Proceedings of the 9ICEG
9th International Congress on Environmental Geotechnics
25-28 June, 2023 | Chania, Greece

https://doi.org/10.53243/ICEG2023-72

Determination of Temporary Accommodation Areas in Earthquake via MCDM and GIS

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ABSTRACT

Disaster is a natural or man-made event that adversely affects the individual or society materially and morally. In order to minimize the damage caused by the disaster and its consequences, it is of vital importance to plan the evacuation of the disaster victims and transport them to safe areas. In this study, temporary accommodation areas for Kocaeli province of Turkey, which experienced a significant earthquake in 1999, were evaluated. Selection and prioritization of the most suitable temporary accommodation areas will be made with Geographic information System (GIS)-based Multi-Criteria Decision-Making Analysis (MCDM). For this purpose, 7 different evaluation criteria were determined by taking literature research and expert opinions. The criteria weights were determined by the Analytical Hierarchy Process (AHP). GIS-based analyses were performed using ArcGIS 10.7 software. The obtained raster maps were classified on the same scale and scored. The maps were combined with the overlap analysis and the most suitable temporary accommodation areas for Kocaeli were determined by manual processes.

Keywords: ArcGIS, Disaster Management, Multi-Criteria Decision-Making Analysis, Temporary Accommodation.

1 INTRODUCTION

Natural disasters cause loss of life and property. Being prepared for disasters is important to prevent possible losses. In addition, a good preparedness plan also provides an idea about the quick measures to be taken in case of disaster. Disaster management is defined as the planning, direction, support, coordination and effective implementation of activities to be carried out at the stages of mitigation, preparedness, response and recovery in order to prevent disasters and reduce their losses (Poser & Dransch, 2010).

An effective disaster management system is very important for the work to be done before and after the disaster. Temporary accommodation areas are determined during the response and recovery phases of disaster management and the victims are placed in these areas. In the event of a disaster, directing people from the area where they live to shelters helps to reduce possible losses.

The Sphere Project is a project initiated in 1997 by a group of Non-Governmental Organizations (NGOs) and the International Red Cross and Red Crescent Movement. The main purpose of the project is to raise the quality of the activities required during the assistance to be applied to the disaster victims affected by any natural or man-made disaster and to set accountable standards. In the Sphere Project, the Humanitarian Aid Agreement has been prepared and the Minimum Standards for life-saving practices have been determined. These practices are grouped under the headings of water supply, food safety, shelter and settlement, health activities, and hygiene (Sphere Project, 1997).

Areas under direct risk of disaster should not be preferred for temporary shelter areas. The basic needs (water, food, heating, etc.) necessary for the survival of the disaster victims should be met. The proximity of temporary accommodation areas to markets, warehouses and health centers should be evaluated in advance in order to meet food, drinking water and other needs. Geographical features such as proximity to transportation networks, morphological features, proximity to water resources, climatic features, hydrographic features, soil characteristics, proximity to vegetation are important in determining these areas (Özdemir, 2002).

Since the evaluation of temporary accommodation areas includes more than one criterion, it can be analyzed with multi-criteria decision-making approaches. Some studies in which temporary accommodation areas are evaluated / prioritized by MCDM techniques are summarized. Omidvar et al. (2013) proposed a model integrating GIS and MCDM approaches for temporary shelter area selection before a possible earthquake. In total, they presented a case study that included 13 criteria and 14 alternative temporary accommodation sites. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elemination and Choice Translating Reality English (ELECTRE), Simple Additive Weighting (SAW) and AHP methods were used. Not combining the results obtained from each method for ranking is considered as an incomplete approach in the relevant study. Nappi and Souza (2015) evaluated the criteria for the selection of temporary accommodation areas and suggested the AHP approach. The related study has inadequacies in terms of application. The criteria have not been evaluated by the decision makers. Hosseini et al. (2016) applied the AHP and integrated value model for sustainable assessment approaches in the selection of site locations for temporary shelters. The integrated value model is important in terms of ensuring the sustainability of the method, but the use of a single decision-making method is seen as an open area of study. While determining the importance weights of the criteria using AHP, the ranking of temporary accommodation areas was obtained with the integrated value model for sustainable evaluation. Trivedi and Singh (2017) proposed a hybrid group decision support approach for the emergency shelter location problem. The weights of the determined criteria were obtained using Fuzzy AHP and alternative accommodation areas were ranked by TOPSIS method. The fact that the fuzzy model structure integrated into the TOPSIS method is not preferred is considered as an aspect of the study that should be discussed. Çelik (2017) evaluated the criteria determined in the problem of selection of temporary accommodation areas in his study using the fuzzy-based Decision Making Trial and Evaluation Laboratory (DEMATEL) method. The inclusion of interval type-2 fuzzy sets in the DEMATEL method has enriched the study. Jahangiri et al. (2019) used GIS and AHP methods to evaluate temporary accommodation areas in rural areas. After determining the criterion weights with the AHP method, the study was enriched by using fuzzy models together with the stratification process in the GIS environment.

