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PROPOSAL OF SPECIFIC MEASURES IN THE CONTEXT OF STREAMLINING OPERATING COSTS IN A SELECTED COMPANY

Summary. The aim of this research is to propose particular measures aimed at streamlining costs in terms of operations in a selected company. A specific proposal is based on the concept related to using services of the transport databank. As at least two out of five major carriers of the investigated company resell shipments to other carriers on such portals, the company could reduce the transport costs by entering shipments into the transport databank on its own. One out of three selected providers will be chosen using multi-criteria evaluation methods, specifically, the Analytic Hierarchy Process (hereinafter referred to as AHP) and the Base-criterion method. Determination of the weights of criteria will be carried out using the Saaty method of quantitative pair wise comparison and the Fuller pair wise comparison method. In this paper, the presented methods are applied for the example of a specific company specialized in the manufacture of metal storage racks and steel structures. In the Czech Republic, the company employs 65 employees in production, storage and administration. Based on the analytical evaluation of the current situation of the company, relevant measures will be proposed with a required effect on the effectiveness of such an enterprise.

1. INTRODUCTION

One of the main financial objectives of a company is to achieve the highest profits possible. The sub-objective is usually to make efforts to maximize their market value. These objectives can be achieved by proper management of business costs. Currently, the market is characterized by strong competition, especially in terms of small- and medium-sized enterprises, which are particularly forced to reduce the prices of their products and services due to strong competition.

Nowadays, it is almost impossible to improve performance without incurring additional costs. The optimal way to maximize the economic result and effectiveness of a company is to reduce costs. Therefore, the company management needs to be able to manage costs effectively and properly to improve the competitiveness of the company. If company management has the ability of proper management, companies can achieve better economic results and tend to be more resilient to possible business risks.

However, company management should be aware of the fact that such reduction must not be to the detriment of the service and product quality so that it does not negatively affect the satisfaction of the current and future customers. The process of reducing costs takes time; it needs to be elaborated, well planned and systematic, and all possible risks need to be considered before it is started.

The biggest cost item of the company under review is customer service – transport, which accounts for 29.13% of all corporate operating costs. The company does not operate its own transport; it uses the services provided by external carriers. The second biggest cost item is customer service – assembly, which accounts for 27.34 %. The company uses the assembly services provided by Czech and Slovak providers or private carriers. The third biggest cost factor is rent (for renting warehouses, offices, equipment, vehicles, tools, etc.), which accounts for 15.52%.

The main aim of this paper is to perform an in-depth analysis of the current state of the company and subsequent efforts towards the reduction of the operating costs of transport while applying relevant rationalization solutions.

2. LITERATURE REVIEW

When dealing with the issue of cost items and their rationalization, the sub-objective for the purposes of this paper was to analyse relevant literary resources. Within the literary research, the authors focused on scientific papers that deal with the application of pair wise comparison and the methods of multi-criteria analyses in the context of transport and logistics. In [1], the authors analyse and apply the methods of multi-criteria analysis. They combine two variants, stochastic and deterministic, in the context of transport. In [2], the authors apply the TOPSIS method and provide two scenarios for solving a specific type of decision-making problem with multiple attributes while evaluating the results on the basis of several approaches to determine the usefulness of the approximation spaces λ. A modified TOPSIS approach implemented in decision-making problems is addressed in [3], where the authors broaden the current knowledge of the issue under review by applying a supply partner selection framework for ongoing public procurement. Specifically, the quantification of criteria weight is carried out using the fuzzy AHP method, while the TOPSIS method is used for the classification of the considered variants of supply partners.

Agarski et al. compare efficiency and safety optimization using multi-criteria decision analyses [4]. The research includes examination of the application of multi-criteria methods for determining the working procedures to streamline work efficiency and safety. For this purpose, a set of economic, technical and safety criteria was determined, and a number of scenarios were compared. Group decision-making of the selection of suppliers is described in [5], which discussed the development of a progressive approach to making decisions on sustainable determination of suppliers using the TOPSIS method in an interval-valued Pythagorean fuzzy environment. The article [6] presents several multi-criteria decision analyses on specific examples. The authors describe the implementation of the AHP, WSA and TOPSIS methods in the location and allocation problems in practice. The evaluation of the supplier quality and transport system user equivalence is specified in [7], where the authors emphasize the definition of the basic approaches and instructions in accordance with the supplier quality evaluation. The manuscript [8] deals with transport interactions and the implementation of multi-criteria decision-making.

