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USING SIPRES – A FUSION OF THE REVISED SIMOS' PROCEDURE AND ZAPROS – IN THE ROAD ROUTE SELECTION PROCESS

Summary

Road route decisions very frequently cause discussions and disagreement since they involve the number of stakeholders with competing interests. Before the construction of the road can start, the route for this road has to be determined, taking into account various facets, e.g. financial, technological, social and environmental ones. Such a situation can be described in the following way: the best possible choice must be made out of a finite set of alternatives (potential road routes) evaluated against a set of criteria. For this purpose different multi-criteria decision aiding methods can be used, e.g. a novel tool called SIPRES. Its algorithm combines the key elements of the revised Simos' procedure and the ZAPROS method. The method is transparent and easy to implement. On the one hand, it allows decision-makers to define their preferences simply and provides a straightforward but effective method for analysing the trade-offs between the alternatives using selected reference alternatives only (the ZAPROS-like approach). On the other hand, the revised Simos' procedure applied in the method allows determining the cardinal scores for the alternatives.

The purpose of this paper is to illustrate how the road route can be selected with the help of the SIPRES method, and to show thereby that this technique may be useful for solving such complex problems and may improve a decision-making process in certain situations.

Key words: road route selection, MCDA, SIPRES

JEL: C44, C65, R42

1. Introduction

Road construction is a complex project which consists of many stages. Before the construction can commence the courses of the proposed route solutions have to be identified and assessed taking into account many different issues, e.g. functional, technical, economic, environmental and social ones. In many instances, several alternatives of the road route are examined (sometimes even over a dozen or tens). Information collected during this stage is used to determine the location and type of the road to be built [Górecka, 2013, p. 24].

Since the selection of a given road investment alternative is connected with certain financial, transport, ecological and safety effects, it is necessary to support the decision-making process with scientific approach. For typical economic and social impact assessment a widely used cost-benefit analysis (CBA) is sufficient. In other cases multi-criteria decision analysis (MCDA) can be applied [Budzyński, Kaszubowski, 2014, p. 2405]. A few examples of such applications are briefly described in Table 1.

Other approaches that can be helpful in the analysis of the road investment alternatives and in choosing the most preferred one are, e.g. control lists and histograms as well as map, network and indicator methods [see: *Podręcznik dobrych praktyk*…, 2008; Szafranko, 2014].

TABLE 1.

Examples of MCDA applications in the road route selection process

No.	Application	Description (alternatives, criteria, approach)
1	**Highway in the Kano area, Nigeria** [Sunusi et al., 2015]	This work presents a model developed by integrating Geographical Information System (GIS) with Analytic Hierarchy Process (AHP) and applies it to select an optimum highway alignment location which is economical and compatible with environment. The aim of this study was to locate a suitable Least Cost Path (LCP) between two points that would pass major towns of Kura, Modobi and Kabo Local Government Areas (LGA) within the area under study. Three route themes were considered, namely engineering, environmental and a hybrid theme, and the last one turned out to be the shortest, the most economical and suitable.
2	**East ring road of Warsaw, Poland** [*Określenie przebiegu*…, 2015]	In this technical, economic and environmental study sixteen alternatives (eight basic ones and eight ones taking into account sub-alternative solutions) were considered. They were assessed using fourteen criteria, e.g. noise, destruction of habitats, number of wells in the area influenced by the project, nuisance of construction works, distance from Nature 2000 Training Ground Rembertów and level of acceptance by self-governments. Analytic Hierarchy Process (AHP) was applied to build a ranking of the alternatives considered.
3	**Ring road of Malbork city, Poland** [Budzyński, Kaszubowski, 2014]	In the paper four alternatives of the Malbork orbital road were considered. Following criteria were taken into account in their evaluation: technology, transport, safety, environment, complementarity and the land availability. A two-step approach was used to select the most appropriate route: firstly, Analytic Network Process (ANP) was applied to determine the weights of the criteria, and secondly, the weights were transferred to the Analytic Hierarchy Process (AHP) to construct a ranking of the alternatives considered.

