Chapter 39

Location Selection for Penitentiary Institutions by VIKOR Method: A Case Study

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Abstract

This paper presents a case study to decide an appropriate land acquisition in Sivas city of Turkey for a penitentiary institution that has a high-cost public building. Criterions that may be effective in the location of the penitentiary institution were determined and weighted according to expert opinions. In order to select the most appropriate choice, the Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method, one of the multi-criteria decision-making models, was utilized. Alternative locations were ranked according to their suitability considering VIKOR method. Therefore, it was decided to build the construction at Kılavuz Street, 181st city block.

Keywords: penitentiary institutions, multi-criteria, decision methods, VIKOR method, location selection

1. Introduction

Penitentiary institutions are public enterprises where convicts and detainees are put in by the state. These institutions have determinant security criterions and contain a number of opportunities such as health, education, rehabilitation, job, and sports under determinant conditions [1]. Additionally, penitentiary institutions take place in top positions of investment plan because of their high costs. Furthermore, when it is taken all together to build construction in a nearly 2-year schedule and to increase the number of convicts and detainees during construction time, it is a serious operation that needs a significant plan.

Legislations, regimes, and even beliefs can change quickly. However, buildings live for a longer time than the ideas that created them [2]. Indeed, constructions, the result of opinions that exist at the design phase, serve the same way after the changing of opinions. Badly designed and well-designed constructions have similar final estimated costs. On the other hand, well-designed constructions need lower operational costs [3, 4]. Existing penitentiary institutions in Turkey are shown in **Table 1**. The capacity of these buildings is 210,682 persons.

Process of location selection is composed of identifying and analyzing of alternatives and making decisions [5]. While the most important criterion of location selection for ordinary companies is a margin of profit, it is also rendering of services safely for penitentiary institutions. It is clear to see in the literature that there are many studies including Vise Kriterijumska Optimizacija I Kompromisno Resenje

Sort	Institution	Number
1	Closed penitentiary institution	289
2	Independent open penitentiary institution	73
3	Child education center	3
4	Women closed penitentiary institution	10
5	Women open penitentiary institution	7
6	Child closed penitentiary institution	7
	Total	389

Table 1.
Type and number information of existing penitentiary institutions.

(VIKOR) method. This is significant to show how much the method is useful and has a wide usage of utilization. International studies have been conducted in order to choose the most efficient option in many different fields related to VIKOR method, in which one of the multi-criteria decisions is making methods [6–35]. Cristóbal determined the importance of contractor selection in the determination of cost analysis by taking VIKOR method into account in increasing project expenses [36]. Civic conducted a study to improve the energy efficiency of the structures by using VIKOR method from a multi-criteria decision-making method [37]. Antucheviciene et al. used the VIKOR method to determine the rate of re-evaluation of abandoned structures [38]. Onder and Yildirim [39] used VIKOR method to categorize 11 logistic villages in Turkey based on 8 different criterions. In this study, criterions such as land values of villages; distances to industrial areas, airports, and railways; etc. were taken into consideration [39]. Uzun and Yildirim used the VIKOR method to select the main machine and generator by using criteria such as cycle volume, investment cost, fuel, and oil consumption in the shipbuilding process [40]. Çelikbilek carried out a study on the selection of the hospital location by VIKOR method using 10 different criterions weighted by the members of the board of directors [41]. Uçakçıoğlu and Eren, using VIKOR method in their study, tried to choose the most suitable alternative among alternative investment projects in air defense industries by considering criteria such as project budget, duration, dependency status, number of personnel, and contribution to economy [42]. In this study, it was carried out to select the most appropriate location among the six alternative lands proposed with the VIKOR method for the penitentiary institution, which is one of the high-cost public enterprises.

2. Issues to be cared for location selection of penitentiary institutions

As defined by the law on the Execution of Penalties and Security Measures with number 5275, penitentiary institutions are places where convicts are safely accommodated in accordance with the basic principles of the execution system, and the main purpose is to ensure that the convicts are reintegrated and prevented from committing a crime.

