JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Providing an Optimal Model for the Design of Transportation and Rail Network using Geospatial Information Systems Models: A Case Study of Sanandaj

Navid Arandian[1], Vajih Allah Bakhtyaran[2], and Mahdi Arabi[3]

[1]MSc in GIS, Department of Civil Engineering, Shahid Rajaee Teacher Training University, Tehran, Iran, 1678815811

[2] MSc in GIS, Department of Civil Engineering, Shahid Rajaee Teacher Training University, Tehran, Iran, 1678815811

[3] Faculty of GIS, Department of Civil Engineering, Shahid Rajaee Teacher Training University, Tehran, Iran, 1678815811

Abstract

Today, with the expansion of cities and the increase in urban population, one of the most important problems people face is finding a solution to reduce the distance and time of their inner-city trips. In this context, the network analysis capabilities in the geographic information system, including the shortest path and the combined use of multi-criteria decision-making models and GIS, can be very effective. In this research, the modeling and spatial analysis of the bus system of Sanandaj city were done in two sections: bus stations and bus routes. By using the TOPSIS decision model, the road network was ranked in terms of the priority of establishing bus stations and suitable locations for bus stations were determined. The results of the TOPSIS model showed that the bus stations do not cover the entire road network.

Another model used in this research is the analysis model of the Sanandaj urban road network in the GIS environment to determine optimal routes and calculate the length and time of the routes on the network. By utilizing the communication network layer and creating a smart database, new and optimal routes were identified using the operation of finding the nearest route in GIS. The total number of bus routes after applying the optimal route value algorithm was 2243 meters for the route and 2477 meters for the return route, with a travel time of 20 minutes.

Keywords: Modeling, Spatial analysis, Transportation Network, AHP, GIS

1- Introduction

Change and transformation are unexplained and necessary principles for the survival of human life and urban societies. The speed and acceleration of these changes differ and depend on several factors. Movement is the main dynamic factor of urban life, driving all economic, social, and cultural activities in cities [1]. The communication network and transportation system, as part of urban activities and integral to urban areas, express the dynamism, movement, and life of an urban complex. It is so intertwined with the daily life of people in society that it is almost impossible to imagine a world without displacement [2]. In the urban system, easy, safe, comfortable, and economical movement is essential. As cities experience economic growth, the need to move people and goods also increases [3]. Typically, the larger cities become and the more their population and activity grow, the more transportation problems within a city become acute and complex, especially in third world and developing countries with high population growth and density. Among these problems is the increase in demand for intra-city travel, which has multiplied the pressure on existing transportation networks and led to issues such as air pollution, noise pollution, environmental pollution, increased travel time, traffic congestion, and accidents [4]. Functional problems in transportation affect the entire urban life system, making it necessary to address urban transportation issues through proper planning and sustainable management to optimize road use and capacity. This is urgent and necessary [5]. Urban transportation can be classified into private and public transportation, with public transportation being the key component of a sustainable transportation system accessible to the community. Public transportation, with its concentrated activity, is preferable to private transportation [6]. Public transportation, like the blood that flows in the veins of the body, moves and transports passengers throughout the city. If this movement is regular and free from defects, passengers will reach their destination faster and more efficiently. This regular movement leads to urban growth and development, increasing the efficiency and performance of urban activities. One of the most important urban public transportation systems is the bus and taxi system, which combines the best features of rail with the flexibility and cost advantages of road transit. This system attracts transportation-oriented development and aims to provide a high level of customer satisfaction. Many cities have adopted the rapid bus system and taxi transportation system as a cost-effective method. Spatial modeling and analysis can be used to improve the quality and efficiency of the bus and taxi system, encouraging their use. One method for spatial modeling and analysis of transportation is the network analysis model in the GIS environment. This method identifies the best routes by creating a spatial relationship between network lines and considering certain criteria. The city of Sanandaj, one of the most populated cities in the country, has experienced significant growth in recent decades. The radial shape of the city has led to the central part dominating other areas, with most commercial, educational, medical, and administrative facilities located there. This central area is a major destination for inner-city trips, leading to heavy traffic congestion, especially on central routes. One solution to reduce traffic congestion is to promote the use of the public transportation system to improve the comfort and safety of citizens.

The purpose of this research is to identify and analyze the bus and taxi system in Sanandaj using the TOPSIS model and network analysis in the ArcGIS environment to optimize travel time and routes. The results of the research aim to encourage public institutions and residents of Sanandaj to use the public transport system. The research suggests that the use of private cars should not be the first choice, and reducing traffic congestion, travel time, air pollution, and costs can be achieved by utilizing a public transportation system based on engineering principles.

2- Research background

One of the essential tasks in any research is to study the sources related to the research topic because the sources of science can be explored in their background. John Dewey believes that studying sources helps the researcher to gain deep insight into different aspects of the research topic. The study of sources should be from both sources directly related to the subject of research and sources indirectly related to that subject. In an article titled "Spatial Analysis of Public Transportation, Case Study: Ardabil Bus Organization," the authors used the network analysis model to model the bus network of Ardabil city. They concluded that the multi-objective mathematical model plays an essential role in minimizing travel costs and travel time. Another article presented a new method for optimizing bus routes entitled "GIS-based Bus Route Optimization Model." The goal of this article is to reduce costs from the perspective of both the operator and the users. To achieve this, a new method was proposed using the adaptive neural fuzzy system (ANFIS) combined with the genetic algorithm to optimize bus network routes. The model was tested, analyzed, and evaluated on an Ahvaz urban network, showing improved performance compared to previous models. The results indicate that using the network analysis model to solve routing problems is a desirable solution, providing optimal or near-optimal solutions for many routing problems. In a research study titled "Traffic Flows of Tehran Metropolis, The Capacities and Powers of Crisis Generation, Case Study: Shahid Hemet Highway," the authors modeled the effect of heavy rain on traffic flow. However, heavy rain is just one of the simplest cases of crisis occurrence in Tehran, with other weather factors like snowfall potentially leading to severe crises. Non-atmospheric factors such as earthquakes also require separate calculations and modeling. This highlights the potential depth of urban disasters and crises on the Shahid Hemet highway that have unfortunately not received serious attention. In an article titled "Presentation of a hybrid meta-heuristic algorithm for solving the simultaneous optimization model of bus network design and terminal location," the role of urban uses in the simultaneous optimization of the bus network and bus terminal location was considered. The results obtained showed that implementing the simultaneous algorithm (hybrid-two-level model) and the two-stage algorithm that solves the problem simultaneously leads to better results. Although less time is needed to solve the problem in two separate stages, solving the problem simultaneously allows for editing the answers in each iteration and ultimately converges to better results. In a study on the location of fire stations, the researchers aimed to demonstrate the effectiveness of integrating the logic of layer valuation with the AHP model in a GIS environment. The hybrid model used showed high capability and adaptability for different purposes, such as choosing the optimal location of a site, in various location conditions [15].