4	**Highway in Sinai Peninsula, Egypt** [Effat, Hassan, 2013]	In this paper Geographic Information System (GIS) tools were used to develop the least-cost path for a corridor to link three cities in a desert environment of Sinai Peninsula. Environmental and economic factors were integrated through a spatial multi-criteria model using Analytic Hierarchy Process (AHP). Three visions (routes) were taken into account: an engineering vision, an environmental vision and a hybrid one. A multi-criteria evaluation was used to compare these three routes and the hybrid route was finally recommended.
5	**E-763 highway entrance into Belgrade, Serbia** [Marković et al., 2013]	The subject of the analysis in this paper is the evaluation of two alternatives of the preliminary design of E-763 highway entrance into Belgrade by either the right or the left bank of the Sava River. In the assessment of these two potential solutions twenty criteria were taken into account and the ranking of the alternatives considered was obtained using VIKOR and PROMETHEE II methods.
6	**Road X, Somewhere** [Górecka, 2013]	Article presents the possibility of using multi-criteria decision aiding methods based on the outranking relation from ELECTRE and PROMETHEE families as well as methods belonging to the verbal decision analysis framework in the analysis regarding drafting of a road route. Input data, i.e. evaluations of five alternatives and weights of criteria, comes from [Biruk et al., 2007]. In the assessment of the route solutions the following four criteria are taken into consideration: cost of realization, vehicle's average travel time, impact on the environment and safety of the travellers.
7	**Expressway 'Via Baltica', Poland** [Jastrzębski, Kaliszewski, 2011]	Study is focused on a real-life problem of choosing the most appropriate route for the expressway 'Via Baltica' from the Lithuanian border to Warsaw [see: *Strategia rozwoju…* 2008]. Forty routes evaluated from the point of view of four criteria (traffic network criterion as well as economic, social and environmental ones) were considered in the article. Solver in Excel and the weighted Chebyshev function were used to find Pareto effective alternatives for the specified weights of the criteria. For selecting the most preferable route the use of an appropriate filter (e.g. cut-off values for the evaluations of the alternatives) within the mechanism of finding effective alternatives was suggested.
8	**Dublin port motorway, Ireland** [Rogers, Bruen, 2000]	This paper describes a practical application of the ELECTRE III method to ranking the various project options considered in a preliminary environmental evaluation conducted on the Port Access and Eastern Relief Route (PAERR) – a motorway proposed for Dublin City.

9	**Expressway S6 (Lębork – Tricity ring road), Poland** [*Wybór wariantu…*]	In this study the Analytic Hierarchy Process (AHP) was applied to select the most preferred road route from the environmental point of view. Eleven alternatives were considered, evaluated and compared using twelve criteria, e.g. noise, collision with protected species of plants, impact on protected species of animals, collision with the main ecological corridors, nuisance of construction works, impact on underground water, impact on soil and impact on material assets.
10	**Expressway S19, Poland** [*Raport o oddziaływaniu…*]	In this study the Analytic Hierarchy Process (AHP) was applied to select the most environmentally preferred road route for the expressway S19 from the border of Lublin and Subcarpathian Voivodeships to Sokołów Małopolski. Analysis was conducted separately for two parts of the expressway. In the case of the first part five alternatives were evaluated with respect to fifteen criteria. For the second part eight alternatives were assessed using nineteen criteria.

Source: own elaboration, [Budzyński, Kaszubowski, 2014; Effat, Hassan, 2013; Jastrzębski, Kaliszewski, 2011; Marković et al., 2013; *Określenie przebiegu…*, 2015; Rogers, Bruen, 2000; *Raport o oddziaływaniu…*; *Wybór wariantu…*; Sunusi et al., 2015].

When it comes to MCDA methods, in the road route selection process AHP [Saaty, 2006; Saaty, Vargas, 1991] is frequently used (see: Table 1.). It is also recommended in document entitled *Podręcznik dobrych praktyk wykonywania opracowań środowiskowych dla dróg krajowych* [2008] in Poland, especially for choosing localization alternatives and environmental protection devices. According to this document, it can also be used in the selection process of technological and organizational alternatives as well as for environmental compensation [*Podręcznik dobrych praktyk…*, 2008, p. 164]. Unfortunately, if the number of alternatives and/or criteria is high, then pair-wise comparisons on which AHP is based, may be really tedious and difficult for decision-makers (since large number of elements decreases the consistency of the comparisons conducted). In such a situation a recently developed technique called SIPRES [Górecka, 2015] can be applied. It has the following advantages: it allows decision-makers to define their preferences qualitatively, in a simple and effortless way, and it allows determining the cardinal scores for the alternatives.

The aim of this paper is to bring the SIPRES method closer to potential users and to show its usefulness in supporting decision-makers in the road route selection process. The article consists of an introduction, a conclusion and two sections. In the first section the SIPRES algorithm is described. The second section provides an illustrative example concerning the eco-challenging problem of a route selection for a road.

2. Overview of the SIPRES method

The acronym SIPRES stands for: **Si**mos' **p**rocedure for **Re**ference **S**ituations. It is based on two methods: revised Simos' procedure [Figueira, Roy, 2002] and ZAPROS

[Larichev, Moshkovich, 1995], and aims at obtaining a complete ranking of the alternatives with scores measured on a cardinal scale. The SIPRES method was introduced in 2015 [Górecka, 2015] as a continuation of the works on a tool for the verbal evaluation of the negotiation template connected with the MARS approach [see: Górecka et al., 2014; Górecka et al., 2016]. Based on the original paper, in which two baseline methods were also presented, a detailed description of the SIPRES algorithm is given below.

