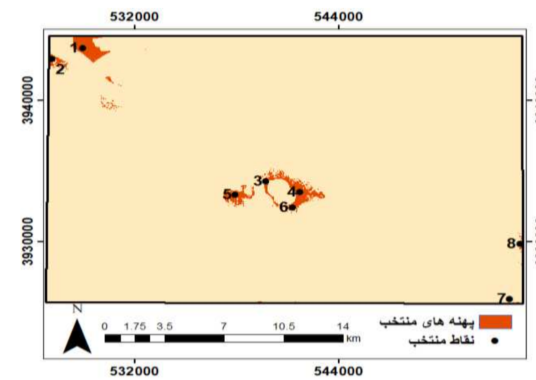

Figure 30. The final map and selected zones for hospital waste disposal site

Based on the final maps, eight locations were selected as hospital waste disposal site in the southeast of Tehran. Such locations are ranked by the MAIRCA method and then the best location was selected as the final location for hospital waste disposal site.

Discussion

Ranking the selected locations

After specifying the selected locations, MAIRCA method was used to rank the selected locations. The SWARA-MAIRCA hybrid model is a new approach in the MCDM field presented for determining the weight of features and ranking of locations (although location was conducted by the GIS process). MCDM methods deal with the decision-making process on finding the most suitable option by using multiple and contradictory criteria. SWARA models were developed after 2010 and the MAIRCA was developed after 2014.

SWARA is used for evaluating and calculating the relative importance of each criterion. MAIRCA method was also used for evaluating the identified options related to the selection (appropriate location for hospital wastes).

Multi-attributive ideal-real comparative analysis (MAIRCA)

MAIRCA method was developed by the Logistics Research Center at Belgrade University of Defense (Serbia) in 2014. The main assumptions of this method are in determining the gap between the values of ideal and empirical weights. The total of these gaps in each criterion presents the total gaps for each observed option. Finally, this case leads to the ranking of options and the option with the smallest total amount of the gaps will obtain the best rank. This option has the closest values to the empirical weights than most of the criteria. The algorithm of this method is conducted in six steps.

Step 1. Creating the primary decision matrix (X)

Criterion values $(\boldsymbol{X_{ij}} = \boldsymbol{i} = \mathbf{1.2} \ldots . \boldsymbol{n}\,; \boldsymbol{j} = \mathbf{1.2} \ldots . \boldsymbol{m})$

$$
A = \begin{array}{c c}
 & \begin{array}{cccc} c_1 & c_2 & & c_n \end{array} \\
\begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} & \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \\ x_{m1} & x_{m2} & & x_{mn} \end{bmatrix}
\end{array} \quad \text{(Equation 8)}
$$

Step 1: The equation, or matrix X, is obtained based on the decision maker's personal preferences or examining the consensus of experts' decisions.

Step 2: Determining the preferences for selecting option ($\boldsymbol{P_{Ai}}$) while choosing an option, the decision maker is neutral in this process.

In fact, the DM has no prioritization for selecting the option. It is assumed that the DM has no interference with selecting the option. The DM looks at each of the options as if there is an equal probability of being displayed for each one.

Thus, the probability of selecting an option from m options is equal to:

$$\boldsymbol{P_{Ai}} = \frac{\mathbf{1}}{\boldsymbol{m}} \quad ; \quad \sum_{i=1}^{m} \boldsymbol{P_{Ai}} = \mathbf{1} \quad ; \quad \boldsymbol{i} = \mathbf{1.2} \ldots . \boldsymbol{m} \quad \text{(Equation 9)}$$

In analyzing the decision-making process with the given probabilities, we assume that the decision maker (DM) is neutral to the risk. Selecting reliable options is equal to:

$$P_{A1} = P_{A2} = \cdots = P_{Am} \quad \text{(Equation 10)}$$

Step 3: Calculating the theoretical evaluation matrix ($\boldsymbol{T_p}$).