Another study [9] proposes a credit scoring model using the hybrid analytic hierarchy process for determining the order of priority on the basis of the similarity to an ideal solution (AHP-TOPSIS). The implementation of integrated management systems, which has become a prerequisite for any organization that aims to become a competitive and sustainable company, is addressed in [10], which is directly related to the paper submitted. The objective of the paper [11] is to propose a model of selecting sub-contractors that would fully consider the influence of company requirements on the selection of sub-contractors. The aim is to understand the process of converting specific requirements of the company into evaluation criteria and calculation of weights. Providers of logistics services may play an important role in supply chain management when maintaining customer satisfaction and reducing the costs of supply chain management. This issue is addressed in [12], where the aim is to apply the approach of the fuzzy-analytic hierarchy process (AHP). Similarly, Phruksaphanrat and Borisutiyanee address the issue of company and supply chains using AHP [13].

3. METHODOLOGY

As mentioned above, a specific provider out of three defined providers will be chosen using opted multi-criteria evaluation instruments, namely, the AHP and the Base-criterion methods, when determining the weights of criteria by the Saaty method of quantitative pair wise comparison and the Fuller pair wise comparison method.

As for the Saaty tool, decision-makers compare each pair of criteria and determine the values of preferences between each other. Subjective assessment of the investigators is partially eliminated by normalization of the geometric mean. Therefore, use of this method for this type of task is suitable. TheFuller method (also known as the Fuller triangle) is one of the techniques used for comparison of criteria as well. The criterion being more important than another one is explicitly marked with respect to all the pairs. Even though it lacks the exact value of significance given to criterion preference, using this method for this type of tasks is suitable.

AHP can effectively handle both qualitative and quantitative data to decompose the problem hierarchically, wherein the problem is thoroughly broken down. Using subjective ratings of pairwise comparison, this tool then assigns quantitative characteristics to each element, indicating their importance. This method does not require the exact values of individual criteria assigned to each variant to determine the overall variants' ranking. Its goal is to select the variant that results in the greatest value of the objective function. This is considered a compensatory optimization approach. In line with the aforementioned, application of the AHP method for this type of tasks is suitable. Last but not the least, the Base-criterion method is suitable for this type of task, given that it entails a general multi-criteria evaluation procedure of variants, which is, in typical cases, assigned for growing or declining priorities of variants considered. Its crucial objective is to compare individual values of variant consequences with values of the so-called Base criterion. In our case, the Base criterion is deemed as a target, in most cases with the most appropriate results (values) of all the criteria taken into consideration.

3.1. Saaty method of quantitative pair wise comparison

This instrument is based on pair wise-comparison of individual criteria when using Saaty 9-point comparison scale. The points presented in Table 1 represent the relationship between two criteria [14].

Table 1

Saaty 9-point comparison scale [14]

Number	Descriptor
1	Criteria are equally important
3	Weak importance of the 1st criterion
5	Strong importance of the 1st criterion
7	Demonstrated importance of the 1st criterion
9	Absolute importance of the 1st criterion

In addition to points 1, 3, 5, 7 and 9, the intermediate steps 2, 4, 6 and 8 can be used. The comparison of criteria pairs is described using the Saaty matrix $S = (s_{ij})$ in Fig. 1.