Let $F = \{f_1, f_2, ..., f_n\}$ be a finite set of n evaluation criteria; X_k – a finite set of possible verbal values on the scale of criterion $k = 1, 2, ..., n$, where $|X_k| = n_k$; $X = \prod_{k=1}^{n} X_k$ is the set of all possible vectors in the decision space of n criteria; and $A = \{a_1, a_2, ..., a_m\} \subseteq X$ is a subset of X describing the alternatives considered.

The SIPRES procedure consists of the following steps:

1. We determine the evaluation scale for each criterion considered in the decision-making problem.
2. We prepare a set of blank cards and a set of cards with hypothetical alternatives (each with the best evaluation for all the criteria but one) as well as the ideal and anti-ideal reference vectors (with the best and the worst evaluations for all the criteria, respectively) and rank them from the worst to the best one.
3. We introduce blank cards between two successive cards if necessary. The greater the difference between the evaluations of the alternatives, the greater the number of blank cards:
   a) no blank card means that the alternatives do not have the same evaluation and that the difference between the evaluations is equal to one unit u used for measuring the intervals between evaluations,
   b) one blank card means a difference of two units, two blank cards mean a difference of three units, etc.
4. We determine how many times the best alternative is better than the worst one in the ranking.
5. We process the information obtained as in the revised Simos' procedure in order to obtain the normalized scores for the elements compared, i.e. to form the Joint Cardinal Scale (JCS).
6. We substitute the evaluations in each vector describing the alternative considered in the decision-making problem by the corresponding scores from the JCS. For each alternative we define the distance from the ideal alternative using the formula:

$$L_i = \sum_{k=1}^{n} \left(p_k^{\max} - p_{ik} \right) \tag{1}$$

where p_{ik} is the score from the JCS substituting the assessment of alternative a_i according to criterion f_k and $p_k^{\max}$ is the score for the best possible assessment for a given criterion.

7. We construct the complete final ranking of the alternatives according to the distance values L_i in ascending order.

Processing the information in the way described in the revised Simos' procedure (mentioned in point 5 above) is as follows [Figueira, Roy, 2002, pp. 322-323]:

1. Let n^* be the number of positions in the ranking, $e_r^{'}$ – the number of blank cards between the positions r and $r+1$, and z – the ratio showing how many times the best element in the ranking is better than the worst one. We calculate:

$$e_r = 1 + e_r^{'} \quad \forall r = 1,...,n^* - 1 \tag{2}$$

$$e = \sum_{r=1}^{n^*-1} e_r \tag{3}$$

$$u = \frac{z - 1}{e} \tag{4}$$

retaining six decimal places for u. Subsequently, we determine the non-normalized score $p(r)$ for each position in the ranking:

$$p(r) = 1 + u \cdot (e_0 + ... + e_{r-1}) \tag{5}$$

where $e_0 = 0$.

We round these scores to two decimal places. If there are several elements in the same position r, all of them obtain the same score $p(r)$.

2. Let g_k be an element in the position r, and $p_k^{'}$ – the non-normalized score of this element, $p_k^{'} = p(r)$. We calculate:

$$P^{'} = \sum_{k=1}^{n} p_k^{'} \tag{6}$$

$$p_k^* = \frac{100 \cdot p_k^{'}}{P^{'}} \tag{7}$$

Subsequently, we determine $p_k^{''}$ by deleting some of the decimal digits from p_k^*. Let s be the number of decimal places taken into account. We compute:

$$P^{''} = \sum_{k=1}^{n} p_k^{''} \leq 100 \tag{8}$$

$$\varepsilon = 100 - P^{''} \leq 10^{-s} \cdot n \tag{9}$$

$$v = 10^s \cdot \varepsilon \tag{10}$$

Finally, we set $p_k = p_k^{"} + 10^{-s}$ for v suitably selected elements and $p_k = p_k^{"}$ for the other $n - v$ elements. We obtain $\sum_{k=1}^{n} p_k = 100$, where p_k is the normalized score of the element g_k, with the required number of decimal places.

The choice of the v elements, whose scores will be rounded, is performed using the following algorithm [Figueira, Roy, 2002, pp. 323-324]:

1. For each element g_k we determine the ratios:

$$d_k = \frac{10^{-s} - (p_k^* - p_k^{"})}{p_k^*} \tag{11}$$

$$d_k^* = \frac{(p_k^* - p_k^{"})}{p_k^*} \tag{12}$$

2. We create two lists, R and R^*:
   - the R list, consisting of the pairs (k, d_k) sorted in the ascending order of d_k,
   - the R^* list, consisting of the pairs (k, d_k^*) sorted in the descending order of d_k^*.
3. We set $M = \{k : d_k > d_k^*\}$, $|M| = m$.
4. We partition the set of n elements into two subsets: F^+ and F^-, where $|F^+| = v$ and $|F^-| = n - v$, as follows:
   - if $m + v \le n$, then F^- consists of the m elements of M and the last $n - v - m$ elements of R^* which are not in M; while F^+ consists of the first v elements of R^* which are not in M;
   - if $m + v > n$, then F^+ consists of the $n - m$ elements not belonging to M and the first $v + m - n$ elements of R which are in M; while F^- consists of the last $n - v$ elements of R which are in M.

