Location Selection and Project Designing for the Penitentiary Institution by using the TOPSIS Method

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Abstract

In this study, it is aimed to select the most appropriate location for penitentiary institutions, which is one of the high cost public buildings, among the 6 alternative locations in Sivas. Factors that are important to select the location of penitentiary institutions are determined and they are weighted according to critics of experts. In order to select the most appropriate alternative, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, which is one of the multi-criteria decision-making methods, is used. Alternative locations are ranked according to their suitability, using the TOPSIS method. Finally, the second alternative (ALT-2) is selected as the most appropriate location.

Keywords: *penitentiary institutions, multi criteria decision making methods, TOPSIS, location selection.*

Introduction

Penitentiary institutions are institutions in which convicts, and detainees are placed by the state, have decisive safety criteria. Health, education, rehabilitation, sports and employment facilities are also provided according to certain criteria and the execution of punishment is provided (Sağlam, 2003). Penitentiary institutions have a great importance on investment plans due to their high cost. Moreover, construction time of penitentiary institutions is approximately 2 years and considering there will be significant increase on convicted prisoners during that time, it is obvious that penitentiary institutions requires a serious planning.

Laws, regimes, even believes, might be subject to changes in a fast manner. However, buildings and the ideas to create those buildings live long (Fairweather & McConville, 2000). Indeed, buildings, which are the results of the ideas during design stage, serve in a same manner even after the change of ideas. A building, which has low efficiency, i.e. has bad design and a building that has good design have similar initial costs. However, operation the well-designed building is more economical (Spens, 1994).

The current penitentiary institutions in Turkey, as of 2018, are represented in Table 1, below. The overall capacity of those institutions is 210682 people. Until 2023, it is planned to construct 226 penitentiary institutions suitable for contemporary execution systems. At the same time, the total capacity will be reached to 341912 by the closing of 108 district penal execution institutions where training and improvement conditions are limited due to physical conditions and capacities (www.cte.adalet.gov.tr, 2018).

Table 1. Existing penitentiary institutions in Turkey.

#	Institution	Number
1	Closed Penitentiary Institution	289
2	Independent Open Penitentiary Institution	73
3	Reformatory School	3
4	Women Closed Penitentiary Institution	10
5	Women Open Penitentiary Institution	7
6	Children Closed Penitentiary Institution	7
	OVERALL	**389**

Building place selection process consists of following stages; definition of alternatives, analysis of alternatives, evaluation of alternatives and final selection (Yang & Lee, 1997). In location selection of a business, the most important criterion is maximizing the profit; in location selection of penitentiary institution the most important criteria are security and providing best execution services. In this study, it is aimed to select the most appropriate location for a penitentiary institution, which is one of the high cost public buildings, among the 6 alternative locations in Sivas, using TOPSIS method.

In the literature, there are many studies from various fields, which utilize one of the multi-criteria decision making methods, TOPSIS method, in order to select the most efficient option (Chang et al., 2015; Choudhary & Shankar, 2012; Erdal et al., 2019; Kaşak & Erdal, 2019; Kurt, 2014; Senvar, 2016; Suder & Kahraman, 2015).

Erden and Coşkun (2009), used Analytical Hierarchy Process (AHP), which is one of the multi-criteria decision-making methods, to determine fire station location. In their study, it has been determined that 35 different fire brigades in Istanbul do not meet international standards and they proposed 17 station areas. Demirdöğen and Bilgili (2004) conducted studies to determine the factors that should be considered in the selection of places for the organized industrial zones in Erzurum. In the study, several criteria such as additional facility facilities, qualified labor, rent, transportation costs and proximity to residential areas were considered. Aydın et al. (2009) investigated optimum location selection of a hospital, which is planned to be built in Ankara. In the study, which utilizes AHP as a multi-criteria decision-making method, alternatives were ranked considering; environmental factors, building characteristics, investment costs, demographic structure and building location etc. Yücel and Ulutaş (2009) have conducted research on location selection of a cargo company in Malatya using ELECTRE method. In the study, alternative lands were ranked according to criteria such as proximity to the market, competition conditions, traffic conditions and closeness to the center. As a result, Şıra Pazar was determined as the most suitable area. Karabacak et al. (2016) used the TOPSIS method in the construction sector, in order to select the location of highway construction sites. In the study, which used 3 main criteria and 9 sub-criterion levels, the most appropriate site was selected considering the weight of each criterion.

