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Multicriteria analysis in planning roads – Part 2. Methodology for selecting the optimal variant of the road

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Abstract. The article presents the methodology for selecting the optimal variant of the road on a regional level. The suggested methodology is based on a combination of criteria value normalization method and the variant assessment method. Based on survey studies conducted using the Delphi method, a starting list of criteria was designed and the significance of the individual groups of main criteria and sub-criteria was determined. The final assessments of the analysed variants are calculated based on the aggregation of the marks obtained for the normalization and assessment methods. The methodology can be divided into six stages: determining the variants for analysis, selecting the variant assessment criteria, creating the assessment matrix, normalizing criteria value, using the variant assessment method, variant ranking. The methodology was tested on the examples of planning a bypass of Mazury and Księżyno towns as a part of Regional Road 678 in Poland.

Key words: normalization, assessment methods, multicriteria analysis.

1. Introduction

When selecting the most beneficial variant of road alignment, multicriteria methods are often used to support the choice [1–3]. In literature a wide variety of procedures and multicriteria methods of decision support are described. There are methods based on the functional model (the American school) and the relation model (the European school) [4–6]. In road planning, technologies such as GIS (Geographic Information System) are becoming increasingly popular [7–10], as well as methods using genetic algorithms [11]. The construction of a road section requires conducting an economic efficiency assessment, i.e. the cost-benefit analysis of the investment [12–14].

Due to the large variety of available methods of multicriteria decision support, of which each one has specific benefits, drawbacks and limitations, it is necessary to conduct a detailed analysis in order to adjust the procedure algorithm appropriate for the analysed decision problem. The lack of clear guidelines and suggestions related to conducting multicriteria analyses fit for regional roads, a wide selection of criteria value normalization methods and assessment methods, as well as a high number of criteria taken into account in road alignment point to the need of designing complex multicriteria system, which would take into account the technical, economic, environmental and social conditions of road alignment.

This article presents the methodology of selecting the most beneficial road alignment variant for roads of class D (access road), L (local road), Z (service road), G (main road), GP (fast traffic trunk road), especially regional roads, which do not have guidelines designed for their alignment – selecting a method of analysis and determining assessment criteria and their weights. Bypasses of cities located along national roads are not considered here, due to their supralocal character. The analyses do not relate to lower class roads such as D and L due to the criteria deciding of their alignment (minimising the costs of construction while ensuring traffic access). The study also excludes roads located in city areas due to the criteria deciding of their alignment (e.g. utility infrastructure, pedestrian and bicycle traffic, junctions, multi-family housing).

The problem of selecting the most beneficial road alignment variant with the use of multicriteria analysis was presented in two articles. Part 1 included the entry criteria list as a proposal for variant assessment [15]. Part 2 presents the methodology for assessing the analysed variants based on the aggregation of the marks obtained with the normalization and assessment methods.

2. Designing the methodology of choosing the optimal road alignment variant

Designing the methodology of the optimal road alignment variant selection required determining the criteria characterising the analysed variants, the methods of criteria value normalization and variant assessment methods. Depending on the character of the decision problem, there are different methods of criteria value normalization and variant assessment methods known [16–19]. The designing of road alignment is characterised by certain rules and not all approaches can be used. One of the characteristic properties are different criteria values of the analysed variants. They can have positive as well as negative values. In some cases they can even equal 0, e.g. no collisions

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with protected areas, no collisions with buildings. The criteria, according to which the variants are assessed can be expressed in various units and can be qualitative or quantitative in character. The goal of normalization of variables is making the criteria unified, which in turn should allow to calculate a final synthetic assessment value for a given variant, leading to the creation of a variant ranking. The case is similar with methods of variant assessment.

A set of specific solution variants is investigated W = {Wi: i = 1, 2, 3 …, n}, for which a set of criteria is formed K = {Kj: j = 1, 2, 3 …, m}, according to which the individual variants are assessed. For each variant the xij value is determined (the value of the Wi variant according to the Kj criterion), creating a data matrix: X = {xij: i = 1, 2, 3,…, n; j = 1, 2, 3, …, m}. In this matrix, the i-th row represents the characteristic of the 'i' variant according to consecutive (all) criteria, and the j-th column represents variants according to the 'j' criterion. In table notation, the matrix has the form of (1):

$$\begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1m} \\ \cdots & \ddots & \cdots & \cdots & \cdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{im} \\ \cdots & \cdots & \cdots & \ddots & \cdots \\ x_{n1} & \cdots & x_{nj} & \cdots & x_{nm} \end{bmatrix} \tag{1}$$

The next stage performed after the normalization of criteria values is the application of the correct assessment method aggregating the normalized criteria [20]. There are basically two groups of aggregation methods [21]: the additive methods, which are various forms of adding the values of normalized criteria multiplied by their corresponding weights, and the multiplicative methods.

