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DETERMINING CRITERIA FOR OPTIMAL SITE SELECTION FOR SOLAR POWER PLANTS

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Summary

Site selection is one of the basic vital decisions in the start-up process, expansion or relocation of businesses of all kinds. Construction of a new industrial system in the form of solar photovoltaic power plant is a major long-term investment, and in this sense determining the location is critical point on the road to success or failure of industrial system. One of the main objectives in industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. This work suggests how to define and classify particular criteria considered for solar PV farm siting. Multi-criteria decision analysis (MCDA) is proposed as a method to process available technical information to support decisions in many fields, especially in environmental decision making. In some cases, due to the lack of reliable information on the impact of various natural factors on the economic activity related to the use of land resources, the method of expert assessments can be used. The peculiarity of this method is the lack of empirical evidence of the influence of a given factor on the final result of decision-making. In this case the value of separate factor is judged by experts. When applying this method, expert groups are formed of leading specialists, the main influence factors is established, a questionnaire and a scale of criteria are compiled. Level of reliability of the results is assessed by the coefficient of concordance.

Keywords

influence criteria • solar photovoltaic power plant • optimal site selection • coefficient of concordance • MCDA • analytical hierarchy process (AHP)

1. Introduction

Siting is a crucial component of developing distributed energy resources such as solar and there are some siting considerations that are common to all energy generation projects. These aspects include things like maximizing energy output, proximity to electrical infrastructure, ecological impacts, and permitting issues.

The main purpose of this work is to determine reliable influence criteria for optimal site selection for solar photovoltaic power plants.

2. Influence criteria identifying and processing

2.1. Determination of influence criteria and requirements for site selection

Studies using GIS to analyse solar power plant siting take into consideration a number of requirements. These include physical features of land, environmental factors, land-use restrictions, social concerns and electrical-infrastructure requirements [Brewer et al. 2015]. In studies using multi-criteria decision analysis researchers frequently classify particular criteria into multiple ranges based on suitability according to literature reviews. The criteria considered for solar PV farm siting are presented in Table 1.

Table 1. Criteria considered for Solar PV power plant siting

No	Criteria	Requirements
	Evaluation criteria	
1	Abundant solar irradiation	minimum is 1100 kWh · m^{-2} per year
2	Certain slope & aspect	• slope < 5–15° • aspect = 110–200° (southeast, south, partly southwest)
3	Transmission lines adjusted to capacity located nearby	TL with equal and more than 35 kV around 600 m nearby
4	Proximity to populated area	< 2500 m
5	Proximity to enterprises	< 3500 m
6	Proximity to road network	< 500 m
7	Average air temperature in July (north hemisphere)	15–40°C
8	Proximity to multi-storey houses (> 16 storeys)	> 100 m
9	Proximity to residential areas	> 500 m
	Exclusion criteria	
10	Land cover	• free of mountains, forests, water bodies, buildings, wetlands, floodplains, • preferably low and medium grassy vegetation, shrublands, barren lands, closed landfills, abandoned mine lands
11	Protected areas	national and regional parks, areas of cultural heritage, paleontological and archaeological sites
12	Shoreline	> 1000 m
13	High altitude areas	> 1500 m

Source: authors' study

The greater amount of solar irradiation, the more electricity generated by a solar cell module. To be economically viable, photovoltaic systems typically require solar irradiation in an amount of 1100 kWh · m^{-2} per year.

With regards to slope of the terrain, in general, flat land is most suitable for solar sites. Steep slopes make construction difficult and more expensive [Brewer et al. 2015, Tahri et al. 2015]. With the increase of the slope the complexity of the design increases, which often leads to a proportional increase in costs. Installation of photovoltaic panels on steep slopes can cause problems related to erosion, drainage systems and the stability of the foundation.

The slope of the earth's surface affects both conditions of optimal orientation and inclination of PV modules and the technical component of all photovoltaic power plant installation. It is believed that the maximum slope that makes installation technically feasible is 15%. If the slope is small, then the orientation is not important, as it can easily be offset by supporting structures for photovoltaic panels, whereas on steeper slopes, slope orientation is a deterrent, and in this case solar power plant could be built only in the south-oriented areas.