If the *j-th* criterion is preferred over the *i-th* criterion, the inverse value is entered into the matrix. On the diagonal of a particular matrix, the value 1 is always entered because the criterion is equivalent to itself. It is an $n \cdot n$ matrix (a square matrix), and the elements of the matrix S_{ij} are expressed by the estimate of the share of the *i-th* and the *j-th* criterion as expressed in formula (1):

$$S_{ij} \approx \frac{v_i}{v_j} \tag{1}$$

where i, j = 1, 2, …, n.

$$S = \begin{pmatrix} 1 & s_{12} & \cdots & s_{1n} \\ 1/s_{12} & 1 & \cdots & s_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/s_{1k} & 1/s_{12} & \cdots & 1 \end{pmatrix}$$

Fig. 1. Saaty matrix

For the elements of the matrix S, it holds that, see formula (2):
$$S_{ii} = 1 \ , \tag{2}$$
where $i, j = 1, 2, \ldots, n$.

However, the elements in the matrix may not be consistent. The consistency of the matrix can be determined by the consistency index using formula (3) [15, 16].
$$I_S = \frac{l_{max} - n}{n - 1} \ , \tag{3}$$
where l_{max} is the largest eigenvalue of Saaty matrix and n is the number of criteria

The consistency of the matrix S is sufficient if $I_S < 0.1$.

Weights v_j can be calculated in several different ways. The most commonly used method is the weight calculation using the normalized geometric mean of rows in the Saaty matrix, which is referred to as the method of logarithmic least squares. The value of g_i is calculated using formula (4) as a geometric mean of matrix rows [17].
$$g_i = \sqrt[n]{\prod_{j=1}^{n} S_{ij}} \ , \tag{4}$$
where $i, j = 1, 2, \ldots$, g_i is the geometric mean, S_{ij} represent values of the matrix and n is the number of criteria.

Weights of criteria are then calculated using the normalization of g_i values, see formula (5):
$$v_i = \frac{g_i}{\sum_{i=1}^{n} g_i} \ , \tag{5}$$
where $i = 1, 2, \ldots, n$.

3.2. Fuller method of pairwise comparison

The Fuller method of pairwise comparison is used to determine the number of priorities for each criterion in relation to the other criteria in the set. The method is used if the ordinal information expresses the relationship between each pair of criteria being evaluated. Every two criteria are mutually compared and the number of comparisons (N) is thus determined as follows, see formula (6):
$$N = \frac{n(n-1)}{2} \ . \tag{6}$$

The comparison is carried out using the so-called Fuller triangle, where the criteria are assigned order numbers 1, 2, …, n. The triangle is presented in Table 2 [18].

For each pair, a criterion that is considered the most important is selected. The number of selections of the *j-th* criterion is indicated as n_j, and the weight of the *j-th* criterion is calculated according to formula (7) [18].
$$v_j = \frac{n_j}{N} \tag{7}$$
where $j = 1, 2, \ldots, n$.

The disadvantages of this variant include the fact that the value n_j for the least preferred criterion is 0. However, value 1 can be added to each resulting value n_j, thus avoiding the zero-resulting value of the criterion [18].

3.3. AHP method

The method of the Analytical hierarchy process was proposed by professor Saaty. Its main purpose is to provide a framework for the preparation of efficient decisions in complex situations, and it also helps to simplify and accelerate the natural decision-making process. The method creates a certain hierarchical system of the problem, and as a decomposition method, it decomposes complex non-

structured situations into more simple components. The Saaty method of quantitative pairwise comparison is used at all levels of the hierarchy structure, which are arranged in the order from general to specific elements. The more general the elements occurring in relation to the decision problem, the higher they are in the hierarchy. The higher level of the hierarchy includes one element only, which defines the objective of the evaluation. The element can thus be assigned the value 1, which is then divided among the elements at the second level of the hierarchy. Similarly, the value of the individual elements is divided at the other low levels until the evaluation of the lowest level, i.e., variant, is obtained [19].

Table 2
Scheme of the Fuller triangle

1	1	1	…	1
2	3	4	…	n
	2	2	…	2
	3	4	…	n
			…	…
			…	…
			n-2	n-2
			n-1	n
				n-1
				n

The basic simple task of the Analytical hierarchy process includes3 levels:
1. evaluation objective,
2. evaluation criteria and
3. evaluated variants.

In more complex problems, the so-called sub-criteria level occurs between the criteria and variants. As can be seen in Figure 2, if two or more evaluators deal with the evaluation of the problem, another level of evaluators (experts) appears between the objective and the criteria. Their weights reflect the degree of its soundness [20].