In this study, the determination of temporary shelter areas after the earthquake was determined as a decision problem. AHP and GIS methods are used to evaluate the temporary accommodation areas in Kocaeli, Turkey. Expert opinion is taken for the evaluation criteria. ArcGIS 10.7 software is used for the GIS integrated multi criteria decision model. In the second part, the study area, evaluation criteria and methods used are explained. In the third part, the findings are given. The fourth chapter contains the conclusion and discussion.

2 MATERIALS AND METHODS

2.1 Study Area

One of the countries with the highest fault activity in the world is Turkey (Tan et al. 2008). Many earthquakes have occurred within the borders of Turkey (Ambraseys and Jackson 2000). The 1999 Marmara Earthquake is one of the most important earthquakes that adversely affected the social, environmental, economic and physical systems of the country in the recent past. The results of the Marmara Earthquake were very devastating for Marmara, one of the most important centers economically and socially. One third of the industrial production in the country was provided from Kocaeli and its surroundings (Bibbee 2000). From this point of view, the result of this earthquake was not limited to death only. It also directly and negatively affected the economic activities and the welfare of the country. Another major earthquake, similar to the 1999 Marmara earthquake, is expected to occur along the North Anatolian Fault, which expands more than 1000 km across Turkey (Aochi and Ulrich 2015).

The view of Kocaeli, which has a surface area of 3,626 km², on the map of Turkey is given in Figure 1.

Figure 1. *Map of Kocaeli, Turkey*

2.2 Evaluation Criteria

The literature summary of the criteria determined for the selection or evaluation of temporary accommodation areas is given in Table 1.

Table 1. *Literature summary of criteria for temporary accommodation areas*

Authors	Criteria
Omidvar et al., 2013	Accessibility, Water Supply, Area Per Capita, Distance, Safety and Protection, Topography and Drainage, Soil Conditions, Vegetation and Fuel resources, Climate Conditions, Local Health and other risks, Public approval, Economic consideration, Earthquake hazard assessment
Hadavi et al., 2014	Land use area, distance from fire stations, age of building, distance from fault lines, distance to main roads
Şentürk and Erener, 2017	Appropriate distance to fuel stations and flammable material storage areas, proximity to road networks, proximity to security centers, land slope, suitable distance to electricity transmission lines, appropriate distance to fault lines, appropriate distance from landslide risk areas, geological structure, proximity to health institutions, appropriate distance from polluting industry, appropriate distance to cultural heritage sites, proximity to water sources, appropriate distance from flood areas, proximity to electricity source.
Trivedi and Singh, 2017	Soil hardness, topography, slope, afforestation, electricity-telecommunication facility, hygiene and sanitation system, proximity to drinking water, drainage system and sewerage infrastructure, solid waste disposal, proximity to education facilities, recreational facilities, low risk of flooding, local road structure, main distance from road, distance from health facilities, distance from humanitarian aid centers, distance from transportation centers
Boostani et al., 2018	Main Factors: Infrastructure, transportation, sustainability, land suitability, communication facilities, proximity to affected areas, proximity to humanitarian aid centers, access to connection networks, access to energy resources, economic factor, environmental factor, political stability.

