Journal of Modern Technology and Engineering
Vol.10, No.3, 2025, pp.173-188
https://doi.org/10.62476/jmte.103173

LOCATION VALUATION ANALYSIS OF UNIVERSITY CAMPUSES BASED ON OWA-DISTANCE: CASE STUDY FOR IZMIR

Resmiye Nasiboglu*

Department of Computer Science, Dokuz Eylul University, Izmir, Turkiye

Abstract. Every year, hundreds of thousands of students across Turkey make their university choices by passing university admission exams. In addition to important issues such as specialization, university recognition, and the city where the university is located, other issues, such as the facilities of university campuses, ease of transportation, and the availability of dormitories nearby, are also important in university choices. In this study, university campuses are evaluated in terms of ease of access to nearby student dormitories and other important points of the city by public transportation. The location valuation index (LVI) based on public transportation network distance (PTND) is used as the evaluation criterion. The main difference of this study from other studies using LVI is the use of the ordered weighted average (OWA) distance in terms of distance. The proposed OWA-based PTND approach was applied to the data of Izmir, the 3rd largest metropolitan city in Turkey, and the university campuses in Izmir.

Keywords: Location valuation index (LVI), Public transportation network (PTN), Ordered weighted average (OWA), OWA-distance.

Corresponding author: Resmiye Nasiboglu, Department of Computer Science, Dokuz Eylul University, Izmir, Turkiye, e-mail: *resmiye.nasiboglu@deu.edu.tr*

Received: 18 September 2025; Revised: 24 October 2025; Accepted: 5 November 2025;
Published: 22 December 2025.

1 Introduction

According to the 2022-2023 academic year data published by the Council of Higher Education (YÖK), there are 6,950,142 students and 184,566 academic staff in 208 higher education institutions in Turkey (YÖK student statistics, 2025). Student admission to universities in Turkey is carried out in a centralized manner through the Higher Education Institutions Exam (YKS). More than 3 million applications were made to the Higher Education Institutions Exam throughout Turkey in 2024. Around 600 thousand students were placed in universities. It is known that the campuses where students will study, as well as specialization and other criteria, have a significant impact on university preferences. In evaluating campuses, in addition to their general facilities, factors such as ease of access from the campus to other parts of the city, the density of student dormitories around the campus, and ease of access to social and recreational areas are important. Since the student body generally uses urban public transportation, it is more logical to use the public transportation network (PTN) based distance to evaluate ease of access.

Evaluating housing or other real estate objects according to various criteria, such as location, etc., is also widely included in urban planning studies (Smith et al., 2006; Ferrero, 2015; Nursoleh 2022). In the study (Nasiboglu & Nasibov 2023), the location valuation index (LVI) was proposed to evaluate a location within the city borders regarding ease of transportation. The studies later developed it (Nasiboglu et al., 2024,2025). Ease of transportation using the public transportation network throughout the city is considered in calculating LVI. While evaluating transportation conditions, various criteria are considered, such as general ease of transportation to other parts of the city, ease of transportation to the hospital, ease of transportation to shopping centers, and ease of transportation to open area recreation areas. For each criterion, a certain number of points of interest (POI) are considered, and transportation to them is evaluated. When calculating the transportation distance, the average distance and the distance to the nearest object are considered. On the other hand, it is possible to use multi-criteria decision-making (MCDM) methods such as analytical hierarchy process (AHP), analytical network process (ANP), best-worst method (BWM) etc. in calculating the weights of different criteria (Saaty, 2001; Triantaphyllou, 2000; Opricovic & Tzeng, 2004; Rezaei, 2015,2020; Pamucar et al., 2020; Nasiboglu, 2025).

This study analyzed university campuses in Izmir, the third-largest metropolitan city in Turkey, in terms of LVI. There are 11 universities and many colleges in Izmir ("List of universities in Izmir, Wikipedia" 2025). Around 200,000 students receive education in these institutions. Therefore, a study that concerns students is important. In evaluating university campuses, the presence of dormitories in their proximity is an important factor. The important difference of this study is that when LVI analysis is performed according to dormitories near the campus, the ordered weighted average (OWA) distance to dormitories within a certain radius is considered. OWA distance maintains a balance between the nearest object and the farthest object by means of weights. By adjusting the criteria in the calculation of the OWA value, measurements such as average distance, distance to the nearest or farthest objects, and average distance to a certain number of nearest neighbors can be made (Nasibova & Nasibov 2010; Ulutagay & Nasibov, 2012). In addition, the best-worst method was used to calculate the criterion weights. The reason for choosing this BWM method is that it can provide more robust results despite the fact that fewer pairwise criteria comparisons are required compared to other methods, such as AHP (Rezaei, 2015,2020).

The article's organization is as follows: Section 2 provides information on the OWA, LVI, and BWM methods. Section 3 presents the proposed PTND-based OWA distance calculation algorithm. Section 4 presents the Izmir data and analyzes the calculation results. The Conclusion section provides a general evaluation of the article and hints at further studies.

2 Background

2.1 Ordered Weighted Average (OWA) and OWA-Distance

The OWA concept is one of the most frequently discussed mathematical concepts in the literature. Since it was first proposed by Yager, various mathematically developed versions of the OWA concept, such as induced OWA (IOWA), generalized OWA (GOWA), induced generalized OWA (IGOWA), etc., have been proposed (Yager, 1988, 2004; Merigó & Gil-Lafuente 2009). The OWA concept has applications in many different fields. Various OWA-based distances have been proposed in the studies (Merigó et al. 2017; Tezel et al. 2017; Ulutagay & Kantarci 2014; Ulutagay & Nasibov 2016; Bozyiğit et al., 2018).

In this study, we will discuss the OWA concept (Definition 1) and the OWA-based distance concept (Definition 2) as follows.