In literature, there is a wide variation of slope values considered suitable for solar power plants: various studies restricted slopes to below 3% [Arán-Carrión et al. 2008a, Uyan 2013], 5% [Stoms 2013], or 15% [Arnette et al. 2011, Castillo et al. 2016].

Air temperature directly affects the performance of solar power plant and the period of its operation. Electrical parameters of any solar cell are determined by the so-called standard testing conditions, such as when the intensity of solar radiation is 1000 $W \cdot m^{-2}$ and panel operating temperature –25°C [Jraidi et al. 2014]. The optimum air temperature 15–40°C.

The issue related to the proximity of a site for the solar plant to a power supply line is considered an economic factor. It reduces the cost of installation and creation of a new infrastructure. The closer a project is located to existing power lines, the cheaper it will be to connect it to the grid and the lower line-loss and transmission expenses [Castillo et al. 2016, Charabi et al. 2011]. The solar PV utility with a capacity of less than 15 MW requires a nearby power line of 35 kV, while solar utility with a capacity of over 15 MW requires special high-voltage transmission lines over 35 kV.

A number of studies consider solar PV farm sites closer to areas of high electricity demand (i.e. cities, villages, enterprises) to be more desirable, because they minimize the distance electricity would have to travel and reduce associated line-loss and transmission expenses [Janke 2010, Tahri et al. 2015, Arán-Carrión et al. 2008a, Arán-Carrión et al. 2008b].

Because roads are expensive to build, selecting sites closer to roads is cheaper and can minimize the environmental impacts associated with building new roads [Janke 2010, Charabi et al. 2011]. The existing road network must be suitable for the transportation of materials needed for the construction of solar power plant. Also, potentially suitable land should have roads about 3 meters wide for the appropriate maintenance of the farm. PV systems could be integrated into infrastructure such as noise barriers along roads.

Multi-storey houses may block sunlight from reaching a solar farm in at certain times of the day. This factor directly affects the performance of solar power plants. Therefore it is appropriate to set solar PV plant away from this type of buildings.

While some studies considered it desirable for projects to be close to urban areas with high demand for electricity, others considered it undesirable to be too close to residential areas. The main reasons for this concern were the increased potential for not-in-my-backyard (NIMBY) opposition and the possibility of impeding urban growth [Janke 2010, Sanchez-Lozano et al. 2013, Castillo et al. 2016, Uyan 2013].

Land use and availability may be an issue both in terms of the actual PV plant site and along the main transmission line interconnection route. These issues need to be addressed early enough in the process to avoid any problems during the operational phase. Typically, the transmission line must cross plots of land held by different owners, which can present a challenge to purchasing or leasing the land. This can ultimately result in some access or availability restrictions to properties along the preferred route. Thus, it is important to check in depth the cadastral documents, ownership titles and land easement agreements.

Regarding land cover potential suitable area must be free of mountains, forests, water bodies, buildings, wetlands, floodplains and preferably has low or medium grassy vegetation or shrublands.

Solar parks are not typically proposed in landscapes designated for natural beauty, or protected areas of archaeological or ecological importance. Nevertheless, a careful assessment of these types of potential fatal flaws should be performed early in the project feasibility stage.

Distance at least 1 000 m from a shoreline could protect a solar farm from consequences of natural sea disasters. Another reason to avoid seaside areas, when installing a solar farm, is their higher price, making such installations less cost-effective.

In addition, high altitude areas have higher transportation cost and are not preferable.

2.2. Reliability of expert assessment for influence criteria

For suitability analysis it is necessary to give a relative weight to each of the participating criteria as per their relative importance in the desired development.

It is worth to mention that we can give the certain values (not null) for weights only of evaluation influence criteria, because exclusion criteria are not taken into account in a further overlay analysis, their purpose is to eliminate all unsuitable territories, consequently, the weights of these criteria are null.

