Technologie, procesy i systemy produkcyjne
Technologies, processes and systems of manufacturing
Engineer of XXI Century'2024

Comparative Analysis of Multi-Criteria Assessment Methods in Service Logistics

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Abstract: The paper presents a comparison of the methods of evaluation of a logistics service provider from the point of view of the interpretation of the criteria adopted for evaluation. In the case of the baseline method, the assessment criteria are taken into account as subjective, relative. On the other hand, when using the modified method, the values of deterministic criteria were taken into account. As a result, two different configurations of the optimal solution were obtained.

Keywords: multi-criteria decision support; optimal quality of services;

Analiza porównawcza metod oceny wielokryterialnej w logistyce usług

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Streszczenie: Praca przedstawia porównanie metod oceny usługodawcy logistycznego z punktu widzenia interpretacji kryteriów przyjętych do oceny. W przypadku metody bazowej kryteria oceny uwzględniono jako subiektywne, względne. Natomiast stosując metodę zmodyfikowaną uwzględniono wartości kryteriów deterministycznych. W rezultacie otrzymano dwie różne konfiguracje rozwiązania optymalnego.

Słowa kluczowe: wielokryterialne wspomaganie decyzji; optymalna jakość usług;

1. Introduction

Contemporary market conditions related to the constantly growing level of competition on a global scale encourage many decision-makers to use tools supporting decision-making processes. The competitiveness of many companies is strictly dependent on the accuracy of decisions accompanying information and material flows within the supply chain. This approach creates opportunities in the area of effective distribution planning. In addition, the pressure of

DOI: https://doi.org/10.53052/9788367652278.06

expectations from contractors participating in supply chains is a factor that increasingly generates the need to use algorithms that allow you to choose the best solution from among the pre-selected (acceptable) solutions [11], [12].
The multifaceted nature of the issues related to logistics management in an enterprise prompts to take into account more than one criterion in decision-making models. In this case, both deterministic criteria are used, as well as subjective point and fuzzy criteria, with the help of which experts usually evaluate both optimality criteria and solution variants, using point scales [6], [7].
Referring to a number of studies that discuss algorithms supporting the assessment and selection of the most preferred variant, it is necessary to specify the criteria of a:

- point [18],
- base [6],
- deterministic [8], [9],
- fuzzy [1],
- deterministic and fuzzy [10], [16],
- deterministic, probabilistic and fuzzy [2], [4].

The food market is considered to be one of the foundations of the so-called fast-moving consumer goods market. One of the key elements determining the market advantage is the proper configuration of distribution logistics, which takes into account factors such as assortment turnover rates, shelf life and timely delivery. For many years, it has been possible to identify a phenomenon related to the increasing use of services offered by specialized transport and forwarding companies by manufacturers. In addition to the obvious benefits resulting from this type of cooperation, special attention should be paid to the proper selection of procedures enabling an objective assessment and, consequently, the selection of a business partner [12].
The goal of the work is to compare the methods of multi-criteria assessment of quality and conditions of cooperation with an external service provider (logistics operator). To achieve this goal, the Yager algorithm will be used, in which both subjective relative and deterministic criteria will be taken into account. The presented approach will be a proposal in the field of substantive support of the decision-making process in line with the distribution strategy of an exemplary enterprise.

2. Algorithm for evaluating and selecting a logistics service provider

The input data in the modified Yager method are [17], [18]:

- number of criteria m,
- number of offers submitted by potential service providers n,
- elements of the importance matrix of individual criteria **B** = $[b_{ij}]$,
- array elements $C = [c_{ij}]$, being standardized point grades of the i-th variant according to the j-th criterion.