Definition 1. *The ordered weighted average (OWA) of real numbers $(a_1,\dots,a_n)$ with respect to weights $W=(w_1,\dots,w_n)$ is defined as in Equation 1:*

$$OWA_W\,(x_1,\dots,x_n)=\sum_{i=1}^{n} w_i a_{(i)}. \tag{1}$$

Here $a_{(i)}$ is the i.th largest value of the numbers $a_1,\dots,a_n$, that is

$$a_{(1)}=max(a_1,\dots,a_n),\, a_{(n)}=min(a_1,\dots,a_n). \tag{2}$$

Definition 2. *The OWA distance between sets* $X=\{x_1,\dots,x_n\}$ *and* $Y=\{y_1,\dots,y_m\}$ *with respect to the weights* $W=(w_1,\dots,w_{nm})$ *is defined as given in Equation 3:*

$$Dist_{OWA}(X,Y;W)=OWA_W(d(x_i,y_j)|i=1,\dots,n;j=1,\dots,m). \tag{3}$$

Here $d(x_i,y_j)$ *is any classical distance measure between* $x_i\in X$ *and* $y_i\in Y$*. For example, it can be any of the Euclidean, Minkowski, etc. distances.*

2.2 Location Valuation Index (LVI)

The Location Valuation Index (LVI) was first proposed in the study (Nasiboglu & Nasibov 2023) to evaluate real estate located in a certain location in the city according to its location. It was subsequently developed in the studies (Nasiboglu et al., 2024, 2025). In the creation of this index, various criteria were used, depending on the user's preference, as follows:

1. Accessibility to other parts of the city from the relevant location,
2. Accessibility to the metro,
3. Accessibility to the green park area,
4. Accessibility to the hospital,
5. Accessibility to the university campus.

To evaluate according to each criterion, a certain number of important POI (Point of Interest) objects from the facilities that meet this criterion were considered. Two types of aggregated distance values, called PTN distance, were created from the distances to these POI objects:

(a) Average ease of access to all POI objects in the group;

(b) Ease of access to the nearest POI in the group.

The PTND value is considered as the length of the optimal path calculated using a modified version of the Dijkstra's shortest path algorithm on the urban public transportation network (Bozyiğit et al., 2018; Nasiboglu, 2022). In other words, the public transport-based distance of the route between a source and destination pair of stops is calculated by adding the number of stops located on the shortest line that can be reached by public transport between these stops, the number of line transfers, and the penalty points given for consecutive walking. Therefore, the PTND distance between two specific stops, depending on the optimal route R, is calculated by Equation 4:

$$PTND\,(R)=D\,(R)+c_T T\,(R)+c_W W(R), \tag{4}$$

In Equation 4, the signs $T\,(R)$ and $D\,(R)$ indicate the number of transfers and the number of stops on the route, respectively. The number of consecutive walks on the route is shown by $W\,(R)$. c_T and c_W parameters are the penalty multipliers used per transfer and per repetitive walk, respectively.

In evaluating a certain location from the perspective of (a) above, the average ease of access from the closest stop to this location to all other city stops is considered. In this case, each stop in the city is a POI object, and the ease of access is calculated on average. For this purpose, the average PTN distance of a certain stop s to a group g that constitutes a certain set of POI objects, is calculated as follows:

$$PTND\,(s,g)=\frac{\sum_{POI\in g} PTND(s,POI)}{n}, \tag{5}$$

Here, $PTND(s,POI)$ is the PTN distance from stop s to a certain POI object.

From the perspective of (b), it may be more logical to calculate the closest distance to POI objects in some groups rather than the average distance. For example, in groups such as hospitals and subways, access to the nearest object may be considered sufficient. In this case, the PTND value can be calculated with the following Equation 6:

$$PTND\,(s,g) = \min_{POI \in g} PTND(s, POI) \tag{6}$$

Definition 3. *A weighted average of separate groups' PTNDs was calculated with the Equation 7 is called an aggregated PTND of a location s:*

$$PTND\,(s) = \sum_{g \in G} v_g \cdot PTND(s,g). \tag{7}$$

Here, v_g is the normalized weight of the $g \in G$ group. Any of the MCDM methods mentioned above, such as AHP, BWM, etc., can be used to determine the v_g weights.

Finally, the location valuation index is calculated based on the aggregated PTND value of the location.

Definition 4. *The value determined by the Equation 8 below is called the Location Valuation Index of location s:*

$$LVI\,(s) = \frac{1}{PTND\,(s)}. \tag{8}$$

2.3 The Best-Worst Method (BWM)

The Best-Worst Method (BWM) is a multi-criteria decision making method handled in papers (Rezaei, 2015,2020; Pamucar et al., 2020). The BWM method has come to the fore in recent times because it requires less comparison and is a more efficient method than AHP. More detailed information about the BWM method is given below.

Let's say we have n criteria and we compare these criteria pairwise using a 1/9 to 9 scale. The resulting matrix will be

$$A = a_{ij}, \tag{9}$$

where a_{ij} represents the relative preference of the criterion i over the criterion j. $a_{ij} = 1$ indicates that i and j are of equal importance, $a_{ij} > 1$ indicates that the criterion i is more important than j.

In the BWM method, it is possible to divide pairwise comparisons into two main categories: reference comparisons and secondary comparisons. The a_{ij} comparison is defined as a reference comparison if i is the best item and/or j is the worst item. If neither i and j are the best or worst elements, the a_{ij} comparison is defined as a secondary comparison. In order for the method to work, only the matrix containing reference comparisons needs to be filled (Fig. 1).

