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A mass vaccination site selection problem: An application of GIS and entropy-based MAUT approach

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ABSTRACT  
Coronavirus disease (COVID-19) was recognized in December 2019 and spread very severely throughout the world. In 2022 May, the total death numbers reached 6.28 million people worldwide. During the pandemic, some alternative vaccines were discovered in the middle of 2020. Today, many countries are struggling to supply vaccines and vaccinate their citizens. Besides the difficulties of vaccine supply, mass vaccination is a challenging but mandatory task for the countries. Within this context, determining the mass vaccination site is very important for recovering, thus a five-step approach is generated in this paper to solve this real-life problem. Firstly the mass vaccination site selection criteria are determined, and secondly, the spatial data are collected and mapped by using Geographical Information System (GIS) software. Then, the entropy weighting method (EWM) is used for determining the relative importance levels of criteria and fourthly, the multiple attribute utility theory (MAUT) approach is used for ranking the potential mass vaccination sites. Lastly, ranked alternative sites are analyzed using network analyst tool of GIS in terms of covered population. A case study is conducted in Gaziantep city which is the ninth most population and having above-average COVID-19 patients in Turkey. As a result, the fourth alternative (around the Şehitkamil Monument) is chosen as the best mass vaccination site for the city. It is believed that the outcomes of the paper could be used by city planners and decision-makers.

1. Introduction  
The first COVID-19 patient was detected in March 11, 2020 in Turkey and since that date, 98,939 people passed away and 15,136,565 million people got infected in the country until May 2022 [1]. There are 38 approved vaccines in the world for now which started with Pfizer BioNTech - that was approved in 158 countries [2]. Until now, 67.4% of the world population has received at least one dose of COVID-19 vaccines [3]. In Turkey, 131,930,475 COVID-19 vaccines are used – which means more than 85% of the total population had the second dose and 93.18% of the population had only one dose of the vaccine [1]. Still, there is a fierce race to obtain the COVID-19 vaccines and the countries are developing strategies for their vaccination programs. The COVID-19 vaccines have special issues such as the need for a cold supply chain. And also as known, there is a need for physically distanced observation for 15–30 min after vaccination and this causes problems for health facilities that have limited space and staff. Since the mass vaccination programs are essential countermeasures to obtain an optimal vaccination rate, many mass vaccination centers are opened in the United States, Gillette Stadium in Massachusetts, State Farm Stadium in Arizona and Dodger Stadium in California. Israel, Italy, Germany and the United Kingdom have also set up mass-vaccination sites in locations such as arenas, stadiums, skating rinks, town squares, cathedrals and museums [4].

There are also some challenges during the mass vaccination programs such as; balancing the supply of and demand for vaccine, community prioritization strategies, determination of vaccination sites and also vaccine logistics [5].

In this study, the mass vaccination site selection problem of Gaziantep – the ninth most crowded city in Turkey [6] – is examined. The two most crowded districts of the city are taken into account, namely, the Şehitkamil and Şahinbey districts. The motivation of the study is both proposing a scientific hybrid methodology that is not used in the literature and solving a real case problem. It is very important to
determine geographic areas and populations that may benefit from mass vaccination sites, especially for populations that do not have access to established vaccination sites. The site must be very well equipped and staffed to provide immediate care in case of an adverse reaction. Also clear exits for emergency medical transport should be determined in advance. Thus it is very important to handle different site selection criteria. In addition, the mass vaccination site selection problem is not examined in the accessible literature yet. There can be thousands of different alternative institutions and places to be used for mass vaccination points in a city. To reduce this complexity, the potential sites are determined as conducted in USA mass vaccination program (Mass. Gov., 2021). According to their parameters, the stadiums, shopping malls, indoor sports facilities, hotels, campuses and congress centers are determined as alternative locations.

In this study, above mentioned wide locations are chosen as vaccination site alternatives and a geographic information system (GIS) and Entropy based Multi Attribute Utility Theory (MAUT) approach is used for the solution of the problem. In the proposed methodology, firstly the mass vaccination site selection criteria are determined by help of the expert group -medical doctors- and by means of the literature. By doing so, 12 criteria are determined for evaluating mass vaccination sites. Secondly, the related spatial information is gathered and plotted on each alternative site by using GIS. Then, the importance levels/weights of the selection criteria are determined with the help of Entropy method and the ranks of the alternative sites are determined by using the MAUT method. Finally, coverage models of ArcGIS are applied to analyze the performance of ranked alternative sites.