Let A be a set of acceptable variants (offers submitted by logistics operators) after initial verification:

$$A = \{a_1, a_2, \dots, a_n\} \quad (1)$$

and K will be a set of subjective relative and deterministic criteria:

$$K = \{k_1, k_2, \dots, k_m\}. \quad (2)$$

Next, a matrix of importance of individual criteria **B** is created:

$$\mathbf{B} = [b_{ij}], \qquad i = 1, 2, \dots, m \qquad j = 1, 2, \dots, m. \quad (3)$$

Matrix **B** is created using the Saaty method [14], [15] which consists in comparing successive pairs of criteria. The individual values of the bits of this matrix are assumed as follows [3]:

- $b_{ij} = 1$, when k_i i k_j are equally important,
- $b_{ij} = 3$, when k_i is slightly more important than k_j,
- $b_{ij} = 5$, when k_i is much more important than k_j,
- $b_{ij} = 7$, when k_i is clearly more important than k_j,
- $b_{ij} = 9$, when k_i is absolutely more important than k_j,
- $b_{ij} = 2, 4, 6, 8$ – intermediate values between the above situations.

In addition, it is assumed that $b_{ji} = 1/b_{ij}$ and for $i = j$ the value $b_{ij} = 1$. For several experts, the **B** criteria importance matrix is created as follows:

- each expert creates a **B** matrix individually,
- from the obtained matrices, called partial matrices, a single, collective matrix of the importance of the criteria is formed (any term of the collective matrix above the main diagonal is calculated as the arithmetic mean of the corresponding terms of the partial matrices, while the terms under the main diagonal are the inverse of the corresponding terms above the main diagonal of the matrix).

Since the criterion importance matrix is formed by comparing successive pairs of criteria, it follows that this matrix is a quadratic matrix with a dimension equal to the number of criteria adopted. This matrix should satisfy, at least approximately, the condition of consistency [5]:

$$CI = \frac{\lambda_{\max} - m}{m-1} \leq 0{,}1 \tag{4}$$

where: $\lambda_{\max}$ – scalar denoting the maximum eigenvalue of **B** matrix; m – number of criteria (row of **B** matrix). Saaty's method shows that satisfactory satisfaction of the condition of consistency $CI \leq 0{,}1$ ensures sufficient adequacy of this method, in which there are values and eigenvectors of matrix **B.**

The next step in the proper phase of searching for the best offer of the logistics service provider is to determine the eigenvector **Y**, which satisfies the following matrix equation:

$$\mathbf{BY} = \lambda_{\max}\mathbf{Y} \tag{5}$$

where: **Y** – eigenvector, which in the above equation is a column matrix. Therefore, a vector is sought for which equation (5) is satisfied for the largest possible value of the number $\lambda = \lambda_{\max}$. The vector you are looking for has as many coordinates as there are criteria. These coordinates must also meet the condition that their sum is equal to the number of adopted criteria:

$$\sum_{j=1}^{m} y_j = m \tag{6}$$

where: y_j – j-th eigenvector **Y** coordinate. The eigenvector coordinates are also weights of individual criteria and are denoted by letters: w_1, w_2, …,w_m. Each of these weights expresses the importance of the corresponding criterion, and the higher the value of the j-th weight, the greater the importance of the j-th criterion.

The next step of the Yager algorithm is to provide the elements of the array $C = [c_{ij}(e)]$ in the base version [6] or modified [7], [8], [9]. In the case of the baseline version, the ratings of individual logistics operators $c_{ij}(e)$are relative, i.e. the so-called baseline offer is adopted, against which the other offers are evaluated. A certain assessment can be associated with each offer in relation to the criterion under consideration. For the base offer, this is the base value. Statements as to whether a given offer is better or worse in comparison with the base offer (in the light of the criterion under consideration) are subjective, vague, and are expressed by the coefficients of belonging $g_{ilj}(e)$, determined by each expert, linking each offer to a certain class l, more often to several classes. Classes are denoted by integers in the range $\langle -L, ..., 0, ..., +L\rangle$, where: $L = 1, 2, 3$. Offers related to negative classes (class) are considered worse than the base offer in relation to the criterion under consideration, and offers related to positive classes (class) – as better. In addition, each class has a percentage value (determined subjectively) expressing how much the offer assigned to it is better (in the case of a positive class) or worse (in the case of a negative class) than the base offer. The above-mentioned values are determined in such a way that each two classes next to each other corresponds to a constant jump expressed as a percentage. The number of classes accepted depends on the subjective feeling as to the diversity of offers. In the case of low differentiation, a smaller number of classes is assumed, e.g. 3 (classes: –1, 0, 1), while in the case of the experts' feeling that the variants are clearly (strongly) differentiated, a larger number of classes, e.g. 5 (classes: –2, –1, 0, 1, 2) is assumed. It is also assumed that the number of negative classes is equal to the number of positive classes. The extent to which a given offer belongs to a given class is expressed by the coefficients of belonging $g_{ilj}(e)$. These coefficients take values from the closed interval $\langle 0; 1\rangle$ and colloquially can be associated with the probability of the considered offer belonging to a given class(s). For the base offer, the membership coefficient of 1 in one of the classes is always assumed. If the value of the affiliation coefficient is related to two or more classes, it means that the expert was not able to clearly determine how much this offer is better or worse than the base offer. In order to reduce the individual elements $g_{ilj}(e)$, called the coefficients of belonging to the i-th offer, determined in the light of the j-th criterion by the e-th expert, to the form (values) of the $c_{ij}(e)$, necessary to create standardized grades, it is necessary to transform according to the following relation:

$$c_{ij}(e) = \frac{L+\sum_{l=-L}^{L} g_{ilj}(e)l}{2L} \tag{7}$$

where: $i = 1, 2, ..., n$ (i – number of the cooperation offer under consideration); $l = -L, ..., 0, ..., L$ (l – class number); $j = 1, 2, ..., m$ (j – criterion number); $e = 1, 2, ..., p$ (e – expert number). Finally, the total normalized grades c_{ij} are created (table 1) by averaging the assessments given by individual experts. This problem boils down to practically averaging all elements of the array $C = [c_{ij}(e)]$ with respect to the index e, denoting the expert's number, using the following relation:

$$c_{ij} = \frac{1}{p}\sum_{e=1}^{p} c_{ij}(e) \tag{8}$$

where: p – number of experts.
In the case of the modified version, the determination of the values of the standardized assessments c_{ij} (Table 1) takes place after prior normalization and transformation of the values of the deterministic criteria against which the acceptable variants are assessed. Normalization of deterministic assessments of the points k_{ij}^{d}, specified in the tenderers' specifications, consists in reducing their values to the range ⟨0,1; 0,9⟩, based on the following relationship:

$$c_{ij}^{*} = 0{,}1 + \frac{k_{ij}^{d} - \min\limits_{1\le i\le n}(k_{ij}^{d})}{\left[\max\limits_{1\le i\le n}(k_{ij}^{d}) - \min\limits_{1\le i\le n}(k_{ij}^{d})\right]1{,}25} \tag{9}$$

where: k_{ij}^{d} – the values of the criteria of the considered options in relation to the individual criteria, $i = 1, 2, \dots, n$; $j = 1,2, \dots, m$; n – number of variants; m – number of criteria. The standardised scores c_{ij}^{*} are then reshaped depending on the optimisation method, i.e. whether the criterion is to be minimised or maximised:

$$c_{ij} = (1 - \mathbf{k}_{rj})(1 - c_{ij}^{*}) + \mathbf{k}_{rj} c_{ij}^{*} \tag{10}$$

for $i = 1, 2, \dots, n$; $j = 1, 2, \dots, m$; where: $\mathbf{k}_{rj}$ – a vector with coordinates 0 or 1 for $j = 1, 2, \dots, m$. If $\mathbf{k}_{rj} = 1$, the best variant is the offer with the highest rating value according to the j-th criterion, if, on the other hand, the $\mathbf{k}_{rj} = 0$, The best variant is the offer with the lowest rating value according to the j-th criterion.

Table 1. Values of total normalized ratings c_{ij}

	a_1	a_2	...	a_n
k_1	c_{11}	c_{21}	...	c_{n1}
k_2	c_{12}	c_{22}	...	c_{n2}
...	...	...	...	...
k_m	c_{1m}	c_{2m}	...	c_{nm}

The next step in the Yager algorithm is to create normalized decisions d_j by raising each component of the total normalized ratings to a power equal to the corresponding weight. In general form, it can be written as follows:

$$d_j = \sum_{i=1}^{n} c_{ij}^{w_j} \tag{11}$$

After writing out, the template (11) is presented in the form of table 2.