The relationships between all components at the hierarchy levels are determined similarly as in the case of criteria. In a four-level hierarchy, i.e., when determining one objective, h experts, n criteria and m variants, the second hierarchy level contains one pairwise comparison matrix with the dimensions of $h \times h$. For the third level, it is h matrices with the dimensions of $n \times n$, and at the fourth level, it is n matrices with the dimensions of $m \times m$.

In simple terms, using these calculations of matrices, the variants divide the weights of the criterion for which the matrix is constructed. If a sum of given values for all the criteria is calculated for each variant, its evaluation is performed in terms of all the criteria that create a basis of the resulting order of variants. The results of the AHP method are verified using the Base-criterion method (see the following section) [21].

3.4. Base-criterion method

The base-criterion method is suitable for the given problem mainly due to the fact that it is a technique of multi-criteria evaluation of variants, which is usually intended for growing or declining priorities. Furthermore, it is a method based on the maximization of utility. Its main principles include, in particular, comparison of the values of variant consequences with the values of the Base criterion. In this case, the Base criterion is perceived as a goal, in most cases, with the best results of all the criteria being evaluated [22].

The overall evaluation of the variant x, which is described by the vectors x_1, x_2, …, x_m of the measured criteria values K_1, K_2, …, K_m, is given by formula (8) when this method of multi-criteria evaluation of variants is applied. Weights v_j can be determined, e.g., by the Saaty or the Fuller method [23].
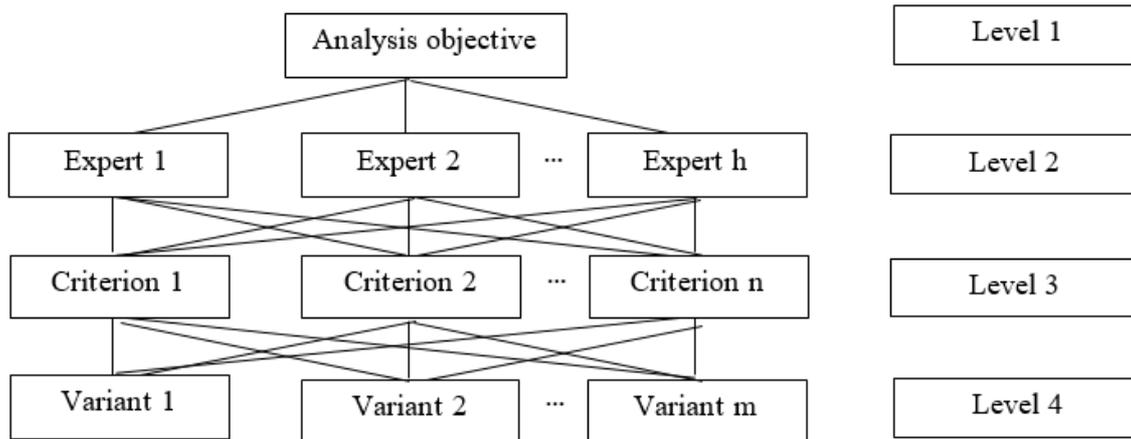
Fig. 2. Hierarchy of the AHP method [20]

$$u(x) = \sum_{j=1}^{m} v_j \cdot u_j(x_j), \ \ \sum_{j=1}^{m} v_j = 1, \ v_j \geq 0, \ j = 1,2,\dots,m \qquad , \tag{8}$$

where the *j-th* partial evaluation of the benefit criterion (with growing priority) is given as follows, see formula (9):

$$u_j(x_j) = \frac{x_j}{x_j^b} \quad . \tag{9}$$

Moreover, for the partial evaluation of the cost criterion (with declining priority), it holds true that, see formula (10):

$$u_j(x_j) = \frac{x_j^b}{x_j}. \tag{10}$$

where the vectors $x_1^b, x_2^b, \dots, x_m^b$ represent the Base-criterion selected as a vector of the best or predetermined values of the criteria in the set. The method represents the basis for performing certain partial evaluation of variants with respect to individual criteria by comparing the values of all variant consequences with the values of the Base criterion [24].