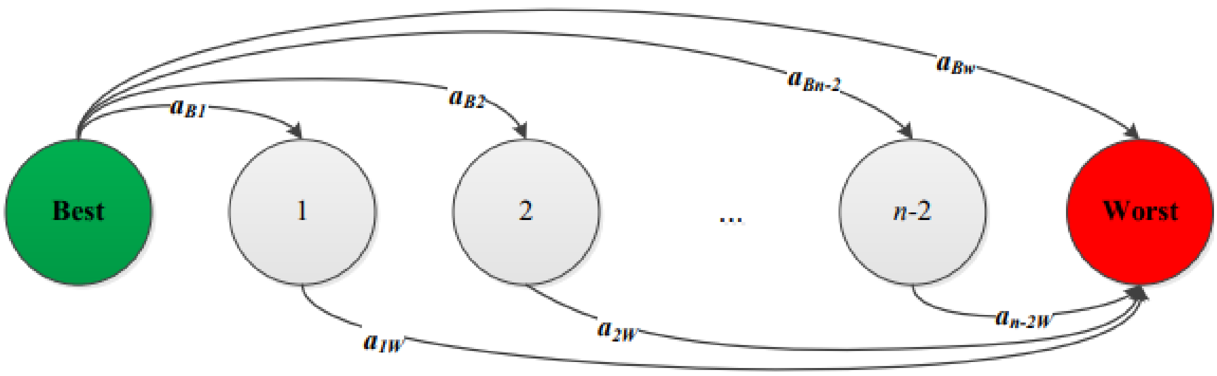

Figure 1: Reference comparisons with the best and the worst alternatives.

For matrix A to be reciprocal, a_{ii}= 1 and a_{ij}=$\frac{1}{a_{ji}}$ for all i and j. The pairwise comparison matrix A is considered to be fully consistent if:

$$a_{ik}a_{kj}{=}a_{ij},\ for\ all\ i,j. \tag{10}$$

After the comparison matrix is filled, the criteria weights are calculated as $(w_1^*, w_2^*, \ldots, w_n^*)$ in the vector $(\xi^*, w_1^*, w_2^*, \ldots, w_n^*)$, which is the solution to the following optimization problem:

$$\min\xi\ , \tag{11}$$

s.t.

$$\left|\frac{w_B}{w_j}{-}a_{Bj}\right|{\le}\xi,\ for\ \ all\ j, \tag{12}$$

$$\left|\frac{w_j}{w_W}{-}a_{jW}\right|{\le}\xi,\ for\ all\ j, \tag{13}$$

$$\sum_j w_j{=}\ 1, \tag{14}$$

$$w_j{\ge}0,\ for\ all\ j. \tag{15}$$

The ξ^* value in the optimal solution of (11)-(15) shows how consistent the comparison matrix is. In the case of a fully consistent comparison matrix, $\xi^* = 0$ is provided. Obviously, it is not very possible to construct a fully consistent comparison matrix. In these cases, the concept of consistency ratio (CR) calculated as follows is used (Rezaei, 2015):

$$CR{=}\frac{\xi^*}{Cosistency\ index}. \tag{16}$$

The smaller the CR value, which is in the [0,1] interval, means that the comparison matrix is more consistent, thus the safer the decision-making result. The values used for the consistency index are given in Table 1. Based on the a_{BW} reference value (the Best-Worst comparison) and the number of criteria, the CR value must be below a certain threshold for the decision result to be acceptable. These threshold values are given in Table 2. According to the table, for example, if there are 6 criteria and $a_{BW} = 7$, then the threshold value for CR is 0.3931, that is, comparison matrices with values of $CR \le 0.3931$ are acceptable.

Table 1: Consistency index values used in the BWM method

a_{BW}	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Consistency index	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Table 2: Acceptable CR thresholds.

Criteria a_{BW}	**3**	**4**	**5**	**6**	**7**	**8**	**9**
3	0.2087	0.2087	0.2087	0.2087	0.2087	0.2087	0.2087
4	0.1581	0.2352	0.2738	0.2928	0.3102	0.3154	0.3273
5	0.2111	0.2848	0.3019	0.3309	0.3479	0.3611	0.3741
6	0.2164	0.2922	0.3565	0.3924	0.4061	0.4168	0.4225
7	0.2090	0.3313	0.3734	0.3931	0.4035	0.4108	0.4298
8	0.2267	0.3409	0.4029	0.4230	0.4379	0.4543	0.4599
9	0.2122	0.3653	0.4045	0.4225	0.4445	0.4587	0.4747

Let's assume that the criteria importance levels are determined by the user as values in a certain range (for example, between 1 and 10). Let w_i be the significance level of each criterion i (the raw weight). In this case, the criteria normalized weights can be calculated as follows:

$$w_i = \frac{w_i}{\sum_i w_i},\ for\ all\ i. \tag{17}$$

Obviously, in this case the criterion normalized weights will satisfy the following normalization conditions:

$$\sum_i w_i = 1,\ and\ w_i \geq 0,\ for\ all\ i. \tag{18}$$

The BWM will be used to calculate the weights of the factors taken into account in calculating the LVI value.

3 OWA-Distance-Based Approach to LVI Analysis

In their studies (Nasiboglu et al., 2024, 2025), aggregation operators such as minimum and average were used in calculating the aggregated PTN distance of a certain stop s to a certain group g (see Equations 5 and 6). However, in some cases, it may be more logical to use different aggregation strategies. For example, the k-nearest neighbor strategy can be used (Dogan, 2025). Or, instead of using the closest dormitory to the university campus in calculating the LVI value or using the average distance of all dormitories in the city, the average distance of a certain number of dormitories around the campus may be more logical. In order to handle all these situations more flexibly, it is suggested to use OWA as the aggregation operator in this study. As it is known, the weights of the OWA operator can be adjusted to make it work like minimum, average, maximum, etc. operators. Methods have also been proposed for inferring the weights of the OWA operator from data (Nasiboglu et al., 2018). Table 3 provides information about transforming OWA operator weights for different operators.

Table 3: The relationship of the OWA operator with other operators.

OWA weights	Matching classical operator	Explanation
$w_n = 1$; $w_i = 0, \quad i \neq n.$	$min(a_1, \ldots, a_n)$	The smallest of all numbers.
$w_1 = 1$; $w_i = 0, \quad i \neq 1.$	$max(a_1, \ldots, a_n)$	The largest of all numbers.
$w_i = \frac{1}{n}, \quad i = 1, \ldots, n.$	$mean(a_1, \ldots, a_n)$	Average of all numbers.
$w_i = \frac{1}{K}, \quad i = 1, \ldots, K$; $w_i = 0, \quad i > K.$	$mean(a_{(1)}, \ldots, a_{(K)})$	Average of the K largest numbers.
$w_i = \frac{1}{K}, \quad i = n-K+1, \ldots, n$; $w_i = 0, \quad i < n-K+1.$	$mean(a_{(n-K+1)}, \ldots, a_{(n)})$	Average of the K smallest numbers.