Table 2. Values of normalized decisions d_j

	a_1	a_2	...	a_n
d_1	$c_{11}^{w_1}$	$c_{21}^{w_1}$	...	$c_{n1}^{w_1}$
d_2	$c_{12}^{w_2}$	$c_{22}^{w_2}$	...	$c_{n2}^{w_2}$
...	...	...	...	...
d_m	$c_{1m}^{w_m}$	$c_{2m}^{w_m}$	...	$c_{nm}^{w_m}$

The last stage of the algorithm consists in creating the most advantageous ranking of variants in terms of the criteria adopted for evaluation, on the basis of which the most advantageous offer is selected, i.e. the variant that best meets all the criteria adopted for evaluation (Table 3).

Table 3. Optimal ranking of options in terms of the criteria adopted for evaluation

	Offers (variants)				
	a_1	a_2	a_3	…	a_n
D_i	D_1	D_2	D_3	…	D_n

Optimal ranking is a minimum decision. The j-th component of the optimal ranking is the smallest j-th component of individual decisions $d_1, d_2, \ldots, d_m$:

$$D_i = \min_j d_j \tag{12}$$

The most preferred offer is the variant that corresponds to the largest component of the optimal decision:

$$a^{\text{opt}} = \max_i D_i \tag{13}$$

3. Example of evaluation and selection of a contractor (transport and forwarding service provider)

The implementation of activities in the field of logistics distribution of food products often encounters various types of problems. In particular, when the subject of deliveries are fresh products with a short shelf life, the proper implementation of the transport and forwarding process becomes a priority. In addition, one of the key factors determining the maintenance of the required level of quality of products reaching the hands of final buyers is the need to implement and comply with appropriate procedures during transport to guarantee the continuity of the so-called cold chain [11].

As part of the initial phase, requirements were formulated in the form of requests for proposals addressed to both current and potential service providers. As a result, offers were processed in which logistics operators declared their readiness to provide services on defined terms, among which the most important are:

- structure of deliveries: groupage shipments (including the so-called half-pallets),
- territorial range: any location in Polish,
- delivery lead time: within 24 hours from the moment of picking up the load from the customer's warehouse, while maintaining the agreed delivery notification schedule,
- transport fleet: required vehicles with a maximum permissible weight of up to 3.5 tonnes, equipped with loading and unloading lifts,
- application of the rules defined by the HACCP system (including the obligation to have an efficient device recording the temperature in the cargo space of the vehicle),
- having an IT platform that allows you to place orders online.

As a result of the initial selection of the received bids, five bidders were qualified for the next stage, thus determining the form of a set of admissible variants (Table 4).

Table 4. Summary of offers submitted by potential service providers

Specification (evaluation criterion)	Offer no.				
	a_1	a_2	a_3	a_4	a_5
Cost of the service (to any recipient in Poland), PLN/PLU*	150	119	169	139	148
Payment date for services provided (in accordance with the provisions of the contract), days	45	30	60	35	60
Average age of the transport fleet (based on detailed documentation), years	6	9	5	10	7
The bidder's experience on the contract logistics market (supported by references), years	9	6	15	12	12

*PLU – Pallet Loading Unit (1 Euro Pallet)

To evaluate and select the best variant from the set of acceptable variants, the Yager algorithm was used. The assessment of the validity of the criteria was entrusted to three appointed experts employed in the company. The first expert (e_1) was the Head of the Logistics Department, the second expert (e_2) – the Sales Director, and the third expert (e_3) – the Chief

Specialist responsible for production economics. The result of the arrangements between the experts was the adoption of bid evaluation criteria [11]:

- k_1 – cost of the service, PLN/PLU;
- k_2 – payment date for services provided, days;
- k_3 – average age of the transport fleet, years;
- k_4 – the bidder's experience on the contract logistics market, years.