Table 1. (continued)

Junian and Azizifar, 2018	Distance from the fault line, close to fire stations, close to medical centers, close to populated areas, close to transportation routes, close to sensitive areas
Dabiri et al., 2020	Distance from faults, creeks and other hazards, suitable ground slope, suitable infrastructure, availability, proximity to service centers, acceptance capacity
Geng et al., 2020	Topography, geology, slope, vegetation, power facilities, sanitation system
Şenik and Uzun, 2021	Proximity to health institutions, proximity to main roads, slope, urban open green spaces, proximity to areas at risk of flooding, proximity to existing buildings, proximity to gas stations

The criteria determined for this study are given below along with their codes.
c1: distance from fault lines
c2: land slope
c3: geological structure
c4: vegetation
c5: proximity to health centers
c6: proximity to main roads
c7: use of water resources

2.3 Methods

In this study, the weights of the criteria determined for evaluation were obtained by using AHP, which is one of the multi-criteria decision-making techniques. After the criterion weights were calculated, the criteria data of Kocaeli province were processed with the ArcGIS package program. The use of GIS is important for data analysis and visualization.

2.3.1 Analytic hierarchy process (AHP)

The analytical hierarchy process is an MCDA tool introduced by Saaty in the 1970s (Sindhu et al. 2017). The AHP method simplifies the evaluation of decision criteria for organizing the problem in a hierarchical order regarding decision making problems (Talinli, 2011).

The AHP steps are summarized as follows (Tahri et al., 2015; Ahmad and Tahar, 2014) :
I. The hierarchical structure of the problem is created.
ii. Pairwise comparisons are made by the decision maker or decision makers for criteria, sub-criteria and alternatives. They are also arranged as pairwise comparison matrices (n × n). The discrepancy rate for all pairwise comparisons should be less than 0.1. In some cases, only criterion weights can be calculated. If criterion A is significantly more important than B, the degree of importance from criterion A to B can be expressed with the number 9. In this case, the importance of criterion B with respect to criterion A will be 1/9. The preference scale is given in Table 2 (Özdemir and Maruf, 2019). In cases of intermediate importance, the decision maker can give score as "2,4,6 or 8". For example, if it is desired to make an evaluation between equal level and intermediate level, the score will be 2.

Table 2. *Scale of AHP for pairwise comparisons*

Level of Significance	Importance
1	Equally
3	Moderate
5	Strong
7	Very Strong
9	Extreme
2,4,6,8	Intermediate Importance

iii. After the weights are calculated, decision matrices are created.
iv. The final weights are obtained by matrix multiplication in decision matrices.
v. The raw weights obtained in the last step are normalized.

2.3.2 Geographic information system (GIS)

Geographic Information Systems (GIS) is a concept consisting of hardware, software, people, data and methods that enable the collection, analysis and synthesis of spatial and non-spatial data on any geographical space in order to solve economic and social problems. GIS has a structure that integrates spatial data with verbal information. GIS can be used as a tool for solving a variety of complex geospatial problems that require spatial and mathematical modelling scenarios (Coppock and Rhind, 1991).

Some spatial analysis tools in GIS are given below.
• Buffer Zoning
• Proximity Analysis
• Overlay Analysis
• Flood Analysis
• Density Analysis
• Visibility (Viewshed) Analysis
• Shortcut and Infrastructure (Network) Management Analysis
• Surface Analysis (3D, Aspect, Slope, Elevation, Visibility, Line of Site, Cut&Fill)
The program that made the most investments on GIS in Turkey and in the world was ArcGIS, the product of ESRI. ArcGIS software is a software used in the preparation and editing of the data necessary for modelling in GIS. ArcGIS 10.7 software was also used in this study.

2.4 Results

The criteria weights obtained as a result of the questionnaire applied to the decision maker in the study are given in Table 3.