In his master's thesis, the researcher utilized network analysis and Dijkstra's algorithm to optimize the public transport fleet in the Golestan region of Ahvaz city. By considering key criteria in routing bus routes and utilizing the operation of finding the nearest route, new and optimal routes were identified. Out of the total number of routes in the Golestan region, 6 routes remained unchanged while 13 bus routes were rerouted. Additionally, suitable locations for constructing bus stations were determined in the rerouted areas. A bus fleet optimization model was presented using a genetic algorithm. The model considers bus network design as a four-step process, including route design, scheduling, fleet allocation, and crew allocation. While examining the goals of bus networks from the perspective of passengers, network operators, and society, the aim of the optimization model is to reduce the costs of the bus system from the operator's point of view. The network and society have contracted this optimization method, which is based on a genetic algorithm. The presented model was tested on an urban network, and its results were analyzed and evaluated [16]. Another model called "the most coverage in the shortest route" was designed for the optimization of bus lines. This model assumes two points, the beginning and the end, as indicators, and the goal is to find the shortest route between these two points with the most demand coverage [17]. Research was conducted on equity in public transportation in Corolis, Oregon (United States of America) using the Lorenz curve technique and analyzing the gap between need and availability. In this study, the researchers clarified the advantages and limitations of the methods used to analyze justice in the enjoyment of public transportation. They aimed to present an optimal method for analyzing justice in the enjoyment of public transportation. Ultimately, the authors concluded that a combination of Lorenz curve methods and gap analysis can provide a more optimal model for investigating justice in public transportation [18]. A mathematical model based on the Veron diagram was proposed to minimize the total travel time of residents for locating bus stops [19]. A sequential method was used to optimize the distribution of bus stops in large cities with a multimodal transportation network in China. The types of bus stops were determined by rank, including connecting, key, and ordinary stations. Connecting stations were manually created to link with other transportation networks such as rail and BRT, while key and normal stations were optimized using coverage models of centrality and potential demand. The results indicated that combining vector and raster data in GIS led to an effective evaluation in the analysis process. In comparison with the current stations, some stations, particularly in central areas, were removed, and new stations were added in marginal areas [20].
In an article titled "TOPSIS model in optimizing the bus network," the goal was to design a new network based on the existing one to improve the network condition and reduce the number of fleets. To achieve this, a combination of the TOPSIS model and neural network was used simultaneously. Two criteria (cost and total travel time) were considered to calculate the objective function. The results demonstrated that the combination of TOPSIS and neural network effectively improved the condition of the bus network and reduced

the number of fleets [21]. A GIS-based platform was utilized to achieve a balance in the distribution of bus stations to reduce redundant stations and enhance the efficiency of bus stations in Wuhan, China. The number and location of candidate stations were determined using the network analysis tool and Thiessen polygons in ArcGIS. Key stations were identified through the random walk algorithm, while normal stations were determined using the spatial service model and public transportation demand in FLOWMAP software [22].

3- Methodology

3-1 Study of area

Sanandaj is the capital of the Kurdistan region, with a longitude and latitude of 46.59 degrees and 35.19 degrees, respectively, and an elevation of 1480 meters above sea level. This city boasts a wonderful climate, especially in spring and autumn. The average annual temperature in Sanandaj is 13.3 degrees Celsius, with the lowest temperature reaching 31 degrees Celsius. The city receives an average annual precipitation of around 473 mm, with an average of 104 cold days throughout the year.

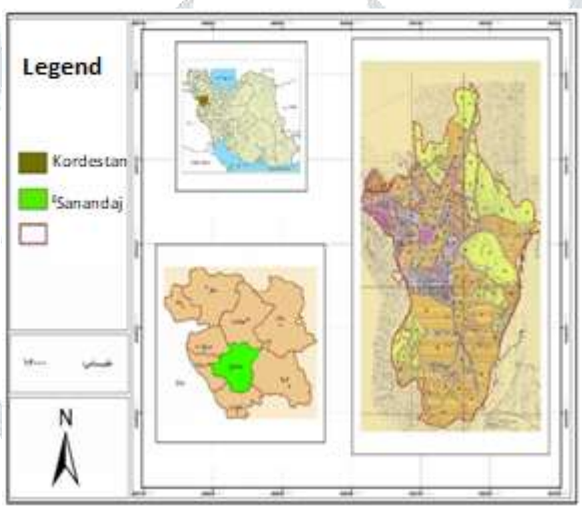

Figure 3-1: Sanandaj geographical position

3-2 Research method

3-2-1 Fuzzy TOPSIS method

According to this method, the best option or solution is the closest solution to the ideal solution or option and the farthest from the non-ideal solution. The ideal solution is the solution that has the highest profit and the lowest cost, while the non-ideal solution is the solution that has the highest cost and the lowest profit. In short, the ideal solution is obtained from the sum of the maximum values of each of the criteria, while the non-ideal solution is obtained from the sum of the lowest values of each of the criteria [23].

3-2-2 steps of the implementation process:

Step 1) For ranking, a decision matrix is formed. The structure of this matrix is as follows:

$$F_1 \quad F_2 \quad \dots \quad F_j \quad \dots \quad F_n$$

$$D = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1j} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2j} & \cdots & f_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{i1} & f_{i2} & \cdots & f_{ij} & \cdots & f_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mj} & \cdots & f_{mn} \end{bmatrix} \quad (1\text{-}3)$$

where $A_i$displays F_j options; i=1… m, i represents the jth index, j = 1..., n and f_{ij} is the value that indicates the performance rate of each option such as A_i according to any criterion or index. It shows like F_j.

Step 2) Calculate the normalized (scaleless) decision matrix R (= $[r_{ij}]$). The normalized values of $r_{ij}$are calculated as equation (1).

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \qquad i = 1, \dots, m\, ; j = 1, \dots, n \quad (2\text{-}3)$$

Step 3) Calculation of the weighted normalized decision matrix (weightless), which is obtained by multiplying the normalized decision matrix by the weights associated with it. The weighted normalized v_{ij} value is calculated as equation (2).

$$v_{ij} = \omega_j r_{ij} \ , \ j = 1, \dots, n\, ; i = 1, \dots, m \quad (3\text{-}3)$$

Step 4) PIS (positive ideal solution) and NIS (negative ideal solution) are determined through relations (3,4).

$$V^+ = \{v_1^+, \dots, v_n^+\} \quad (4\text{-}3)$$
$$= \{\left(\max_i v_{ij} | j \in J\right), \left(\min_i v_{ij} | j \in J'\right)\}$$
$$V^- = \{v_1^-, \dots, v_n^-\} \quad (5\text{-}3)$$
$$= \{(\min_i v_{ij} | j \in J), \left(\max_i v_{ij} | j \in J'\right)\}$$

where J represents the profit criterion and J' represents the cost criterion.