In some cases, due to the lack of reliable information on the impact of various natural factors on the economic activity related to the use of land resources, the method of expert assessments can be used [Perovych and Vynarchyk 2013]. The peculiarity of this method is the lack of well-formalized evidence of the influence of a certain factor on the final result of decision-making. Because it is impossible to receive a clear, complete and reliable information as the value of a separate factor is hard to calculate, the assessment must be carried out by an expert.

When applying this method, expert groups are forming of leading specialists, the main influence factors are established, a questionnaire and a scale of evaluation criteria are compiled.

In practice, it is believed that the number of factors should not exceed 15, and in order to obtain objective results, number of experts should exceed the number of factors by 2–3 times.

In order to determine the significance of individual factors and judgements of experts, mostly the method of rank correlation is used. Its implementation involves three stages [Legendre 2010]. In the first stage, the system of ranks of factors and their significance are determined, in the second – the level of consistency of the results of experts is established and in the third, final stage, the significance of the coefficients of the rank correlation is calculated, which allows to make conclusions about the reliability of the results. The criteria of determining the coherence of experts' judgements is the coefficient of concordance.

$$W = \frac{12\sum_{j=1}^{n} d_j^2}{m^2(n^3 - n) - m\sum_{i=1}^{m} T_i}, \tag{1}$$

where:

m – number of experts,
n – number of factors.

Value d_j represents the deviation of the rank sum of a separate j factor from the average of all factors. In other words,

$$d_j = S_j - \frac{\sum_{j=1}^{n} S_j}{n}, \tag{2}$$

where:

S_j – rank sum of j factor.

Value $\sum_{j=1}^{m} T_i$ is found by the formula:

$$\sum_{j=1}^{m} T_i = \sum_{i=1}^{e} (t_e^3 - t_e), \tag{3}$$

where:

e – number of groups of connected (identical) factors,
t_e – number of connected ranks of each group.

In case of absence of connected factors, formula (3) takes the form:

$$W = \frac{12\sum_{j=1}^{n} d_j^2}{m^2(n^3 - n)}. \tag{4}$$

In practice, level of reliability of the results obtained by the coefficient of concordance is established on the basis of the values of obtained coefficients. With the value of coefficient 0–0.2 experts' conclusions are not consistent, in the range 0.2–0.4 their conclusions are poorly consistent, 0.4–0.6 – moderately consistent, 0,6–0,8 – fairly consistent, 0.8–0.9 – highly consistent and 0.9–1.0 – entirely consistent.

Only after completing these actions and determining the level of experts` consistency, one can proceed to the next stage – determination of relative importance of criteria, and then, finally, reliable criteria' weights.

2.3. Applying analytical hierarchy process for determination of criteria weights

Analytical hierarchy process (AHP) [Saaty 1997] is used to assign weights to each evaluation criteria, and thus determine their relative importance in the final decision adopted within the model. The method is based on pairwise comparison within a reciprocal matrix, in which the number of rows and columns is defined by the number of criteria. Accordingly, it is necessary to establish a comparison matrix between pairs of criteria, contrasting the importance of each pair with all the others. Subsequently, a priority vector is computed to establish weights (W_j). These weights are a quantitative measure of the consistency of the value judgements between pairs of criteria [Saaty 1992]. Scale of measurement is used as follows:

$$S = \{1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/\,2, 1, 2, 3, 4, 5, 6, 7, 8, 9\}.$$

The comparisons ratings and factors are discussed with experts and the pairwise comparison matrix (Table 3) is constructed based on Table 2.