Penitentiary institutions have been constructed in 23 different types until today in Turkey. However, today, seven different types are being constructed. These are high security, L, S, T, R, open, child (**Figure 1**), and women penitentiary institutions.

Both the convict profile and the region conditions are considered in the regions needed for the penitentiary institutions. In order to determine the suitability of the parcels examined within the process to the construction of the penitentiary



Figure 1.
Child closed penitentiary institution.

institutions, the evaluation criterions and the weight ratios of these criterions are determined by the experts in this field. After this process, the main goal is to select the most appropriate option among alternatives. In the following part of the study, information about nine criterions, chosen as a result of a survey with experts, is given.

2.1 Expense required for infrastructure

Water, electricity, and sewage lines are the important components of an infrastructure system. In case of a water cut in penitentiary institutions, it is highly possible to cause a disorder. Based on this example, it is preferred, and it will be beneficial to locate these facilities close to the water conveyance pipelines. In case of decision for a location far away from these lines, it will both have a high investment cost because of water conveyance pipes construction and extension of construction time.

2.2 Surface slope

Minor elevation differences can lead to very large excavation and filling costs because the penitentiary institutions are buildings with a large sitting area. The balancing option of cut-fill of parcels depends if quality of the fill material is adequate or not. High-security closed penitentiary institutions with a 492-person capacity have 22,000 m^2 sitting area approximately. To place the long side of the structure over less inclined direction is highly effective for reducing excavation and filling costs.

2.3 Premises' width

In addition to main buildings, penitentiary institutions are composed of a heat center, a gendarmerie building, main entrance building, reception office, and housings. In open penitentiary institutions, wide prison workshops are built additionally. Furthermore, the area of existing land is very important in case a new penitentiary institution is required. If the area is suitable and large enough, it can lead to a new construction in it.

2.4 Suitability for prison workshop activities

If the prison workshops for the products to be produced in the region on the parcel are built, both convicts will acquire a profession as a result of their work

activities, and a source of income will be created for the state. Therefore, the conditions of the region where the proposed premises are located are also taken into consideration in the preliminary investigation stage for the construction of the penitentiary institution.

2.5 Area to be demolished on land

In case of existing buildings in the proposed parcels for the construction of the penitentiary structure, firstly it should be thought to preserve and be used according to the needs of the institution. However, the structures will have to be demolished if they are an obstacle to the construction of the penitentiary institution. In this case, inevitable costs for demolition will be one of the determinants for land selection.

2.6 Transportation to city/town center

Penitentiary institutions may need materials from outside at any time because they work for 24 hours. Thus, distance is critical for requirements such as food, cleaning, and maintenance-repair services. If the employees in the institution stay in the district center, the problems they will have in transportation will also affect their performance. For this reason, the penitentiary institutions are not constructed far away from the regional centers.

2.7 Closest constructions

Security is at the forefront for penitentiary institutions, and construction activities around the land are perceived as a threat. The penitentiary institutions, which were built many years ago and filled with buildings due to the development of the region, always carry a risk in terms of their security vulnerabilities with the entry of banned substances. This issue is taken into consideration when investigating the land in order to avoid similar situations.

2.8 Ground reinforcement costs

Due to the weight of the building, the penitentiary institutions consisting entirely of reinforced concrete walls for safety reasons are built on high-strength grounds. Otherwise, it is possible to see cracks over construction materials such as walls because of ground subsidence. It is also a vulnerability for security. Therefore, ground investigations should be made strictly.

2.9 Suitability of season conditions

The penitentiary institutions are one of the institutions that have continuous transfers due to their dynamic nature. Especially the transportation to the courthouse and to the hospital should be without any problem. The construction of a penitentiary institution in a region, where transportation cannot be provided or can be provided only at certain times of the year, may both cause security weakness and lead to difficulties when considering the visitors of prisoners and convicts. For this reason, it is necessary to obtain detailed information about the seasonal conditions of the region and analyze that information well.