The key characteristics of the SIPRES approach are summarized below.

TABLE 2.

SIPRES approach – summary

Application
Designed to elicit a sound preference relationship that can be applied to future cases; especially useful in the case of decision-making problems with mostly qualitative parameters and no objective model for their aggregation
Decision-making problem
More oriented to tasks with a fairly large number of alternatives, while the number of criteria is usually relatively smaller
Decision-makers
Does not require any special knowledge of decision analysis from the decision-makers; allows decision-makers to define their preferences in a simple and user-friendly way
Methodology
Combines the key elements of revised Simos' procedure and ZAPROS method to construct universal decision rules in the criteria space and then use them on any set of actual alternatives

Source: own elaboration.

3. Illustrative example

The present study illustrates the application of the SIPRES method in transport planning decision-making. Its usefulness for decision aiding processes connected with route selection will be demonstrated by an example which concerns the problem of choosing the most environmentally preferred alternative of the road construction out of twenty five that have been identified at the stage of drawing up the project concept.

Let us assume that in this eco-challenging problem the following issues are discussed and taken into account in the alternatives' assessment:

- f_1 – negative project's impact on the inhabitants (noise, clearance of buildings, drinking water contamination),
- f_2 – negative project's impact on the monuments and historical treasures (churches and chapels endangered, noise),
- f_3 – negative project's impact on the landscape (endangered beauty spots, road slopes, areas visible from the road),
- f_4 – negative project's impact on the environment (endangered trees, endangered habitats, intersections with the protected areas, endangered birds species from the Birds Directive, endangered plant species that are under strict protection).

Evaluation scales for all the criteria considered have been defined linguistically. They are presented in Table 3. Table 4 provides the performance matrix for the twenty five potential routes considered and the four criteria used to evaluate them.

TABLE 3.

Criteria and scales for route selection

Criterion		Evaluation scale
f_1	Negative project's impact on the inhabitants	L1. Lack
		W1. Weak
		M1. Moderate
		S1. Strong
		E1. Extreme
f_2	Negative project's impact on the monuments and historical treasures	L2. Lack
		W2. Weak
		M2. Moderate
		S2. Strong
f_3	Negative project's impact on the landscape	L3. Lack
		W3. Weak
		M3. Moderate
		S3. Strong
f_4	Negative project's impact on the environment	L4. Lack
		W4. Weak
		M4. Moderate
		S4. Strong
		E4. Extreme

Source: own elaboration.

TABLE 4.

Evaluations of the alternatives considered in the illustrative example

Alternatives	Criteria			
	f_1	f_2	f_3	f_4
a_1	W1	W2	L3	W4
a_2	L1	M2	L3	M4
a_3	W1	W2	M3	L4
a_4	W1	L2	W3	L4
a_5	M1	W2	L3	W4
a_6	M1	W2	W3	L4
a_7	M1	L2	M3	L4
a_8	L1	W2	S3	L4
a_9	W1	W2	L3	L4
a_{10}	L1	W2	W3	L4
a_{11}	M1	L2	W3	L4
a_{12}	W1	L2	L3	W4
a_{13}	L1	M2	W3	W4
a_{14}	M1	W2	L3	L4
a_{15}	L1	W2	L3	W4
a_{16}	L1	M2	L3	W4
a_{17}	L1	W2	M3	L4
a_{18}	W1	M2	L3	L4
a_{19}	W1	W2	W3	L4
a_{20}	L1	M2	W3	L4
a_{21}	E1	L2	W3	L4
a_{22}	W1	L2	L3	M4
a_{23}	W1	W2	L3	M4
a_{24}	S1	L2	W3	L4
a_{25}	L1	L2	W3	S4

Source: own elaboration.

Table 5 presents the ranking of cards with hypothetical alternatives, determined by the decision-maker in accordance with steps 2 and 3 of the SIPRES algorithm. The ranking includes the alternatives with the best evaluations for all the criteria but one along with the ideal and anti-ideal alternatives. Additionally, the information required by step 4 of the algorithm is provided on how many times, in the decision-maker's opinion, the best alternative is better than the worst one.

TABLE 5.