3. Analysis of normalization methods for application in the subject issue

When selecting the most beneficial road alignment variant, mainly for regional roads or less significant national roads, the criteria value normalization methods for individual variants should fulfil the following requirements:

- they allow for normalizing criteria assessment values which have the value of 0. This property is crucial for, e.g., the group of environmental criteria due to the fact that the variants of road alignment are analysed for their collisions with environmentally valuable areas such as Nature 2000 areas in Poland. According to the environment protection act (i.e. the Polish Journal of Laws from 2016, item 2134 with later changes) analysed variants should bypass Nature 2000 areas. In such a case the criterion of collision with a Nature 2000 area can have the value of 0 (variant does not pass through the protected area),
- the criteria values after normalization should be positive. In reality, there are criteria which can have negative values, especially economical criteria. Negative values of economical indicators can occur when the length of the analysed road variant is significant in relation to a non-investment variant, the planned road collides with a high number of buildings, because of the need for buying out land beyond the right-of-way area. Taking into account the scope of the analysed issue related to regional roads, variants characterised by negative economical indicators are generally not included in the analysis. In such a case, other economical criteria need to be included, (e.g. cost of vehicle usage, demolition costs),
- normalized values are within the range of <0, 1>.

Based on the conducted analysis supported by the methodological requirements for selecting the optimal road alignment variant, five normalization methods were selected. The schematic for the selection of normalization methods is presented in Fig. 1, and the calculation formulas in Table 1.

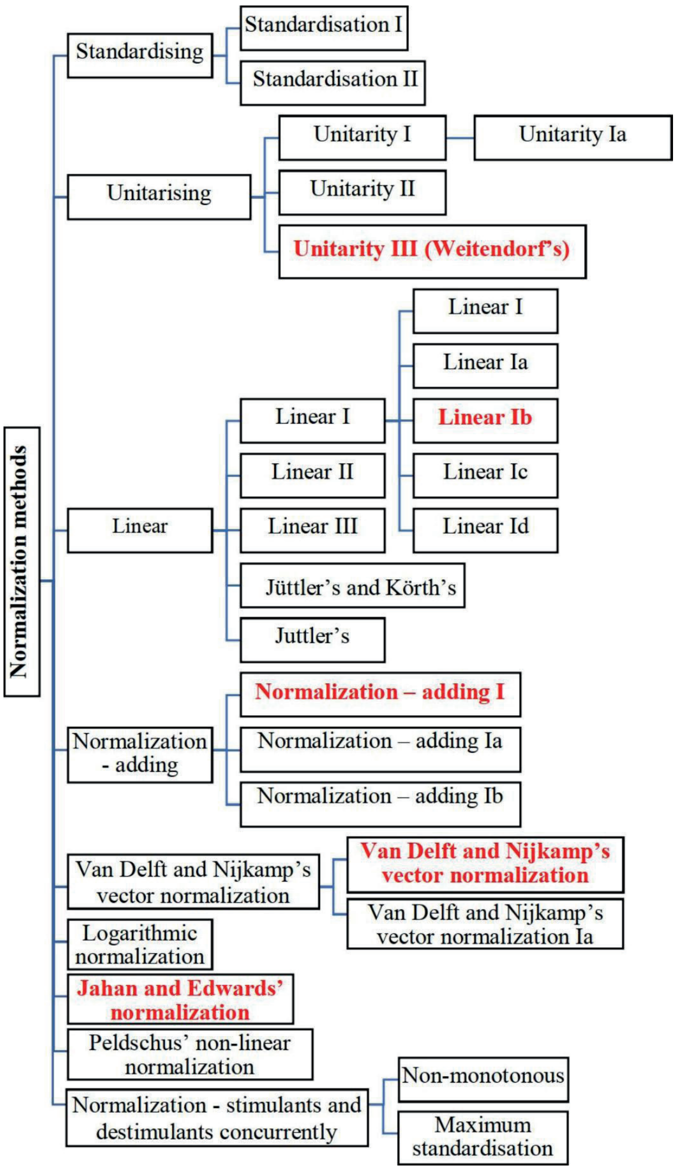

Fig. 1. Schematic for selecting criteria value normalization methods (red colour – methods selected to design the algorithm)

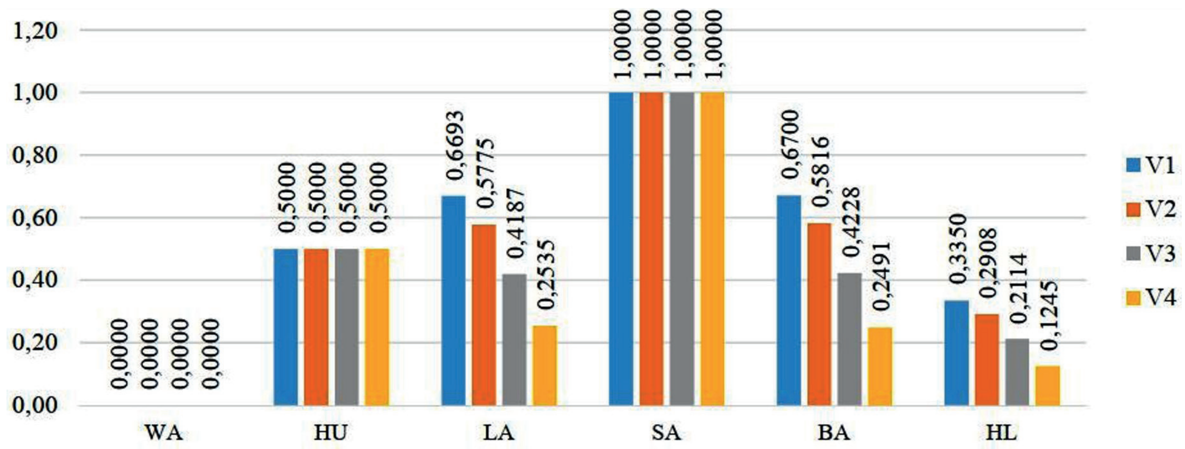

Fig. 2. Variant ranking according to Weitendorf's normalization [22]

