Solid Waste Landfill Site Selection in the Sense of Environment Sensitive Sustainable Urbanization: Izmir, Turkey Case

Şule Tüdeş 1, Kadriye Burcu Yavuz Kumlu 2

1 Gazi University, Faculty of Architecture, Dept. of City and Regional Planning, Ankara, Turkey
2 Gazi University, Faculty of Architecture, Dept. of City and Regional Planning, Ankara, Turkey
sulegoktudes@gmail.com

Abstract. Each stage of the planning process should be based on the natural resource protection, in the sense of environmental sensitive and sustainable urban planning. Values, which are vital for the continuity of the life in the Earth, as soil, water, forest etc. should be protected from the undesired effects of the pollution and the other effects caused by the high urbanization levels. In this context, GIS-MCDM based solid waste landfill site selection is applied for Izmir, Turkey, where is a significant attraction place for tourism. As Multi criteria Decision Making (MCDM) technique, Analytical Hierarchy Process (AHP) is used. In this study, geological, tectonically and hydrological data, as well as agricultural land use, slope, distance to the settlement areas and the highways are used as inputs for AHP analysis. In the analysis stage, those inputs are rated and weighted. The weighted criteria are evaluated via GIS, by using weighted overlay tool. Therefore, an upper-scale analysis is conducted and a map, which shows the alternative places for the solid waste landfill sites, considering the environmental protection and evaluated in the context of environmental and urban criteria, are obtained.

1. Introduction
Solid waste disposal is one of the most significant problems in Turkey and in the world, arising as a consequence of rapid urbanization. Proper landfill site selection is the most important process in the waste disposal management system; especially, in the sense of environment sensitive sustainable urbanization. The suitable landfill site selection involves natural, physical, environmental, geological, social and economic parameters. Criteria, which define those parameters are varied, considering study scale, natural and geological characteristics of the land, spatial planning decisions and land use. Therefore, increasing number of criteria makes it difficult to take proper site selection decisions. In this context, GIS-based MCDM makes easier to take proper decisions.

In the literature, researchers used different MCDM techniques and GIS-based decision support systems [1; 2]. There are site selection models, which use different MCDM techniques and include different criteria groups for solid waste site selection [3; 4; 5; 6]. In this study, AHP is used and it is implemented in the context of İzmir Metropolitan Area, constituting an upper-scale study.
In brief, it could be stated that the rapid population growth and migration from rural to urban in Turkey and in the world bring about unplanned urbanization and environmental problems. While taking land use decisions in the urban planning process, parameters related with the nature and geology should be scientifically analysed and synthesised. Therefore, it is possible to live in sustainable and healthy urban areas. As in the case of many metropolitan area, there is limited land for the construction of solid waste landfill sites, considering the natural pattern of the area. In İzmir Metropolitan area, the problem of solid waste is getting increasing. For many years, wastes are stored near to the surface waters and highways by the district municipalities. Hence, the region is faced with the water, land and air pollution problems. In this context, solid waste landfill site selection is implemented via GIS-based AHP technique for İzmir Metropolitan Area (1:100 000 scale).

2. Theoretical background of the method

In this study, Analytical Hierarchy Process (AHP) is used to determine the best suitable area for solid waste landfill site selection in İzmir. AHP is developed by Saaty [7]. The fundamental base of AHP relies on sorting the criteria, depending on their significance levels. This process is based on the pairwise comparison. This comparison requires the usage of a scale, which is varied from 1 to 9. The least significant criterion is assigned to 1, while the highest significant criterion is assigned to 9 in the context of pairwise comparison stage of AHP (Table 1):

| Intensity of importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1                       | Equal importance | Two attributes contribute equally to the objective |
| 3                       | Moderate importance of one over another | Experience and judgment strongly favour one activity over another |
| 5                       | Essential or strong importance | Experience and judgement strongly favour one activity over another |
| 7                       | Very strong importance | An activity is strongly favoured and its dominance demonstrated in practice |
| 9                       | Extreme importance | The evidence favouring one activity over another is of the highest possible order of affirmation |
| 2, 4, 6, 8              | Intermediate values between the two adjacent judgements | When compromise is needed |
| Reciprocals             | If activity $i$ has one of the above numbers assigned to it when compared with activity $j$, then $j$ has the reciprocal value when compared with $i$ |
| Rationales              | Ratios arising from the scale | If consistency were to be forced by obtaining numerical values to span the matrix |

After sorting the criteria depending on their significance levels and assigning their intensity of importance in the context of 1 to 9 scale (pairwise comparison), a pairwise comparison matrix is constituted as illustrated below (Table 2).