In this study, the recommended aggregated PTN distance for the campus group is calculated by the following Eq. 19:

$$PTND_{OWA}(s, POI_g) = OWA_W\left(PTND\left(s, POI_g\right)\right) = \sum_{POI \in g} w_i PTND(s, POI_g)_{(i)}. \tag{19}$$

Here $PTND(s, POI_g)_{(i)}$ shows the largest i-th distance when the distances from stop s to all POIs of group g are listed. The w_i weights are the weights of the OWA operator. Obviously, by adjusting the w_i weights in Equation 19 in various ways, strategies such as the nearest, the farthest, the average, the average of the nearest k number of PTN distances from stop s to group g, etc. can be adopted (Table 3).

Thus, when all criteria are considered, the aggregated PTND distance of the campus to other groups is calculated using Equation 20.

$$PTND\,(s) = \sum_{g \in G} v_g \cdot PTND_{OWA}(s, POI_g). \tag{20}$$

Here v_g is the normalized weight of the criterion group $g \in G$. As a result, the LVI value of location s will be calculated using Equation 8.

In light of the above, the methodology used in this study to calculate the LVI value of the campus at any location s can be summarized as the Pseudocode 1.

Table 4: Pseudocode 1. Calculation of a Campus LVI value.

1	The location of the campus must be specified;
2	LVI evaluation criteria (groups) should be determined;
3	Criteria weights should be calculated with the BWM method;
4	According to each group:
4.a	- Set OWA weights for the group;
4.b	- Determine the set of POI objects for the group;
4.c	- Calculate the PTN distance values from the campus location to the
4.d	POI objects specified in Step 4.b;
	- The OWA aggregated value of the distances calculated in Step 4.c
5	should be taken as the aggregated PTND value of the group;
6	The overall PTND value of the campus should be calculated as a
7	weighted average, taking into account the aggregated PTND values of
	the groups and the group criteria weights;
	The LVI value of the campus should be calculated inversely proportional
	to the overall PTND value.

4 Application

4.1 Data Collection

The location valuation index approach was applied using the public transportation network data of the city of Izmir, the data of the student dormitories in the city, and the data of the university campuses in the city. As the 3rd largest city in Turkey with a population of over 4 million, Izmir has nearly 6,500 stops and nearly 700 public transportation lines. In addition to the stop name and number, the geographical coordinates of the stop are also given. The dormitory database collected the student dormitory's name, status (state or private), student accommodation capacity, latitude, and longitude coordinates. For example, information on 20 student dormitories is given in Table 4.

The campus database collects information such as the name of the university and the campus to which it belongs, latitude and longitude coordinates, and the nearest bus stop to the campus. Information on some campuses, which are generally located in the Science and Engineering Faculties, is given in Table 5.

Table 5: Information about student dormitories in Izmir.

No.	Name	Status	Capacity	Latitude	Longitude
1	İzmir Barbaros Kyk Erkek Öğrenci Yurdu	state	285	38.3681373596	27.1796188354
2	İzmir Urla Kyk Erkek Öğrenci Yurdu	state	350	38.3184483846	26.6438172658
3	Urla Latife Hanım Kyk Kız Öğrenci Yurdu	state	456	38.3184483846	26.6438172658
4	Gazi Ayşe Hanım Kyk Kız Öğrenci Yurdu	state	1394	38.3742218018	27.1845207214
5	Hanzade Hatun Kyk Kız Öğrenci Yurdu	state	1185	38.3730621338	27.1869239807
6	Zübeyde Hanım Kyk Kız Öğrenci Yurdu	state	350	38.4571342468	27.2329559326
7	Bornova Kyk Erkek Öğrenci Yurdu	state	650	38.4535408020	27.2261524200
8	Çiğli Kyk Erkek Öğrenci Yurdu	state	1150	38.5146598816	27.0388164520
9	Atatürk İnciraltı Kyk Erkek Öğrenci Yurdu	state	320	38.4132041931	27.0291614532
10	Hoca Ahmet Yesevi Kyk Kız Öğrenci Yurdu	state	920	38.3905410767	27.1811580658
11	Maya Erkek Öğrenci Yurdu	private	100	38.4640312195	27.2139511108
12	Özel Palmira Kız Rezidans	private	200	38.3757362366	27.1806392670
13	İzmir Pelikan Erkek Öğrenci Apartları	private	120	38.4506072998	27.2302017212
14	Üniversite Öğrenci Evi - Erkek Yurdu	private	150	38.3677291870	27.1964149475
15	Bornova Yükseliş Kız Öğrenci Yurdu	private	300	38.4541015625	27.2040996552
16	Özel Kılıçoğlu Kız Öğrenci Yurdu	private	250	38.4519329071	27.2012147903
17	Özel Yükseliş Erkek Öğrenci Yurdu	private	300	38.4537696838	27.1997432709
18	Adef Kız Öğrenci Yurdu	private	280	38.3698959351	27.1895465851
19	Özel Kılıçoğlu Erkek Öğrenci Yurdu	private	250	38.4519329071	27.2012147903
20	Buca Sim Kız Öğrenci Yurdu	private	210	38.3757362366	27.1806392670

Table 6: Information about university campuses in Izmir.