Table 1
Selection of criteria value normalization methods

No	Normalization method	Stimulants	Destimulants
1	Weitendorf's normalization (NW)	$x_{ij}^{*}=\frac{x_{ij}-x_j^{-}}{x_j^{+}-x_j^{-}}$	$x_{ij}^{*}=\frac{x_j^{+}-x_{ij}}{x_j^{+}-x_j^{-}}$
2	Linear normalization (NL)	$x_{ij}^{*}=\frac{x_{ij}}{x_j^{+}}$	$x_{ij}^{*}=1-\frac{x_{ij}-x_j^{-}}{x_j^{+}}$
3	Normalization – addition (NA)	$x_{ij}^{*}=\frac{x_{ij}}{\sum_{i=1}^{n}x_{ij}}$	$x_{ij}^{*}=1-\frac{x_{ij}}{\sum_{i=1}^{n}x_{ij}}$
4	Van Delft and Nijkamp's vector normalization (NDN)	$x_{ij}^{*}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{n}x_{ij}^{2}}}$	$x_{ij}^{*}=1-\frac{x_{ij}}{\sqrt{\sum_{i=1}^{n}x_{ij}^{2}}}$
5	Jahan and Edward's normalization (NJE)	$x_{ij}^{*}=1-\frac{x_j^{+}-x_{ij}}{\sum_{i=1}^{n}\left(x_j^{+}-x_{ij}\right)}$	$x_{ij}^{*}=1-\frac{x_{ij}-x_j^{-}}{\sum_{i=1}^{n}\left(x_{ij}-x_j^{-}\right)}$

4. Analysis of variant assessment methods for application in the subject issue

As criteria having 0 values before normalization can occur in multicriteria analysis (such as the environmental criteria mentioned above), detailed analysis cannot include synthetic assessment methods from the multiplicative group due to the lack of possibility of calculating the synthetic assessment value.

The Wald, Savage and Hurwicz's methods cannot be included in the detailed analysis as their combination with the Weitendorf's normalization method does not make it possible to create a variant ranking. This is due to the fact that some criteria after normalization have the value of 0 or 1 [22], (Fig. 2).

In order design the methodology for selecting the optimal road alignment, variant assessment methods were used, which can be used in combination with the selected normalization methods (Table 1) and which in aggregation take into account criteria with a value of 0. The schematic for selecting the variant assessment methods is presented in Fig. 3. These methods include additive methods with weights (Bayes' method) and without weights as well as the Hodges-Lehmann's method. The additive method without weights is assumed as a referential

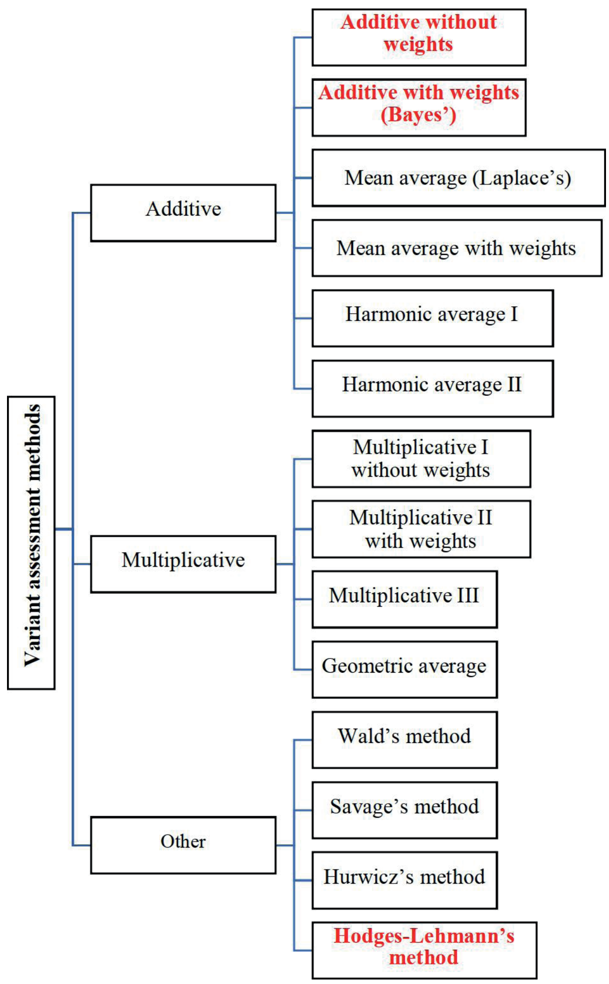

Fig. 3. Schematic for selecting variant assessment methods (red colour – methods selected to design the algorithm)

method. This method does not take weights into account – only the influence of the used criteria value normalization method (Table 2). The decision-maker can thus select the most beneficial variant in a situation, when there are no determined weights of the analysed criteria, using the so called balanced scenario.