The weighting of the criteria given by each expert and the resulting aggregate weight matrix of criteria **B** are shown in Table 5.

Table 5. Criteria importance matrices created by experts and a summary criteria importance matrix

e_1	k_1	k_2	k_3	k_4
k_1	1	3	7	5
k_2	1/3	1	1/3	7
k_3	1/7	3	1	2
k_4	1/5	1/7	1/2	1

e_2	k_1	k_2	k_3	k_4
k_1	1	4	3	7
k_2	1/4	1	5	4
k_3	1/3	1/5	1	3
k_4	1/7	1/4	1/3	1

e_3	k_1	k_2	k_3	k_4
k_1	1	1	6	7
k_2	1	1	6	7
k_3	1/6	1/6	1	2
k_4	1/7	1/7	1/2	1

B	k_1	k_2	k_3	k_4
k_1	1,0000	2,6667	5,3333	6,3333
k_2	0,3750	1,0000	3,7778	6,0000
k_3	0,1875	0,2647	1,0000	2,3333
k_4	0,1579	0,1667	0,4286	1,0000

In the next step of the algorithm, the eigenvalues of the collective criterion importance matrix **B** were calculated, its determinant was equated to zero and the equation of degree $n = 4$ with respect to λ:

$$\begin{vmatrix} 1{,}0000-\lambda & 2{,}6667 & 5{,}3333 & 6{,}3333 \\ 0{,}3750 & 1{,}0000-\lambda & 3{,}7778 & 6{,}0000 \\ 0{,}1875 & 0{,}2647 & 1{,}0000-\lambda & 2{,}3333 \\ 0{,}1579 & 0{,}1667 & 0{,}4286 & 1{,}0000-\lambda \end{vmatrix} = 0 \tag{14}$$

The solution of equation (14) is the eigenvalues λ of matrix **B**: 4,1180; –0,0176 – 0,6953i; –0,0176 + 0,6953i; –0,0830. Thus, the searched maximum eigenvalue of matrix **B** was: $\lambda_{max} = 4{,}1180$, consistency condition (4), since the $CI = 0{,}0393 < 0{,}1$.

Then the coordinates of the eigenvector **Y** for λ_{max} were determined, taking into account the condition (5) and solving the system of equations:

$$\begin{cases} (1-4{,}1180)y_1 + 2{,}6667y_2 + 5{,}3333y_3 + 6{,}3333y_4 = 0 \\ 0{,}3750y_1 + (1-4{,}1180)y_2 + 3{,}7778y_3 + 6{,}0000y_4 = 0 \\ 0{,}1875y_1 + 0{,}2647y_2 + (1-4{,}1180)y_3 + 2{,}3333y_4 = 0 \\ 0{,}1579y_1 + 0{,}1667y_2 + 0{,}4286y_3 + (1-4{,}1180)y_4 = 0 \end{cases} \tag{15}$$

As a result of solving the system of equations (15), the following values were obtained: $y_1 = 2{,}1753$; $y_2 = 1{,}1918$; $y_3 = 0{,}4036$; $y_4 = 0{,}2293$, which were treated in the further calculations as weights of the different criteria.

In the next step of the algorithm, the values of the total normalized ratings c_{ij} were determined by comparing the baseline and modified methods.

In the case of the baseline method, based on the information contained in the offers submitted by potential contractors (Table 4) and using the extensive knowledge and professional experience of the appointed experts, the coefficients of belonging $g_{ilj}(e)$ binding each offer of cooperation with a specific class (l) were determined (Table 6). Then, using the relationship (8), the total normalized c_{ij} ratings were created (Table 7).

In the case of the modified method, in order to find the values of the normalized assessments c_{ij}, the values of deterministic assessments (given in Table 2) were first normalized to the range ⟨0,1; 0,9⟩ using formula (9) and then transforming them according to formula (10). In the example under consideration, the cost of service provision and the average age of the transport fleet were minimized criteria (for which $\mathbf{k}_{rj} = 0$), while the payment term for the services provided and the bidder's experience on the contract logistics market were maximized criteria ($\mathbf{k}_{rj} = 1$). As a result, normalized assessments c_{ij} were established for individual criteria and each considered proposal (variant) submitted by the tenderer (Table 7).