The construction of pairwise comparison matrix is the most significant stage of AHP. After the construction of pairwise comparison matrix, the algebraic calculations of AHP is started. The second important step in AHP is the calculation of the weights and the last crucial step in AHP depends on the values of consistency index ($CI$), random index ($RI$) and consistency ratio ($CR$). Especially, the final value of CR is significant in the sense that CR should be less than 0.1 in order to show that the pairwise comparison is consistent [7].
Table 2. An example pairwise comparison matrix

| Criteria | C₁ | C₂ | C₃ | C₄ |
|----------|----|----|----|----|
| C₁       | a₁₁ = 1 | a₁₂ = 1/a₁₂ | a₁₃ = 1/a₁₃ | a₁₄ = 1/a₁₄ |
| C₂       | a₂₁ | a₂₂ = 1/a₂₁ | a₂₃ = 1/a₂₃ | a₂₄ = 1/a₂₄ |
| C₃       | a₃₁ | a₃₂ | a₃₃ = 1 | a₃₄ = 1/a₃₄ |
| C₄       | a₄₁ | a₄₂ | a₄₃ | a₄₄ = 1 |

3. Results and discussions
In this section; criteria, which are used in AHP, the implementation of AHP and the evaluation of the analysis will be mentioned. But, before those explanations, it would be better to illustrate the whole procedure as below (Figure 1):

3.1. Criteria
In the process of landfill site selection determination of İzmir city, 5 degree of rating and 8 criteria (surface waters are divided to three) were described, based on related legal regulation, expert opinions and advices from the literature [9].

In this study, eight criteria are used in the context of AHP in order to determine the best location for the solid waste landfill site. These could be listed as: geology, land use, surface water, erosion, fault zones, distance to settlement areas, distance to highways and slope (Figure 2a-b-c-d-e-f-g-h-i-j).

3.1.1. Geology. A landfill should be located in areas with a low risk of groundwater contamination [9]. The contamination of groundwater primarily depends on the permeability and the depth of the strata beneath the landfill [9; 10]. Since the study is an upper-scale study, the permeability of the geological units is determined by considering their lithological characteristics (via the helps of 1: 100 000 scale...
geological maps, prepared by General Directorate of Mineral Research and Exploration). For instance, Yeniköy formation is assigned to 1, since it has higher permeability. On the other hand, the other permeable areas as having limestone, Kırkağaç formation, Loras formation, Nohut formation, Soma formation, Tekedağ formation are assigned to 2. Peridotites are assigned to 5, since they are assuming as having the least permeability.
3.1.2. Land use. In the site selection process; forests, vineyards and gardens, as well as agricultural areas are not included in the analysis process. On the other hand, stony and rocky areas are assigned to 5, considering as one of the most suitable areas for the solid waste landfill site.

3.1.3. Distance from surface waters. By considering the related legal regulations [11; 12] in Turkey; distance analysis is implemented to the surface waters.

3.1.4. Erosion. Erosion map, gathered from the 1/1 000 scaled Survey Report of Ege Plan Urban Planning Office, is used in the site selection analysis process. Areas having no risk is assigned to 5, while areas having high severe and severe risk are considered as restricted.

3.1.5. Distance from fault zones. Fault zone map, gathered from The General Directorate of Mineral Research and Exploration [13], is used to create buffer zones to faults, by using distance analysis in the GIS environment. In this sense, areas closer to the fault zones are assigned to the lowest scores, since they have higher risk levels.

3.1.6. Distance from settlements. Solid waste landfill sites should not be located close to the people, since they might cause different types of pollution. For this reason, landfill constructions should be implemented far away from the settlements. In this context, buffers are constructed around the central points of the settlements, by using GIS-based distance analysis. The lowest scores are assigned to the nearest distances.

3.1.7. Distance from highways. The distance from the highways is significant in the sense of transport costs. The transport costs of the solid wastes are increasing, while moving away from the highways. However, being located on nearby the highways might cause odour and the other related pollutions. For this reason, the nearest and the farthest areas to the highways are assigned to lowest scores, while the moderate distances are assigned to the highest. In addition, the usage of the existing highways for the solid waste transport eliminates new highway construction costs.

3.1.8. Slope. Slope is the basic criterion for landfill site selection. High slope areas are not suitable for landfill site due to construction cost and probable mass movement hazards. For this reason, areas having higher slope degrees are assigned to comparatively low scores.