Table 2
Selection of the assessment method

No	Assessment method	Equation	Notes
1	Additive method (MA)	$S_i = \sum_{j=1}^{m} x_{ij}^*$	does not include weights
2	Additive method with weights (Bayes' method) (MAW)	$S_i = \sum_{j=1}^{m} x_{ij}^* \cdot \varpi_j \cap \sum_{j=1}^{m} \varpi_j = 1$	includes weights
3	Hodges-Lehmann's method (MHL)	$S_i = \max_i \left[\lambda \sum_{j=1}^{n} \varpi_j x_{ij}^* + (1-\lambda) \min_j x_{ij}^* \right]$	includes weights

5. The algorithm for the selection the optimal road alignment variant

Based on the conducted analysis of criteria value normalization methods and the variant assessment methods according to the determined requirements, a methodology for selecting the optimal road alignment variant was designed. The methodology uses five criteria value normalization methods and three assessment methods. The selected normalization methods enable the normalization of criteria which have a value of 0, while the normalized values are positive and fall within the range of $<0, 1>$. In turn, the selected assessment methods aggregate the obtained criteria assessment values which have a value of 0 and have the possibility of applying the selected criteria value normalization methods. The usage of the additive method only allows for determining the problem solution in a case when the decision-maker does not know the weights of criteria, and the application of the MAW and MHL methods – in the case of knowing the weights of the criteria. Figure 4 presents the behaviour algorithm for selecting the optimal road alignment variant.