Table 3. *Weights of Criteria*

Criteria	Weights of Criteria
c1	0.033
c2	0.300
c3	0.093
c4	0.043
c5	0.235
c6	0.206
c7	0.090

The data are detailed so that the criteria and the data related to the criteria obtained from Kocaeli Metropolitan Municipality can be processed in the ArcMap environment in the ArcGIS 10.7 package program. Classification methods and conformity scores defined for criteria classes are given in Table 4.

Table 4. *Criteria, analysis and classification methods classification value, score of class*

Criteria	Analysis Method	Classification Type	Value Interval	Score of Class
c1	Buffer Analysis	Manual	0-1000	1
			1000>	5
c2	Reclassification	Natural Breaks	%28,70-%86,11	1
			%19,58-%28,70	2
			%12,16-%19,58	3
			%5,74-%12,16	4
			%0,00-%5,74	5
c3	Reclassification	Manual	Alluvium	1
			Hard Soil	3
			Soft Rock	4
			Hard Rock	5

Table 4. (continued)

c4	Reclassification	Manual	(most efficient) 0	5
			(very efficient) 1	4
			(medium yield) 2	3
			(less efficient) 3	2
			(very little efficient) 4	1
c5	Buffer Analysis	Manual	7000-15000	1
			5000-7000	2
			3000-5000	3
			1000-3000	4
			0-1000	5
c6	Buffer Analysis	Manual	7000-15000	1
			3000-7000	2
			1500-3000	3
			500-1500	4
			0-500	5
c7	Buffer Analysis	Manual	1000>	1
			0-1000	5

After the data of the criteria are imported into the GIS program, vector data is converted to raster data. Kocaeli borders are shown in Figure 2 in ArcGIS ArcMap 10.7 package program for GIS.

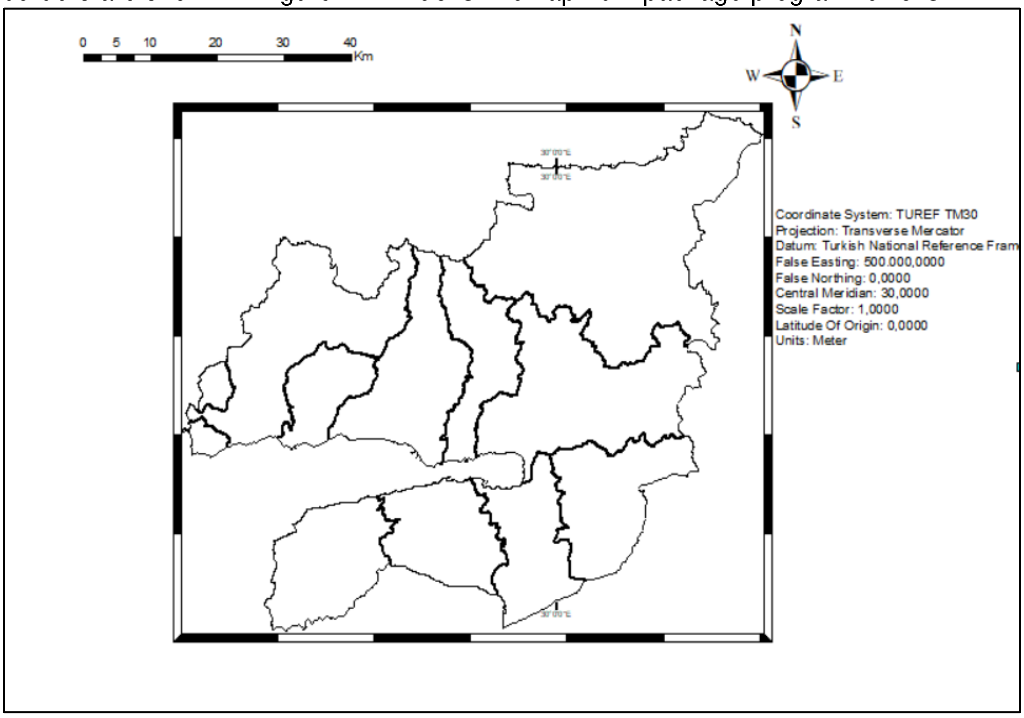
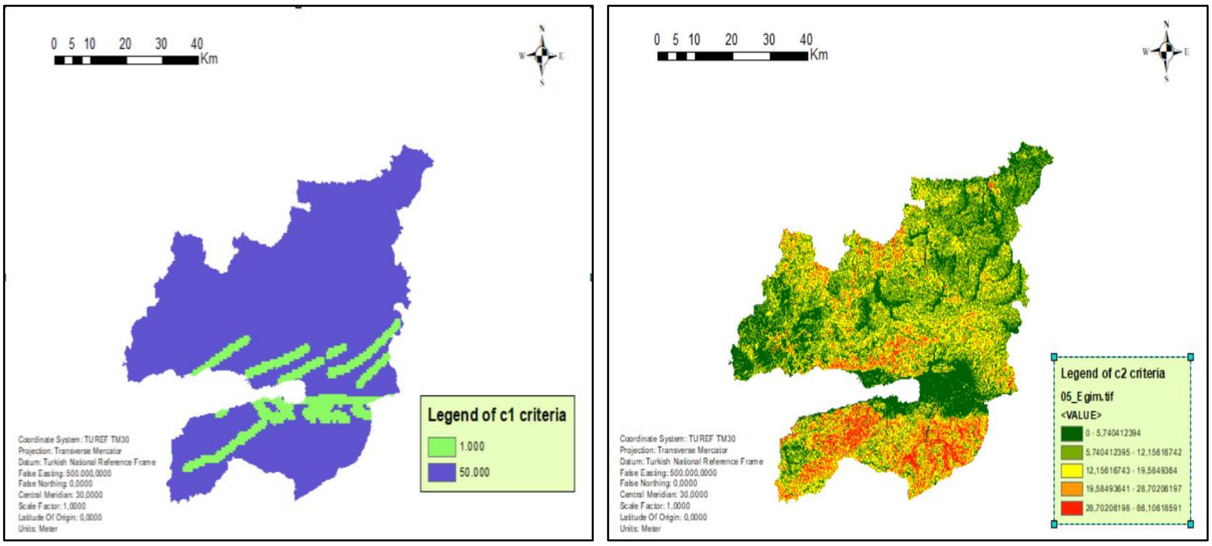