Step 5) The amount of separation (distance) is calculated using the Euclidean distance of dimension m. The value of separation (distance) with D_i^+ corresponding to each option of PIS is obtained from equation (5).

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \ , \ i = 1, \dots, m \quad (6\text{-}3)$$

In the same way, the value of separation (distance) D_i^-corresponding to each option of NIS is obtained from equation (6).

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \ , \ i = 1, \dots, m \quad (7\text{-}3)$$

Step 6) The relative proximity to the ideal solution is calculated and the options are ranked in descending order. The relative closeness of option A_i according to PIS V^+ is obtained from equation (7).

$$\overline{C}_i = \frac{D_i^-}{D_i^+ + D_i^-} \ , \ i = 1, \dots m \quad (8\text{-}3)$$

where the index value $\overline{C}_i$ is between 0 and 1. The higher the value of this index, the better the option.

A set of suppliers can be compared according to the criteria through the above steps. The performance of each option for each criterion is expressed in the form of a decision matrix. The references of (1-3) – (8-3) is [24]

3-2-3 evaluation criteria

Building a bus network requires consideration of numerous parameters and criteria. Identifying all these criteria involves time-consuming field and statistical studies. Many quantitative and qualitative criteria play a role in evaluating efficiency and determining the optimal locations of city bus stations. Therefore, a method is needed to analyze and judge them collectively using a single scale [25]. In this research, the library-document method was utilized. Information from bus organizations, municipalities, and input from experts and professors helped identify effective criteria for evaluating efficiency and determining optimal bus station locations. The TOPSIS model was then used to analyze and evaluate these criteria.

Distance from residential centers	reduced mode score code	distance from educational centers	reduced mode score code
0-300	4	0-300	4
300-500	3	300-500	3
500-800	2	500-800	2
>800	1	>800	1
Distance from cultural centers	reduced mode score code	Distance from commercial centers	reduced mode score code
0-300	4	0-300	4
300-500	3	300-500	3
500-800	2	500-800	2
>800	1	>800	1
Distance from administrative centers	reduced mode score code	distance from recreational centers and green space	reduced mode score code
0-300	4	0-300	4
300-500	3	300-500	3
500-800	2	500-800	2
>800	1	>800	1
Distance from health and treatment centers	reduced mode score code	distance from intersections	reduced mode score code
0-300	4	0-300	4
300-500	3	300-500	3
500-800	2	500-800	2
>800	1	>800	1

Table 3-1: Criteria for use in TOPSIS model

As stated, the existence of different and sometimes conflicting criteria for decision-making requires the use of multivariate methods. To perform the TOPSIS model, we must first descale or standardize the layers, and in this research, the linear scale conversion method was used for de-scaling [26]. For this purpose, in order to standardize each of the layers, linear scale formulas were implemented according to the type of criteria (good or bad) in the Raster Calculator environment of ArcGIS software on each of the layers. The existing administrative use in Sanandaj city is based on the land use map. The city has been classified that the highest degree of suitability of use for organizing public transportation is assigned to the use (commercial, educational, administrative) and the lowest degree of suitability is given to the use (military, barren, garden).

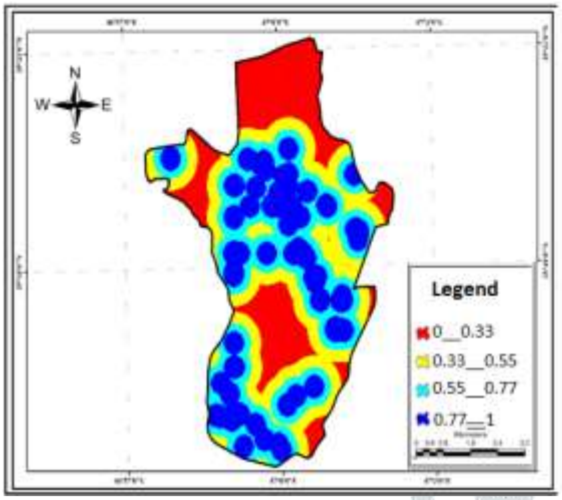

Figure 3-2 Map of the distance from commercial centers

Business centers are among the users compatible with public transportation, as a result, keeping a distance from them is one of the basic principles of achieving transportation. According to the valuation of the layers, the minimum distances are 0.0-33 and the maximum distance is more than 1500 meters.

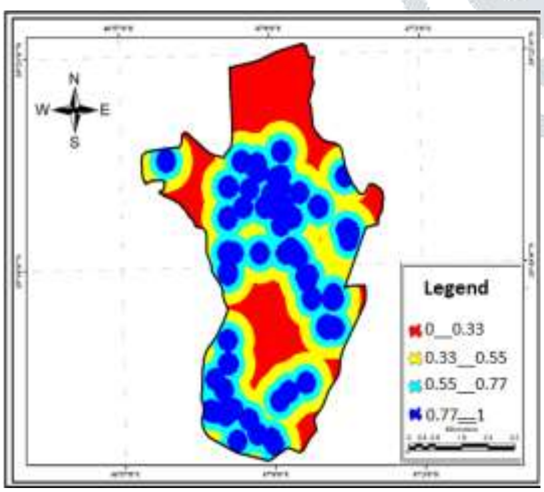

Figure 3-3 Map of distance from administrative centers

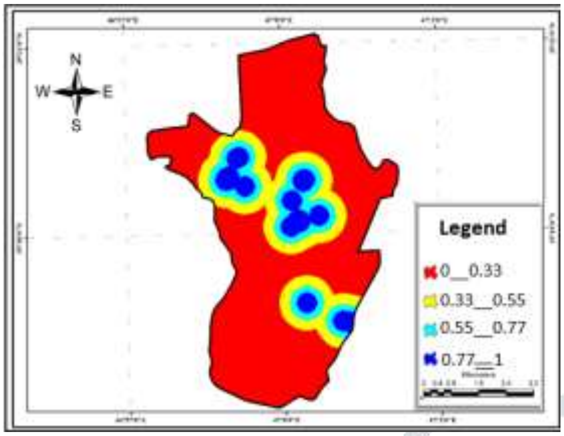

Figure 3-4 distance map from educational

Educational space is a space that is special for human education. It includes collections such as kindergartens, kindergartens, elementary schools, middle schools, high schools, conservatories, and university centers. The amount and manner of spatial distribution of educational centers at community levels and in different areas of a city shows special attention to educational issues, which itself is the basis of socio-economic and cultural factors. Therefore, the amount and number of education per capita is considered as one of the effective indicators to determine the areas of the poor.