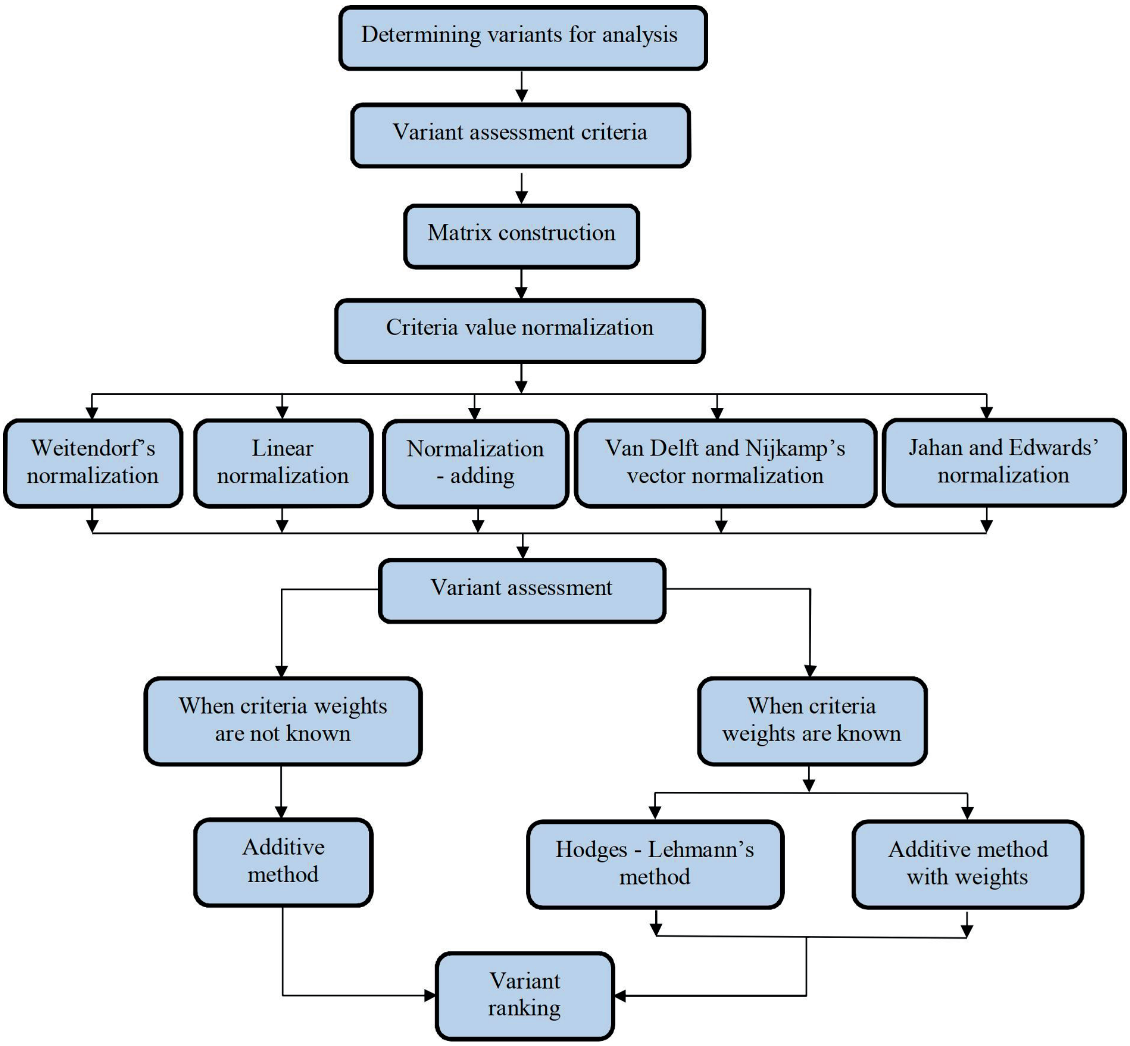

Fig. 4. The algorithm for selecting the optimal road alignment variant

Final assessment values of the analysed variants are calculated by bringing the sum of the S_i^* value to a single unit based on equation (2):

$$S_i^* = \frac{S_i}{\sum_{j=1}^{n} S_i} \tag{2}$$

where:
S_i^* – is the normalized variant assessment value $S_i \left(\sum_{j=1}^{n} S_i = 1 \right)$.

The optimal variant is the one characterised by the highest value of S_i^*.

The final assessment of the analysed variants is determined based on the aggregation of assessment values obtained using normalization methods and variant assessment methods. In the case of the point value being equal a sensitivity analysis should be additionally conducted for four scenarios of preference: transport, environmental, economical and social or only for the selected scenarios depending on the specific situation (e.g. the area has high environmental significance or an important transport role). The weights of the main criteria should be changed gradually by 5%, 10%, 15%, 20%, 25%, 30%, assuming that the sub-criteria of the assessed main group have an equal share in the analysis.

6. The application of the designed methodology in selecting a road alignment variant – case studies

The multicriteria analysis for the selection of the most beneficial bypass of the towns of Księżyno and Mazury in Poland as a segment of Regional Road 678 Białystok–Wysokie Mazowieckie was conducted based on the set of variants presented in Fig. 5a and Fig. 5b.

6.1. The bypass of the town of Księżyno as a segment of Regional Road 678. The multicriteria analysis for the selection of the most beneficial bypass of the town of Księżyno as a segment of the Regional Road 678 Białystok–Wysokie Mazowieckie was conducted based on the set of variants presented in Fig. 5a.