Table 2. Saaty's nine-point weighing scale

Intensity of Importance	Description	Suitability Class
1	Equal importance	Lowest suitability
2	Equal to moderate importance	Very low suitability
3	Moderate importance	Low suitability
4	Moderate to strong importance	Moderately low suitability
5	Strong importance	Moderate suitability
6	Strong to very strong importance	Moderate high suitability
7	Very strong importance	High suitability
8	Very to extremely strong importance	Very high suitability
9	Extremely importance	Highest suitability

Source: Saaty AHP

Table 3. Pairwise comparison matrix

	F1	**F2**	**F3**
F1	1	F1F2	F1F3
F2	F2F1	1	F2F3
F3	F3F1	F3F2	1
Σ			

Source: Saaty AHP

This process is generating an auxiliary matrix – normalized pairwise comparison matrix (Table 4) in which the value in each cell is the result of the division of each value judgment (a_{ij}) by the sum of the corresponding column. Finally, the average of normalized values of rows is obtained, which corresponds to the priority vector (ω_j). This is normalized by dividing each vector value by n (the number of vectors), thus obtaining the normalized overall priority vector, representing all factor weights (ω_j).

Table 4. Normalized pairwise comparison matrix

	F1	**F2**	**F3**	**Priority Vector (average for each factor-Weight**
F1	1/ΣF1	F1F2/ΣF2	F1F3/ΣF3	ω1
F2	F2F1/ΣF1	1/ΣF2	F2F3/ΣF3	ω2
F3	F3F1/ΣF1	F3F2/ΣF2	1/ΣF3	ω3
Σ				1

Source: Saaty AHP

Estimation of consistency involves the following steps:

1. Determination of the weighted sum vector (by multiplying matrix of comparisons on the right by the vector of priorities to get a new column vector; then first component of new column vector is divided by the first component of priorities vector, the second component of new column vector by the second component of priorities vector, and so on).
2. Determination of consistency vector (by dividing the weighted sum vector by the criterion weights).

Once the consistency vector is calculated it is required to compute values for lambda (λ) and the consistency index (CI). Lambda is the average value of the consistency vector.

$$\lambda = \frac{\sum C_1,\ C_2,\ \ldots,\ C_i}{n}, \tag{6}$$

where:
λ – average of consistency vectors,
C_i – consistency vector,
n – number of factors.

The calculation of CI is based on the observation that λ is always greater than or equal to the number of criteria under consideration (n) for positive, reciprocal matrices and $\lambda = n$, if the pairwise comparison matrix is consistent matrix. Accordingly, $\lambda - n$ can be considered as a measure of the degree of inconsistency. This measure can be normalized as follows:

$$CI = \frac{(\lambda - n)}{(n - 1)}, \tag{7}$$

where:
CI – consistency index,
λ – average of consistency vectors,
n – number of factors.

The term CI, referred to as consistency index, provides a measure of departure from consistency. To determine the goodness of CI, AHP compares it by random index (RI), and the result is what we call CR, which can be defined as:

$$CR = \frac{CI}{RI}, \tag{8}$$

where:
CI – consistency index,
RI – random index.

Random index is the CI of a randomly generated pairwise comparison matrix of order 1 to 10 obtained by approximating random indices using a sample size of 500 [Saaty 1980], Table 5 show the value of RI sorted by the order of matrix.

The consistency ratio (CR) is designed in such a way that if CR < 0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR > 0.10, then the values of the ratio are indicative of inconsistent judgements. In such cases one should reconsider and revise the original values in the pairwise comparison matrix.

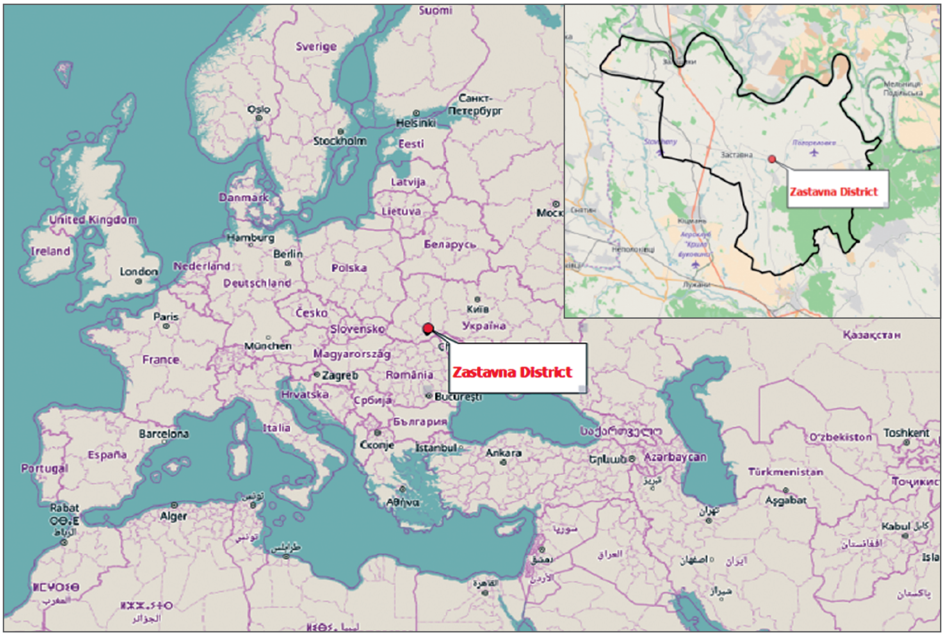
Table 5. Random index (RI)