Theoretical evaluation matrix ($\boldsymbol{T_p}$) in the format n × m (n: total number of criteria, m: total number of options).

Elements of theoretical evaluation matrix ($\boldsymbol{t_{pij}}$) is calculated as the preference coefficient for each $\boldsymbol{P_{Ai}}$ and standard weights$\boldsymbol{W_i}$; $\boldsymbol{i} = \mathbf{1.2} \ldots . \boldsymbol{n}$.

$$
T_p = \begin{array}{c} \\ P_{A1} \\ P_{A2} \\ \vdots \\ P_{Am} \end{array}
\begin{array}{c} \begin{array}{cccc} w_1 & w_2 & & w_n \end{array} \\ \begin{bmatrix} t_{p11} & t_{p12} & \cdots & t_{p1n} \\ t_{p21} & t_{p22} & \cdots & t_{p2n} \\ \vdots & \vdots & \ddots & \\ t_{pm1} & t_{pm2} & & t_{pmn} \end{bmatrix} \end{array}
= \begin{array}{c} \\ P_{A1} \\ P_{A2} \\ \vdots \\ P_{Am} \end{array}
\begin{array}{c} \begin{array}{cccc} w_1 & w_2 & & w_n \end{array} \\ \begin{bmatrix} P_{A1}W_1 & P_{A1}W_2 & \cdots & P_{A1}W_n \\ P_{A2}W_1 & P_{A2}W_2 & \cdots & P_{A2}W_n \\ \vdots & \vdots & \ddots & \vdots \\ P_{Am}W_1 & P_{Am}W_2 & & P_{Am}W_n \end{bmatrix} \end{array}
$$

(Equation 11)

Since the decision maker (DM) is neutral to the initial selection of options, all preferences $\mathbf{P_{Ai}}$ for all options is equal. Then, the above matrix or equation can achieve the following conditions or equation where n is the total number of criteria and $\mathbf{t_{pi}}$ is the theoretcial evalaution.

$$
\begin{array}{ccccc} & W_1 & W_2 & \dots & W_n \end{array} \qquad \begin{array}{ccccc} & W_1 & W_2 & \dots & W_n \end{array}
$$

$$
T_p = P_{Ai} \; [\; t_{p1} \;\; t_{p2} \;\; \dots \;\; t_{pn} \;] = P_{Ai}[\; P_{Ai}W \;\; P_{Ai}W_2 \;\; \dots \;\; P_{Ai}W_n \;]
$$

(Equation 12)

Step 4: Determining the equation (matrix) of real evaluation

$$
T_r = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array}
\begin{array}{c} \begin{array}{cccc} c_1 & c_2 & & c_n \end{array} \\ \begin{bmatrix} t_{r11} & t_{r12} & \cdots & t_{r1n} \\ t_{r21} & t_{r22} & \cdots & t_{r2n} \\ \vdots & \vdots & \ddots & \\ t_{rm1} & t_{rm2} & & t_{rmn} \end{bmatrix} \end{array}
\qquad \text{(Equation 13)}
$$

Since n is the total number of criteria, m is the total number of options.

Calculating the elements of real evaluation matrix ($\mathbf{T_r}$) by multiplying the elements of the real evaluation matrix ($\mathbf{T_p}$) and primary decision matrix elements (X) based on the equations:

a: For the type of profit (i.e., the positive aspect), (i.e., the bigger criterion is desirable) as:

$$t_{rij} = t_{pij}\left(\frac{X_{ij}-X_i^-}{X_i^+-X_i^-}\right) \qquad \text{(Equation 14)}$$

b: For the type of cost (i.e., the negative aspect) (i.e., the smaller criterion is desirable) as:

$$t_{rij} = t_{pij}\left(\frac{X_{ij}-X_i^+}{X_i^--X_i^+}\right) \qquad \text{(Equation 15)}$$

X_{ij} : The matrices in the primary decision matrix.

X_i^+: The biggest value with the primary matrix value.