The Criteria to be Considered in the Selection of the Place for the Penitentiary Institutions

As stated in the related sections of the Law on Criminal and Security Measures Enforcement No. 5275, the penitentiary institutions are the institutions in which the convicts are kept safely in accordance with the basic principles of the execution system. The penitentiary institutions were built in 23 different types throughout the country until this time. Today, however, there are 7 types that are under construction, which are: High Security, L, S, T, R, Open, Child (Figure 1) and Women prison execution institutions. Studies are being carried out in the regions, where penitentiary institutions are required, considering both the prisoner profile and the conditions of the region. In order to determine the suitability of the parcels examined in the study for the construction of the penitentiary institution, evaluation criteria and weight ratios of these criteria are determined by experts in the field. Following that the most suitable option among the alternatives is determined. The selected criteria determined according to the results of the questionnaire with the experts, and the reasons for selecting these criteria are explained below.



Figure 1: Child closed penitentiary institutions.

Expenditures Required for Infrastructure

Under the title of infrastructure, the basic elements can be listed as water, electricity and natural gas facilities and sewerage lines. Water cut for 24-hour in prison institutions will cause undesirable events in the institution. In the case of a water supply line built by the related municipalities near the land, water is supplied using the connections through the land. However, for example, if a penitentiary institution is constructed at a remote location from the province/district center, the construction of an intercity line by the relevant municipality will increase the cost and extend the construction period.

Slope of the Surface

Due to the fact that the penitentiary institutions have large ground area, even the small changes in the level of the surface can lead to very large excavation and filling costs. The balancing option in parcels with +/- inclination in itself depends on the quality of the material to be filled. The ground area for a 492-person high-security penitentiary closed penal execution institution is approximately 22000 m^2. In the construction of the structures with such a large foundation area in the site plan study, the positioning of the long side of the building in a relatively less inclined direction reduces the excavation and filling costs.

Width of the Land

The penitentiary institutions are composed of main building, control building, visitor acceptance building, heat center, gendarmerie building and lodgings. In the open penitentiary institutions, large workshops are being constructed in addition to these constructions. For this reason, the size of the proposed land provides convenience in the study of the site plan. In addition, if a new penitentiary institution is needed in the region in the future, the breadth of the existing land may enable the construction of a second penitentiary institution in the same parcel.

Feasibility for Workshop Activities

If the necessary workshops are built for the products that can be produced in the region on the parcel, as a consequence of workshop activities, convicts can get a profession. Moreover, those activities would be a revenue source for the state. For this reason, the conditions of the area in which the proposed immovable is located are also considered in the preliminary examination stage for the construction of the penitentiary institution.

Building Area to be Demolished on the Land

If there are already existing structures in the parcels proposed for the construction of the penitentiary institution, it should be considered to use these structures in line with the needs of the institution. However, the buildings will have to be demolished if they are in the way of obstacles to the construction of the penitentiary institution. In this case, additional costs for demolition should be considered in land selection.

Transportation to City/District Center

Penitentiary institutions are constantly in need of outsourcing materials due to their 24-hour work. Distances to regional centers are important in meeting the essential needs of food, cleaning and maintenance. Moreover, if the staff in charge of the institution stay in the center of the city, problems that they will encounter during the transportation to institution, will affect their performances'. For this reason, the penitentiary institution should not be built far away from the regional centers.

Settlement in Surrounding Parcels

Penitentiary institutions are the ones for which your safety is preliminary. For this reason, the circulation around the institution is always perceived as a threat. The penitentiary institutions built many years ago and filled with the surrounding structures due to the development of the region are always at risk of prohibited substance entry and security weaknesses. Attention should be paid to this issue in the investigation of the land in order not to encounter similar situations.

Ground Reinforcement Costs

For security reasons, the penitentiary institutions consisting entirely of reinforced concrete walls, should be built on high grounds with high carrying capacity due to the weight of the building. Otherwise, due to the different amount of settlement, cracks can occur in the building. This situation also causes security weakness. For this reason, soil surveys to be carried out in the land investigation process should be analyzed correctly.

Weather Conditions

Penitentiary institutions are the places, where there is a continuous detention and transfer occurs, due to its dynamic structure. Especially, transportation between the courthouse and the hospital should be continuous. The construction of a penitentiary institution in a region where transportation cannot be provided or can be provided with difficulties during certain periods of the year can lead to both security problems and difficulties for the visitors of detainees and prisoners. For this reason, during the land survey, extensive information about the seasonal conditions of the region should be obtained and the information should be analyzed well.