Order matrix	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty AHP

3. Results and discussion

The reliability of criteria that help decision makers in planning renewable solar energy development could be testified and proven on a pilot area. A good choice as a pilot area is Zastavna district within Chernivtsi region (Ukraine) with total area 615 km^2 (Figure 1).



Source: openstreetmap.com

Fig. 1. Location of Zastavna District on OpenStreetMap

The amount of solar irradiation in Zastavna district according to the Map of Global Irradiation and Solar Electricity Potential in Ukraine for horizontally mounted PV modules created by Renewable Energy Unit of Institute for Energy and Transport in EU Joint Research Centre is around 1150–1250 kWh $\cdot$ m^{-2}.

Average temperature in warm period of the year (from May to October in 2007–2016) in Zastavna district is favourable – around +18/+19°C.

Criteria of insolation and temperature are not included in the analysis of pilot area but they are relevant to solar siting. While insolation is one of the most common factors identified in the literature, we assumed insolation and air temperature would be sufficient throughout all pilot area because the variation of 48°30' latitude across Zastavna district is relatively small and meets the requirements regarding sufficient amount of solar irradiation.

Other criteria which are not included is proximity to seashore, because of absence either sea or ocean near and within research area.

Zastavna district is mostly rural district with only two small cities which do not have buildings with more than 8 storeys. As a result, criterion about proximity to such type of buildings is also excluded.

Considering criterion about high altitude areas, in this research case this criterion is not included into analysis because of whole "pilot" territory has lower heights than constraint – 1 500 m. Zastavna district is a picturesque part of the Dniester-Prut Interfluve. In the east of the district the Khotyn Upland is situated, which has the highest mountain – Berda. Its height is 515.7 m a.s.l. Berda is the highest peak in the plain part of Ukraine and one of the highest points of the East European Plain.

Not-in-my-backyard sentiments in this case could be not considered because of high demand of electricity, especially near residential areas.

Unfortunately, for the territory of pilot region there are no free-available spatial information about location of national and regional parks, areas of cultural heritage, paleontological and archaeological sites that can be downloaded or vectorized. But these territories would be excluded later during the analysis of final Land Suitability Map and Public Cadastral Map of Ukraine which contains spatial and descriptive data about each land plot in the country.

While including these criteria would have been beneficial, we do not believe they would have substantially changed the results.

After reviewing the literature and analysing pilot Zastavna district, six criteria were chosen for the analysis which are listed in Table 6.

Table 6. Chosen criteria considered for solar PV farm siting

No	Criteria	Requirements
	Evaluation criteria	
1	Certain slope & aspect	• slope < 5–15° • aspect = 110–200° (southeast, south, partly southwest)
2	Transmission lines tailored to capacitylocated nearby	TL with equal and more than 35 kV around 600 m nearby
3	Proximity to populated area	< 2500 m
4	Proximity to enterprises	< 3500 m
5	Proximity to road network	< 500 m
	Exclusion Criteria	
6	Land Cover	• free of mountains, forests, water bodies, buildings, wetlands, floodplains, • preferably low and medium grassy vegetation, shrublands

Source: authors' study

Next step is assigning a reliable weight to each participating criteria. This process consists of the following steps: to determine the points of influence of each of the six criteria, establish the objectivity of expert judgements, determine relative importance of criteria, and, therefore, each criteria weight.