Decision-maker's preferences based on the card play procedure

<table>
<tr><td>E1</td><td>S2</td><td>S3</td><td>E4</td><td rowspan="24">According to decision-maker [L1, L2, L3, L4] is 25 times better than [E1, S2, S3, E4]</td></tr>
<tr><td colspan="4">10 blank cards</td></tr>
<tr><td>L1</td><td>L2</td><td>L3</td><td>E4</td></tr>
<tr><td>E1</td><td>L2</td><td>L3</td><td>L4</td></tr>
<tr><td colspan="4">1 blank card</td></tr>
<tr><td>L1</td><td>L2</td><td>L3</td><td>S4</td></tr>
<tr><td>S1</td><td>L2</td><td>L3</td><td>L4</td></tr>
<tr><td colspan="4">1 blank card</td></tr>
<tr><td>L1</td><td>L2</td><td>S3</td><td>L4</td></tr>
<tr><td>L1</td><td>S2</td><td>L3</td><td>L4</td></tr>
<tr><td colspan="4">2 blank cards</td></tr>
<tr><td>L1</td><td>L2</td><td>L3</td><td>M4</td></tr>
<tr><td>M1</td><td>L2</td><td>L3</td><td>L4</td></tr>
<tr><td colspan="4">1 blank card</td></tr>
<tr><td>L1</td><td>L2</td><td>M3</td><td>L4</td></tr>
<tr><td>L1</td><td>M2</td><td>L3</td><td>L4</td></tr>
<tr><td colspan="4">1 blank card</td></tr>
<tr><td>L1</td><td>L2</td><td>L3</td><td>W4</td></tr>
<tr><td>W1</td><td>L2</td><td>L3</td><td>L4</td></tr>
<tr><td colspan="4">1 blank card</td></tr>
<tr><td>L1</td><td>W2</td><td>L3</td><td>L4</td></tr>
<tr><td>L1</td><td>L2</td><td>W3</td><td>L4</td></tr>
<tr><td colspan="4">2 blank cards</td></tr>
<tr><td>L1</td><td>L2</td><td>L3</td><td>L4</td></tr>
</table>

Source: own elaboration.

Following step 5 of the algorithm, the information on decision-maker's preferences is processed to obtain the normalized scores for the elements compared, i.e. to form the Joint Cardinal Scale (JCS). The calculations conducted are shown in Tables 6-8.

TABLE 6.
Determining the non-normalized scores of the hypothetical alternatives (z=25)

Position r	Alternatives in the position r				Number of blank cards between the positions r and r+1	e_r	Non-normalized scores p(r) rounded to 2 decimal places
	f_1	f_2	f_3	f_4			
1	E1	S2	S3	E4	10	11	1.00
2	L1	L2	L3	E4	0	1	8.76
3	E1	L2	L3	L4	1	2	9.47
4	L1	L2	L3	S4	0	1	10.88
5	S1	L2	L3	L4	1	2	11.59
6	L1	L2	S3	L4	0	1	13.00
7	L1	S2	L3	L4	2	3	13.71
8	L1	L2	L3	M4	0	1	15.82
9	M1	L2	L3	L4	1	2	16.53
10	L1	L2	M3	L4	0	1	17.94
11	L1	M2	L3	L4	1	2	18.65
12	L1	L2	L3	W4	0	1	20.06
13	W1	L2	L3	L4	1	2	20.76
14	L1	W2	L3	L4	0	1	22.18
15	L1	L2	W3	L4	2	3	22.88
16	L1	L2	L3	L4			25.00
					19	**34**	**248.23**

Source: own elaboration.

TABLE 7.
Determining the normalized scores of the hypothetical alternatives (s=2, z=25)

Position r	Alternatives in the position r				p_k^*	p_k”	d_k	d_k^*	Set M	p_k
	f_1	f_2	f_3	f_4						
1	E1	S2	S3	E4	0.402852	0.40	0.017743	0.007080	(M)	0.40
2	L1	L2	L3	E4	3.528985	3.52	0.000288	0.002546		3.53
3	E1	L2	L3	L4	3.815010	3.81	0.001308	0.001313		3.82
4	L1	L2	L3	S4	4.383032	4.38	0.001590	0.000692	(M)	4.38
5	S1	L2	L3	L4	4.669057	4.66	0.000202	0.001940		4.67
6	L1	L2	S3	L4	5.237079	5.23	0.000558	0.001352		5.24
7	L1	S2	L3	L4	5.523104	5.52	0.001249	0.000562	(M)	5.52
8	L1	L2	L3	M4	6.373122	6.37	0.001079	0.000490	(M)	6.37
9	M1	L2	L3	L4	6.659147	6.65	0.000128	0.001374		6.66
10	L1	L2	M3	L4	7.227168	7.22	0.000392	0.000992		7.23
11	L1	M2	L3	L4	7.513193	7.51	0.000906	0.000425	(M)	7.51
12	L1	L2	L3	W4	8.081215	8.08	0.001087	0.000150	(M)	8.08
13	W1	L2	L3	L4	8.363212	8.36	0.000812	0.000384	(M)	8.36
14	L1	W2	L3	L4	8.935262	8.93	0.000530	0.000589		8.94
15	L1	L2	W3	L4	9.217258	9.21	0.000297	0.000787		9.22
16	L1	L2	L3	L4	10.071305	10.07	0.000863	0.000130	(M)	10.07
Sum					**100**	**99.92**				100

Source: own elaboration.