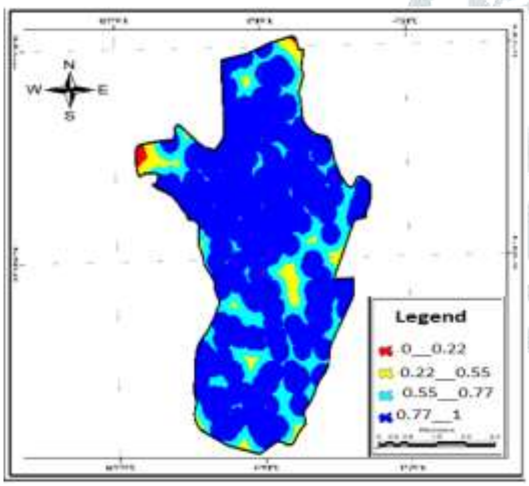

Figure 3-5 Distance map from residential centers

Normally, about 60% of the area of each city is covered by residential space. While this amount in Sanandaj city is 31.57% equivalent to 1980 hectares. Considering the population of Sanandaj city of 485,000 people, the per capita residential area is 44.8 square meters for each person, which represents a favorable per capita (master plan the closer the residential centers are to the hospital centers, the higher the score, and the further away from the residential centers, the lower the score. According to the valuation of the layers, the minimum distance is 0-100 and the maximum distance is more than 500 meters.

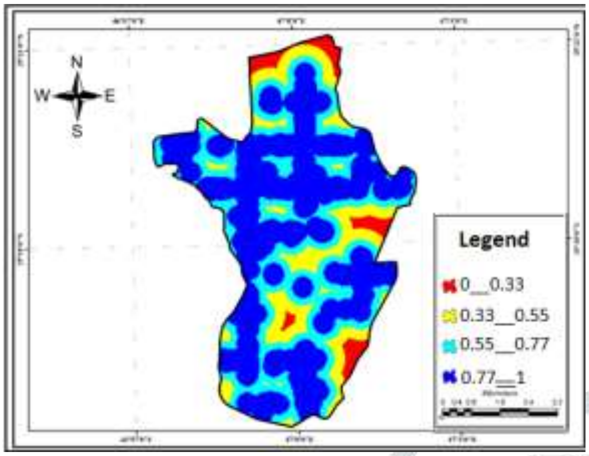

Figure 3-6 Map of the distance from recreation centers and green spaces

One of the most important indicators in public transportation is access to green space [27]. Due to our innate nature, humans are drawn to nature and establishing a relationship with green spaces. In addition to the effects, it has on the human psyche, green space also reduces atmospheric pollution. On a larger scale, green space has reduced noise pollution in Sanandaj city, covering about 5.09% of the total area, equivalent to 319.38 hectares. This means that per capita green space is calculated at 7.7 square meters per person, which is considered desirable and meets global standards. Based on the evaluation of the layers, the minimum distance to green space is 200-200 meters, while the maximum distance is more than 1000 meters.

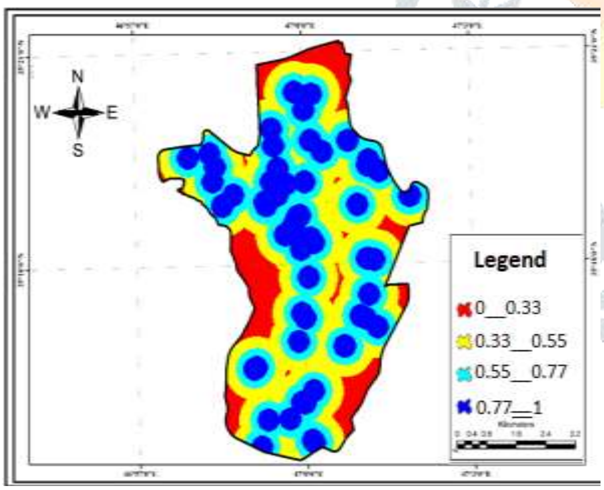

Figure 3-7 Map of the distance from health centers

Another important urban use is spaces dedicated to healthcare services [28]. Access to this use can be considered one of the main indicators in determining the level of spatial justice in the field of public transportation, as less developed areas have less access to these spaces.

Quantitative and qualitative investigation of therapeutic use at the level of Sanandaj neighborhoods shows the relative deprivation of most of the city's neighborhoods and the inappropriate distribution and concentration of most of these services in the center of the city. The closer the medical centers are to existing public transportation access, the higher the score, and the farther away they are, the lower the score.

According to the evaluation of the layers, the minimum distance is 0-300 meters and the maximum distance is more than 1500 meters.

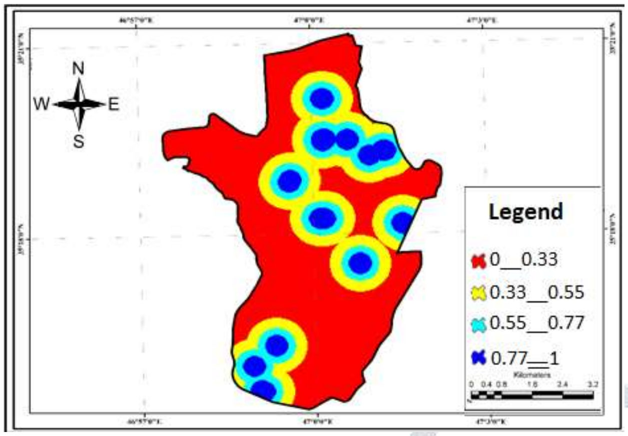

Figure 3-8 Map of the distance from cultural centers

Cultural use is one of the important service uses in the use system of a neighborhood that can meet the needs of different classes and age groups [29]. The amount and accessibility of this use can be used to identify developed areas.