: X_i^- The smallest value with the primary matrix value.

$X_i^+ = \mathrm{Max}(x_1.x_2.\ldots.x_m)$ (Equation 16)

X_i^-=Min $(x_1.x_2.\ldots.x_m)$ (Equation 17)

Step 5: calculating the total gap matrix (G)

The elements of matrix are calculated as the gap between theoretical evaluation t_{pij} and real evaluation t_{pij} or by subtracting the theoretical evaluation matrix T_p with real evaluation elements T_r .

$$G=T_p - T_r = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & \ddots & \\ g_{m1} & g_{m2} & & g_{mn} \end{bmatrix} = \begin{bmatrix} t_{p11}-t_{r11} & t_{p12}-t_{r12} & \cdots & t_{p1n}-t_{r1n} \\ t_{p21}-t_{r21} & t_{p22}-t_{r22} & \cdots & t_{p2n}-t_{r2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{pm1}-t_{rm1} & t_{pm2}-t_{rm2} & & t_{pmn}-t_{rmn} \end{bmatrix}$$

(Equation 18)

In which n represents the total number of criteria and m represents the total number of options.

Gap (distance) $g_{ij} \in [0.(t_{pij} - t_{rij})]$ (Equation 19)

$$g_{ij} = \begin{cases} 0 \text{ if } t_{pij} = t_{rij} \\ t_{pij} - t_{rij} if\ t_{pij} > t_{rij} \end{cases}$$ (Equation 20)

Because the option was selected with the smallest difference between theoretical evaluation t_{pij} and real evaluation t_{rij}.If option A_i is for criterionC_i, the value of theoretical evaluation will equal to the real value ($t_{pij} = t_{rij}$).

Then, the gap for option A_i for C_i is $g_{ij} = 0$. In fact, option A_i for C_i is the best option of X_i^+. If option A_i is for C_i, it will have theoretical evaluation value and the real value will become allowed $t_{rij} = 0$. Then, the gap A_i for C_i is $g_{ij} = t_{pij}$. In fact, option A_i for C_i is the worst option of X_i^-.

Step 6: Calcualting the values of final criterion fucntion (Q_i) for options. The value of criterion functions is obtained from the total gaps g_{ij} for options or only the addition of matrix G elements in the columns through the following equation:

$Q_i = \sum_{j=1}^{n} g_{ij}$ (Equation 21)

Based on the MAIRCA algorithm, a 8*9 matrix which is called the decision matrix will solve the problem of ranking hospital waste disposal sites (options). The information of this matrix is shown in Table 10:

Table 10. Decision matrix for locating the hospital waste disposal site

Criterion	slope	Height	Soil type	Distance from fault	Distance from surface water	Groundwater depth	Distance from residential areas	Distance from hospitals	Distance from road
Criterion nature	negative	negative	positive	positive	positive	positive	positive	negative	negative
W	0.303	0.2196	0.1657	0.1251	0.0759	0.0514	0.0279	0.0192	0.012
L_1	1.97	1096	1	2580.2	11317	23.7	720.6	1018.2	849.1
L_2	1.035	1098	1	2100	10658	23.6	865.3	1235.5	725.6
L_3	1.39	1016	1	3960.1	4744.6	13.4	342.1	3878.8	2419
L_4	0.34	1008	1	4841.3	4428.8	12	457	4749.6	1598
L_5	1.22	1012	1	4174.2	6570	11.6	446	1853.2	1073
L_6	0.75	1008	1	3750	4360.9	14	416.8	4980	2554
L_7	2.05	973	1	4811.3	323.1	9.7	402.5	9301.5	4478
L_8	2.13	976	1	4440.1	2225.1	10.9	1209.3	6128.3	2972

Since all options for soil type are equal to 1, this factor will have no effect on the response and will not be considered while its weigh was shared among other evaluation criteria. Then, the decision matrix was normalized using the normalization equations as shown in Table 11:

Table 11. Normalized decision matrix

Criterion	Slope	Height	Distance from fault	Distance from surface water	Groundwater depth	Distance from residential areas	Distance from hospitals	Distance from road	Total
L_1	0.0368	0.0296	0.015	0	0	0.0034	0	0.0001	0.085
L_2	0.0157	0.03	0.0182	0.0007	6E-05	0.0024	0.0001	0	0.067
L_3	0.0237	0.0103	0.0059	0.0072	0.0066	0.0061	0.0017	0.0019	0.063
L_4	0	0.0084	0	0.0076	0.0075	0.0053	0.0022	0.001	0.032

L_5	0.0199	0.0094	0.0044	0.0052	0.0078	0.0054	0.0005	0.0004	0.053
L_6	0.0093	0.0084	0.0073	0.0076	0.0062	0.0056	0.0024	0.002	0.049
L_7	0.0387	0	0.0002	0.0121	0.009	0.0057	0.005	0.0041	0.075
L_8	0.0405	0.0007	0.0027	0.01	0.0082	0	0.0031	0.0025	0.068

Finally, the values of each of the options for all obtained metrics were added together and the Q value was obtained as indicated in the above table. Then the Q values were sorted ascendingly and the options with lower Q values will have higher ranks and the final result is shown in Table 12:

Table 12. Ranking the hospital waste disposal sites by the MAIRCA method

Option	Q	rank
L4	0.032	1
L6	0.0488	2
L5	0.0529	3
L3	0.0634	4
L2	0.0673	5
L8	0.0676	6
L7	0.0747	7
L1	0.085	8

Based on the results of Table 12, the ranking of selected locations indicates that the fourth location (option) obtained the first rank among the eight selected locations for hospital waste disposal site. However, the sixth, fifth, third, second, eighth, seventh and first locations obtained the second, third, fourth, fifth, sixth, seventh and eighth ranks for hospital waste disposal site in the southeast of Tehran. Table 13 indicates the results of alternative ranking based on the criteria of Table 8 with the MOORA, TOPSIS, and VIKOR methods and its comparison with the ranking of options by the MAIRCA.

Table 13. Ranking the options using VIKOR, TOPSIS, MOORA, and MAIRCA methods

MAIRCA		MOORA		TOPSIS		VIKOR		option
rank	Q	rank	Q	rank	Q	rank	Q	
8	0.085	5	-0.100	6	0.35	8	0.944	A_1
5	0.067	2	-0.035	3	0.619	5	0.671	A_2
4	0.063	6	-0.107	5	0.425	4	0.536	A_3
1	0.032	1	-0.014	1	0.759	1	0	A_4
3	0.053	4	-0.069	4	0.527	3	0.377	A_5
2	0.049	3	-0.063	2	0.658	2	0.172	A_6
7	0.075	8	-0.196	8	0.201	7	0.875	A_7

6	0.068	7	-0.158	7	0.222	6	0.836	A_8

Comparing the results obtained from the MAIRCA with MOORA, TOPSIS and VIKOR methods indicated that the ranking of the options by the MAIRCA method is very similar to the VIKOR method. In both methods, the fourth, sixth, fifth, third, second, eighth, seventh and eighth locations gained the first to eighths ranks. Meanwhile, in the MOORA and TOPSIS methods, the fourth location ranked first among the eight selected locations, while the ranks are slightly different in other options. One of the reasons that the MAIRCA and VIKOR methods presented quite similar results is that they both have the same method of data normalization.