We apply the method of multiple coefficient of rank correlation – the coefficient of concordance. For this purpose, ten experts have been asked to rank six factors by their degree of influence on the optimal location of solar farm. This will make possible to establish the objectivity of expert judgements.

Next thing is to explore the influence of the following criteria: 1 – slope, 2 – aspect, 3 – proximity to transmission line (TL) 35, 110 kV, 4 – proximity to enterprises, 5 – proximity to settlements, 6 – proximity to road network.

To evaluate the generalized degree of consistency of experts' opinion according to all criteria, we use the coefficient of concordance (formulas 1–4).

When evaluating the influence of individual criteria we use a ten-point scale. On the basis of the scale and criteria scores provided by ten experts, the influence scores of each of the six criteria for the optimal location of solar power plant construction are determined. In Table 7, the scores for each of the six criteria are given by ten experts.

Having analysed the results of Table 7, we can conclude that the aspect of the ground surface and proximity to high voltage transmission lines, i.e. the second and third criterion, had the greatest significance in determining the optimal locations of solar power plants. The least significant one is the proximity to the road network.

Table 7. Average values of the criteria ranks

Criteria	**Experts**										**Σ ranks**	**d_j**	**d_j^2**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**			
1	4	5	7	8	4	4	5	3	2	5	47	−3.5	12.25
2	9	9	8	9	8	8	8	9	8	6	82	31.5	992.25
3	7	4	6	5	6	7	9	6	5	6	61	10.5	110.25
4	3	4	5	4	5	4	4	4	3	3	39	−11.5	132.25
5	3	5	4	2	5	8	6	5	3	4	45	−5.5	30.25
6	2	5	1	2	3	3	2	4	4	3	29	−21.5	462.25
Σ	28	32	31	30	31	34	34	31	25	27	303	0	1739.5

Source: authors' study

Table 8. Expert ranks

Ranks	**Experts**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sum	28	32	31	30	31	34	34	31	25	27
Average value	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Deviation	−2.3	1.7	0.7	−0.3	0.7	3.7	3.7	0.7	−5.3	0.6
Expert rank	5	4	3	1	3	6	6	3	7	2

Source: authors' study

Presented results allow us to conclude that the highest rating has fourth expert, second and third ranks at once four experts have – the third, fifth, eighth and tenth, the lowest rating the ninth expert has (Table 8).

To determine how close the relationship between an arbitrary number of ranked attributes is, we use a multiple coefficient of rank correlation (coefficient of concordance).

Consequently, the coefficient of concordance is equal:

$$W = \frac{12 \cdot 1739.5}{10^2 \cdot (6^3 - 6)} = 0.984.$$

Coefficient of concordance can take values from 0 to 1. The higher the value of coefficient of concordance, the higher the degree of consistency of expert opinion is. When $W = 1$, there is a complete consistency of expert opinion; if $W = 0$, then consistency is practically absent.

In our case it is equal to 0.984, which means almost complete coherence of experts' opinions.

Analytical hierarchy process [Saaty 1997] is used to assign weights to each evaluation criteria, and as a result to determine their relative importance in the final decision adopted within the model. A comparison matrix between pairs of criteria, contrasting the importance of each pair with all the others, is constructed on the basis of the experts' opinions (Table 9). This process generated an auxiliary matrix: the normalized pairwise comparison matrix (Table 10) in which the value in each cell is the result of the division of each value judgement (a_{ij}) by the sum of the corresponding column. Finally, the average of the normalized values of rows is obtained, which corresponds to the priority vector (ω_j).