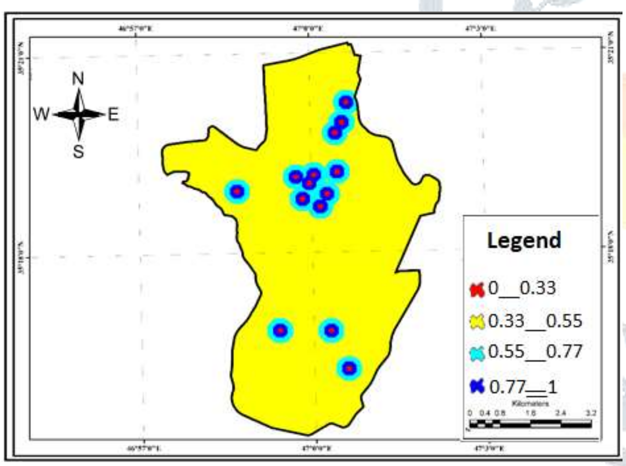

Figure 3-9 Map of distance from intersections

One of the components of the communication network is fast and timely access to the intersections [30]. Based on this, the proximity to first-class accesses has been the best option. In this study, after the buffer operation, the highest score was given to the shortest distance from the roads and the lowest score was assigned to the longest distance. According to the valuation of the layers, the minimum distances are 0-100 and the maximum distances are more than 500 meters.

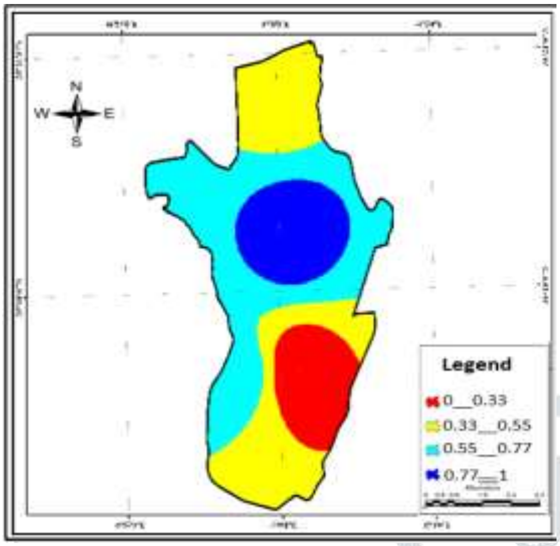

Figure 3-10 Map of distance from population centers

3-2-4 Obtaining positive and negative ideals (dj) and (dj)

After standardizing the criteria layer and calculating their weights, the V matrix is obtained from the product of the standard layers of each index in their respective weights [31]. After this step, we define the positive ideal solution (A) and the negative ideal solution (A) and based on that we calculate the distance of each option from the positive and negative ideal, Figure 4-12 is the positive ideal and Figure 4-13 It shows the negative ideal.

v^-	V^+	Criteria
0.0933333	0.28	population density
0.0173333	0.052	Distance from administrative centers
0.024667	0.074	Distance from commercial centers
0.716667	0.215	Distance from residential centers
0.0373333	0.112	Distance from educational centers
0.00633333	0.019	Distance from cultural centers
0.00533333	0.016	Distance from entertainment centers and green spaces
0.0133333	0.04	Distance from health centers
0.00933333	0.028	Distance from intersection

0.0546667	0.164	Access

Table 3-2 the highest and lowest value of each criterion based on the matrix

After finding the distance from the positive ideal, each criterion has been added together and their square root has been obtained according to the formula through the raster calculator (calculation of separation size). This process is repeated for the negative ideal as well. The obtained maps will include (separation size for positive ideal and separation size for negative ideal) which are shown in figures 3-13 and 3-14.

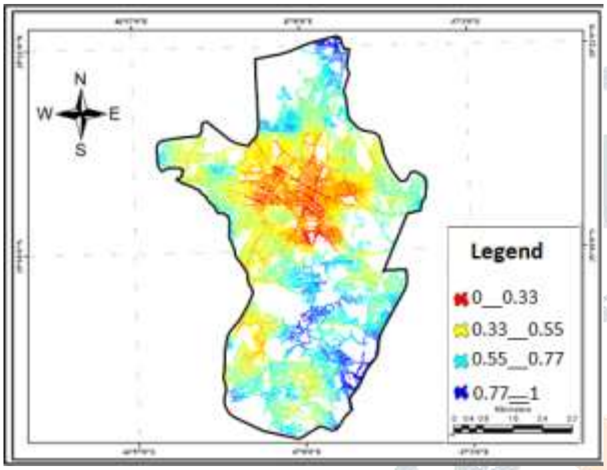

Figure 3-11 Map of the distance from the positive ideal

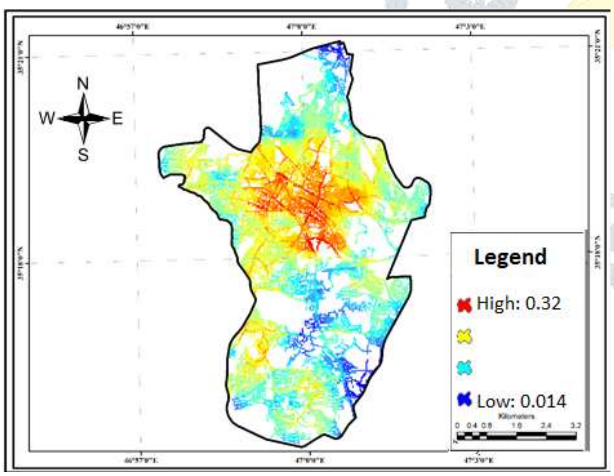

Figure 3-12 Map of the distance from the negative ideal

3-2-5 Final map of TOPSIS model

Finally, by inputting the CLi formula, we were able to identify and specify the ranking of urban streets and areas suitable for the construction of bus stations. The road network, which was represented by values between zero and one in the raster layer, was divided into four classes. The last class indicates the best locations for bus and taxi stations (Figure 14-4). Based on these results, it is clear that the map alone cannot efficiently evaluate and determine the optimal locations for bus stations. Therefore, in the final step, after creating the urban network, we determined the standard distance of existing stations using network analysis in the GIS environment. This research aims to demonstrate the effectiveness of integrating layer valuation logic with the AHP model and TOPSIS in a GIS environment. The hybrid model utilized has a high capability and can be adapted for different purposes and various local conditions.