No	Name	Latitude	Longitude	The nearest stop to the campus
1	DEÜ Eğitim Fakültesi	38.38691052	27.16777781	5363
2	DEÜ Merkez kampüs	38.37051327	27.196923	5023
3	DEÜ Tıp Fakültesi	38.3885603	27.03054488	5675
4	Ege Ü. Müh. Fakültesi	38.453409	27.232285	4107
5	Ege Ü. Tıp Fakültesi	38.45701996	27.21134599	3922
6	İzmir Bakırçay Ü	38.58758773	26.963274	3283
7	İzmir Demokrasi Ü	38.39350142	27.073536	245
8	İzmir Ekonomi Ü	38.38784	27.04449	5794
9	İzmir Katip Çelebi Ü	38.51213743	27.0294551	3153
10	İzmir Yüksek Teknoloji E	38.31523565	26.6377564	6106
11	Yaşar Ü. Müh. Fakültesi	38.45493219	27.2016452	3930

4.2 Determination of Criteria Weights

In this study, the following criteria were used as evaluation criteria: 1. General access, 2. Proximity to student dormitories, 3. Access to the metro, 4. Access to the green park area, 5. Access to the shopping mall, 6. Access to the hospital, 7. Access to the intercity bus terminal, and 8. Access to the airport. The Best Worst Method method mentioned above was used to determine the criteria weights. The most important criterion was determined as "2. Access to dormitories" and the least important criterion as "5. Access to the hospital". The most important criterion and the reference comparison values are as follows:

a_{B1}= 3 (important), a_{B2}= 1 (equally important), a_{B3}= 5 (highly important), a_{B4}= 3 (important), a_{B5}= 5, (highly important), a_{B6}= 7 (extremely important), a_{B7}= 7 (extremely important), a_{B8}= 7, (extremely important).

The comparison values with the least important criterion are:

a_{1W}= 5 (highly important), a_{2W}= 7 (extremely important), a_{3W}= 5 (highly important), a_{4W}= 5 (highly important), a_{5W}= 5 (highly important), a_{6W}= 1 (equally important), a_{7W}= 3 (important), a_{8W}= 3 (important).

Using these comparisons, the weights of the criteria are calculated as follows:

$$w_1 = 0,12;\ w_2 = 0,35;\ w_3 = 0,12;\ w_4 = 0,13,\ w_5 = 0,12,\ w_6 = 0,04;\ w_7 = 0,07,\ w_8 = 0,05.$$

A total of 43 metro stations, 63 student dormitories, 5 hospitals, 5 large green parks, an intercity bus terminal, and an airport were used to create POI objects based on criteria (groups). In order to evaluate the general transportation to other parts of the city, 10 stops were randomly selected throughout the city. Table 6 provides POI groups (criteria), criteria weights, the number of POIs in each group, and the method of calculating the aggregate values in the same group.

Table 7: Criteria used in calculating LVI.

Group No.	Group name	Weights of criteria	POI count (n)	OWA weights	Aggregation method
1	General access	0,12	10	$w_i = \frac{1}{n}, \quad i = 1, \ldots, n.$	Average
2	Dormitories	0,35	63	$w_i = \frac{1}{K}, \quad i = n-K+1, \ldots, n;$ $w_i = 0, \quad i < n-K+1.$	K-NN (K=3)
3	Metro	0,12	43	$w_n = 1;\ w_i = 0, \quad i \neq n.$	Minimum
4	Green Park Area	0,13	5	$w_n = 1;\ w_i = 0, \quad i \neq n.$	Minimum
5	Shopping mall	0.12	5	$w_n = 1;\ w_i = 0, \quad i \neq n.$	Minimum
6	Hospital	0,04	5	$w_n = 1;\ w_i = 0, \quad i \neq n.$	Minimum
7	Bus terminal	0.07	1	$w_n = 1;\ w_i = 0, \quad i \neq n.$	Minimum
8	Airport	0.05	1	$w_n = 1;\ w_i = 0, \quad i \neq n.$	Minimum

Table 7 provides information on the General Access and Dormitory Access criteria for each campus. Tables 8-13 provide information on other criteria.

Table 8: Information was calculated for General access and Dormitory access groups.

Campus	Average distance by bus (km)		Average walking distance (m)		Average number of transfers		Average PTND	
	General Access	Dormitory Access	General Access	Dormitory Access	General Access	Dormitory Access	General Access	Dormitory Access
DEÜ Eğitim Fakültesi	34.5	0	341.1	513.4	2,5	0	75.9	6.0
DEÜ Merkez kampüs	36.7	0	601.0	85.00	2.7	0	85.7	2.0
DEÜ Tıp Fakültesi	36.0	3.8	316.2	37.0	1.9	1	66.0	16.67
Ege Ü. Müh. Fakültesi	38.4	0	672.4	180.4	2.6	0	72.8	2
Ege Ü. Tıp Fakültesi	36.2	1.2	386.1	54.6	1.7	0	61.0	7.0
İzmir Bakırçay Ü	55.2	11.4	409.4	146.8	3.3	1	101.9	25.33
İzmir Demokrasi Ü	35.1	0.0	550.6	57.9	2.8	0	66.3	2.0
İzmir Ekonomi Ü	36.0	3.5	508.4	95.1	2.2	0.0	69.9	12.0
İzmir Katip Çelebi Ü	46.3	1.2	357.8	0.0	3.3	0.0	89.3	5.67
İzmir Yüksek Teknoloji E	63.2	40.0	293.2	37.0	2.5	1.0	11.4	79.67
Yaşar Ü. Müh. Fakültesi	36.8	0.0	587.9	155.5	2.4	0	65.3	2.0

Table 9: Calculated information for the nearest stop for the metro group.

Campus	The nearest stop of the group	Total distance by bus (km)	Total walking distance (m)	Number of transfers	PTND
DEÜ Eğitim Fakültesi	5608	1.7	0	0	8.0
DEÜ Merkez kampüs	5608	5.3	0	0	18
DEÜ Tıp Fakültesi	6248	3.7	0	0	13.0
Ege Ü. Müh. Fakültesi	4092	2.0	271.5	0	11.0
Ege Ü. Tıp Fakültesi	3795	0.4	0	0	4.0
İzmir Bakırçay Ü	3214	7.5	0	0	13.0
İzmir Demokrasi Ü	242	0.3	0.0	0	4.0
İzmir Ekonomi Ü	6250	3.1	281.3	0	16.0
İzmir Katip Çelebi Ü	2468	3.9	0.0	0	11.0
İzmir Yüksek Teknoloji E	6266	39.5	293.2	0	78.0
Yaşar Ü. Müh. Fakültesi	3930	0.0	0.0	0	0.0

Table 10: Calculated information for the nearest stop for the green parking area group.