Figure 2. *Map of ArcMap for Kocaeli, Turkey*

Among the criteria data received from Kocaeli Metropolitan Municipality, only the slope data is in raster format. Data for other criteria are vector data. All data must be in raster format for layering on ArcMap. For this purpose, vector data is converted to raster data format by using the feature to raster tool in the conversion tools.

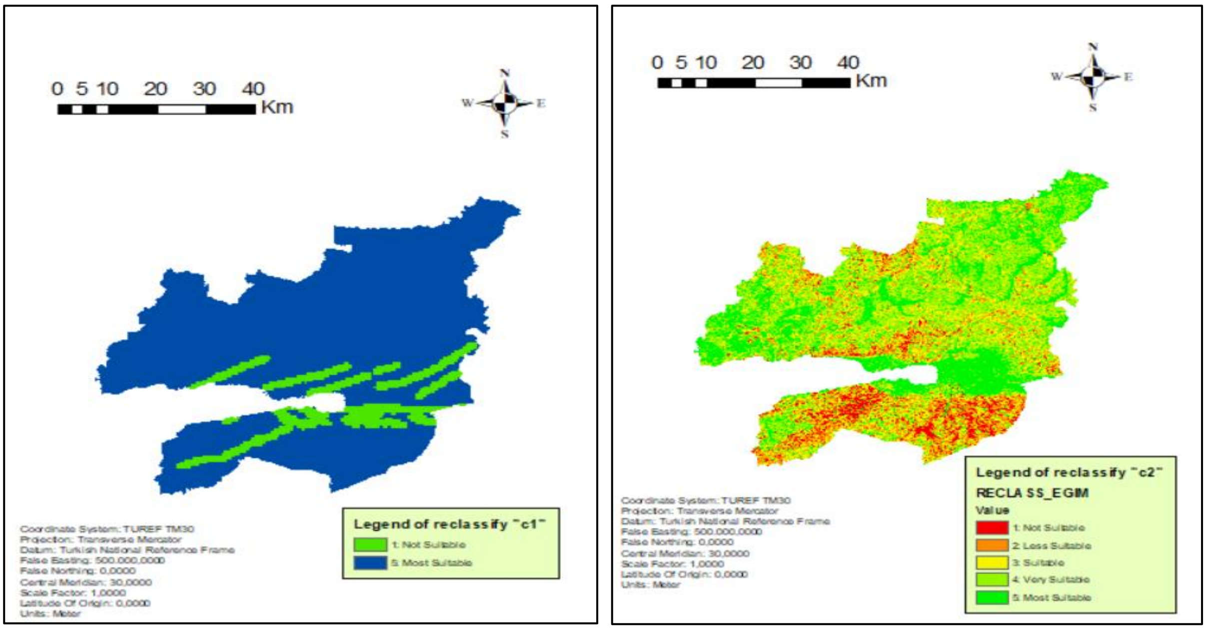
Before converting to raster format, buffer analysis is performed on the distance from fault lines (c1) data. In addition, distance analysis is performed for the criteria of proximity to main roads (c6) and proximity to health centers (c5) Value ranges are based on the ranges in Table 4. Example raster format representations for distance from fault lines (c1) and land slope (c2) criteria are given in Figure 3. The sections that are available in ArcMap and that explain what special symbols mean are called legends for short. It explains what the special signs in the section called legend mean.