The next section summarizes the literature on; GIS-based MCDM problems in addition to both Entropy and MAUT methodologies. Section 3 presents the proposed methodology and section 4 includes the proposed case study, scenario analysis and discussion. Finally, section 5 summarizes the study and gives future study directions for researchers.

2. Literature review

The site selection problems are famous in the literature and there are much different approaches to solve these problems. In this part of the study, GIS-based MCDM problems are summarized that apply Entropy and MAUT methodologies. Since there is no study in the literature that uses the proposed methodology (GIS-based MCDM) on mass vaccination site selection problem, different problems are summarized that apply similar methodology in different fields. For the mathematical modeling applications to locate mass vaccination sites, the reader is referred to recent studies of Bertsimas et al. [7] and Bravo et al. [8].

As a methodologically close study, Alp et al. [9] measured the corporate sustainability performance of a company named Linde by using the MAUT method. They used three criteria in the proposed study and they used Entropy method to determine criteria weights. The related data were obtained from the sustainability reports regarding the years of 2009–2013. As a result, while the social sustainability and economic performances were in an increasing trend, the performance of environmental sustainability showed an unstable trend. In another study, Ommark et al. [10] measured the performance of automotive companies listed on Istanbul Stock Exchange by using multi criteria decision making techniques. They used ten criteria in the study and related data are gathered from the reports of companies in 2014. They used Entropy weighting method to determine the criteria weights and MAUT and Simple Additive Weighting methods were used to rank company performances. As a result, they summarized that three companies remained the same in ranks regardless of the applied method.

In a GIS-based approach, Borouchaki [11] presented an entropy-based TOPSIS algorithm within GIS for calculating the heat vulnerability index. They used nine criteria in the proposed study. The model was applied in a real case study in San Fernando, Los Angeles. As a result, it was emphasized that the findings of the paper could be used by the city planners effectively.

Later, Apan et al. [12] measured the financial performance of the paper industry firms listed in Istanbul Stock Exchange. They took the period between 2011 and 2013 for performance analyses. They determined the criteria weights by using the entropy weighting method and they ranked the firms by using MAUT method. They underlined that the multi criteria decision making on financial performance was rare and there was a gap in the literature. In a land suitability determination study, Ding et al. [13] proposed a framework to solve the landfill site selection problem for construction wastes. They used sixteen criteria in the study and made use of entropy method and the analytic hierarchy process (AHP) to determine the criteria weights. The divided the potential landfill sites into three levels as; the most appropriate (0.38%), appropriate (17.58%), and inappropriate (82.04%). They highlighted that the most suitable areas were found insignificant and the findings of the paper could help decision makers on the selection of waste landfill sites.

In a methodologically closer study, Sepehri et al. [14] proposed a model for flood hazard mapping in Hamadan city Iran, and used geographical information based entropy weighting method. They used five criteria in the study and according to the results they determined 15.83% of the total study area as very highly hazardous. It was mentioned that the proposed study created a roadmap to reduce the consequences of floods.

As for an environmental study, Kaplanoglu [15] measured the performances of ten factories affiliated to the General Directorate of Machinery and Chemical Industry Institution of Turkey that produces products for defense industry. He used seven criteria in the proposed study and made use of entropy weighting method for determining the criteria weights and MAUT method was used to rank the ten factories. The related data belonged to 2015 and 2016 and interestingly the ranks of these years were found the same. Thus the author suggested trying additional multi criteria decision making techniques for future studies.

In addition, there are papers in the literature that solves problems for emergency situations. One of them is proposed by Da Silva et al. [16] to prioritize the flooding risks in urban areas by using MAUT. A case study was carried out in the Northeast of Brazil in order to validate the model. GIS was used for the visualizations of risk mapping. It was mentioned that the model was flexible and could be replicated in any region of the world. And another emergency related study was done by Nyimbili and Erden [17] dealing with the assessment of suitable areas for new emergency facilities for Istanbul province in Turkey. They used six criteria in the study and made use of AHP and Entropy methods for determining the criteria weights. In addition, GIS was used for the analysis and visualization of the model. Also a sensitivity analysis was conducted to understand the effects of adjusted criteria weights. As a result, they found that 28.1% of the study area was likely to be exposed to fire risks and new emergency facilities should be constructed within the area.