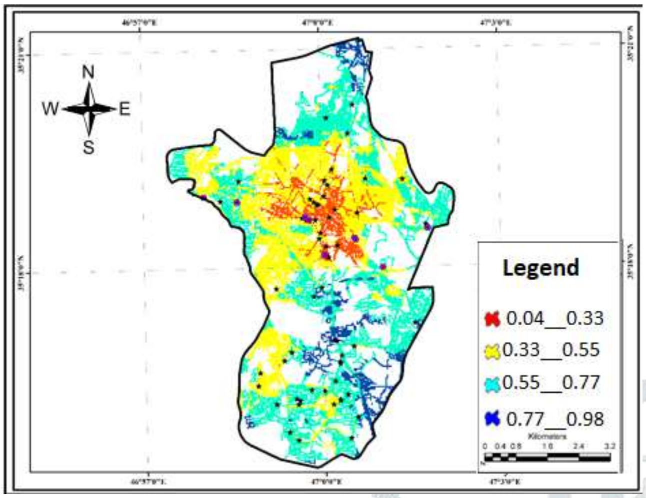

Figure 3-13 The final map of TOPSIS model

As can be seen in the final map of the stations, most of the stations are located in a suitable location, but due to the fact that these urban facilities are operating at the level of the roads of the study area, in this part of the research, with the overlap of these facilities and the network of roads and the communication network identified the sections that have a high weight and no stations are located in them and examined them. As mentioned in the previous paragraph, this network was divided into four exit classes, which are high priority routes in the sections without station coverage. It is that the sections of the northern girdle are very important.

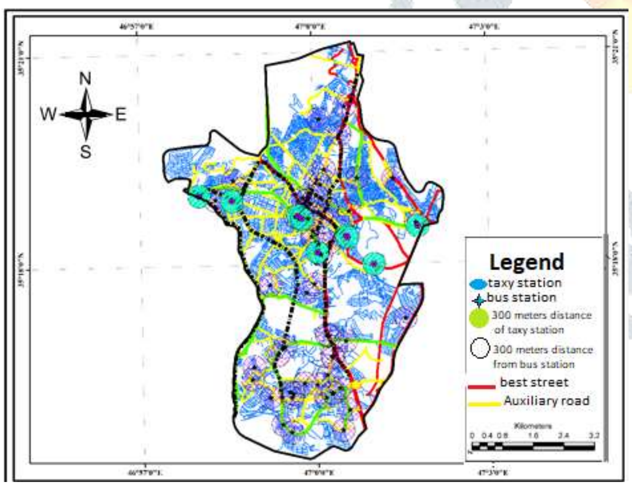

Figure 3-14 The final map of taxi and bus stations

However, it is not possible to achieve an effective analysis from the overlap of the network and the stations alone. Therefore, the privacy of the stations within a radius of 300 meters was also analyzed in the network analysis in the GIS environment. This allows for checking the proper distance between stations [32]. The distance between stations must strike a balance between providing the shortest access to maximize system coverage and operational speed to minimize travel time for users. However, this balance can also affect operating speed, travel comfort, and other factors in the system. Additionally, as the number of stations increases, so do the system costs in terms of station equipment. The suggested distance between stations is inversely proportional to the population distribution in different areas. Areas with higher populations warrant shorter distances between stations. Based on the bus and taxi system station guide, it is recommended that in residential and commercial areas with high population density, the distance between stations should be 300 to 400 meters. In rural areas with lower density and fewer attractive travel centers, a distance of 600 to 700 meters should be considered.

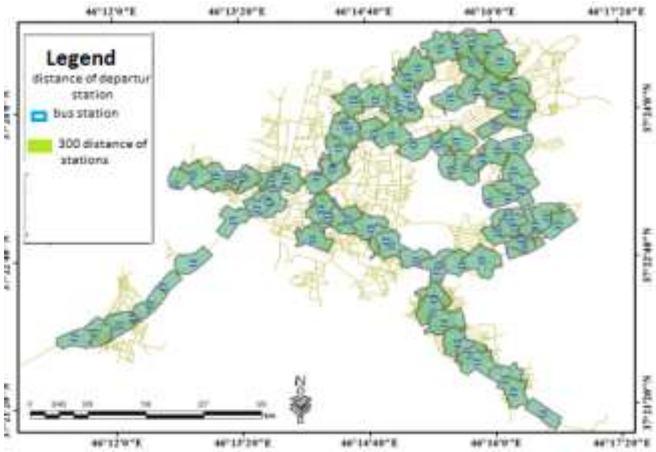

Figure 3-15 300-meter distance map of bus stops

As the results show, the appropriate distance of the departure stations from each other, which in this research is considered to be 300 meters according to the standards and the scope of the study, is not observed in most of the stations in Sanandaj city. It has also reduced the operating speed of buses.

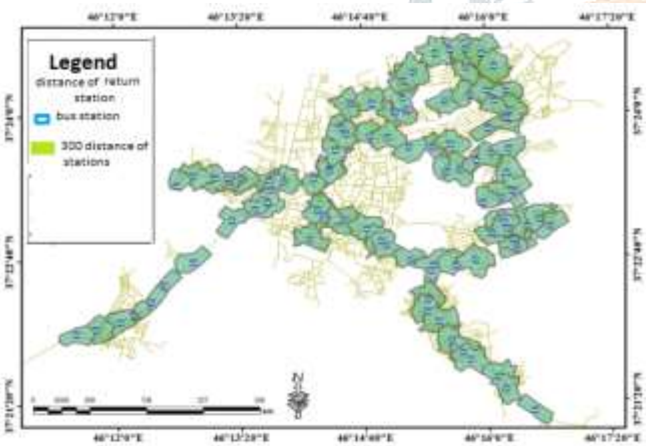

Figure 3-16 300-meter distance map of bus return stations

Although the existing stations of Sanandaj according to the evaluation map of the TOPSIS road network are mostly located in suitable locations, but their distance from each other is not suitable, especially in the southeast and southwest parts where the population density and travel attraction centers are low. This distance should be considered more than 300 meters, but even this distance of 300 meters has not been observed.

3-3 network analysis

As mentioned, the capabilities of the geographic information system in the field of optimal management of intra-city trips are getting more and more attention of users. In order for this system to gain the trust of its users, it is necessary to increase the accuracy of its calculations and capabilities. One of the problems that can be very useful in increasing the accuracy of the results of the shortest path problems. The network analysis in the geographic information system can be done based on various criteria. One of the most important and widely used criteria is time, length, type of road network [33].

Calculating the shortest path is one of the most important operations in most network analysis. Finding the shortest and best public transportation routes in the GIS environment requires network construction and network analysis in the first step. For this purpose, by using the existing layers, especially the road layer, a smart network has been built. After building the network in the GIS environment, the optimal bus routes have been modeled assuming that the origin and destination are fixed and considering the criteria of length, time, and type of one-way and two-way passages, which are followed by the optimal access routes along with the required distance and time. It is shown in the figure below.