Table 9. Pairwise comparison matrix

	F1 Slope	**F2 Aspect**	**F3 Proximity to TL**	**F4 Proximity to enterprises**	**F5 Proximity to settlements**	**F6 Proximity to road network**
F1 Slope	1	0.250	0.500	2	1	4
F2 Aspect	4	1	3	6	4	7
F3 Proximity to TL	2	0.333	1	3	2	4
F4 Proximity to enterprises	0.500	0.167	0.333	1	0.500	2
F5 Proximity to settlements	1	0.250	0.500	2	1	3

F6 Proximity to road network	0.250	0.143	0.250	0.500	0,333	1
Total	8.750	2.143	5.583	14.500	8.833	21.000

Source: authors' study

Table 10. Normalized pairwise comparison matrix

	F1 Slope	**F2 Aspect**	**F3 Proximity to TL**	**F4 Proximity to enterprises**	**F5 Proximity to settlements**	**F6 Proximity to road network**	**Priority vector = weight (W)**
F1 Slope	0.114	0.117	0.090	0,138	0.113	0.190	0.13
F2 Aspect	0.457	0.467	0.537	0.414	0.453	0.333	0.44
F3 Proximity to TL	0.229	0.156	0.179	0.207	0.226	0.190	0.20
F4 Proximity to enterprises	0.057	0.078	0.060	0.069	0.057	0.095	0.07
F5 Proximity to settlements	0.114	0.117	0.090	0.138	0.113	0.143	0.12
F6 Proximityto road network	0.029	0.067	0.045	0.034	0.038	0.048	0.04
Total	1	1	1	1	1	1	1.00

Source: authors' study

Table 11. Calculation of the consistency vector

Criteria	**Weight sum vector**	**Consistency vector**
F1 Slope	0.768	6.043
F2 Aspect	2.740	6.178
F3 Proximity to TL	1.219	6.161
F4 Pr. to enterprises	0.419	6.048
F5 Proximity to settlements	0.724	6.082
F6 Proximity to road network	0.262	6.054

Source: authors' study

For estimating consistency of vectors, weighted sum vectors and consistency vectors are determined (Table 11).

Once the consistency vector is calculated it is required to compute values for two more terms, lambda (λ) and the consistency index (CI).

$$\lambda = \frac{\sum C_1, C_2, C_3, C_4, C_5, C_6}{n} = \frac{6.043 + 6.178 + 6.161 + 6.048 + 6.082 + 6.054}{6} = 6.094$$

$$CI = \frac{(\lambda - n)}{(n-1)} = \frac{(6{,}094 - 6)}{5} = 0.019$$

To determine the goodness of CI, AHP compares it by random index (RI). In this case for $n = 6$, RI = 1.24. The result is consistency ratio (CR), which is defined as:

The ratio indicates a reasonable level of consistency in the pairwise comparisons, so comparison matrix can be used for the weight determination.

$$CR = \frac{CI}{RI} = \frac{0.019}{1.24} = 0.015 < 0.10$$

Table 12 shows the weight of each layer (total weight is 100).

Table 12. Weights of each participating evaluation criteria

No	Input layer	Weight value
1	Slope	13
2	Aspect	44
3	Proximity to TL 35, 110 kV	20
4	Proximity to enterprises	7
5	Proximity to settlements	12
6	Proximity to road network	4

Source: authors' study

4. Conclusions

When chosing a solar power plant siting a number of evaluation criteria must be fulfilled, e.g. abundant solar irradiation, adequate slope (5–15°) and aspect (south, south east, south west), transmission lines with at least 35 kV no further than 600 m, proximity to populated area, enterprises, road network, and some exclusion criteria should be met: certain type of land cover (preferably low and medium grassy vegetation, shrublands and free of mountains, forests, water bodies, buildings).

The method of multiple coefficient of rank correlation – coefficient of concordance – is applied. For this purpose, ten experts have been asked to rank criteria by their influence on the choice of optimal location for solar farm. Complete coherence of experts' opinion has been determined. Analytical hierarchy process (AHP) was used to assign the weights to each evaluation criteria, and thus determine their relative importance in the final decision adopted within the model.

The reliability of criteria that help decision makers in planning renewable solar energy development has been testified and proven on a pilot area. For these reasons, the study may be useful for potential investors in solar park investments.

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