Conclusions

The selection of inappropriate locations for hospital waste disposal in the southeast of Tehran is one of the environmental problems in this area causing damages to the environment and the pollution of groundwater. Since waste disposal site is currently the most significant, accepted, and economical method of disposal in many areas, the first step in the process of hospital waste disposal site is to locate an appropriate area for this purpose. In general, a disposal site should be located where it has the least damage to environmental, social and economic issues. In this regard, first the criteria which were important according to experts in geography and urban planning in this area were collected. Such criteria included slope, height, soil, distance from fault, distance from vegetation, distance from surface water, groundwater depth, distance from residential areas, distance from hospitals, distance from wildlife species, power transmission lines and distance from road. Using the fuzzy Delphi method, the criteria of slope, height, soil, distance from fault, distance from surface water, groundwater depth, distance from residential areas, distance from hospitals, and distance from road were selected. Then, layer preparation, standardization, and their weighing were determined by combining the layers and applying the model to locate an appropriate disposal site. The present study used the FSWARA-MAIRCA for the first time in the field of hospital waste disposal site location problems. In this method, the combination of information related to several criteria is used to form an evaluation index and helps decision makers with the best location by providing the conditions for considering different criteria. The results indicated that the current study was more effective due to using the fuzzy method based on quantitative and qualitative criteria.

1: Both methods of FSWARA for weighting the criteria and the MAIRCA method for ranking allow the decision maker to select decision-making indices in an interval scale rather than binary scale.

2: The MAIRCA method has the ability of applying qualitative measures with descriptive or sequential scales in the original nature without any scale conversion. The main assumptions of this method are in determining the gap (distance) between ideal and empirical weight values. The total of these gaps (distances) (in each criterion) presents the total gaps for each observed option. Finally, this case will lead to the ranking of options, and the option with the least total amount of gaps will have the best rank. This option has the closest values to the empirical weights based on the maximum criteria.

3: Locating the selected locations in the areas with high environmental standards. Using the hybrid method mentioned above, eight locations were selected as the preferred locations among the located zone to determine the location of hospital waste disposal site in the southeast of Tehran. Finally, the fourth point was selected as the final location for hospital waste disposal site in the southeast of Tehran based on the criteria with 34 degree slope, 1008 meters high, 3.4841 meter distance from fault, 8.4428 meters distance from surface water, 12 meters groundwater depth, 457 meters distance from residential areas, 6.4749.6 meters distance from hospitals, and 1598 meters distance from road. The MOORA, TOPSIS and VIKOR methods were used to rank the selected options and validate the results. Comparing the results obtained from the MAIRCA with MOORA, TOPSIS and VIKOR methods showed that all four methods considered the fourth location as the selected location for hospital waste disposal site.

Abbreviations

MCDM: Multiple Criteria Decision-Making; HWM: Hazardous Waste Management; AHP: Analytic hierarchy process; GIS: Geographic information system; DEMATEL: Decision Making Trial and Evaluation Laboratory; FANP: Fuzzy Atrial natriuretic peptide; VIKOR; from Serbian: VIseKriterijumska Optimizacija I Kompromisno Resenje; ELEKTERE: ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality); FSWARA: Stepwise Weight Assessment Ratio Analysis; OR: Operation Research; MAIRCA: Multi-attributive ideal-real comparative analysis; MOORA:The Multiobjective Optimization On the basis of ratio analysis; TOPSIS: The Technique for Order of Preference by Similarity to Ideal Solution.

Acknowledgements

We gratefully thank the experts in Tehran Province Water and Wastewater Organization and Department of Geography, Faculty of GIS of University of Tehran for their great support in conducting this work.

Authors' contributions

FHP wrote structuring the main manuscript text, problem statement, review about previous researches, gathering information, implementing methods and concluding about results. Implementing Fuzzy-Delphi method was by FHP and MM that the data analysis of the Delphi-Fuzzy method is presented in tables 1- 4 also gathering information about criteria details was collected by FHP and MM, tables 7-11 is showing criteria details. FHP implemented GIS method and prepared figures 3-30. MM, FHP and KFH performed SWARA algorithm and prepared tables 5-6 and figures 1-2. MM and F.H.P run MAIRCA method and prepared table 12. MM, FHP and ARK ranked options with using VIKOR, TOPSIS, MOORA, and MAIRCA methods that is showed in table 13. All authors read and approved the final manuscript.

Funding

This work did not receive any fund from any institute.