As a recent study in the literature, Meng et al. [18] tried assessing geothermally favorable areas in the northeastern China by using GIS-based MCDM method. They used five criteria in the study and proposed an AHP and Entropy Weighting Method to determine the criteria weights. In addition, they compared their findings with existing geothermal wells. According to the results the proposed favorable geothermal area prediction was effective.

Lastly, Chae et al. [19] proposed a framework to analyze the urban public services based on sustainable redevelopment. They used 24 indicators as evaluation criteria in the study and they made use of entropy weighting method to determine the criteria weights. In addition, GIS was used for suitability analysis. A case study was conducted in Jung-nang district, Seoul. They concluded that the proposed method could provide a valuable base for determining the public service locations.

In addition, there are also different studies on this topic which are not directly related with the proposed paper’s methodology. For example, in a mass vaccination center review study, Gianfredi et al. [20]
reviewed the previous experiences on mass vaccination centers. They chose 15 papers from the literature and summarized their findings. The identification of the vaccination site, the layout of the center, the identification of the number, role and type of the staff members, the training of the staff, the necessary equipment and vaccine transportation, cold-chain maintenance and storage were found as the most important issues in planning stage. Also Asgary et al. [21] proposed a simulation of a real drive-through COVID-19 mass vaccination clinic and reported the outputs. They used multiple integrated discrete event simulation (DES) and agent-based modeling method in AnyLogic software. Their simulations were helpful in aiding the optimization of UCHealth drive through mass vaccination clinic design and operations by exposing potential bottlenecks, overflows, and queuing. Thus the simulation tools were proven very useful for effective planning, design, and operations management of mass vaccination facilities. A vaccination capacity estimation paper was studied by Hanly et al. [22] in Australia. They used stochastic queuing network model for the capacity estimation of mass vaccination sites and small clinics. Also an interactive web-based queue simulation applet was proposed for allowing the users to explore their own assumptions. In summary, they could see the benefits of each distribution modes and the outcomes could be used for maximizing the vaccination rate.

Lastly, the cost estimation of mass vaccination at different COVID-19 vaccination locations in Beijing is studied by Zhang et al. [23]. They used questionnaire to collect the information of vaccination locations and semi-structured interviews and scan field records to acquire the detailed costs.

In summary, the proposed paper fills the gap in the literature since it makes use of a hybrid GIS, Entropy weight method and MAUT methodology and applies it to a real case study. In the next section, the applied methodology is defined in detail.

3. Methodology

In this paper, the applied methodologies namely entropy weight and MAUT methods are described, respectively. Then the flow chart of the study is given.

3.1. Entropy weight method

Since decision makers may have different opinions and perspectives in the evaluation of criteria, it cannot be said and assumed that each evaluated criterion has equal importance [24]. The criteria weights in MCDM problems can be handled in two different groups as subjective and objective weighting. While subjective methods determine the weights depending on the decision makers’ preference or judgment, objective methods get results by using the existing values exactly, without considering their preferences [25]. In cases where the preferences and judgments of decision makers are not reflected in the problem, objective methods such as entropy method is used to determine the criteria weights. In addition, the method is one of the preferred MCDM methods because it does not require complex mathematical calculations and can be easily applied to different multi criteria problems [26]. The Entropy method is preferred depending on the bases mentioned below:

- The decision maker’s preferences and judgments are not reflected in the decision problem.
- The subjective weights are not obtained; objective weights are used.
- The researchers are not required to have superior knowledge of mathematics to apply the Entropy method.

The entropy method starts with the decision matrix and reaches the solution with the following 5 steps respectively [27].

Step 1 Construct the decision matrix (D).

\[
D = \begin{bmatrix}
    x_{11} & x_{12} & \cdots & x_{1n} \\
    x_{21} & x_{22} & \cdots & x_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    x_{m1} & x_{m2} & \cdots & x_{mn}
\end{bmatrix}
\]  

\( x_{ij} \) is the performance value of the alternative \( i \) for the criterion \( j \) (\( i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \))

Step 2 Normalize the decision matrix \((P)\).

\[
p_j = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \quad \forall i, j
\]