3.2. Analysis and evaluation

As stated, the most significant stage of AHP is to construct pairwise comparison matrix. In this sense, first, all the criteria are sorted, depending on their significance levels (e.g., geology is the most significant criterion, while slope is the least significant criterion). Before the construction of the pairwise matrix, it would be beneficial to illustrate the suitability and rating of the criteria and their sub-criteria (Table 3). The ratings are assigned considering the expert opinion and the related literature [14].
| CRITERIA | SUITABILITY AND RATING |
|----------|------------------------|
| Geology  | Restricted (0) | Very low suitability (1) | Low suitability (2) | Moderate suitability (3) | High suitability (4) | Very high suitability (5) |
|          | Lornes formation | Sonsegrageted quaternary | Spilite | Brekevolcanit | Granit | Peridotite |
|          | Kirkağaç formation | Kentboy formation | Soma formation | Akçağay tuff | Kaçakçak tuff | Kocak granodiorite | Kocadağ volcanoite |
|          | Cambohaz formation | Nohutallanı formation | Güüvenil formation | Yamanlar tuff | Kocakşur formation | Rahmanlar agglomeration | Armağandat volcanoite |
|          | Soma formation | Güvenci formation | Yeniköy formations | Loras formation | Kirkbuddak formation | Fillad | Urla volcanites |
|          | Nohutallanı formation | Yeniköy formations | Alandere formation | Kırkağaç formation | Göüen formation | Çukurkyö volcanoite | Kocadağ volcanoite |
|          | Nohutallanı formation | Emel formation | Aktepe formation | Çałdağ limestone | Güvercin formation | Gneiss | Karaburun volcanoite |
|          | Nohutallanı formation | Emel formation | Anadag limestone | Camiboğazı formation | Loras formation | Karaburun granite | Migmätite |
|          | Nohutallanı formation | Emel formation | Ayçalıtepe formation | Göüen formation | Loras formation | Serpantinite | Serpantinite |
|          | Nohutallanı formation | Emel formation | Boynuzcu formation | Güvercin formation | Loras formation | Yayaşölky volcanoite | Yayaşölky volcanoite |
|          | Nohutallanı formation | Emel formation | Başlamış formation | Kırkağaç formation | Loras formation | Dedeğölü basalt | Dedeğölü basalt |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Schist | Schist |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Quartzite | Quartzite |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Ophiolitic melange | Ophiolitic melange |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Marble | Marble |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Yaylaköy pyroclastic | Yaylaköy pyroclastic |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Çavdarştepe formation | Çavdarştepe formation |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Granadiorite | Granadiorite |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Kocadağ pyroclastic | Kocadağ pyroclastic |
|          | Nohutallanı formation | Emel formation | Limestone | Loras formation | Loras formation | Yenilimana fallout | Yenilimana fallout |
| Land use  | Dry farm land | Shrubbery, macquis groves | Forests, Vineyards | Stone pine forest | Pasture lands and meadows | Stony-rocky areas |
|          | Other fruit gardens | Olive groves | Shrubbery, macquis groves | Pasture lands and meadows | Pasture lands and meadows | Stony-rocky areas |
|          | Olive groves | Marshy places | Olive groves | Marshy places | Pasture lands and meadows | Stony-rocky areas |
|          | Marshy places | Olive groves | Marshy places | Marshy places | Pasture lands and meadows | Stony-rocky areas |
|          | Stone pine forest | Marshy places | Stone pine forest | Stone pine forest | Pasture lands and meadows | Stony-rocky areas |
|          | Stream beds | Marshy places | Stream beds | Stream beds | Pasture lands and meadows | Stony-rocky areas |
|          | Forests, Vineyards | Marshy places | Forests, Vineyards | Forests, Vineyards | Pasture lands and meadows | Stony-rocky areas |
|          | Irrigated farm lands | Marshy places | Irrigated farm lands | Irrigated farm lands | Pasture lands and meadows | Stony-rocky areas |
|          | Citrus gardens | Marshy places | Citrus gardens | Citrus gardens | Pasture lands and meadows | Stony-rocky areas |

### Surface Water
| CRITERIA | SUITABILITY AND RATING |
|----------|------------------------|
| Stream   | 100 m 250 m 750 m 1250 m 1500 m 2000 m 2500 m 3000 m 5000 m 10000 m 15000 m |
| Lake     | 100 m 250 m 500 m 750 m 1000 m 1250 m 1500 m 2000 m 2500 m 3000 m 5000 m 10000 m 15000 m 30000 m 45000 m |
| Dam lake | 100 m 250 m 500 m 750 m 1000 m 1250 m 1500 m 2000 m 2500 m 3000 m 5000 m 10000 m 15000 m 30000 m 45000 m |