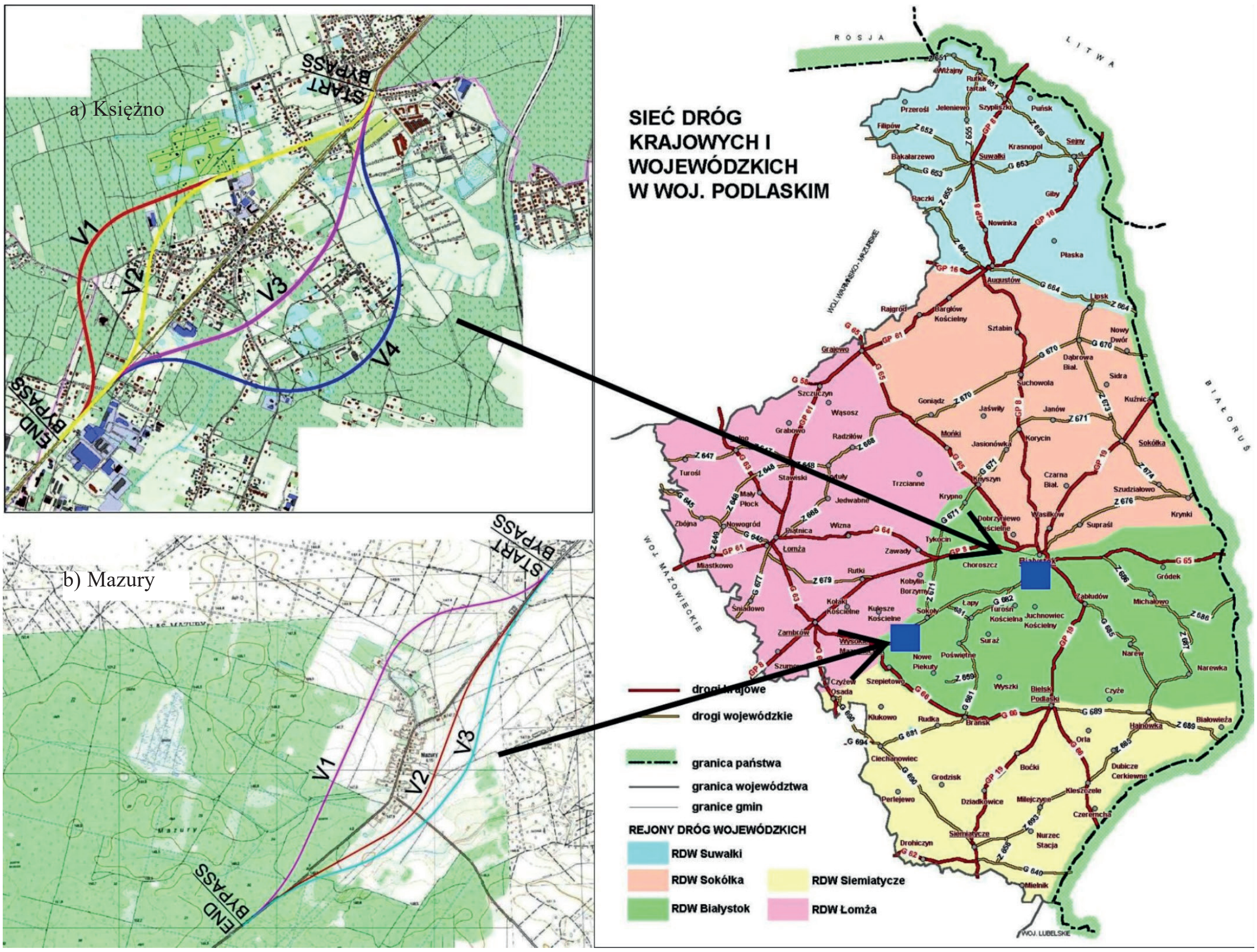

Fig. 5. The variants of bypass alignment for Księżyno (a) and Mazury (b) towns in Poland

Variants V1 and V2 are bypasses of the town of Księżyno from the north-western side, while variants V3 and V4 – from the south-eastern side. The criteria values and their weights in relation to variants V1, V2, V3 and V4 are presented in Table 3.

Table 3
Criteria selected for analysis and their weights for the town of Księżyno

No.	Criteria	*	Variant				Assessment of importance	Weight
			V1	V2	V3	V4		
TRANSPORT (0.2577)								
K1	Traffic safety [acc./year]	–	4.38	4.10	4.04	5.02	6.24	0.0431
K2	Accessibility [number of intersections]	+	4	4	3	3	5.51	0.0381
K3	Length of segments passing through urban areas [km]	–	0.502	0.825	0.732	1.087	5.47	0.0378
K4	Journey time [min]	–	2.75	2.57	2.55	3.19	5.43	0.0375
K5	Degree of usage of existing transport routes [km]	+	0.441	0.723	0.597	0.531	5.01	0.0346
K6	Road length [km]	–	3.214	3.000	2.980	3.718	4.85	0.0335
K7	Number of planned engineering structures [number]	–	1	1	2	1	4.80	0.0331
ENVIRONMENTAL (0.2368)								
K8	Length of segments passing difficult terrain (peatlands, wetlands, flood plains) [km]	–	0.436	0.494	0.556	0.735	5.14	0.0355
K9	Air pollution [kg/day]	–	56.08	52.34	52.00	64.87	5.10	0.0352
K10	Size of areas in which noise pollution limits are exceeded [ha]	–	11.25	10.5	11.92	14.87	4.92	0.0340
K11	Number of lost sites of protected species [number of species]	–	6	4	3	2	4.88	0.0337
K12	Influence on monuments [km]	–	1.703	1.371	0.547	0.058	4.83	0.0334
K13	Influence on surface waters – collisions with watercourses [number of points]	–	1.66	1.66	1.99	2.65	4.83	0.0334
K14	Crossing migration corridors of mammals and amphibians [km]	–	0.2	0.375	0.875	0.925	4.58	0.0316
ECONOMIC (0.2517)								
K15	Construction costs [10^6 PLN]	–	38.57	36.00	35.76	44.62	5.68	0.0392
K16	Cost of traffic incidents [10^6 PLN]	–	77.03	71.90	71.42	89.10	5.36	0.0370
K17	Buy-out costs of ground, objects and compensations [10^6 PLN]	–	13.74	11.479	11.538	15.747	5.31	0.0367
K18	Maintenance costs [10^6 PLN]	–	13.89	12.97	12.88	16.07	5.31	0.0367
K19	Costs of environment conservation equipment [10^6 PLN]	–	3.92	5.79	8.91	6.91	4.96	0.0343
K20	Time costs in passenger transport and freight [10^6 PLN]	–	1406.10	1312.48	1303.73	1622.11	4.92	0.0340
K21	Costs of toxic components of fumes emission [10^6 PLN]	–	4.87	4.54	4.52	5.64	4.90	0.0338
SOCIAL (0.2538)								
K22	Number of persons exposed to excessive noise levels [number]	–	8	12	6	2	5.50	0.0380
K23	Health threat – risk of road incidents with dangerous materials [(km · year) − 1]	–	1.16 $*10^{-5}$	1.19 $*10^{-5}$	1.05 $*10^{-5}$	1.01 $*10^{-5}$	5.46	0.0377
K24	Social conflicts [number]	–	818	1951	878	931	5.24	0.0362
K25	Inhabited buildings for demolition [number]	–	6	11	2	9	5.22	0.0360
K26	Tremors and vibrations [number]	–	14	25	12	13	5.19	0.0358
K27	Number of inhabited buildings within 0–100 m from the road axis [number]	–	43	80	51	49	5.09	0.0352
K28	Number of lost connections between areas located on both sides of the planned road [number]	–	7	7	8	8	5.06	0.0349
*„+” stimulants, „–” destimulants						∑	144.79	1.0000

The proposed methodology for selecting the optimal road alignment variant clearly showed that variant V3 is the most optimal solution, both when using criteria weights and without knowing them (Table 4).