\( p_j \) is the normalized value of the alternative \( i \) for the criterion \( j \)

\[
P = \begin{bmatrix}
    p_{11} & p_{12} & \cdots & p_{1n} \\
    p_{21} & p_{22} & \cdots & p_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    p_{m1} & p_{m2} & \cdots & p_{mn}
\end{bmatrix}
\]
Table 1

| #  | Criteria                           | Explanation                                  | Data Source                  | Analysis          |
|----|------------------------------------|----------------------------------------------|------------------------------|-------------------|
| C1 | Proximity to the hospitals         | Should be close to the hospitals in case       | Digitalized by operators     | Euclidean dist.,  |
|    |                                    | of emergencies                               |                              | Normalization     |
| C2 | Proximity to the crossroads        | Should be close to the crossroads to increase | Open Street Map Data         | Euclidean dist.,  |
|    |                                    | accessibility                                |                              | Normalization     |
| C3 | Proximity to the bus stops         | Should be close to the bus stops to increase  | Local authority             | Euclidean dist.,  |
|    |                                    | accessibility                                |                              | Normalization     |
| C4 | Proximity to the highways          | Should be close to the highways to increase   | Open Street Map Data         | Euclidean dist.,  |
|    |                                    | accessibility                                |                              | Normalization     |
| C5 | Proximity to the tram network      | Should be close to the tram network to increase| Digitalized by operators     | Euclidean dist.,  |
|    |                                    | accessibility                                |                              | Normalization     |
| C6 | Proximity to the heliports         | Should be close to the heliports to increase  | Local authority             | Euclidean dist.,  |
|    |                                    | accessibility                                |                              | Normalization     |
| C7 | Proximity to the medical waste     | Should be close to the medical waste centers  | Produced by operators        | Euclidean dist.,  |
|    | centers                             | to enhance sustainability                    |                              | Normalization     |
| C8 | Acreage                            | Should have enough space for mass vaccination | Area of the selected center  |                  |
|    |                                    | with 25 × 25 m                               |                              |                  |
| C9 | Proximity to the infrastructures   | Should be close to the infrastructures to serve| Open Street Map Data        | Euclidean dist.,  |
|    |                                    | efficiently                                   |                              | Normalization     |
| C10| Distance to the traffic jam        | Should be away from traffic jam to enhance    | Open Street Map Data         | Euclidean dist.,  |
|    |                                    | operation efficiency                          | Local expert                 | Normalization     |
| C11| Proximity to the parking lots      | Should be close to the parking lots to serve  | Digitalized by operators     | Euclidean dist.,  |
|    |                                    | efficiently                                   |                              | Normalization     |
| C12| Proximity to the population density| Should be close to the population density to  | Local authority             | Density,         |
|    |                                    | minimize transportation cost and traffic jam  |                              | Normalization     |

Step 3 Calculate the Entropy values ($E_j$).

$$E_j = -k \sum_{i=1}^{n} p_i \ln p_i, \forall j$$

where “k” ($k = 1/\ln m$) is a constant and satisfies $0 \leq E_j \leq 1$

Step 4 Calculate the degree of diversification ($d_j$).

$$d_j = 1 - E_j, \forall j$$

The higher value of $d_j$ means the criterion $c_j$ is more important for the problem.

Step 5 Calculate criteria weights.

The objective weight for each criterion can be obtained.

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \forall j$$

$$w_1 + w_2 + ... + w_c = 1$$

The mathematical formulation of the Entropy method is explained in detail at different studies [28–31]. In the next section, MAUT theory is defined.

3.2. Multiple attribute utility theory method

MAUT theory is based on the foundations of Von Neumann and Morgenstern’s utility theory, and the techniques of the method were developed by Keeney and Raiffa [33]. The aim of the theoretical study of MAUT is to simplify the multi-attribute utility evaluation process [27]. The MAUT method provides a logical and reasonable way to choose between conflicting criteria. The MAUT method works systematically to decide the variables and to provide a common basis, the most valuable alternative is tried to be selected [34]. In the MAUT method, qualitative and quantitative criteria could be used together. MAUT method is used in the study because of the qualitative and quantitative data within the study and the method’s easily understandable evaluation process.

Criteria which will be used in the evaluation process and alternatives are first determined in the MAUT method. The decision matrix that shows the performance values of alternatives ($a_i$) according to the criteria ($c_j$) is formed. Criteria weights ($w_j$) are calculated by using MCDM techniques.

$$\sum_{j=1}^{n} w_j = 1 \quad (i = 1, 2, ..., m; j = 1, 2, ..., n)$$ (8)

The various MCDM techniques such as Entropy, AHP, ANP, DEMATEL, etc. can be applied until this step. After forming the decision matrix and determination of the criteria weights, the steps of the MAUT method are applied [35,36].