### Erosion
- Areas having high risk
- Areas having very high risk
- Areas having moderate level risk
- Areas having no risk
- Areas having none or quite a little risk

### Fault Zones
- - 100 m 500 m 1000 m 1250 m 1500 m 2000 m 2500 m 3000 m 5000 m 10000 m 15000 m
- - 1000 m 1400 m 2000 m 2250 m 3000 m 5000 m 10000 m 15000 m
- - 1000 m 1400 m 2000 m 2250 m 3000 m 5000 m 10000 m 15000 m
- - 1000 m 1400 m 2000 m 2250 m 3000 m 5000 m 10000 m 15000 m

### Distance to Settlement Areas
- - 100 m 1000 m 1500 m 2000 m 2500 m 3000 m 5000 m 10000 m 15000 m
- - 1000 m 1400 m 2000 m 2250 m 3000 m 5000 m 10000 m 15000 m
- - 1000 m 1400 m 2000 m 2250 m 3000 m 5000 m 10000 m 15000 m
- - 1000 m 1400 m 2000 m 2250 m 3000 m 5000 m 10000 m 15000 m

### Distance to Highways
- - 100 m 1000 m 15000 m 20000 m 5000 m 10000 m 15000 m 20000 m 30000 m 45000 m
- - 100 m 1000 m 15000 m 20000 m 5000 m 10000 m 15000 m 20000 m 30000 m 45000 m
- - 100 m 1000 m 15000 m 20000 m 5000 m 10000 m 15000 m 20000 m 30000 m 45000 m

### Slope
- >20% - 10-20% 5-10% - 0-5% - 0-5%
Therefore; in this analysis, the pairwise comparison matrix is constructed as below (Table 4):

**Table 4. Pairwise comparison matrix**

|            | Geology | Land use | Surface water | Erosion | Fault zones | Settlement areas | Highways | Slope |
|------------|---------|----------|---------------|---------|-------------|------------------|----------|-------|
| Geology    | 1       | 2        | 2             | 3       | 4           | 5                | 7        | 9     |
| Land use   | 1/2     | 1        | 3             | 4       | 4           | 5                | 5        | 7     |
| Surface water | 1/2   | 1/3      | 1             | 2       | 3           | 3                | 4        | 6     |
| Erosion    | 1/3     | 1/4      | 1/2           | 1       | 2           | 2                | 3        | 5     |
| Fault zones | 1/4   | 1/4      | 1/3           | 1/2     | 1           | 2                | 3        | 5     |
| Distance to settlement areas | 1/5 | 1/5 | 1/3 | 1/2 | 1 | 2 | 3 |
| Distance to highways | 1/7 | 1/5 | 1/4 | 1/3 | 1/3 | 1/2 | 1 | 3 |
| Slope      | 1/9     | 1/7      | 1/6           | 1/5     | 1/5         | 1/3              | 1/3      | 1     |

After constituting the pairwise comparison matrix, the weights are calculated as (Table 5):

**Table 5. The weights of the criteria**

|            | Geology | Land use | Surface water | Erosion | Fault zones | Settlement areas | Highways | Slope |
|------------|---------|----------|---------------|---------|-------------|------------------|----------|-------|
| Geology    | 30%     | 25%      | 15%           | 10%     | 8%          | 5%               | 5%       | 2%    |

Following stage of the determination of the weights includes the calculation of CR. In this study, CR is calculated as equal to 0.04, which is less than 0.1. This shows that the pairwise comparison is constructed as consistent. Therefore, after the evaluation of AHP analysis, the following map, which shows the suitable lands for solid waste landfill sites in Izmir Metropolitan Area is obtained, Figure 3.