The amount of optimization	Optimal return path	return path	The optimal value	The optimal path went	the outgoing path	the name of the path
472	4053	4525	1136	4526	5662	Nesar
1720	5123	6849	142	6575	6717	Kurdistan town
67	6060	6127	965	6088	7053	Hasan Abad
146	6070	6216	0	5043	5043	Keshavarz Town
72	3267	3339	0	2330	2330	Nizamabad

Table 3-3, the results of implementing network analysis before and after optimization in 5 routes

The highest optimal value of the outgoing route is related to Nesar axis station which is 1136 and the lowest optimal value which is unchanged is related to Keshavarz Town and Nizamabad axis and the highest optimal value of the return route is related to Kurdistan town which is 1720 and the lowest optimal value is related to Hassan Abad axis which was 67 meters.

4- Discussion

Today, in cities, public transportation, including urban buses and taxis, holds a special place. The discussion surrounding public transportation systems in cities has expanded beyond technical and engineering aspects to encompass social, health, and economic considerations [34]. Public transportation systems are seen as a key strategy in reducing the reliance on private cars and providing a public service that ensures mobility for all citizens. Bus services are essential for quick and affordable access, making conventional methods inadequate due to high costs and time requirements. Therefore, there has been a recent trend towards utilizing new technologies in traffic and urban transportation management, particularly in optimizing bus systems in various countries, recognized by managers and urban planners as the most effective solution. One of the technologies being used today to address urban transportation challenges is Geographic Information Systems (GIS), which can help manage and organize bus systems efficiently. The capabilities of GIS in optimizing intra-city travel are gaining attention from different users. To build trust with users, it is crucial to enhance the accuracy and capabilities of these systems. In the initial stage of this research, effective factors in modeling bus and taxi stations were identified, and necessary information layers were prepared for modeling, ranking the road network, and determining suitable locations for stations. Criteria such as proximity to residential, administrative, commercial, educational, cultural, recreational, and green spaces, as well as health and medical centers, distance from intersections, accessibility, and population density were selected as key factors. After identifying and standardizing the criteria, they were weighted based on their importance using the Analytic Hierarchy Process (AHP) model. Results showed that population density carried the most weight in determining suitable bus and taxi station locations. By applying the CLi formula and the TOPSIS model, urban streets and areas suitable for station construction were identified and ranked. The TOPSIS model indicated that the optimal distance between stations should be 300 meters, yet this standard was not met in most areas of Sanandaj city. The close proximity of stations along routes has slowed down bus operations. While existing stations in Sanandaj are generally well-located according to the TOPSIS assessment maps, their spacing from each other is inadequate, especially in low-density areas like the southeast and southwest. Adhering to a 300-meter distance between stations is crucial for efficient urban transportation.

Network analysis model: To implement this model, first, the layers of Sanandaj city roads network and the location of the origin and destination stations of each line were prepared. After preparing and updating the road network layer and fixing topological and non-topological errors and correcting them, a smart database was created to implement network analysis in the geographic information system. After creating the network and adding the origin and destination stations and considering the ranking of the road network obtained from the TOPSIS model, the shortest route was modeled and the optimal routes were determined by taking into account the criteria of length and time.

5- Conclusion

Today, public transportation, including urban buses and taxis, holds a significant place in cities. The discussion surrounding public transportation systems has expanded beyond technical and engineering aspects to encompass social, health, and economic considerations. These systems are viewed as a key strategy in reducing private car usage and are seen as a public service that ensures the mobility of all citizens. The results of the network analysis reveal the following information: Route number 1, centered around Nasar, has an optimized outgoing route value of 1136 and a return route value of 472. Route number 2, focused on Kurdistan settlement, has an optimized outgoing route value of 142 and a return route value of 142, totaling 1726. Route number 3, along the Hassan Abad axis, has an optimized outgoing route value of 965 and a return route value of 67. Route number 4, in Keshavarz Town, has an optimal outgoing route value of 0 and a return route value of 146. Lastly, route number 5, in Nizamabad, has an optimal outgoing route value of 0 and a return route value of 72. The most optimal departure route is related to the Nasar axis at 1136, while the least optimal route, without optimization, is associated with Keshavarz Town and Nizam Abad axes at 0 meters. The highest optimal return distance is tied to Kurdistan Town at 1726, while the lowest optimal return path is linked to the Hassan Abad axis at 67 meters. In total, the optimal value of the total return path is 2243 and the optimal value of the total return path is 2477.

References

[1] Alemi, F., Circella, G., Handy, S., Mokhtarian, P.: What influences travelers to use Uber? Exploring the factors affecting the adoption of on-demand ride services in California. Travel Behav. Soc. **13**, 88–104 (2018)

[2] Gao, F., Li, S., Tan, Z., Wu, Z., Zhang, X., Huang, G., Huang, Z.: Understanding the modifiable areal unit problem in dockless bike sharing usage and exploring the interactive effects of built environment factors. Int. J. Geogr. Inf. Sci. **35**, 1905–1925 (2021)

[3] Chen, F., Wu, J., Chen, X., Wang, J.: Vehicle kilometers traveled reduction impacts of transit-oriented development: evidence from Shanghai City. Transp. Res. Part D Transp. Environ. **55**, 227–245 (2017)

[4] Faber, R., Merkies, R., Damen, W., Oirbans, L., Massa, D., Kroesen, M., Molin, E.: The role of travel-related reasons for location choice in residential self-selection. Travel Behav. Soc. **25**, 120–132 (2021)

[5] Kim, S.H., Mokhtarian, P.L., Circella, G.: *The Impact of Emerging Technologies and Trends on Travel Demand in Georgia*. Georgia Department of Transportation. https://rosap.ntl.bts.gov/view/dot/56095 (2019)

[6] Jaff, M.M., Hamsa, A.A.K.: Estimating commute-travel implications of telecommuting by female employees in Kuala Lumpur, Malaysia. J. Traffic Transp. Eng. English Ed. **5**, 148–155 (2018). https://doi.org/10.1016/j.jtte.2018.03.001

[7] Marra, A.D., Becker, H., Axhausen, K.W., Corman, F.: Developing a passive GPS tracking system to study long-term travel behavior. Transp. Res. Part C Emerg. Technol. **104**, 348–368 (2019). https://doi.org/10.1016/J.TRC.2019.05.006

[8] Brands, T., Dixit, M., van Oort, N.: Impact of a new metro line in amsterdam on ridership, travel times, reliability and societal costs and benefits. Eur. J. Transp. Infrastruct. Res. **20**, 335–353 (2020)

[9] Nielsen, O.A., Eltved, M., Anderson, M.K., Prato, C.G.: Relevance of detailed transfer attributes in large-scale multimodal route choice models for metropolitan public transport passengers. Transp. Res. Part A Policy Pract. **147**, 76–92 (2021). https://doi.org/10.1016/J.TRA.2021.02.010