Table 6. Values of the coefficients of belonging $g_{iij}(e)$ for the considered offers of logistics operators in the light of the adopted criteria determined by three experts

k_j	e	a_i	Class						
			–3	–2	–1	0	1	2	3
			30%	20%	10%	–	10%	20%	30%
k_1	1	a_1	0	0,2	0,8	0	0	0	0
		a_2	0,1	0,3	0,6	0	0	0	0
		a_3	0	0	0	1	0	0	0
		a_4	0	0,05	0,95	0	0	0	0
		a_5	0,2	0,3	0,5	0	0	0	0
	2	a_1	0,1	0,2	0,7	0	0	0	0
		a_2	0,1	0,4	0,5	0	0	0	0
		a_3	0	0	0	1	0	0	0
		a_4	0,4	0,4	0,2	0	0	0	0
		a_5	0,7	0,3	0	0	0	0	0
	3	a_1	0	0,5	0,5	0	0	0	0
		a_2	0	0	0	1	0	0	0
		a_3	0,2	0,4	0,4	0	0	0	0
		a_4	0,7	0,3	0	0	0	0	0
		a_5	0,8	0,2	0	0	0	0	0
k_2	1	a_1	0	0	0	0	0,1	0,4	0,5
		a_2	0	0	0	0	0,2	0,5	0,3
		a_3	0	0	0	0	0,15	0,25	0,6
		a_4	1	0	0	0	0	0	0
		a_5	0	0	0	0	0	0,5	0,5
	2	a_1	0	0	0	0	0,2	0,3	0,5
		a_2	0	0	0	0	0,2	0,4	0,4
		a_3	1	0	0	0	0	0	0
		a_4	0	0	0	0	0,1	0,2	0,7
		a_5	0	0	0	0	0,7	0,3	0
	3	a_1	0	0	0	0	0,2	0,2	0,6
		a_2	0	0	0	0	0,3	0,4	0,3
		a_3	1	0	0	0	0	0	0
		a_4	0	0	0	0	0	0,3	0,7
		a_5	0	0	0	0	0,7	0,2	0,1
k_3	1	a_1	0	0	0	0	0,4	0,35	0,25
		a_2	0	0	0	1	0	0	0
		a_3	0	0	0	0	0,85	0,1	0,05
		a_4	0,1	0,4	0,5	0	0	0	0
		a_5	0	0,3	0,7	0	0	0	0
	2	a_1	0	0	0	0	0,2	0,5	0,3
		a_2	0,1	0,4	0,5	0	0	0	0
		a_3	0	0	0	0	0,3	0,4	0,3
		a_4	0	0	0	1	0	0	0
		a_5	0,2	0,4	0,4	0	0	0	0
	3	a_1	0	0	0	0	0	0,95	0,05
		a_2	0,1	0,2	0,7	0	0	0	0

DOI: https://doi.org/10.53052/9788367652278.06

		a_3	0	0	0	0	0,7	0,2	0,1
		a_4	0	0	0	1	0	0	0
		a_5	0,1	0,4	0,5	0	0	0	0
k_4	1	a_1	0,2	0,3	0,5	0	0	0	0
		a_2	0,2	0,2	0,6	0	0	0	0
		a_3	0	0	0	1	0	0	0
		a_4	0,1	0,1	0,8	0	0	0	0
		a_5	0,1	0,1	0,8	0	0	0	0
	2	a_1	0,1	0,2	0,7	0	0	0	0
		a_2	0,1	0,4	0,5	0	0	0	0
		a_3	0	0	0	1	0	0	0
		a_4	0,1	0,1	0,8	0	0	0	0
		a_5	0,1	0,1	0,8	0	0	0	0
	3	a_1	0,1	0,1	0,8	0	0	0	0
		a_2	0,2	0,2	0,6	0	0	0	0
		a_3	0	0	0	0	0,8	0,1	0,1
		a_4	0	0	0	1	0	0	0
		a_5	0	0	0	1	0	0	0