a) Raster for c1 criteria b) Raster for c2 criteria

Figure 3. *Examples raster format representations*

In ArcMap, raster data is reclassified and made suitable for scores with the reclassify tool in spatial analyst tools. Example reclassified representations for distance from fault lines (c1) and land slope (c2) criteria are given in Figure 4. In the reclassification, “5” represents the most suitable areas and “1” represents the most unsuitable areas.



a)Reclassify for c1 criteria b) Reclassify for c2 criteria

Figure 4. *Examples reclassify format representations.*

All other criteria are also reclassified. Then, the "overlay" tool in the spatial analysis tools is selected for overlay analysis. In this study, the weighted sum method was chosen for overlay analysis. Weighted Sum works by multiplying the designated field values for each input raster by the specified weight. It then sums (adds) all input rasters together to create an output raster.

After all analyses are completed, the view in Figure 5 is obtained according to the results of the weighted sum method. The most suitable areas as earthquake shelter areas are shown with 5 and the most unsuitable areas with 1.

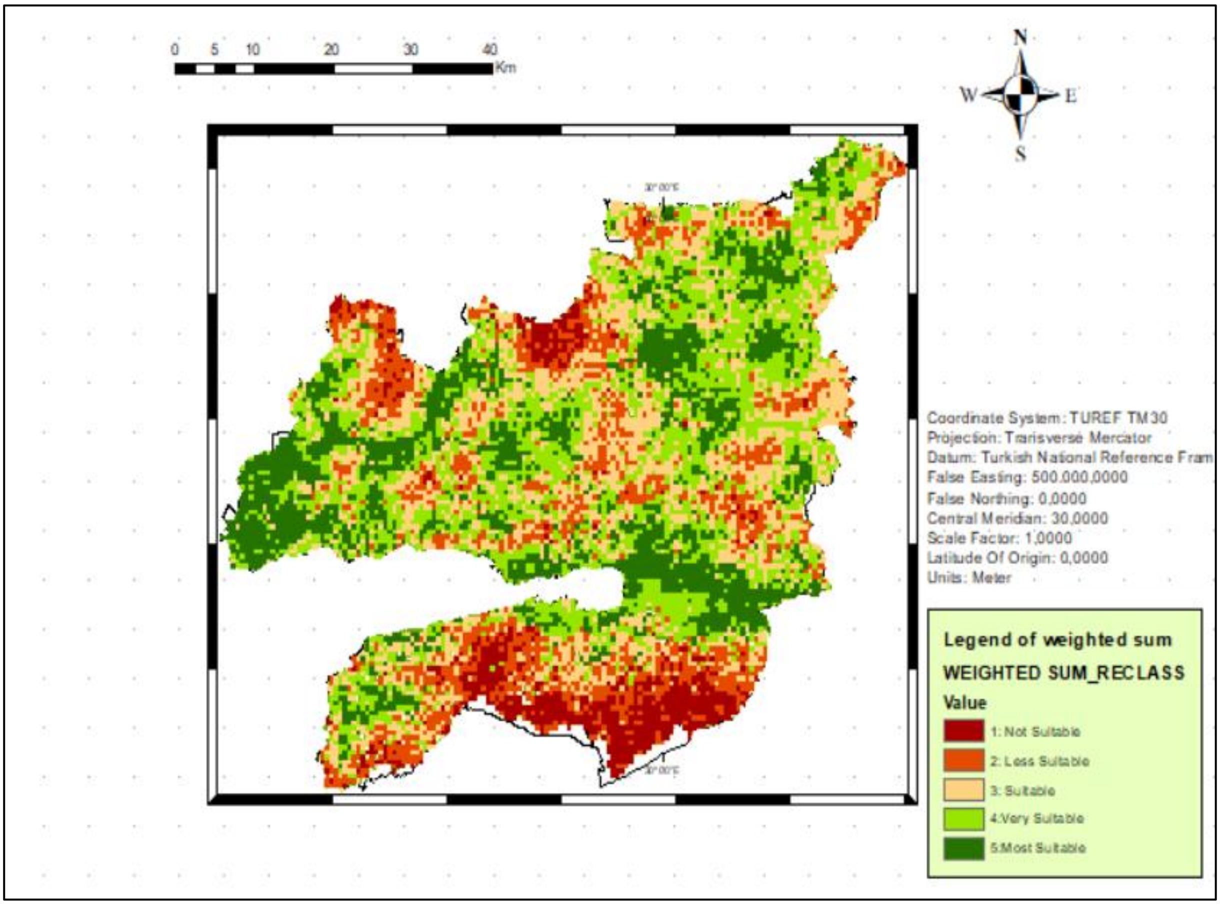


Figure 5. *The suitability map of temporary shelter areas*

3 CONCLUSIONS

In this study, a contribution is made to the response and recovery phases of a possible earthquake disaster for Kocaeli, Turkey. It is critical to direct disaster victims to temporary shelters and to minimize possible losses. In this context, a model that is hybridized with a multi-criteria decision-making approach, which takes into account the judgments of the decision