4. RESULTS

4.1. Determining criteria weights for the application of the multi-criteria evaluation of variants

Table 3 presents the basic data important for deciding on the most suitable supplier for the company. The method of securing against defaulters or non-payers is intentionally not mentioned, since, in terms of the needs of the company, this information is not relevant. The price for the databank services is a price for inland transport and transport to the Slovak Republic (this is sufficient for the purposes of the paper). The remaining two providers offer uniform prices for transport across Europe (i.e. e.g. shipments to Germany, Hungary, etc. can be entered). All three databanks offer public databases for their users with android access.

Table 4 shows the criteria based on the data in Table 3. They are a basis for making decisions on the selection of the most suitable provider. Criterion K_5 is not numerical. It will be quantified as follows: if the databank does not have the possibility of mutual evaluation of clients using its services, the value of the criterion is 0. If the databank offers this service, the criterion is assigned the value 1.

For the Saaty method of quantitative pair wise comparison of criteria, to enable the application of the AHP method and the Base-criterion method, weights of given criteria in the Saaty matrix were determined based on consultation with an expert team. As the first step, it is necessary to specify the relationship of each pair of criteria being evaluated, in which the degree of importance on a point scale of 1-9 is calculated. In terms of criteria weights, all input values can be obtained through a survey, i.e., a survey of expert opinions needs to be conducted.

Table 3

Basic information on databank providers for determining criteria

	RAALTRANS	Trans.eu	Transpen
Price of using databank services in the 1st	17,700 CZK	23,652 CZK	7,188 CZK
Price of using databank services in the 2nd	7,200 CZK	23,652 CZK	7,188 CZK
Number of offers or demands for transportation or available vehicle (currently in the database of the transport databank)	110,000	209,000	8,500
Number of users currently present in the database of the transport databank	10,500	25,000	4,900
Possibility of mutual evaluation of transport databank clients (contractors and carriers)	No	Yes	Yes

Source: Authors

Table 4

Criteria for application of the multi-criteria evaluation of variants

Criterion
K_1 price of using databank services for the 1st year
K_2 price of using databank services for the 2nd year
K_3 number of offers or demands for transportation or available vehicle (currently in the database of the transport databank)
K_4 number of users currently present in the database of the transport databank
K_5 possibility of mutual evaluation of transport databank clients (contractors and carriers)

Source: Authors

Table 5 below presents the information on experts who participated in the survey in terms of the definition of a set of criteria as well as the evaluation of their weights (input weights of compared pairs of criteria).

As for the Saaty matrix, the factors evaluated by experts were scored, and the arithmetic means of all sub matrix values were calculated. The individual values of the Saaty matrix were implemented in the process of gradual quantification, i.e., determining the geometrical mean and calculation of the resulting vector of criteria weights. The results presented in Table 6 show that the largest weight was calculated for K_3, which was followed by K_2, K_1 and K_5. The smallest weight was calculated for K_4 [25].

Fuller method of pair wise comparison of criteria– the method of the Fuller triangle is based on priorities, where the list of criteria was presented to the above-mentioned expert team, who described the requirements for their prioritization and determined the input weights between the pairs of criteria being compared [26]. Table 7 shows the calculation of specific criteria weights.

Table 8 presents criteria with their weights. The results, i.e., the weights obtained using the Fuller method, are, in terms of importance, the same as in the case of weights obtained using the Saaty method. Since criterion K_4 has a zero weight, the weight of each criterion was increased by 1. The largest weight was determined in the case of criterion K_3, followed by K_2 (lower importance), K_1, K_5 and K_4 (the smallest weight). The calculation using the AHP method and the Base-criterion method is based on the values presented in Table 9.

4.2. Results – Method of Analytic hierarchy process (AHP)

The first method to determine which of the three databank providers is the most suitable in terms of the management requirements is the method of the Analytical hierarchy process (AHP). The

allocation of ratios using the Saaty scale was discussed with the above-mentioned expert team. Partial results of Saaty matrices are presented in the graph of AHP in Figure 3. By summing up the partial results on the left in the arrays P_1, P_2 and finally P_3, it is possible to calculate their resulting value with weights obtained through the application of the Saaty method [27]. Summing up the values in the right column provides the final result for the calculation with weights obtained from the Fuller triangle.