TABLE 8.

R and R* lists (s=2, v=8, m=8, n=16)

List R						List R*					
r	Alternatives				d_k	r	Alternatives				d_k^*
	f_1	f_2	f_3	f_4			f_1	f_2	f_3	f_4	
9	M1	L2	L3	L4	0.000128	1	E1	S2	S3	E4	0.007080
5	S1	L2	L3	L4	0.000202	2	L1	L2	L3	E4	0.002546
2	L1	L2	L3	E4	0.000288	5	S1	L2	L3	L4	0.001940
15	L1	L2	W3	L4	0.000297	9	M1	L2	L3	L4	0.001374
10	L1	L2	M3	L4	0.000392	6	L1	L2	S3	L4	0.001352
14	L1	W2	L3	L4	0.000530	3	E1	L2	L3	L4	0.001313
6	L1	L2	S3	L4	0.000558	10	L1	L2	M3	L4	0.000992
13	W1	L2	L3	L4	0.000812	15	L1	L2	W3	L4	0.000787
16	L1	L2	L3	L4	0.000863	4	L1	L2	L3	S4	0.000692
11	L1	M2	L3	L4	0.000906	14	L1	W2	L3	L4	0.000589
8	L1	L2	L3	M4	0.001079	7	L1	S2	L3	L4	0.000562
12	L1	L2	L3	W4	0.001087	8	L1	L2	L3	M4	0.000490
7	L1	S2	L3	L4	0.001249	11	L1	M2	L3	L4	0.000425
3	E1	L2	L3	L4	0.001308	13	W1	L2	L3	L4	0.000384
4	L1	L2	L3	S4	0.001590	12	L1	L2	L3	W4	0.000150
1	E1	S2	S3	E4	0.017743	16	L1	L2	L3	L4	0.000130
F^+={2, 5, 9, 6, 3, 10, 15, 14}; F^-={1, 4, 7, 8, 11, 12, 13, 16}											

Source: own elaboration.

Tables 9 and 10 present the normalized scores for the hypothetical reference alternatives and the Joint Cardinal Scale respectively. The normalized scores reflect the scale of concessions required, when the ideal alternative is replaced by the alternative under consideration.

TABLE 9.

Normalized scores of the hypothetical alternatives

Alternatives				p_k
f_1	f_2	f_3	f_4	
E1	S2	S3	E4	0.40
L1	L2	L3	**E4**	3.53
E1	L2	L3	L4	3.82
L1	L2	L3	**S4**	4.38
S1	L2	L3	L4	4.67
L1	L2	**S3**	L4	5.24
L1	**S2**	L3	L4	5.52
L1	L2	L3	**M4**	6.37
M1	L2	L3	L4	6.66
L1	L2	**M3**	L4	7.23
L1	**M2**	L3	L4	7.51
L1	L2	L3	**W4**	8.08
W1	L2	L3	L4	8.36
L1	**W2**	L3	L4	8.94
L1	L2	**W3**	L4	9.22
L1	**L2**	**L3**	**L4**	10.07

Source: own elaboration.

TABLE 10.

Joint Cardinal Scale

JCS	
Evaluation $f_k(a_i)$	**Score**
E4	3.53
E1	3.82
S4	4.38
S1	4.67
S3	5.24
S2	5.52
M4	6.37
M1	6.66
M3	7.23
M2	7.51
W4	8.08
W1	8.36
W2	8.94
W3	9.22
L1	10.07
L2	10.07
L3	10.07
L4	10.07

Source: own elaboration.

Following step 6 of the SIPRES algorithm we substitute the evaluations in each vector describing the alternative by the corresponding scores from the JCS. For each alternative we define the distance from the ideal alternative and on this basis we build the ranking of the alternatives. The distances to the ideal alternative for each alternative considered as well as their ranks are given in Table 11.

Taking into account preferences determined by the decision-maker the most environmentally friendly road route is alternative a_{10}. Straight after it, on the second and on the third place respectively, are alternatives a_4 and a_9. In turn, the worst alternative from the ecological point of view is alternative a_{21}.

TABLE 11.