maker, has been proposed. With the AHP method, the criteria used in the evaluation of temporary accommodation areas were weighted and a suitability map was created with GIS technology by using these weight values. According to the suitability map, the most suitable areas are located in the north and northeast of Kocaeli province. Coordinate values of the relevant regions can be reached and different plans can be made.

REFERENCES

Ahmad, S., & Tahar, R. M. (2014). Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. Renewable energy, 63, 458-466.

Ambraseys, N. N., & Jackson, J. A. (2000). Seismicity of the Sea of Marmara (Turkey) since 1500. Geophysical Journal International, 141(3), F1-F6.

Aochi, H., & Ulrich, T. (2015). A probable earthquake scenario near Istanbul determined from dynamic simulations. Bulletin of the Seismological Society of America, 105(3), 1468-1475.

Bibbee, A., Gönenç, R., Jacobs, S., Konvitz, J., & Price, R. (2000) Economic effects of the 1999 Turkish earthquakes : an interim report economics department working papers No. 247. Organisation for Economic Co-operation and Development, 144.

Boostani, A., Jolai, F., & Bozorgi-Amiri, A. (2018). Optimal location selection of temporary accommodation sites in Iran via a hybrid fuzzy multiple-criteria decision making approach. Journal of Urban Planning and Development, 144(4), 04018039.

Coppock, J. T., & Rhind, D. W. (1991). The history of GIS, geographic information system. London: Longman Inc, 21, 39.

Çelik, E. (2017). A cause and effect relationship model for location of temporary shelters in disaster operations management. International Journal of Disaster Risk Reduction, 22, 257-268.