3. VIKOR method

VIKOR method aims at selecting the most appropriate option likewise other multi-criteria decision-making methods. VIKOR method was discovered by Serafim Opricovic. This method is preferred for determining the solution among the alternatives with contradictory properties [43]. In order to use VIKOR method, a comparison is made with the features, which can be more moderate and have alternative, rather than the essential criterions, and the result is achieved [44]. Steps of VIKOR method are listed and explained with five subheadings [45].

3.1 Step 1: to constitute decision matrix (A) and to calculate the best and worst criterion values

Decision matrix is the first and most important step of VIKOR method. In order to constitute this matrix, data used must be correct. Otherwise, even if all calculation is true, correct alternative will not able to be selected. In the decision matrix, the rows show alternatives and the columns show the criteria:

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

After constituting the matrix, the best and worst values were detected by using Eqs. (2) and (3). It does not mean that the highest value is the best and the lowest one is the worst at this stage. The main objective is public welfare. The value that enhances the public welfare will be accepted as the highest value independently of high or low numerical values.

$$f_i^* = \max_{x_{ij}} \quad (2)$$

$$f_i^- = \min_{x_{ij}} \quad (3)$$

3.2 Step 2: to obtain normalized decision matrix (N)

In the second step, by normalization process performed in a problem including m alternatives and n criterions, r normalization matrix is obtained. The elements of r matrix are calculated with Eq. (4):

$$r_{ij} = \frac{f_i^* - x_{ij}}{f_i^* - f_j^-} \quad (4)$$

3.3 Step 3: to obtain weighted normalized decision matrix (V)

In the third step, each of the r_{ij} values obtained in the previous step is multiplied by the weight values (w_j). The elements of the new matrix obtained are called v_{ij}. The v_{ij} value is calculated by using Eq. (5):

$$V_{ij} = r_{ij}.w_j \quad (5)$$

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1p} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2p} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mp} \end{bmatrix} \rightarrow V_{ij} = \begin{vmatrix} v_{11} & v_{12} & \dots & v_{1p} \\ v_{21} & v_{22} & \dots & v_{2p} \\ . & & & . \\ . & & & . \\ . & & & . \\ v_{m1} & v_{m2} & \dots & v_{mp} \end{vmatrix} \quad (6)$$

3.4 Step 4: to obtain S_i, R_i, S_i^*, S_i^- values

After obtaining the weighted normalized matrix, the sum of the criteria for each alternative is called S_i, and the maximum value between the criteria is called $R\dot{I}$. These values are calculated with Eqs. (7) and (8):

$$S_i = \sum_{j=1}^{n} w_j . \frac{f_i^* - x_{ij}}{f_i^* - f_j^-} \quad (7)$$

$$R_i = \text{Max}\left(w_j . \frac{f_i^* - x_{ij}}{f_i^* - f_i^-} \right) \quad (8)$$

3.5 Step 5: to calculate Q_i values, to find out the most appropriate alternative, and to control stage

In VIKOR method, there are two different control mechanisms to determine the consistency of the most appropriate alternative found as a result of the calculations. In order to calculate the Q_i value used in the control mechanisms, Eq. (9) is utilized.

The first audit condition is called the *Acceptable Advantage*. In this condition, when the Q_i values are sorted from small to large, the first alternative is called A^1, and the second one is called A^2. In order to provide the acceptable advantage condition, the operations specified in Eqs. (10) and (11) are made. The value of m in Eq. (11) shows the alternative number. If equality is provided, the initial audit condition is completed:

$$Q_i = \frac{q.(S_i - S^*)}{S^- - S^*} + \frac{(1-q).(R_i - R^*)}{R^- - R^*} \quad (9)$$

$$Q(A^2) - Q(A^1) \geq DQ \quad (10)$$

$$DQ = \frac{1}{m-1} \quad (11)$$

The second audit condition is the *Acceptable Stability Condition*. At this stage, it is desirable to have the minimum value of S_i and R_i of the most appropriate A alternative. If the condition is provided, the alternative of A^i is considered the most appropriate choice.