Alternatives considered, their distances to the ideal alternative and ranks

a_i	Criterion value				Score				Distance L_i	Rank
	f_1	f_2	f_3	f_4	p_{i1}	p_{i2}	p_{i3}	p_{i4}		
a_{10}	L1	W2	W3	L4	10.07	8.94	9.22	10.07	1.98	1
a_4	W1	L2	W3	L4	8.36	10.07	9.22	10.07	2.56	2
a_9	W1	W2	L3	L4	8.36	8.94	10.07	10.07	2.84	3
a_{15}	L1	W2	L3	W4	10.07	8.94	10.07	8.08	3.12	4
a_{20}	L1	M2	W3	L4	10.07	7.51	9.22	10.07	3.41	5
a_{19}	W1	W2	W3	L4	8.36	8.94	9.22	10.07	3.69	6
a_{12}	W1	L2	L3	W4	8.36	10.07	10.07	8.08	3.70	7
a_{17}	L1	W2	M3	L4	10.07	8.94	7.23	10.07	3.97	8
a_{11}	M1	L2	W3	L4	6.66	10.07	9.22	10.07	4.26	9
a_{18}	W1	M2	L3	L4	8.36	7.51	10.07	10.07	4.27	10
a_{14}	M1	W2	L3	L4	6.66	8.94	10.07	10.07	4.54	11
a_{16}	L1	M2	L3	W4	10.07	7.51	10.07	8.08	4.55	12
a_1	W1	W2	L3	W4	8.36	8.94	10.07	8.08	4.83	13
a_6	M1	W2	W3	L4	6.66	8.94	9.22	10.07	5.39	14
a_{13}	L1	M2	W3	W4	10.07	7.51	9.22	8.08	5.40	15
a_{22}	W1	L2	L3	M4	8.36	10.07	10.07	6.37	5.41	16
a_3	W1	W2	M3	L4	8.36	8.94	7.23	10.07	5.68	17
a_8	L1	W2	S3	L4	10.07	8.94	5.24	10.07	5.96	18
a_7	M1	L2	M3	L4	6.66	10.07	7.23	10.07	6.25	19.5
a_{24}	S1	L2	W3	L4	4.67	10.07	9.22	10.07	6.25	
a_2	L1	M2	L3	M4	10.07	7.51	10.07	6.37	6.26	21
a_5	M1	W2	L3	W4	6.66	8.94	10.07	8.08	6.53	22
a_{25}	L1	L2	W3	S4	10.07	10.07	9.22	4.38	6.54	23.5
a_{23}	W1	W2	L3	M4	8.36	8.94	10.07	6.37	6.54	
a_{21}	E1	L2	W3	L4	3.82	10.07	9.22	10.07	7.10	25

Source: own elaboration.

4. Conclusions

The SIPRES method presented in this article is an uncomplicated and functional technique that can improve the road route selection process, especially when the number of alternatives considered is large. In such a situation it is much less laborious and time-consuming than frequently used AHP.

Furthermore, this simple method requires the decision-makers to supply the basic preferential information only – they are able to operate with an intuitively interpreted card tool when defining preferences. Thanks to this technique we are able to determine the cardinal scale for the alternatives and build their ranking, in which no two alternatives will be incomparable.

Finally, it should be remembered that the applications of the SIPRES method are not limited to the complex transportation problems connected with the road route selection. It can be also applied in negotiation support to build a negotiation offers scoring system as well as in policy-making, strategic planning, R&D project selection and human resource management to order alternatives considered or to select the best one.

References

Biruk S., Jaworski K. M., Tokarski Z., 2007, *Podstawy organizacji robót drogowych*, Wydawnictwo Naukowe PWN, Warszawa, 217-218.

Budzyński M., Kaszubowski D., 2014, *Metoda AHP/ANP jako narzędzie wyboru wariantów inwestycji drogowej z uwzględnieniem aspektu bezpieczeństwa ruchu drogowego,* „Logistyka", 6, 2405-2413.

Effat H. A., Hassan O. A., 2013, *Designing and Evaluation of Three Alternatives Highway Routes Using the Analytical Hierarchy Process and the Least-Cost Path Analysis, Application in Sinai Peninsula, Egypt*, "The Egyptian Journal of Remote Sensing and Space Sciences", 16, 141-151.

Figueira J., Roy B., 2002, *Determinig the Weights of Criteria in the ELECTRE Type Method with a Revised Simos' Procedure*, "European Journal of Operational Research", 139, 317-326.

Górecka D., 2015, *Evaluating the Negotiation Template with SIPRES – A Fusion of the Revised Simos' Procedure and the ZAPROS Method*, "Multiple Criteria Decision Making", Vol. 10, 48-64.

Górecka D., 2013, *Multi-Criteria Decision Aiding in Project Management – Outranking Approach and Verbal Decision Analysis*, [in:] *Project Planning in Modern Organization*, M. Nowak (red.), „Studia Ekonomiczne, Zeszyty Naukowe Wydziałowe Uniwersytetu Ekonomicznego w Katowicach", 137, 11-38.