The decision matrix is normalized using formula (9), the value “1” is assigned the best value and the value “0” is assigned to the worst value for each criterion. Utility values for each alternative is calculated by formula (10), higher utility value is better and alternatives are finally ranked.

$$u_i(x_i) = \frac{X - x_i}{x_i^* - x_i}$$ (9)

$$U(a_i) = \sum_{j=1}^{n} u_i(x_i)^* w_j$$ (10)

$x_i^*$ The best value for the related criterion.

$x_i$ The worst value for the related criterion.

$X$ Performance value of the alternative $i$ for the criterion $j$.

$u_i(x_i)$ The normalized value.

$w_j$ The weight value for the criterion $j$.

$U(a_i)$ The utility value for the alternative $i$.

In the next section, the proposed approach for the solution of the problem is given.

3.3. Proposed approach

The procedure followed in the evaluation and selection of mass vaccination sites is given in Fig. 1. As can be seen, the methodology is applied in five basic phases which are shown with the circled numbers.

The first stage of process is to determine the 12 evaluation criteria which will be summarized in the next section. Due to the lack of similar studies in literature, the authors and two doctors who work for the Gaziantep University Hospital assisted on the determination of criteria. In the second stage, the data (such as the locations of hospitals, tram network of the city, the locations of medical waste centers, and etc.) related to each criterion is collected and raster maps are overlaid. GIS data obtained from various sources are used to perform the spatial analysis conducted by ESRI ArcGIS 10.7.1 software. To ensure measurement integrity, the results of all are normalized after conducting the analysis. Then, a suitability map is produced. In the third stage (in...
Fig. 2. Criteria maps (part1).
(parallel to second step), each criterion is prioritized using Entropy Weight method. In the fourth phase, candidate locations such as stadiums, shopping malls, congress centers, and similar locations within the suitability map, are determined as potential sites, and the candidate locations are ranked using MAUT method. Although the “proximity to the population” is considered as a criterion, the candidate sites coverage capabilities are analyzed at the last step. To do so, the network analyst tool of ArcGIS is used for analyzing the amount of population to reach a candidate place.

In the next section, the case study and site selection criteria are given.

4. Case study

In this section, firstly the study area and considered criteria are described and then the methodology is applied.
4.1. Study area and description of criteria

Gaziantep city—which is the ninth most population and having above-average COVID-19 patients in Turkey—is selected to test the proposed model. Although Gaziantep city has nine different districts (most of them are far from city center), two main districts namely Sehitkamil and Şahinbey are considered as the study area. These two districts contain 68% of the total population.

In the proposed methodology, firstly the mass vaccination site selection criteria are determined by the help of expert group -medical doctors- and by means of the literature. As a result, comprehensive 12 criteria are determined and given in Table 1. Information about the data source and analysis is also given in Table 1. According to Table 1, it is clear to see that most of the criteria are based on proximity or distance.

The geographic values of each criterion are obtained using ESRI ArcGIS 10.7.1 software. In order to ensure measurement integrity, the
1 is represented in the figure by a completely white color, a completely black color represents 0. Thus, the favorable areas are illustrated in Table 2, the raw data for each criterion are available upon request.

The following assumptions are accepted while conducting this study, (i) the decision makers express their opinions without prejudice.

4.2. Prioritisation of the criteria

Entropy weights of the mass vaccination site selection criteria are calculated using the equations in Section 3.1. According to Table 3, the criterion C12 (Population) is the most important one. Other consider-able criteria are ranked as follows: “C4 (Proximity to the highways)” (weight is 0.361), “C5 (Proximity to the rail network)” (0.404) and “C6 Proximity to the airports” (0.039). The criterion C8 (Acreage) has the value of zero depending the whole alternative sites have the required acreage. As a result, the criterion C8 does not have a distinguishing feature at this application but it can be reevaluated for different mass vaccination site selection problems.

4.3. Ranking of alternatives

After calculating the entropy weights, ranking for the alternative sites are determined by using MAUT method. In Table 4, firstly all of the utility values $U(a_i)$ are calculated for each alternative with Eqs. (9) and (10) given in Section 3.2. The preferred site will have the highest total score. A4 gets the first rank according to the total utility value and A9, A11, A10, A1 are ranked, respectively. A1 gets the first rank with its favorable population and proximity to the highways. A9 comes 2nd position in spite of its most favorable proximity to the highways and A11 comes to 3rd position in spite of its most favorable population.