Dabiri, M., Oghabi, M., Sarvari, H., Sabeti, S., Kashefi, H. R. (2020). A combination risk-based approach to post-earthquake temporary accommodation site selection: A case study in Iran, Iranian Journal of Fuzzy Systems, 17(6), 57-74.

Geng, S., Hou, H., & Zhang, S. (2020). Multi-criteria location model of emergency shelters in humanitarian logistics. Sustainability, 12(5), 1759.

Hadavi, F., Zamani, M., Movasati, M., Koohgard, K., & Hadavi, M. (2014). Optimal site selection for temporary housing after an earthquake in urban areas using multiple criteria decision making methods and GIS (a case study of municipal district 6, Tehran metropolis). Journal of Applied Environmental and Biological Sciences, 5(1), 6-13.

Hosseini, S. A., de la Fuente, A., & Pons, O. (2016). Multicriteria decision-making method for sustainable site location of post-disaster temporary housing in urban areas. Journal of Construction Engineering and Management, 142(9), 04016036.

Jahangiri, K., Borgheipour, H., Gendeshmin, S. B., Matin, A., & Tehrani, G. M. (2019). Site selection criteria for temporary sheltering in urban environment. International journal of disaster resilience in the built environment.

Junian, J., Azizifar, V. (2018). The evaluation of temporary shelter areas locations using geographic information system and analytic hierarchy process, Civil Engineering Journal, 4(7), 1678-1688.

Nappi, M. M. L., & Souza, J. C. (2015). Disaster management: hierarchical structuring criteria for selection and location of temporary shelters. Natural Hazards, 75(3), 2421-2436.

Omidvar, B., Baradaran-Shoraka, M., Nojavan, M. (2013). Temporary site selection and decision-making methods: a case study of Tehran, Iran, Disasters, 37(3), 536-553.

Özdemir, H., 2002. Determination of Temporary Shelter Areas in Disaster Preparedness Studies. Eastern Geographical Review, 12, 237-254.

Özdemir, A. & Maruf, M. (2019). Differentiation of Service Speed With Multi Criteria Decision Making Techniques in Waiting Line Problems. Ankara Hacı Bayram Veli University Journal of the Faculty of Economics and Administrative Sciences, 20 (3) , 470-482 .

Poser, K., Dransch, D., (2010). Volunteered geographic information for disaster management with application to rapid flood damage estimation. Geomatica, 64(1), 89-98.

Sindhu, S., Nehra, V., & Luthra, S. (2017). Investigation of feasibility study of solar farms deployment using hybrid AHP-TOPSIS analysis: Case study of India. Renewable and Sustainable Energy Reviews, 73, 496-511.

Sphere Project, (1997). Retrieved December 10, 2022, from website: https://spherestandards.org/wp-content/uploads/2018/06/The_Sphere_Handbook_2011_Turkish.pdf

Şenik, B., & Uzun, O. (2021). An assessment on size and site selection of emergency assembly points and temporary shelter areas in Düzce. Natural Hazards, 105(2), 1587-1602.

Şentürk, E., & Erener, A. (2017). Determination of temporary shelter areas in natural disasters by gis: A case study, Gölcük/Turkey. International Journal of Engineering and Geosciences, 2(3), 84-90.

Tahri, M., Hakdaoui, M., & Maanan, M. (2015). The evaluation of solar farm locations applying Geographic Information System and Multi-Criteria Decision-Making methods: Case study in southern Morocco. Renewable and sustainable energy reviews, 51, 1354-1362.

Talinli, I., Topuz, E., Aydin, E., & Kabakcı, S. B. (2011). A holistic approach for wind farm site selection by FAHP. Wind farm: technical regulations, potential estimation and siting assessment. InTech, Croatia, 3(1), 213-234.

Tan, O., Tapirdamaz, M. C., & Yörük, A. (2008). The earthquake catalogues for Turkey. Turkish Journal of Earth Sciences, 17(2), 405-418.

Trivedi, A., & Singh, A. (2017). Prioritizing emergency shelter areas using hybrid multi-criteria decision approach: A case study. Journal of Multi-Criteria Decision Analysis, 24(3-4), 133-145.