**Figure 3. Suitability map for solid waste landfill site selection of İzmir Metropolitan Area**
4. Conclusions
Especially in the big cities and metropolitan areas, solid waste disposal constitutes a significant problem. It endangers the maintenance of the nature and the natural life, in the context of environmental pollution and natural protection acts. Accordingly, landfill site selection is an important task in terms of the land use decisions, in the sense of environment sensitive sustainable urbanization. In this paper, the selection of suitable areas for landfill was determined using GIS and multi criteria decision making (MCDM) analysis, namely AHP. GIS was used for spatial analyses and to create databases. Final map obtained demonstrates grading of İzmir Metropolitan Area from restricted area to the high suitable area for landfill site selection. Spatial data are used for analysis are gathered from various resources. The analysis was carried out eight criteria, as geology, land use, distance from the surface waters, distance from the settlements, distance from the active fault zones, distance from the highways and slope. Highest weights are designated in the sense of geo-environmental and natural conservation parameters, such as geology, natural land use and water surfaces. This study defines five zones as restricted areas, areas having very low suitability, areas having low suitability, areas having moderate suitability and areas having high suitability. Besides, 98% of the study area is calculated as the restricted area to develop a solid waste landfill site (lower-scale analyses should be conducted). The model is created via MCDM analysis and GIS and in this study; it is used as a MCDM support system. It supplies proper site selection for landfill site to the decision makers in terms of waste management and geo-environmental, natural conservation and urban criteria. This study, which constitutes upper-scale site selection model, provides a decision support approach to the decision makers to enable them to take proper decisions, related with the urban areas. Suitable areas obtained from this study, should be re-checked for the sub-scale implementations (egg. 1/25 000, 1/5 000, 1/1 000), with the related additional criteria as physical environment, economic, social etc. and new microzonation maps should be constituted by considering these new criteria, by supported with field surveys. Solid waste site selection and disposal are vital in the sense of human life and natural environment. Environment sensitive urban planning should consider geo-environmental risks for a sustainable life and this requires the integration of related criteria in the context of spatial and statistical methods. In this context, GIS-based MCDM enables decision makers to take proper decisions in the sense of complicated decision making environment, related with the urban areas. Therefore, this model could be applicable to the other related analyses, having different criteria and scales. The model created in this study is constituted for solid waste landfill site selection, considering geo-environmental criteria. Additionally, the study could be considered as a guide for waste management and site selection, as well as it is a proposal for different purposes and decisions.

References
[1] Ş. Tüdeş, “An Analytic Model Proposal Related with the Evaluation of Geological Thresholds In the Context of Planning-Portsmouth (England) Case”. Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 26.2, 2011.
[2] Ş.Tüdeş & N.D. Yiğiter, “Preparation of land use planning model using GIS based on AHP: case study Adana-Turkey.” Bulletin of engineering geology and the environment, 69.2: 235-245, 2010.
[3] K. Ghoseiri; J. Lessan. “Waste disposal site selection using an analytic hierarchal pairwise comparison and ELECTRE approaches under fuzzy environment.” Journal of Intelligent & Fuzzy Systems, 26.2: 693-704, 2014.
[4] D. Khan & S.R. Samadder. “A simplified multicriteria evaluation model for landfill site ranking and selection based on AHP and GIS”, Journal of Environmental Engineering and Landscape Management, 23:4, 267-278, DOI: 10.3846/16486897.2015.1056741, 2015.
[5] A. Ohri & P.K. Singh,"GIS based environmental decision support system for municipal landfill site selection", Management of Environmental Quality: An International Journal, Vol. 24 Issue: 5,pp, 583-598, doi: 10.1108/MEQ-08-2012-0056. 2013.
[6] O. E. Demesouka & A. P. Vavatsikos & K. P. Anagnostopoulos. “Suitability analysis for siting
MSW landfills and its multicriteria spatial decision support system: method, implementation and case study.” *Waste management*, 33.5: 1190-1206, 2013.

[7] T. L. Saaty, “The Analytic Hierarchy Process”, McGraw-Hill, New York, 1980.

[8] T. L. Saaty, “How to make a decision: the analytic hierarchy process.” *European journal of operational research*, 48.1: 9-26, 1990.

[9] D. J. Sekulović & G. L Jakovljević, “Landfill site selection using GIS technology and the analytic hierarchy process.” *Vojnotehnički glasnik*, 64(3), 769-783, 2016.

[10] P.V. Gorsevski & K.R. Donevska & C.D. Mitrovski, & J.P. Frizado, “Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average.” *Waste Management*, 32(2), pp.287-296. pmid:22030279, 2012.

[11] Ministry of Environment and Forestry, Regulation of Regular Storage of Wastes. No: 27533, 26 Mart 2010.

[12] Regulation of Waste Management. Official Journal No: 29314http://www.mevzuat.gov.tr/Metin.Aspx?MevzuatKod=7.5.20644&MevzuatIliski=0&s ourceXmlSearch=at. Resmi Gazete Tarihi: 02.04.2015.

[13] Ö. Emre & S. Özalp & A. Doğan & V. Özaksoy & C. Yıldırım & F. Göktas, “Active Faults and Earthquake Potential of İzmir and Its Near Environment”, General Directorate of Mineral Research and Exploration Report No: 10754, 2005.

[14] M. Kıcıkönder & M. Karabulut. “Determination of Waste Storage Area in Kahramanmaraş by Using Multicriteria Analysis Technique” *Coğrafi Bilimler Dergisi*, 5.2: 55-76, 2007.