Górecka D., Roszkowska E., Wachowicz T., 2014, *MARS – A Hybrid of ZAPROS and MACBETH for Verbal Evaluation of the Negotiation Template*, [in:] *Proceedings of the Joint International Conference of the INFORMS GDN Section and the EURO Working Group on DSS*, P. Zaraté, G. Camilleri, D. Kamissoko, F. Amblard (red.), Toulouse University, Toulouse, 24-31.

Górecka D., Roszkowska E., Wachowicz T., 2016, *The MARS Approach in the Verbal and Holistic Evaluation of the Negotiation Template*, "Group Decision and Negotiation", Vol. 25, Issue 6, 1097-1136, DOI 10.1007/s10726-016-9475-9.

Jastrzębski P., Kaliszewski I., 2011, *Komputerowe wspomaganie podejmowania decyzji: ujęcie wielokryterialne, na przykładzie wyboru przebiegu drogi ekspresowej Via Baltica*, „Zeszyty Naukowe Wydziału Informatycznych Technik Zarządzania Wyższej Szkoły Informatyki Stosowanej i Zarządzania *Współczesne Problemy Zarządzania*", 1, 63-70.

Larichev O.I., Moshkovich H. M., 1995, *ZAPROS-LM – A Method and System for Ordering Multi-Attribute Alternatives*, "European Journal of Operational Research", 82, 503-521.

Marković L., Cvetković M., Milić Marković L., 2013, *Multi-Criteria Decision-Making when Choosing Variant Solution of Highway Route at the Level of Preliminary Design*, "Facta Universitatis, Series: Architecture and Civil Engineering", Vol. 11, No. 1, 71 – 87, DOI: 10.2298/FUACE1301071M.

Określenie przebiegu projektowanej wschodniej obwodnicy Warszawy. Studium techniczno-ekonomiczno-środowiskowe. Tom VI. Raport o oddziaływaniu na środowisko, 2015, Jacobs Polska Sp. z o.o. na zlecenie GDDKiA, Warszawa, http://www.siskom.waw.pl/materialy/s17wow/ROS_2015/ROS_tekst.pdf (accessed: 07.11.2016).

Podręcznik dobrych praktyk wykonywania opracowań środowiskowych dla dróg krajowych, 2008,(red.) J. Bohatkiewicz, GDDKiA, Kraków.

Raport o oddziaływaniu na środowisko. Droga ekspresowa S19 na odcinku od granicy województwa lubelskiego i podkarpackiego do Sokołowa Małopolskiego (Część ogólna - Tom 1), ARCADIS Sp. z o.o. na zlecenie GDDKiA, http://bip.rudnik.pl/pdf/obw/2013/drogas19/Tom_1_Czesc_ogolna.pdf (access: 07.11.2016).

Rogers M., Bruen M., 2000, *Using ELECTRE III to Choose Route for Dublin Port Motorway*, "Journal of Transportation Engineering", Vol. 126, Issue 4, 313-323.

Wybór wariantu najkorzystniejszego pod względem środowiskowym, GDDKiA, http://gddkia.pomagier.info/SIWZ_koncepcja_lebork_obwodnica/Za%C5%82%C4%85cznik%20nr%203%20-%20ROO%C5%9A/Aneks%20V/TOM%20II.%20Analiza%20Wielokryterialna%20kryterium%20%C5%9Brodowiskowe/Analiza%20wielokryterialna%20met%20AHP%20-%20S6%20Trasa%20Kaszubska%20(wersj.pdf (accessed: 07.11.2016).

Saaty T. L., 2006, *Fundamentals of Decision-Making and Priority Theory with the Analytic Hierarchy Process. Vol. VI of the AHP Series*, RWS Publications, Pittsburgh.

Saaty T. L., Vargas L. G., 1991, *The Logic of Priorities. Applications of the Analytic Hierarchy Process in Business, Energy, Health* & *Transportation. Vol. III of the AHP Series*, RWS Publications, Pittsburgh.

Strategia rozwoju I Pan-Europejskiego Korytarza Transportowego. Część I: korytarz drogowy - dokument końcowy 2011, [http://viabaltica.scottwilson.com.pl, access: 07.11.2016].

Sunusi A., Agrawal V.C., Lal D., Suleiman S. 2015 *Selection of Road Alignment Location in Kano-Nigeria Using GIS and Analytical Hierarchy Process (AHP) Model*, "International Journal of Scientific Engineering and Technology Research", Vol. 04, No. 43, 9449-9455.

Szafranko E., 2014, *Metody analizy wariantów inwestycji drogowych*, „Drogownictwo", 1, 18-25.