4. Location selection for penitentiary institutions by VIKOR method in Sivas city

The information regarding the six locations proposed for the construction of the penitentiary institution in Sivas is given in **Table 2**, and the criterions to be used in the application are given in **Table 3**.

Alternative	Abbreviation
Çayboyu street 5584 city block 304 parcels	ALT-1
Kılavuz street 181 city block 12-14-15-16-17-43-44-45-46-64-203-204-205 parcels	ALT-2
Kılavuz street 195 city block 8 parcels	ALT-3
Budaklı street 576 parcel	ALT-4
Şarkışla town Elmalı village 1576-1577-1578 parcels	ALT-5
Hafik town Durulmuş village 104 city block 1 parcel	ALT-6

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

Criterion	Name	Weight coefficient (w)
Expenses required for infrastructure (₺)	A	0.15
Surface slopes (%)	B	0.23
Location area (m^2)	C	0.21
Eligibility for prison workshops (yearly profitability ₺)	D	0.05
Area to be destroyed on location (m^2)	E	0.02
Transportation to city/town center (km)	F	0.11
Closest constructions (m)	G	0.03
Ground reinforcement costs (₺)	H	0.13
Suitability of season conditions (0–100)	K	0.07

Table 3.
Abbreviations to be used in the application and coefficient of weights.

The weight coefficients (w) given in **Table 3** are arithmetical means of the values determined as a result of the survey conducted with the persons who are involved in the selection of places for the penitentiary institutions.

4.1 Step 1: to constitute decision matrix (A) and to calculate the best and worst criterion values

Critical criterions for the selection of locations for penitentiary institutions and technical data of alternative lands belonging to Sivas province were prepared by the decision matrix. Since the errors in this process will cause the wrong alternative to be selected, the technical data should be analyzed well while preparing the matrix. The matrix is presented in **Table 4**.

	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

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
f_i^*	200,000	3%	250,000	2,500,000	0	4.00	850	150,000	100
f_i^-	2,000,000	15%	59,000	550,000	1000	75.00	400	5,000,000	15

Table 5.
Decision matrix with f_i^* and f_i^- values.

	A	B	C	D	E	F	G	H	K
ALT-1	0.58333	1.00000	1.00000	1.00000	0.250	0.05634	1.00000	—	0.23529
ALT-2	0.02778	0.16667	—	—	1.000	0.01408	0.22222	0.07216	—
ALT-3	—	0.33333	0.89005	0.87179	—	—	0.77778	0.17526	—
ALT-4	1.00000	0.25000	0.88482	0.87179	—	0.23592	1.00000	0.06186	0.29412
ALT-5	0.44444	0.16667	0.52356	0.51282	—	1.00000	—	0.17526	0.58824
ALT-6	1.00000	—	0.94241	0.92308	—	0.35211	0.22222	1.00000	1.00000

Table 6.
Normalized decision matrix.

The first step is completed by adding the best (f_i^*) and the worst (f_i^-) criterion values to end of the matrix. In determining these criterions, the ones close to the optimum numerical value for each alternative are determined as the best value (**Table 5**).

4.2 Step 2: to obtain normalized decision matrix (N)

Equation (4) was applied to each criterion and normalized decision matrix was obtained (**Table 6**).

4.3 Step 3: to obtain weighted normalized decision matrix (V)

At this stage, the weight coefficients (w) which show the effect of each criterion in the construction of the penitentiary institution as a result of the institutional experiences were determined by multiplying the data in **Table 6**. Weighted normalize matrix is presented in **Table 7**.

4.4 Step 4: to obtain S_i, R_i, S_i^*, and S_i^- values

S_i and R_i are calculated by using Eqs. (7) and (8), respectively. The lowest values of calculated S_i and R_i numbers are called as R^- and S^-; the highest ones are also called as R^* and S^*. The results obtained in this step are shown in **Table 8**.