The following Table 10 summarizes the results obtained on applying the AHP method.

Table 5

List of experts participating in the process of determining criteria weights

Name of the expert	Specialization of the expert	Date of survey
Expert 1	Rail transportation planning and modeling; traffic engineering; supply logistics; economy	November 10, 2020
Expert 2	Road transport and forwarding; combined transport and logistics; integrated transport systems	December 05, 2020
Expert 3	Supply chain management; Operations Research in logistics; road and urban transport	January 22, 2020
Expert 4	Transport engineering; urban transport planning; supply logistics; transport management and scheduling	January 22, 2020
Expert 5	Personal management in transport and logistics	February 13, 2021
Expert 6	Automotive engineering; Operations Research in transport; public passenger transport	February 13, 2021
Expert 7	Sustainable transport development; urban planning; automotive engineering	February 13, 2021
Expert 8	Supply chain management; transport planning and management; transport engineering and logistics	February 19, 2021
Expert 9	Industrial logistics; structural analysis and dynamics; computational mechanics; simulation modeling	February 27, 2021
Expert 10	Rail transportation planning and modeling; traffic engineering; supply logistics; accident analysis	February 27, 2021

Source: Authors

Table 6

Resulting weights of criteria calculated using the Saaty method

	K_1	K_2	K_3	K_4	K_5	g_i	Resulting weights v_S
K_1	1	$^1/_4$	$^1/_5$	5	3	0.9441	0.1246
K_2	4	1	$^1/_2$	7	5	2.339	0.3086
K_3	5	2	1	8	7	3.5452	0.4677
K_4	$^1/_5$	$^1/_7$	$^1/_8$	1	$^1/_3$	0.2601	0.0343
K_5	$^1/_3$	$^1/_5$	$^1/_7$	3	1	0.4911	0.0648
						∑ 7.5795	∑ 1

Source: Authors

Table 7

Fuller triangle for K_1-K_5

$K_1 = 2$ $K_{1+1}=3 \rightarrow 3/15 = 0.2\ v_1$

$K_2 = 3$ $K_{2+1}=4 \rightarrow 4/15 = 0.27\ v_2$

$K_3 = 4$ $K_{3+1}=5 \rightarrow 5/15 = 0.33\ v_3$

$K_4 = 0$ $K_{4+1}=1 \rightarrow 1/15 = 0.07\ v_4$

$K_5 = 1$ $K_{5+1}=2 \rightarrow 2/15 = 0.13\ v_5$

$\sum$ 15

1	1	1	1
2	3	4	5
	2	2	2
	3	4	5
		3	3
		4	5
			4
			5

Source: Authors

Table 8

Resulting weights of criteria calculated using the Fuller method

Criterion	Resulting weights v_F
K_1 price for the 1st year	0.2
K_2 price for the following year	0.27
K_3 number of offers in the	0.33
K_4 number of companies in	0.07
K_5 mutual evaluation of clients	0.13
	$\sum 1$

Source: Authors

Table 9

Initial matrix for the application of multi-criteria evaluation of variants

	K_1	K_2	K_3	K_4	K_5
RAALTRANS	17 700	7 200	110 000	10 500	0
Trans.eu (*P2*)	23 652	23 652	209 000	25 000	1
Transpen (*P3*)	7 188	7 188	8 500	4 900	1
Type	MIN	MIN	MAX	MAX	MAX
v_S	0.1246	0.3086	0.4677	0.0343	0.0648
v_F	0.2	0.27	0.33	0.07	0.13

Source: Authors

Table 10

Results of application of the AHP method

	Results by SM	Order	Results by FT	Order
RAALTRANS	0.2897	2.	1.4172	3.
Trans.eu	0.4298	1.	2.4890	1.
Transpen	0.2805	3.	2.0941	2.