TOPSIS Method

TOPSIS was developed by Hwang and Yoon in 1981. TOPSIS is also defined as positive ideal dissociation similarity or relative affinity index (Lin et al., 2008). It is preferred to obtain the ideal solution by profit maximization and cost minimization. In the TOPSIS method the result is obtained step by step (Dumanoğlu & Ergül, 2010).

Step 1: Formation of the decision matrix (A)

The decision matrix is the first and most important step of the TOPSIS method. Therefore, the input data must be correct when this matrix is generated. Otherwise, even if the mathematical calculations are done correctly, the correct alternative will not be found. In the decision matrix, the rows indicate alternatives, and the columns indicate criteria.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1p} \\ a_{21} & a_{22} & \dots & a_{2p} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \dots & a_{mp} \end{bmatrix} \quad (1)$$

Step 2: Obtaining normalized decision matrix (N)

For each value in the matrix created in the first step, Eq. 2 is applied. The new matrix generated is called as normalized decision matrix.

$$N_{\text{ij}} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \; (i = 1, \dots, m \; ve \; j = 1, \dots, n) \quad (2)$$

Step 3: Obtaining weighted normalized matrix (V)

At this stage, the weight coefficients (w) of each criterion obtained in the course of earlier studies for the solution of the problem are multiplied by the data given in the matrix in the second step. This new matrix created is called the weighted normalized matrix.

$$V_{ij} = \begin{bmatrix} w_1 n_{11} & w_2 n_{12} & \dots & w_n n_{1p} \\ w_1 n_{21} & w_2 n_{22} & \dots & w_n n_{2p} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 n_{m1} & w_2 n_{m2} & \dots & w_n n_{mp} \end{bmatrix} \rightarrow \quad V_{ij} = \begin{bmatrix} v_{11} & v_{12} & \dots & v_{1p} \\ v_{21} & v_{22} & \dots & v_{2p} \\ . & & & . \\ . & & & . \\ . & & & . \\ v_{m1} & v_{m2} & \dots & v_{mp} \end{bmatrix} \tag{3}$$

***Step 4:* Obtaining ideal (S_i^*) and negative ideal (S_i^-) solution values**

In this step, the analysis of numerical data becomes important. The optimum values required by the project manager for each criterion must be determined. This situation may correspond to the highest value for some criteria and the lowest for the others (Azizi, 2017).

***Step 5:* Determination of distances to ideal (S_i^*) and negative ideal (S_i^-) solution values**

The predetermined ideal distance values are determined by Eq. 4 and the negative ideal distance values are determined by Eq. 5.

$$S_i^* = \sqrt{\left(\sum_{j=1}^{a} \left(V_{ij} - V_j^* \right)^2 \right)} \tag{4}$$

$$S_i^- = \sqrt{\left(\sum_{j=1}^{n} \left(V_{ij} - V_j^- \right)^2 \right)} \tag{5}$$

***Step 6:* Calculation of relative closeness to ideal solution**

The coefficient C_i^* varies from 0 to 1. Considering the ideal and negative ideal values, these coefficients obtained separately for each alternative are sorted from 1 to 0. The closest value to 1, will be the best alternative.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{6}$$

Selection of The Best Land Alternative in Sivas for Construction of Penitentiary Institution Using TOPSIS Method

The information on the 6-land proposed for the construction of the penitentiary institution in Sivas is given in Table 2 and the criteria to be used in practice are given in Table 3.

Table 2. Proposed parcels and the abbreviation to be used in application.

Alternative	Abbreviation
Block Number 5584, Parcel 304, Çayboyu District,	ALT-1
Block Number 181, Parcel 12,14,15,16,17,43,44,45,46,64,203,204,205, Kılavuz District,	ALT-2
Block Number 195, Parcel 8, Kılavuz District,	ALT-3
Parcel 576, Budaklı District	ALT-4
Parcel 1576,1577,1578, Şarkışla -Elmalı District,	ALT-5
Block Number 104, Parcel 1, Hafik-Durulmuş District	ALT-6

Table 3. Abbreviation for the criteria to be used in application and their weight coefficient.