(w)	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	0.08750	0.23000	0.21000	0.05000	0.005	0.00620	0.03000	—	0.01647
ALT-2	0.00417	0.03833	—	—	0.020	0.00155	0.00667	0.00938	—
ALT-3	—	0.07667	0.18691	0.04359	—	—	0.02333	0.02278	—
ALT-4	0.15000	0.05750	0.18581	0.04359	—	0.02595	0.03000	0.00804	0.02059
ALT-5	0.06667	0.03833	0.10995	0.02564	—	0.11000	—	0.02278	0.04118
ALT-6	0.15000	—	0.19791	0.04615	—	0.03873	0.00667	0.13000	0.07000

Table 7.
Weighted normalize matrix.

	S_i	R_i	0.00	0.25	0.50	0.75	1.00
			Q_i (q = 0.00)	Q_i (q = 0.25)	Q_i (q = 0.50)	Q_i (q = 0.75)	Q_i (q = 1.00)
ALT-1	0.635168	0.230000	1.000000	0.998082	0.996164	0.994247	0.992329
ALT-2	0.080097	0.038333	0	0	0	0	0
ALT-3	0.353284	0.186911	0.775188	0.703489	0.631789	0.560090	0.488391
ALT-4	0.521481	0.185812	0.769451	0.774360	0.779269	0.784177	0.789086
ALT-5	0.414549	0.110000	0.373913	0.429914	0.485915	0.541916	0.597916
ALT-6	0.639459	0.197906	0.832552	0.874414	0.916276	0.958138	1.000000
S^*	0.080097						
S^-	0.639459						
R^*	0.038333						
R^-	0.230000						

Table 8.
S_i, R_i, S_i^*, and S_i^- *values.*

4.5 Step 5: to calculate Q_i values, to find out the most appropriate alternative, and to control stage

Besides S_i, R_i, S_i^*, *and* S_i^- values obtained in the fourth step, the number of q expressing the weight for the maximum group benefit is included in the calculations as 0.00-0.25-0.50-0.75-1.00 which is used as a standard in the VIKOR method, and Q_i value was obtained by using Eq. (9). Results are presented in **Table 8**.

As a result of the calculations for each value of q, the most appropriate alternative was determined as ALT-2. The ALT-2 option, which provides two different audit conditions to the VIKOR method, is the most appropriate location for the construction of the penitentiary institution. The numerical data and results required for the audit conditions are given in **Table 9**.

5. Conclusions

Public buildings are constructed with taxes from the citizens of the state. For this reason, all citizens have a share in each public expenditure. In the constructions

	Ranking				
	Q_i (q = 0.00)	**Q_i (q = 0.25)**	**Q_i (q = 0.50)**	**Q_i (q = 0.75)**	**Q_i (q = 1.00)**
ALT-1	6	6	6	6	5
ALT-2	**1**	**1**	**1**	**1**	**1**
ALT-3	4	3	3	3	2
ALT-4	3	4	4	4	4
ALT-5	2	2	2	2	3
ALT-6	5	5	5	5	6
$Q(A^2)$	0.373913	0.429914	0.485915	0.541916	0.4883907
$Q(A^1)$	0	0	0	0	0
$Q(A^2) - Q(A^1)$	0.373913	0.429914	0.485915	0.541916	0.488391
DQ	0.2	0.2	0.2	0.2	0.2
Condition-1	Correct	Correct	Correct	Correct	Correct
Condition-2	Correct	Correct	Correct	Correct	Correct

Table 9.
Ranking.

built with the contributions of all citizens in Turkey, it is necessary to build the most efficient structures with the least cost. Public employees are responsible for providing these criterions in investments. Due to their high costs and their positive and negative impacts on the region, detailed studies need to be carried out for penitentiary institutions. These institutions serve for approximately 50 years. In this study, VIKOR method was used to make the best choice for the least amount of expenses in both construction and usage phases. As a result of the study conducted, in order to determine the most appropriate location for the construction of the penitentiary institution, it was determined that the most suitable option was the second alternative. The VIKOR method used in the selection of places for penitentiary institutions is considered to be beneficial in all investments, and it will be favorable in terms of effective and efficient use of public resources.

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