Availability of data and materials

The datasets used during the current study are reasonable from the corresponding author.

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors agree to publish this work.

Competing interests

The authors stated that they have no competing interests.

Author details

[1] Department of Industrial Management, Faculty of management, South Tehran Branch, Islamic Azad University, Phd. of student Operation Research, Tehran, Iran. [2] Department of Industrial Management, Faculty of management, South Tehran Branch, Islamic Azad University, Assistant Professor Assistant Professor of Operations Research Group Tehran, Iran. [3] Department of Industrial Management, Faculty of management, South Tehran Branch, Islamic Azad University, Assistant Professor Assistant Professor of Production Management Group, Tehran, Iran.[4] Department of Industrial Engineering, Faculty of Industrial management, Firoozkooh Branch, Islamic Azad University, Associate Professor Industrial Engineering Group, Tehran, Iran.

References

Abdullah, L., Zulkifli, N., Liao, H., Herrera –Viedma,E., Al-Barakati, A., 2019. An interval-valued intuitionistic fuzzy DEMATEL method combined with Choquet integral for sustainable solid waste managemen. Engineering Applications of Artificial Intelligence. 82, 207-215.

Alam, S., Kolekar, K.A., Hazra, T., Chakrabarty, S.N., 2019. Selection of Suitable Landfill Site for Municipal Solid Waste Disposal: A Fuzzy Logic Approach. Waste Management and Resource Efficiency. 109-129.

Aghdaie, M.H., Zolfani, S.H., Zavadskas, E.K, 2014. Synergies of data mining and multiple attribute decision making. Procedia - Social and Behavioral Sciences. 110, 767 – 776.

Aydi, A., Zaire, M., Shia H.B., 2013. Minimization of environmental risk of landfill site using fuzzy logic, analytical hierarchy process, and weighted linear combination methodology in a geographic information system environment. Environment Earth Science. 68, 1375- 1389.

Basu, S., Sharma, M., Ghosh, P.S., 2015. Metaheuristic applications on discrete facility location problems: a survey. Opsearch. 52(3), 530–61.

Chauhan, A., Singh, A., 2016. A hybrid multi-criteria decision making method approach for selecting a sustainable location of healthcare waste disposal facility. Journal of Cleaner Production. 139 ,1001-1010.

Chabuk, A., Al-Ansari, N., Musa-Hussain, H., Knutsson, S., Pusch, R., Laue, J., 2017. Combining GIS Applications and Method of Multi-Criteria Decision-Making (AHP) for Landfill Siting in Al-Hashimiyah Qadhaa, Babylon, Iraq. Sustainability. 9(11), 1932, 1-17.

Danesh, G., Monavari, S.M., Omrani, G.A., Karbasi, A., Farsad, F., 2019. Compilation of a model for hazardous waste disposal site selection using GIS-based multi-purpose decision-making models. Environmental Monitoring and Assessment. 191(122), Pages 1-14.

De-Feo, G., De-Gisi, S., 2014. Using MCDA and GIS for hazardous waste landfill siting considering land scarcity for waste disposal. Waste Management. 34(11), 2225-2238.

Ding, Z., Zhu, M., Wu, Z., Fu, Y., Liu, X., 2018. Combining AHP-Entropy Approach with GIS for Construction Waste Landfill Selection—A Case Study of Shenzhen. International journal of environmental. Public Health. 15, 2254.

Donevska, K.R., Gorsevski, P.V., Jovanovski, M., Pesevski, I., 2012. Regional non-hazardous landfill site selection by integrating fuzzy logic. AHP and geographic information systems. Environment Earth Science. 67, 121- 131.

Ebadi-Torkayesh, A., Fathipoir, F., Saidi-Mehrabd, M., 2019. Entropy-based Multi-criteria Analysis of Thermochemical Conversions for Energy Recovery from Municipal Solid Waste Using Fuzzy VIKOR and ELETRE III: Case of Azerbaijan Region, Iran, Volume 3, Issue 1, 17-29.