Criteria	Notation	Weigh Coefficient (w)
Expenditures Required for Infrastructure	A	0,15
Slope of the Surface (%)	B	0,23
Width of the Land (m^2)	C	0,21
Feasibility for Workshop Activities (Annual Profit ₺)	D	0,05
Building Area to be Demolished on the Land (m^2)	E	0,02
Transportation to City / District Center (km)	F	0,11
Settlement in Surrounding Parcels (m)	G	0,03
Ground Reinforcement Costs (₺)	H	0,13
Weather Conditions (0-100)	K	0,07

The weighting coefficients (w) given in Table 2, consist of the arithmetic mean of the values determined on the basis of the questionnaire survey conducted with the persons who were involved in the place selection for the penitentiary institutions.

Step 1: Formation of the decision matrix

At this stage, each alternative has been classified according to the previously mentioned criteria. It should be noted that an error in decision matrix will lead to wrong results (Table 4).

Table 4. Decision matrix.

	A	B	C	D	E	F	G	H	K
ALT-1	1 250 000	15%	59 000	550 000	250	8,00	400	150 000	80
ALT-2	250 000	5%	250 000	2 500 000	1000	5,00	750	500 000	100
ALT-3	200 000	7%	80 000	800 000	0	4,00	500	1 000 000	100
ALT-4	2 000 000	6%	81 000	800 000	0	20,75	400	450 000	75
ALT-5	1 000 000	5%	150 000	1 500 000	0	75,00	850	1 000 000	50
ALT-6	2 000 000	3%	70 000	700 000	0	29,00	750	5 000 000	15

Step 2: Obtaining normalized decision matrix

The normalization of decision matrix is done by applying Eq. 2 to each criterion (Table 5).

Table 5. Normalized decision matrix.

	A	B	C	D	E	F	G	H	K
ALT-1	0,38276	0,78087	0,18093	0,16915	0,24254	0,09561	0,25726	0,02862	0,42915
ALT-2	0,07655	0,26029	0,76663	0,76887	0,97014	0,05975	0,48237	0,09539	0,53644
ALT-3	0,06124	0,36441	0,24532	0,24604	0,00000	0,04780	0,32158	0,19078	0,53644
ALT-4	0,61242	0,31235	0,24839	0,24604	0,00000	0,24798	0,25726	0,08585	0,40233
ALT-5	0,30621	0,26029	0,45998	0,46132	0,00000	0,89632	0,54668	0,19078	0,26822
ALT-6	0,61242	0,15617	0,21466	0,21528	0,00000	0,34658	0,48237	0,95390	0,08047

Step 3: Obtaining weighted normalized matrix (V)

At this stage, the weighted normalized matrix is obtained by multiplying the weight coefficients (w), which represents effect of each criterion on the construction of the penitentiary institution as a result of institutional experiences and the values in Table 5. Obtained results are given in Table 6.

Table 6. Weighted normalized matrix.

Weight Coefficient	**0,15**	**0,23**	**0,21**	**0,05**	**0,02**	**0,11**	**0,03**	**0,13**	**0,07**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**K**
ALT-1	0,05741	0,17960	0,03799	0,00846	0,00485	0,01052	0,00772	0,00372	0,03004
ALT-2	0,01148	0,05987	0,16099	0,03844	0,01940	0,00657	0,01447	0,01240	0,03755
ALT-3	0,00919	0,08381	0,05152	0,01230	0, 00000	0,00526	0,00965	0,02480	0,03755
ALT-4	0,09186	0,07184	0,05216	0,01230	0, 00000	0,02728	0,00772	0,01116	0,02816
ALT-5	0,04593	0,05987	0,09660	0,02307	0, 00000	0,09860	0,01640	0,02480	0,01878
ALT-6	0,09186	0,03592	0,04508	0,01076	0, 00000	0,03812	0,01447	0,12401	0,00563

Step 4: Obtaining ideal (S_i^*) and negative ideal (S_i^-) solution values

The ideal solution values have been determined for the criteria to be considered in the selection of the place for the penitentiary institution. These values are those closest to 0 in criteria that brings cost and closest to 1 in criteria that benefits the organization (Table 7).

Table 7. Ideal and negative ideal solution values.