Table 4
Results of the analysed variants of the bypass of Księżyno

Method	Criteria value normalization method					Ranking			
	NW	*NL*	*NA*	*NDN*	*NJE*	*V1*	*V2*	*V3*	*V4*
MA	V3	V1	V3	V3	V3	1	0	4	0
					∑	**1**	**0**	**4**	**0**
MAW	V3	V3	V3	V3	V3	0	0	5	0
MHL	V3	V3	V2	V4	V1	1	1	2	1
					∑	**1**	**1**	**7**	**1**

Sensitivity analysis was conducted by changing the weight of the criteria. The weights of the criteria in the main groups were changed by 5%, 10%, 15%, 20%, 25%, 30% and it was analysed how the final rankings change (Table 5).

The sensitivity analysis showed that preference scenarios influence the selection of the most beneficial variant of bypassing Księżyno in the following way:

- in the case of the transport scenario, the increase of the weight of this criterion by 10%, 15%, 20%, 25%, 30% makes variants V1 and V3 comparable,
- in the case of the environmental scenario, the increase of the weight of this criterion by 25% and 30% makes variants V2 and V3 comparable,
- in the case of the economical scenario, the increase of the weight of this criterion by 20% and 25% makes variants V1 and V3 comparable, and for a weight increase by 30% – variant V1 becomes the best solution,
- in the case of the social scenario, the increase of the weight of this criterion strengthens variant V3.

Table 5
Results for the analysed preference scenarios for Księżyno

Preference scenarios					
5%	10%	15%	20%	25%	30%
according to the transport criteria					
V3	V1/V3	V1/V3	V1/V3	V1/V3	V1/V3
according to the environmental criteria					
V3	V3	V3	V3	V2/V3	V2/V3
according to the economical criteria					
V3	V3	V3	V1/V3	V1/V3	V1
according to the social criteria					
V3	V3	V3	V3	V3	V3

6.2. The bypass of the town of Mazury as a segment of Regional Road 678. The multicriteria analysis for the selection of the most beneficial bypass of the town of Mazury located in the Podlaskie county as a segment of Regional Road 678 Białystok–Wysokie Mazowieckie was conducted based on the variant set presented in Fig. 5b.

Variant V1 is a bypass of the town of Mazury on the north-western side, whereas variants V2 and V3 – on the south-eastern side. The analysed roads are of G 1 x 2 class, having a common beginning and end. The presented criteria values and their weights in relation to variants V1, V2 and V3 are presented in Table 6.

Table 6
Criteria used in the analysis and their weights for the town of Mazury

No.	Criteria	*	Variant			Assessment of importance	Weight
			V1	V2	V3		
TRANSPORT (0.2793)							
K1	Traffic safety [acc./year]	–	3.57	2.46	3.45	6.24	0.0471
K2	Accessibility [number of intersections]	+	3	2	2	5.51	0.0416
K3	Journey time [min]	–	2.01	1.97	2.01	5.43	0.0410
K4	Alignment of the road with the directions of main traffic weights [point value]	+	0	1	1	5.23	0.0395
K5	Degree of usage of existing transport routes [km]	+	0.3	1.02	0.830	5.01	0.0378
K6	Road length [km]	–	3.02	2.95	3.02	4.85	0.0366
K7	Road tortuosity [°/km]	–	40.07	22.71	35.25	4.73	0.0357
ENVIRONMENTAL (0.2537)							
K8	Length of segments passing difficult terrain (peatlands, wetlands, flood plains) [km]	–	0.2	0.1	0.1	5.14	0.0388
K9	Air pollution [kg/day]	–	23.06	22.53	23.06	5.10	0.0385
K10	Size of areas in which noise pollution limits are exceeded [ha]	–	7.55	7,37	7,55	4.92	0.0372

No.	Criteria	*	Variant			Assessment of importance	Weight
			V1	V2	V3		
K11	Influence on surface waters – collisions with watercourses [point amount]	–	0.66	0.33	0.33	4.83	0.0365
K12	Collisions with natural monuments [km]	–	0.160	0.330	0.490	4.82	0.0364
K13	Passing of road through forest areas [km]	–	1.04	0.680	0.680	4.42	0.0334
K14	Occupation of new terrain [ha]	–	6.84	4.19	5.47	4.35	0.0329
ECONOMIC (0.2727)							
K15	Construction costs [10^6 PLN]	–	9.06	8.85	9.06	5.68	0.0429
K16	Cost of traffic incidents [10^6 PLN]	–	42.15	41.17	42.15	5.36	0.0405
K17	Buy-out costs of ground, objects and compensations [10^6 PLN]	–	3.42	2.09	2.73	5.31	0.0401
K18	Maintenance costs [10^6 PLN]	–	6.05	5.91	6.05	5.31	0.0401
K19	Time costs in passenger transport and freight [10^6 PLN]	–	25.15	24.57	25.15	4.92	0.0375
K20	Economic internal rate of return EIRR [%]	+	9.0	22.96	10.32	4.75	0.0359
K21	Economic net present value ENPV [10^6 PLN]	+	10.54	21.44	11.26	4.72	0.0357
SOCIAL (0.1943)							
K22	Number of persons exposed to excessive noise levels [number]	–	4	12	0	5.50	0.0416
K23	Social conflicts [number]	–	21	16	16	5.24	0.0396
K24	Tremors and vibrations [number]	–	1	3	0	5.19	0.0392
K25	Number of inhabited buildings within 0–100 m from the road axis [number]	–	1	4	0	5.09	0.0385
K26	Number of lots to expropriate [number]	–	38	41	38	4.69	0.0354
* „+” stimulants, „–” destimulants						132.38	1.0000