Feyzi, S., Khanmohammadi, M., Abedinzadeh, N., Aalipour, M., 2019. Multi- criteria decision analysis FANP based on GIS for siting municipal solid waste incineration power plant in the north of Iran, Sustainable Cities and Society. Energy Management and Technology. Volume 47, 101513, 1-12.

Fagbohun, B.J., Aladejana, O.O, 2016. Integrating knowledge-based multi-criteria evaluation techniques with GIS for landfill site selection: A case study using AHP. Original scientific paper. published by De Gruyter Open, RMZ – M&G. 63, 169–0182.

Guler, D., Yomralıoglu, T., 2017. Alternative suitable landfill site selection using analytic hierarchy process and Geographic Information Systems: A case study in Istanbul. Environ Earth Science. 76(678), 1-13.

Hariz, H.A, Çağrı-Dönmez, C., Sennaroglu, B., 2017. Siting of a central healthcare waste incinerator using GIS-Based Multi-Criteria Decision analysis. Journal of Cleaner Production. 91, 1-33.

.Joghtaei, M., Mahmoodian, V,.Fazli, M., Bozorgi-Amiri, A., 2016. A multi objective Location-Routing model for treatment,recycling and disposal centers of hospital wastes. International Journal Of Industrial Engineering & Production Management. 27(2), 261-274.

Islam, A., Ali, S.M., Afzaal, M., Iqbal, S., Zaidi, F.S.N., 2018. Landfill sites selection through analytical hierarchy process for twin cities of Islamabad and Rawalpindi, Pakistan. Environmental Earth Sciences. 77(72), 1-13.

Keršulienė, V., Zavadskas, E. K., Turskis, Z., 2010. Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). Journal of Business Economics and Management. 11(2), 243–258.

Kersuliene, V., Turskis, Z., 2011. Integrated fuzzy multiple criteria decision making model for architect selection. Technological and Economic Development of Economy, 17(4), 645–666.

Kersuliene, V., Turskis, Z., 2011. Integrated Fuzzy Multiple Criteria Decision Making Model for Architect Selection. Technological and Economic Development of Economy. 17(4), 645-666.

Kharat, M.G., Kamble, SH.J, Rakesh, D., RautSachin, S.K., 2016 . Identification and evaluation of landfill site selection criteria using a hybrid Fuzzy Delphi, Fuzzy AHP and DEMATEL based approach. Modeling Earth Systems and Environment. 2(98), PP 1-13.

Makajic-Nikolic, D., Petrovic, N., Belic, A., Rokvic, M., Radakovic, J.A., Tubic, V., 2017. The fault tree analysis of infectious medical waste management. Journal of Cleaner Production, 113, 365-37

Memarbashi, E., Azadi, H., Barati, A.A., Mohajeri, F., Passel S.V., Witlox, F., 2017. Land-Use Suitability in Northeast Iran: Application of AHP-GIS Hybrid Model. International Journal of Geo-Information, 6(396), 1-15.3.

Midatana, S., Saran, S., Ramana, K.V., 2018. SITE SUITABILITY ANALYSIS FOR INDUSTRIES USING GIS AND MULTI CRITERIA DECISION MAKING, Annals of Photogrammetry. Remote Sensing & Spatial Information Sciences. 4(5), 447-454.

Mohammed, H.I., Majid, Z., Yusof, N.B., Yamusa, Y.B., 2017. Analysis of Multi-Criteria Evaluation Method of Landfill Site Selection for Municipal Solid Waste Management ,International Conference on Civil & Environmental Engineering. E3S Web Conf. 34, 2018.

Mohammed, H.I., Majid, Z., Yusof, N.B., Yamusa Y.B., 2017. A Review of GIS-Based and Multi-criteria Evaluation Method for Sustainable Landfill Site Selection Model. Global Civil Engineering Conference. 741-751.