	A	B	C	D	E	F	G	H	K
Ideal Solution Values	0,00919	0,03592	0,16099	0,03844	0,00000	0,00526	0,01640	0,00372	0,03755
Negative Ideal Solution Values	0,09186	0,17960	0,03799	0,00846	0,01940	0,09860	0,00772	0,12401	0,00563

Step 5: Determination of distances to ideal (S_i^*) and negative ideal (S_i^-) solution values

S_i^* and S_i^- values are determined using Eq. 4 and 5. These values for each alternative are used in the calculation of the value of C_i^*, which is indicated in Step 6 (Tables 8 and 9).

Table 8. Table of ideal solution values.

	A	B	C	D	E	F	G	H	K	TOTAL	S_i^*
ALT-1	0,0023	0,0206	0,0151	0,0009	0,0000	0,0000	0,0001	0,0000	0,0001	0,0392	0,1979
ALT-2	0,0000	0,0006	0,0000	0,0000	0,0004	0,0000	0,0000	0,0001	0,0000	0,0010	0,0322
ALT-3	0,0000	0,0023	0,0120	0,0007	0,0000	0,0000	0,0000	0,0004	0,0000	0,0155	0,1243
ALT-4	0,0068	0,0013	0,0118	0,0007	0,0000	0,0005	0,0001	0,0001	0,0001	0,0214	0,1461
ALT-5	0,0014	0,0006	0,0041	0,0002	0,0000	0,0087	0,0000	0,0004	0,0004	0,0158	0,1258
ALT-6	0,0068	0,0000	0,0134	0,0008	0,0000	0,0011	0,0000	0,0145	0,0010	0,0376	0,1939

Table 9. Table of negative ideal solution values.

	A	B	C	D	E	F	G	H	K	TOTAL	S_i^-
ALT-1	0,0012	0,0000	0,0000	0,0000	0,0002	0,0078	0,0000	0,0145	0,0006	0,0242	0,1556
ALT-2	0,0065	0,0143	0,0151	0,0009	0,0000	0,0085	0,0000	0,0125	0,0010	0,0588	0,2425
ALT-3	0,0068	0,0092	0,0002	0,0000	0,0004	0,0087	0,0000	0,0098	0,0010	0,0362	0,1902
ALT-4	0,0000	0,0116	0,0002	0,0000	0,0004	0,0051	0,0000	0,0127	0,0005	0,0305	0,1747
ALT-5	0,0021	0,0143	0,0034	0,0002	0,0004	0,0000	0,0001	0,0098	0,0002	0,0306	0,1748
ALT-6	0,0000	0,0206	0,0001	0,0000	0,0004	0,0037	0,0000	0,0000	0,0000	0,0248	0,1574

Step 6: Calculation of relative closeness to ideal solution (C_i^*)

The C_i^* value for each alternative is calculated using Eq. 6 (Table 10). By sorting these calculated values from largest to smallest, the first alternative has been determined as the most appropriate solution to solve the problem.

Table 10. Relative closeness values to ideal solution.

ALTERNATIVE	S_i^*	S_i^-	C_i^*	RANKING
ALT-1	0,197940983	0,155630503	0,440167007	6
ALT-2	**0,032186767**	**0,242514298**	**0,882829844**	**1**
ALT-3	0,12430601	0,190159409	0,6047069	2
ALT-4	0,146140493	0,174734506	0,544556311	4
ALT-5	0,125760994	0,174812901	0,581597084	3
ALT-6	0,193931091	0,157411302	0,448028206	5

Conclusion

Public buildings are built on taxation from the citizens of the state based on the law. For this reason, every citizen has a share in each public expenditure. Therefore, for the constructions that are constructed with the contributions of all the citizens of our country, the most productive solutions should be obtained with the least cost. Public employees are responsible for providing these criteria for the relevant investments.

Penitentiary institutions are the ones that should be studied in detail because of their high costs and positive and negative effects on the region where they are built. These institutions will provide service for about 50 years. In order to ensure that the costs in both construction and use phases are minimized for those institutions and that they are built at the most suitable place, TOPSIS method is used for finding the most appropriate option. In this study, it is determined that the 2nd alternative is the most suitable option among the 6 land alternatives in Sivas, for

the construction of the Penitentiary institutions. The alternatives, which are in order from highest C_i^* to lowest C_i^* are 2-3-5-4-6-1, respectively.

It is believed that the TOPSIS method, which is used in the selection of the places for the penitentiary institutions, should be preferred in all investments, in order to use public resources efficiently and effectively.

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