Campus	**The nearest stop of the group**	**Total distance by bus (km)**	**Total walking distance (m)**	**Number of transfers**	**PTND**
DEÜ Eğitim Fakültesi	5368	0.7	300.0	0	8.0
DEÜ Merkez kampüs	5008	2.2	0	0	9.0
DEÜ Tıp Fakültesi	4574	28.3	420.5	1	26.0
Ege Ü. Müh. Fakültesi	4574	2.0	551.7	0	14.0
Ege Ü. Tıp Fakültesi	4573	0.6	0	0	5.0
İzmir Bakırçay Ü	172	28.2	83.5	1	47.0
İzmir Demokrasi Ü	179	8.4	105.9	2	24.0
İzmir Ekonomi Ü	179	11.2	281.3	1	25.0
İzmir Katip Çelebi Ü	3054	10.5	278.3	1	25.0
İzmir Yüksek Teknoloji E	179	47.9	98.3	2	91.0
Yaşar Ü. Müh. Fakültesi	4573	1.3	255.4	0	9.0

Table 11: Calculated information for the nearest stop for the shopping mall group.

Campus	**The nearest stop of the group**	**Total distance by bus (km)**	**Total walking distance (m)**	**Number of transfers**	**PTND**
DEÜ Eğitim Fakültesi	35	8.3	0	0	18.0
DEÜ Merkez kampüs	35	12.0	0	1	31.0
DEÜ Tıp Fakültesi	6256	3.6	0	0	13.0
Ege Ü. Müh. Fakültesi	4903	1.8	400.9	1	17.0
Ege Ü. Tıp Fakültesi	332	15.7	163.8	0	9.0
İzmir Bakırçay Ü	2594	17.0	83.5	1	34.0
İzmir Demokrasi Ü	1984	0.3	148.2	0	7.0
İzmir Ekonomi Ü	6263	3.0	281.3	0	16.0
İzmir Katip Çelebi Ü	2594	7.4	0.0	0	16.0
İzmir Yüksek Teknoloji E	6253	39.8	0.0	0	76.0
Yaşar Ü. Müh. Fakültesi	4903	2.8	255.4	1	15.0

Table 12: Calculated information for the hospital group to the nearest stop.

Campus	**The nearest stop of the group**	**Total distance by bus (km)**	**Total walking distance (m)**	**Number of transfers**	**PTND**
DEÜ Eğitim Fakültesi	5363	0	0	0	0.0
DEÜ Merkez kampüs	5023	0.0	0	0	0.0
DEÜ Tıp Fakültesi	5673	0.4	0	0	4.0
Ege Ü. Müh. Fakültesi	3921	5.2	430.7	1	26.0
Ege Ü. Tıp Fakültesi	3921	2.6	163.8	0	14.0
İzmir Bakırçay Ü	188	30.0	369.3	3	56.0
İzmir Demokrasi Ü	5674	3.4	280.7	1	18.0
İzmir Ekonomi Ü	5674	1.4	133.3	1	13.0
İzmir Katip Çelebi Ü	188	20.4	285.8	3	42.0
İzmir Yüksek Teknoloji E	5673	36.6	0.0	0	67.0
Yaşar Ü. Müh. Fakültesi	3921	1.9	0.0	0	10.0

Table 13: Information calculated for the nearest stop for the intercity bus terminal group.

Campus	The nearest stop of the group	Total distance by bus (km)	Total walking distance (m)	Number of transfers	PTND
DEÜ Eğitim Fakültesi	3821	12.3	0	2	33.0
DEÜ Merkez kampüs	4759	15.9	9.6	0	36.0
DEÜ Tıp Fakültesi	4056	24.9	155.7	1	21.0
Ege Ü. Müh. Fakültesi	4056	5.5	467.2	1	19.0
Ege Ü. Tıp Fakültesi	4056	2.9	163.8	0	7.0
İzmir Bakırçay Ü	3821	32.8	366.6	3	68.0
İzmir Demokrasi Ü	4056	22.3	436.3	2	20.0
İzmir Ekonomi Ü	4056	24.3	437.0	2	27.0
İzmir Katip Çelebi Ü	3821	23.2	283.1	3	54.0
İzmir Yüksek Teknoloji E	4056	61.1	155.7	2	87.0
Yaşar Ü. Müh. Fakültesi	4056	3.6	419.3	1	14.0

Table 14: Calculated information for the airport group to the nearest stop.

Campus	The nearest stop of the group	Total distance by bus (km)	Total walking distance (m)	Number of transfers	PTND
DEÜ Eğitim Fakültesi	350	15.0	146.9	1	41.0
DEÜ Merkez kampüs	398	13.9	1046.6	2	51.0
DEÜ Tıp Fakültesi	398	17.0	0.0	1	25.0
Ege Ü. Müh. Fakültesi	398	22.9	467.2	2	32.0
Ege Ü. Tıp Fakültesi	398	20.3	163.8	1	20.0
İzmir Bakırçay Ü	398	44.0	83.5	3	75.0
İzmir Demokrasi Ü	398	14.5	280.7	2	24.0
İzmir Ekonomi Ü	398	16.4	281.3	2	31.0
İzmir Katip Çelebi Ü	398	34.3	0.0	3	61.0
İzmir Yüksek Teknoloji E	398	53.2	0.0	2	91.0
Yaşar Ü. Müh. Fakültesi	398	21.0	419.3	2	27.0

5 Results and Discussion

The code of the algorithm we propose for calculating the location valuation index is written in Python 3 programming language. The walking distance at a time is limited to 300 meters. The value of the penalty point added for each additional walking and each line transfer number on the route is equal to 3. Depending on the criteria group, the OWA weights are adjusted, the PTND values are calculated according to Equation 7, and the LVI value is calculated according to Equation 5.