Mohseni, N., Behzadian A., 2011. Bridge Construction site location by using analytical hierarchy process and fuzzy logic in GIS. IJIEPM. 22, 1-12.

Mortazavi-Chamchali, M., Ghazifard, A., 2019. The use of fuzzy logic spatial modeling via GIS for landfll site selection (case study: Rudbar Iran). Environmental Earth Sciences. 78(305), 1-16.

Nabi-Dar, S., Ahmad-Wani, M., Ahmad-Shah, SH., Skinder, S., 2018. Identification of suitable landfill site based on GIS in Leh Ladakh Region. GeoJournal. 1-15.

Saatsaz, M., Monsef, I., Rahmani, M., Ghods, A., 2018. Site suitability evaluation of an old operating landfill using AHP and GIS techniques and integrated hydrogeological and geophysical surveys. Environmental Monitoring and Assessment. 190(144).

Shah, S.A., Musvi, SH.A., Tameez, A., Alam, M., Nawaz, A., 2019. Analyzing site suitability for solid waste disposal through Gis Multi-Criteria decision making hierarchy process. 3C TECNOLOGÍA - EDICIÓN. 28(2), 65-79.

Soroudi, M., Omrani, GH., Moataar, F., Jozi, S.A., 2018. A comprehensive multi-criteria decision making-based land capability assessment for municipal solid waste landfill sitting. Environmental Science and Pollution Research. 25(28), 27877–27889.

Soroudi, M., Omrani, GH., Moataar, F., Jozi, SA., 2018. Modelling an Integrated Fuzzy Logic and Multi-Criteria Approach for Land Capability Assessment for Optimized Municipal Solid Waste Landfill Siting Yeast. Journal Of Environmental Studies. 27(1), 313–323.

Syed-Ismail, S.N., 2017. Landfill Site Selection Model Using an Integrated Approach of GIS and Multi Criteria Decision Analysis (MCDA): Example of Selangor, Malaysia. Asian Journal of Earth Sciences. 10 (1), 1-8.

Wadhwa, S.S., 2018. Site selection using multi attribute decision analysis in GIS - A case study on brownfields of Minnesota. International open Journal of Agriculture and Environmental Research. 1(1), 1-18.

Wichapa, N., Khokhajaikiat, P., 2018. A Hybrid Multi-Criteria Analysis Model for Solving the Facility Location–Allocation Problem: A Case Study of Infectious Waste Disposal. Journal of Engineering and Technological Sciences. 50(5), 698-718.

Yildirim, V., Memisoglu, T., Bediroglu, S., Ebru-Colak, H., 2018. Municipal Solid Waste landfill site selection using Multi-Criteria decision making and gis: case study of bursa province. Journal of Environmental Engineering and Landscape Management. 26(2), 107–119.

Yousefi, H., Javadzadeh, Z., Noorollahi, Y., Yousefi-Sahzabi, A., 2018. Landfill Site Selection Using a Multi-Criteria Decision-Making Method: A Case Study of the Salafcheghan Special Economic Zone, Iran. Sustainability. 10(4), 1-16.

Zolfani, SH., Zavadskas, E.K., Turskis, Z., 2013. Design of products with both International and Local perspectives based on Yin-Yang balance theory and SWARA method. Journal Economic Research-Ekonomska Istraživanja. 26(2), 153-166.

Zolfani, SH., Saparauskas, J., 2013. New Application of SWARA Method in Prioritizing Sustainability Assessment Indicators of Energy System. Inzinerine Ekonomika-Engineering Economics. 24(5), 408-414.

Zolfani, SH., Esfahani, M.H., Bitarafan, M., Zavadskas, E.K., Arefi, L.SH., 2013. Developing a new hybrid MCDM method for selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents. Transport. 28(1), 89-96.

Zolfani, SH., Bahrami, M., 2014. Investment prioritizing in high tech industries based on SWARA-COPRAS approach. Technological and Economic Development of Economy. 20(3), 534-553.