The proposed methodology for selecting the optimal road alignment variant clearly showed that variant V3 is the optimal solution, both when using criteria weights and without knowing them (Table 7).

Table 7
Results of the analysed variants of the bypass of Mazury

Method	Criteria value normalization method					Ranking		
	NW	*NL*	*NA*	*NDN*	*NJE*	*V1*	*V2*	*V3*
MA	V2	V3	V3	V3	V2	0	2	3
					∑	**0**	**2**	**3**
MAW	V2	V3	V3	V3	V2	0	2	3
MHL	V2	V3	V3	V3	V3	0	1	4
					∑	**0**	**3**	**7**

Sensitivity analysis was conducted by changing the weight of the criteria. The weights of the criteria in the main groups were changed by 5%, 10%, 15%, 20%, 25%, 30% and it was analysed how the final rankings change (Table 8).

Table 8
Results for the analysed preference scenarios for Mazury

Preference scenarios					
5%	10%	15%	20%	25%	30%
according to the transport criteria					
V3	V3	V3	V2/V3	V2/V3	V2
according to the environmental criteria					
V3	V3	V3	V3	V2/V3	V2/V3
according to the economical criteria					
V3	V3	V2/V3	V2/V3	V2	V2
according to the social criteria					
V3	V3	V3	V3	V3	V3

The sensitivity analysis showed that the preference scenarios influence the selection of the most beneficial variant of bypassing the town of Mazury in the following way:

- in the case of the transport scenario, the increase of the weight of this criterion by 20% and 25% makes variants V2 and V3 comparable, and with a weight increase by 30% – variant V2 becomes the most beneficial solution,

- in the case of the environmental scenario, the increase of this criterion weight by 25% and 30% makes variants V2 and V3 comparable,
- in the case of the economical scenario, the increase of the weight of this criterion by 15% and 20% makes variants V2 and V3 comparable, and with a weight increase by 25% and 30% – variant V2 becomes the best solution,
- in the case of the social scenario, the increase of the criterion weight only makes the V3 variant stronger.

7. Conclusions

The aim of this work was to design the methodology for selecting the optimal alignment variant for a regional road. The proposed methodology is based on a combination of criteria value normalization methods and variant assessment methods. The final assessment values of the analysed variants are calculated based on assessment value aggregation obtained for normalization methods and assessment methods. The methodology can be divided into six stages: selecting variants for analysis, determining variant assessment criteria, creating the assessment matrix, conducting criteria value normalization, applying variant assessment method, and variant ranking.

In the paper titled "Multicriteria analysis in planning roads – Part 1. Criteria in determining the alignment of regional roads", an entry criteria list had been designed as a suggestion to be taken into account for variant assessment of regional roads. The criteria were classified into four main groups: transport, environmental, economical or social. The number of criteria in each group was set at seven. Based on survey studies conducted using the Delphi method (CAWI technique), the importance of individual main criteria groups and sub-criteria was determined.

In this paper, useful criteria value normalization methods were determined to solve the problem of selecting the road alignment variant. 25 criteria value normalization methods were analysed, representing, among others, such methods as: standardisation, unitisation, linear method, summing, vector methods, logarithmic methods. The most suitable were determined to be: the Weitendorf's method, the linear method, the summing method, Van Delft and Nijkamp's vector method, and the Jahan and Edwards' method. The selected methods allow for normalizing the criteria assessment values which have the value of 0, the criteria values after normalization are positive, and the normalized values are within the range of $<0, 1>$.

The methods of variant assessment for the selection of the optimal regional road alignment variant were determined. Of the 14 variant assessment methods representing additive methods, multiplicative methods, methods using minimal or maximal values of normalized criteria, the useful ones were: the additive method without weights, the additive method taking into account the criteria weights and the Hodges-Lehmann's method. The chosen methods can be used in combination with the selected normalization methods and taken into account in aggregating criteria which have the value of 0.

The methodology for determining the most beneficial road alignment variant was tested on the examples of planning bypasses of the town of Mazury (variants: V1, V2, V3) and Księżyno (variants: V1, V2, V3, V4) located in the stretch of Regional Road 678. The variants were assessed using an entry criteria list. The entry criteria lists consisted of 26 and 28 criteria, respectively, including aspects such as transport, environmental, economical and social criteria. The calculations were performed based on five criteria value normalization methods and three variant assessment methods. Based on the calculations, a variant ranking was created – from the best to the worst. In order to verify the stability of the variant rankings, a sensitivity analysis was conducted.

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