Source: Authors

The results of the AHP method presented in the above table show that the calculations with both weights determined the services provided by the databank Trans.eu, s.r.o., to be the best variant. The second best variant in the case of calculations with v_S weights was RAALTRANS, followed by Transpen, with a difference of only 0.0092. According to the weights obtained using the Fuller

triangle, Trans.eu was confirmed to be the best variant, while the order of Transpen and RAALTRANS changed, with the difference being 0.6769. In both cases, the compromise variant (Trans.eu, s.r.o.) turned out to be the best option.
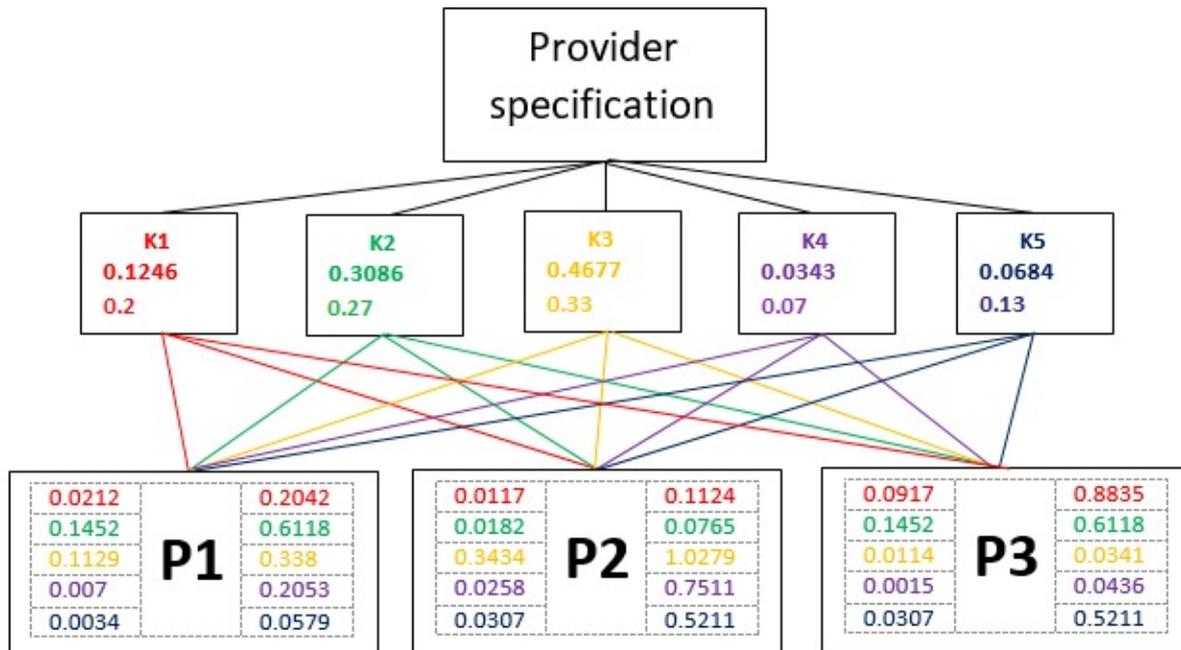
Fig. 3. Partial results of the AHP method - graphical representation

4.3. Results – Base-criterion method

The application of this method is based on the matrix presented in Table 11. The first two criteria are minimizing (prices); the remaining three criteria are maximizing.

The resulting matrix is presented in Table 12. The column by SM shows the calculated resulting value for the criteria multiplied by the weights obtained using the Saaty method, while the column by FT shows the results calculated using the weights obtained using the Fuller method. It is obvious at first glance that the variants are non-dominated.

The order of variants (providers) in Table 13is the same as that in the case of the AHP method. The best option appears to be Trans.eu, whose result when calculated with the weights obtained using the Saaty method is 0.0793 higher than the result of RAALTRANS. Transpen rated third, with a difference of 0.0955 compared to RAALTRANS. The calculations using the weights obtained using the Fuller method confirm the results obtained through the application of the AHP method. Based on the results, Trans.eu is a compromise variant, followed by Transpen and RAALTRANS.