Table 7. Values of the total grades of the normalized grades c_{ij} obtained by the methods: baseline and modified

	Baseline method					**Modified method**				
	a_1	a_2	a_3	a_4	a_5	a_1	a_2	a_3	a_4	a_5
k_1	0,2722	0,2722	0,3278	0,4000	0,1694	0,4040	0,9000	0,1000	0,5800	0,4360
k_2	0,8944	0,8944	0,8500	0,3028	0,6278	0,5000	0,1000	0,9000	0,2333	0,9000
k_3	0,8333	0,8333	0,3333	0,7556	0,4111	0,7400	0,2600	0,9000	0,1000	0,5800
k_4	0,2556	0,2556	0,2333	0,5722	0,3556	0,3667	0,1000	0,9000	0,6333	0,6333

The next step of the algorithm was to create standardized decisions by raising each normalized grade to a power equal to the corresponding weight, according to formula (11). The values of standardized decisions for each of the compared methods are presented in Table 8.

Table 8. Values of decisions d_j evaluated obtained using the following methods: base and modified

	Baseline method					**Modified method**				
	a_1	a_2	a_3	a_4	a_5	a_1	a_2	a_3	a_4	a_5
k_1	0,0590	0,0884	0,1363	0,0210	0,0067	0,1392	0,7952	0,0067	0,3058	0,1644
k_2	0,8755	0,8239	0,2408	0,5741	0,7538	0,4378	0,0643	0,8820	0,1765	0,8820
k_3	0,9291	0,6419	0,8930	0,6985	0,5611	0,8856	0,5806	0,9584	0,3948	0,8026
k_4	0,7314	0,7163	0,8799	0,7889	0,7889	0,7945	0,5897	0,9761	0,9005	0,9005

As part of the last stage of the Yager algorithm, the optimal rankings for the base and modified methods were determined. According to formula (12), from the method used, the optimal ranking is a minimum decision, which is illustrated in Table 9.

Table 9. Optimal ranking of logistics service providers' offers obtained using the following methods: base and modified

	Baseline method					**Modified method**				
	a_1	a_2	a_3	a_4	a_5	a_1	a_2	a_3	a_4	a_5
D_i	0,0590	0,0884	**0,1363**	0,0210	0,0067	0,1392	0,0643	0,0067	**0,1765**	0,1644

DOI: https://doi.org/10.53052/9788367652278.06

Using the relationship (13), the most advantageous variants were indicated, i.e.:

- for the base method: the a_3 variant, because it corresponded to a maximum ranking value of 0.1363,
- for the modified method: the a_4 variant, because it had a corresponding maximum ranking value of 0.1765.

On the basis of the best offers of cooperation with the logistics service provider, the provisions of the contract were in force, according to which:

- for the base method: the cost of service provision was set at PLN 169 per PLU, with the applicable payment term for the proper provision of services being 60 days, assuming that the selected service provider had a 5-year fleet of vehicles, while documenting 15 years of experience related to the provision of transport and forwarding services;
- for the modified method: the cost of service provision was set at PLN 139 per PLU, with the applicable payment term for the proper provision of services being 35 days, assuming that the selected service provider had a 10-year fleet of vehicles, while documenting 12 years of experience related to the provision of transport and forwarding services.

4. Conclusions

The presented comparative analysis of the methods of determining the total ratings standardized within the Yager algorithm is an example of the possibility of using one of the quantitative methods in making decisions related to business activity. The presented algorithm is dedicated mainly to decision-making processes in which the knowledge and professional experience of experts play a fundamental role. If the methods of determining the total standardized assessments give different results (different variants are optimal), it is proposed to use another method of multi-criteria assessment. An example is the Pareto optimum method, which in the vast majority of cases does not provide a single solution. In a situation where the obtained set of solutions would not be one-elementary, in the second stage it would be justified to use the distance function method in order to choose the optimal variant.

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