The haversine formula specified in equation 21 is used to calculate the distance between any $X=(\phi_1,\lambda_1)$ and $Y=(\phi_2,\lambda_2)$ points given by geographical latitude and longitude coordinates (Brummelen 2013):

$$d\,(X,Y)=2R\ sin^{-1}\left(\left[sin^2\left(\frac{\phi_1-\phi_2}{2}\right)+cos\phi_1 cos\phi_2 sin^2\left(\frac{\lambda_1-\lambda_2}{2}\right)\right]^{0.5}\right), \tag{21}$$

In Equation 21, R is the radius of the Earth (R= 6367450 m); ϕ is latitude, λ longitude of the relevant locations.

The software calculates information such as the nearest stop, length of the bus route, walking distance, number of transfers between lines, and PTND value for each campus and each group. Records are saved in a file. Then, the general LVI values of the campuses are calculated. Aggregated PTND and LVI values for each campus are given in Table 14.

Table 15: Aggregated PTND and LVI values of campuses.

No	Campus name	Aggregated PTND	LVI
1	DEÜ Eğitim Fakültesi	19.73	5.0689
2	DEÜ Merkez kampüs	23.10	4.3283
3	DEÜ Tıp Fakültesi	23.13	4.3228
4	Ege Ü. Müh. Fakültesi	18.59	5.3804
5	Ege Ü. Tıp Fakültesi	14.03	7.1276
6	İzmir Bakırçay Ü	43.59	2.2939
7	İzmir Demokrasi Ü	16.42	6.0916
8	İzmir Ekonomi Ü	23.64	4.2305
9	İzmir Katip Çelebi Ü	27.70	3.6102
10	İzmir Yüksek Teknoloji E	84.88	1.1781
11	Yaşar Ü. Müh. Fakültesi	14.24	7.0244

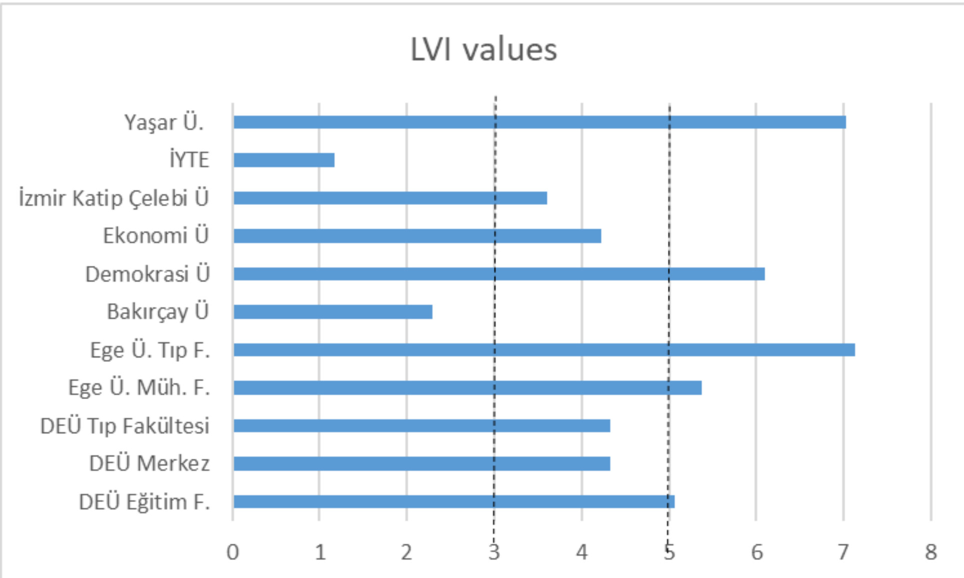

Figure 2: LVI values of university campuses.

The general transportation criterion reflects the general ease of access to other city points. Since it takes a long time to calculate the access to each of the 6475 stops in the city, 10 stops covering various parts of the city were randomly selected to represent them. The average method was used as the aggregation method for the PTND values in this group. The number of POIs and aggregation methods used in the other groups are given in Table 6.

It was seen that the LVI values of the campuses were in the range of [1.1781, 7.1276] based on the general criteria (Table 14). This range was divided into 3 bins from points 3.0 and 5.0 (Figure 2). Color adjustments were made for each bin. The colors were set as "Orange" for low LVI values, "Salmon" for medium LVI values , and "Red" for high LVI values. Color adjustments of the bins according to LVI values are given in Table 15. The heatmap of university campuses according to LVI values is given in Figure 3. As seen in Figure 3, the Ege University campuses have high LVI values. This is because metro stations and bus lines are more frequent in the Bornova region, where these campuses are located. Conversely, the Buca region, where the DEU central campus is located, has lower LVI values due to the lack of metro stations and its location on the city's outskirts.

Table 16: Color settings of campuses according to their general LVI values.

LVI interval	**Color**
[1.1781, 3.0)	"#FFA500" (Orange)
[3.0, 5.0)	"#FA8072" (Salmon)
[5.0, 7.1276]	"#FF0000" (Red)

Figure 3: Heatmap of university campuses according to LVI values.

6 Conclusion

When students make university choices, in addition to basic criteria such as specialization, university recognition, the city where the university is located, the locations of university campuses, the presence of nearby dormitories, the cost of transportation to other important places in the city, and the time spent on the road are also important. In this study, an analysis of university campuses was conducted. Considering that the student body generally uses public transportation within the city, we thought that it would be more logical to use PTND based on public transportation as the transportation distance. In the study, LVI analysis based on PTND of university campuses in Izmir was conducted based on these issues. According to the general LVI values, it is seen that university campuses in Bornova region stand out more. This is primarily due to the presence of a metro line and other public transportation lines in the Bornova region. Furthermore, this region is located close to the city center, meaning there are numerous green parks, hospitals, shopping malls, and other services nearby. It is seen that university campuses in Buca and Narlıdere regions are next. İYTE and Bakırçay University Campuses were observed to have the lowest LVI values because they are located very far from the city center; therefore, there are not many service areas, such as hospitals, shopping centers, etc., nearby.