In addition to the ranking of alternatives, decision makers may perform sensitivity analysis to reveal the effect of changing the priority weights of decision attributes on the evaluation process and ranking of alternatives. The scenario that the whole criteria with equal weight (0.083) reveals the ranking A11, A4, A13, A14, A9, A15, A8, A6, A12, A2, A1, A3, A5, A7 respectively. The alternatives A4, A6, A8, A9, A10, A11 have similar ranking within the Entropy weighted and equal weighted scenario. On the other side, the alternatives A5, A13, A14, A15 have various ranking at these scenarios depending their performance scores at the criterion C3, C8, and C9, especially. The most important criterion is C12 with the weight degree 0.493. We increase and decrease the priority value of the criterion C12 at Table 5 to see the effects of the most important criterion on the ranking. In other words, the priority value (0.493) of the proximity to the population density is decreased and all criteria values are fixed and does not change, (ii) the COVID-19 is still in existence, and (iii) the decision makers express their opinions without prejudice.
remain generally stable for the criterion C12 wt from 0.1 to 0.8. The weight 0.9 and 1.0 causes some changes for the alternative A3, A6, and A9, especially. When the criterion C12 wt equals to these values (0.9 and 1.0), the most of the other criteria get the value of “0” at the normalization process. The sensitivity analysis results indicate that the alternatives A4, A9, A10, and A11 are the best in terms of mass vaccination because they tend to have the highest rankings despite exchanging priority weights.

In the next section, scenario analysis is conducted.

4.4. Scenario analysis and discussion

In this sub-section, the coverage performances of the pre-determined alternative locations are analyzed. To do so, the location-allocation analysis of ESRI ArcGIS 10.7.1 software is used. One of the objectives of mass vaccination centers is to maximize the covered population in acceptable access time or distance. The maximum coverage approach at the network analyst toolbar is applied under seven different radius values ranging from 1 km to 7.5 km. To see the performance of ranking,
The total population of the study area is 1,401,177 people. According to the results of Table 6, all population is covered when there is a radius of 7.5 km. As expected, first five alternatives (A4-A9-A11-A10-A1) provide better coverage than the five middle alternatives (A6-A8-A5-A3-A2) and also the middle five alternatives provide better coverage than the last five alternatives (A14-A12-A7-A15-A13).

Fig. 5 indicates the covered population ratios of each scenario with different distances. From scenario #1 to scenario 3, the decreased population ratio proves that the MAUT method provides reasonable and practical results. If all alternative locations operated as a vaccination center, approximately 96% of whole population will be covered. As an example, Fig. 6 shows the results of each scenario in case of 1 km radius.

5. Conclusion

The COVID-19 pandemic has an impact on almost every part of daily life, causing global economies to hold back, changing the work life and compelling the healthcare systems. Many governments implemented restrictions on human life to minimize the spread of the illness. But thanks to the approved COVID-19 vaccines, the world is forcing a way out of the pandemic. Although there are new mutations of the virus, some of the applied vaccines are still proven effective. In this scheme, mass vaccination is very important for the countries. Recently, many countries determined the mass vaccination sites and following a well-planned vaccination program such as USA, UK, Italy, Israel and Germany.

In this study, the mass vaccination site selection problem is solved for the ninth most crowded city of Turkey, namely Gaziantep. First, the selection criteria are determined, and the spatial data are collected. A GIS and the entropy weighting method is used for determining and mapping the relative importance levels of criteria and the MAUT method is used for ranking the potential mass vaccination sites. The population criterion is found as the most important selection criteria and the least important one is the acreage. Among possible fifteen mass vaccination site alternatives, the A4 (around the Şehitkamil Monument) performed the best and determined as the promising alternative. Since the results of MCDM technique differs depending on the weights of the criteria, scenario analysis is conducted to see the changes on the problem solution.

The main limitation of the study is that, MCDM techniques are based on human judgments and there is no “best” technique in the literature. But the use of GIS minimizes this issue because it is very useful with spatial information. Although twelve criteria are used for determining the mass vaccination site, other researchers may propose more or lesser criteria.

For the future work, alternative MCDM methods can be used and the results can be compared, additional site selection criteria can be proposed and the problem can be resolved. Also the same methodology can be applied in other crowded cities of Turkey, or the problem can be solved for other countries. It is believed that the outcomes of the proposed study could be used by city planners and decision makers to maximize the daily vaccination rates.

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