[10] Yap, M., Cats, O., van Arem, B.: Crowding valuation in urban tram and bus transportation based on smart card data. Transp. A Transp. Sci. **16**, 23–42 (2020). https://doi.org/10.1080/23249935.2018.1537319

[11] Bulteau, J., Feuillet, T., Dantan, S.: Carpooling and carsharing for commuting in the Paris region: a comprehensive exploration of the individual and contextual correlates of their uses. Travel Behav. Soc. **16**, 77–87 (2019). https://doi.org/10.1016/j.tbs.2019.04.007

[12] Do, M., Jung, H.: The socio-economic benefits of sharing economy: colleague-based carpooling service in Korea. J. Open Innov. Technol. Market Complex. **4**, 40 (2018). https://doi.org/10.3390/joitmc4030040

[13] Ali, J., Perumal, S., Shaari, H.: Application of the stimulus-organism-response model in the airline industry: examining mediating role of airline image in repurchase intention. Int. J. Supply Chain Manag. **9**(2), 981–989 (2020)

[14] Barrero, G.A., Rodriguez-Valencia, A.: Asking the user: a perceptional approach for bicycle infrastructure design. Int. J. Sustain. Transp. (2021). https://doi.org/10.1080/15568318.2020.1871127

[15] Huertas, J.A., Palacio, A., Botero, M., Carvajal, G.A., van Laake, T., Higuera-Mendieta, D., Cabrales, S.A., Guzman, L.A., Sarmiento, O.L., Medaglia, A.L.: Level of traffic stress-based classification: a clustering approach for Bogotá, Colombia. Transp. Res. Part D Transp. Environ. (2020). https://doi.org/10.1016/j.trd.2020.102420

[16] Akter, T., Hernandez, S., Corro-Diaz, K., Chi, N.: Leveraging open-source GIS tools to determine freight activity petterns from anonymous GIS data. Edited by AASHTO GIS for Transportation Symposium, pp. 55–69 (2018).

[17] M. Marzouk, M.M. Ashmawy. Assessment of highways concrete and asphalt pavements using superiority inferiority ranking technique. Constr. Innov., 21 (2021), pp. 259-278, 10.1108/CI-10-2019-0107

[18] A. Nautiyal, S. Sharma. Scientific approach using AHP to prioritize low volume rural roads for pavement maintenance. J. Qual. Maint. Eng., 28 (2022), pp. 411-429, 10.1108/JQME-12-2019-0111

[19] S.Y. Park, C.L. Lan, R.S. Rao, G.L. Chang. Field evaluation of the dilemma zone protection system at suburban intersections. Transp. Res. Rec., 2672 (21) (2018), pp. 51-62, 10.1177/0361198118774235

[20] T. Urbanik, A. Tanaka, B. Lozner, E. Lindstrom, K. Lee, S. Quayle, S. Beaird, S. Tsoi, P. Ryus, D. Gettman, S. Sunkari, K. Balke, D. Bullock, Signal timing manual. National Cooperative Highway Research Program (NCHRP) Report 812. 2015. https://transops.s3.amazonaws.com/uploaded_files/Signal%20Timing%20Manual%20812.pdf

[21] K. Nguyen, J.M. Goicolea, F. Galbadon. Comparison of dynamic effects of high-speed traffic load on ballasted track using a simplified two-dimensional and full three-dimensional model. Proc. Inst. Mech. Eng., 228 (2) (2014), pp. 128-142

[22] A. Lukas, O. Moerth-Teo, L. Schwarz, H.P. Schnöll, M. Wolf, C. Ramsauer. Agile powertrain development: considerations to incorporate agile principles. Designs, 5 (4) (2021), p. 60, 10.3390/designs5040060

[23] Kaya T, Kahraman C. An integrated fuzzy AHP-ELECTRE methodology for environmental impact assessment. *Expert Syst Appl* 2011;38:8553-62.

[24] Bentes AV, Carneiro J, da Silva JF, Kimura H. Multidimensional assessment of organizational performance: Integrating BSC and AHP. *J Bus Res* 2012;65:1790-9.

[25] Arandian N., Behzadi S. (2020). Providing a Web_Based Platform based on Predicted Weights from existing. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, https://doi.org/10.5194/isprs-archives-XLII-4-W18-1169-2020

[26] J. Benítez et al. An approach to AHP decision in a dynamic context. Decision Support Systems. (2012)

[27] Zhu, G.-N., Hu, J., & Ren, H. (2020). A fuzzy rough number-based AHP-TOPSIS for design concept evaluation under uncertain environments. *Applied Soft Computing*, *91*, 106228. https://doi.org/10.1016/j.asoc.2020.106228

[28] T.L. Saaty, L.T. Tran. On the invalidity of fuzzifying numerical judgments in the Analytic Hierarchy Process, Math Comput Model, 46 (2007), pp. 962-975

[29] V.K. Varma et al. Decision support system for the sustainable forest management. Forest Ecology and Management. (2000), https://doi.org/10.1016/S0378-1127(99)00271-6

[30] T. Aksoy, A. Dabanli, M. Cetin, M.A. Senyel Kurkcuoglu, A.E. Cengiz, S.N. Cabuk, B. Agacsapan, A. Cabuk

Evaluation of comparing urban area land use change with Urban Atlas and CORINE data

Environ. Sci. Pollut. Res., 29 (19) (2022), pp. 28995-29015, 10.1007/s11356-021-17766-y

[31] M. Cetin, Using GIS analysis to assess urban green space in terms of accessibility: case study in Kutahya

Int. J. Sustain. Dev. Ecol., 22 (5) (2015), pp. 420-424, 10.1080/13504509.2015.1061066

[32] X. Chuansheng, D. Dapeng, H. Shengping, X. Xin, C. Yingjie, Safety evaluation of smart grid based on AHP entropy method, Sys. Eng. Procedia., 4 (2012), pp. 203-209, 10.1016/j.sepro.2011.11.067

[33] H. Fan, Q. Cai, Research progress of freeze-thaw erosion [in Chinese], Sci. Soil Water Conserv., 1 (4) (2003), pp. 50-55, 10.16843/j.sswc.2003.04.012

[34] Y. Gan, Q. Duan, W. Gong, C. Tong, Y. Sun, W. Chu, A. Ye, C. Miao, Z. Di. A comprehensive evaluation of various sensitivity analysis methods: A case study with a hydrological model. Environ. Model Softw., 51 (2014), pp. 269-285, 10.1016/j.envsoft.2013.09.031