Finally, in efforts to address traffic congestion and reduce air pollution in major cities, it's clear that while public transportation is crucial, alternatives to public transportation, such as private cars, bike paths, and pedestrian walkways, are also crucial. Therefore, LVI assessments based on trip analysis by other modes of transportation could also be considered in future studies.

References

Bozyiğit, A., Alankus, G., & Nasibov, E. (2018). A public transport route recommender minimizing the number of transfers. *Sigma Journal of Engineering and Natural Sciences, 9*(4), 437–446.

Brummelen, G.R. (2013). *Heavenly Mathematics: The Forgotten Art of Spherical Trigonometry.* Princeton University Press.

Dogan, A. (2025). An Improved Version of Edited Nearest Neighbor Undersampling Method Based on the kNN Approach. *DEU FMD, 27*(4), 376-381.

Ferrero, A. (2015). House price booms, current account deficits, and low interest rates. *Journal of Money, Credit and Banking, 47*(S1), 261–293. https://www.jstor.org/stable/26614933

Merigó, J.M., Gil-Lafuente, A.M. (2009). The induced generalized OWA operator. *Information Sciences, 179*(6), 729–741.

Merigó, J.M., Palacios-Marqués, D., & Soto-Acosta, P. (2017). Distance measures, weighted averages, OWA operators and Bonferroni means. *Applied Soft Computing, 50*, 356–366.

Nasiboglu, R. (2022). Dijkstra solution algorithm considering fuzzy accessibility degree for path optimization problem. *Applied Soft Computing, 130*(2), Article 109674.

Nasiboglu, R. (2025). Comparative analysis of the major TOPSIS-related algorithms. *Journal of Modern Technology and Engineering, 10*(2), 71–82.

Nasiboglu, R., Balbal, K.F., Rusiman, M.S., & Nasibov, E. (2025). Location-based housing valuation index proposal: Izmir example. *Journal of the Faculty of Engineering and Architecture of Gazi University, 40*(1), 189–201.

Nasiboglu, R., Nasibov, E. (2023). Determination of the location valuation index based on public transportation in big cities. In *2023 5th International Conference on Problems of Cybernetics and Informatics (PCI)* (pp. 1–3). IEEE. https://doi.org/10.1109/PCI60110.2023.10325931

Nasiboglu, R., Rusiman, M.S., Koroglu, H.I., & Nasibov, E. (2024). Comparative analysis of the optimal route recommendation models based on city public transportation network data. *Problems of Information Society, 15*(2), 14–23.

Nasiboglu, R., Tezel, B.T., & Nasibov, E. (2018). Learning the stress function pattern of ordered weighted average aggregation using DBSCAN clustering. *International Journal of Intelligent Systems, 34*(3), 477-492.

Nasibova, R.A., Nasibov, E.N. (2010). Linear aggregation with weighted ranking. *Automation and Remote Control, 44*, 96–102. https://doi.org/10.3103/S0146411610020057

Nursoleh, N. (2022). Location analysis of interest in buying housing in South Tangerang City. *AKADEMIK: Jurnal Mahasiswa Ekonomi dan Bisnis, 2*(1), 35–42. https://doi.org/10.37481/jmeb.v2i1.247

Opricovic, S., Tzeng, G.H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research, 156*, 445–455.

Pamucar, D., Ecer, F., Cirovic, G., & Arlasheedi, M.A. (2020). Application of improved Best Worst Method (BWM) in real-world problems. *Mathematics, 8*(8), 1342. https://doi.org/10.3390/math8081342

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega, 53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J. (2020). A concentration ratio for non-linear Best Worst Method. *International Journal of Information Technology & Decision Making, 19*(3), 891–907.

Saaty, T. L. (2001). *Decision making with dependence and feedback: The analytic network process.* RWS Publications.

Smith, S.J., Munro, M., & Christie, H. (2006). Performing (housing) markets. *Urban Studies, 43*(1), 81–98. https://doi.org/10.1080/00420980500409276

Tezel, B.T., Nasiboglu, R., & Nasibov, E. (2017). Using fuzzy c-regression approach to obtain stress functions for OWA operators. In *2017 International Conference on Computer Science and Engineering (UBMK)* (pp. 528–531). IEEE. https://doi.org/10.1109/UBMK.2017.8093452

Ulutagay, G., Kantarci, S. (2014). Classification with fuzzy OWA distance. In *2014 International Conference on Fuzzy Theory and Its Applications (iFUZZY2014)* (pp. 195–198). IEEE. https://doi.org/10.1109/iFUZZY.2014.7091258

Ulutagay, G., Nasibov, E. (2012). OWA aggregation based CxK-nearest neighbor classification algorithm. In *2012 6th IEEE International Conference Intelligent Systems* (pp. 219–224). IEEE. https://doi.org/10.1109/IS.2012.6335139

Ulutagay, G., Nasibov, E. (2016). C × K-nearest neighbor classification with ordered weighted averaging distance. In Hadjiski, M., Kasabov, N., Filev, D., & Jotsov, V. (Eds.), *Novel Applications of Intelligent Systems* (Vol. 586, pp. 103–120). Springer. https://doi.org/10.1007/978-3-319-14194-7_6

Wikipedia contributors. (2025). *List of universities in Izmir.* Wikipedia. https://en.wikipedia.org/wiki/List_of_universities_in_%C4%B0zmir[Accessed:19-Feb-2025]

Yager, R.R. (1988). On ordered weighted averaging aggregation operators in multi-criteria decision making. *IEEE Transactions on Systems, Man, and Cybernetics, 18*, 183–190.

Yager, R.R. (2004). Generalized OWA aggregation operators. *Fuzzy Optimization and Decision Making, 3*, 93–107. https://doi.org/10.1023/B:FODM.0000013074.68765.97

YÖK. (2025). YÖK student statistics. https://www.yok.gov.tr/Sayfalar/Haberler/2023/yuksekogretimde-yeni-istatistikler.aspx[Accessed:17-Feb-2025]