Table 11

Default matrix for the application of the Base-criterion method

	K_1	K_2	K_3	K_4	K_5
RAALTRANS (P_1)	17 700	7 200	110 000	10 500	0
Trans.eu (P_2)	23 652	23 652	209 000	25 000	1
Transpen (P_3)	7 188	7 188	8 500	4 900	1
v_S	0.1246	0.3086	0.4677	0.0343	0.0648
v_F	0.2	0.27	0.33	0.07	0.13
Type	MIN	MIN	MAX	MAX	MAX

Source: Authors

Table 12

Matrix of calculation of theBase-criterion method

	K_1	K_2	K_3	K_4	K_5	SM	FT
RAALTRANS	0.4061	0.9983	0.5263	0.42	0	0.6192	2.9420
Trans.eu	0.3039	0.3039	1	1	1	0.6985	4.2598
Transpen	1	1	0.0407	0.196	1	0.5237	3.8529
v_S	0.1246	0.3086	0.4677	0.0343	0.0648		
v_F	0.2	0.27	0.33	0.07	0.13		
Type	MIN	MIN	MAX	MAX	MAX		
x_j^b	7 188	7 188	209 000	25 000	1		

Source: Authors

Table 13

Results of the Base-criterion method application

	Results by SM	Order	Results by FT	Order
RAALTRANS	0.6192	2.	2.9420	3.
Trans.eu	0.6985	1.	4.2598	1.
Transpen	0.5237	3.	3.8529	2.

Source: Authors

5. DISCUSSION

Based on the application of the methods, it can be concluded that the best option for the company is to use the services provided by the transport databank of Trans.eu, s.r.o. This compromise variant ranks first in the application of all methods. The ranking of the other two variants is not clearly defined, but as in the case of calculations that included weights obtained using the Saaty method, the difference is less significant than in the case of the Fuller method. We recommend to apply ranking based on the second type of weights (i.e., Fuller method).

If follows from the findings of the AHP method that the compromise variant significantly exceeds the values of the other two providers in the case when the calculations included the weights obtained using the Saaty method, with the difference between the best variant and the second best one being 0.0793. In the case of using weights obtained using the Fuller method, the difference is 0.4069. It can thus be concluded that the best variant is Trans.eu, s.r.o.

The application of the Base-criterion method confirmed the rating provided by the AHP method. Using the weights obtained using the Saaty method, the difference between the best variant and the second best one is 0.0793; in the case of the Fuller method, it is 0.4069. Thus, it is recommended to cooperate with the Trans.eu, s.r.o. company in the future.

6. CONCLUSION

A step towards rationalization of costs was the selection of one of the three providers of transport databank services using multi-criteria evaluation of variants, specifically the AHP method and the Base-criterion method. Using transport databank services enables the company to streamline its transport costs. The criteria weights were determined using the Saaty method of quantitative pair wise comparison and the Fuller method of pair wise comparison of criteria. Based on the method applied, it can be concluded that the most suitable provider of databank services for the company is Trans.eu, s.r.o., which was rated first in all the cases. The ranking of the other two variants is not clearly defined, however since the value-difference between the criteria weights obtained by the Saaty method

is not as clear as the weights of the criteria determined by the Fuller method, it is recommended so that the company under investigation takes into account the weights calculated by the Fuller triangle.

From the point of view of the given company, it is not possible to find out how many shipments are carried out via transport databanks entered into the portal by two carriers. However, they demonstrably use the services of the RAALTRANS databank. The proposal for the rationalization of costs consisted of selecting one of the three providers of databank services. Since at least two major carriers use these services, charging the company an average additional fee of 1,220 CZK per carriage, the company was recommended to use the databank services itself. The most suitable provider was selected using the method of multi-criteria evaluation of variants, specifically the AHP and the Base-criterion techniques. The criteria weights were calculated using the Saaty method of quantitative pair wise comparison and the Fuller pairwise comparison of criteria. As for the AHP method as well as the Base-criterion method, both types of weights were considered for verification. The best option turned out to be Trans.eu, whose use, calculated with the weights obtained using the Saaty method, is 0.0793 higher than the value of RAALTRANS. Transpen rated third, with a difference of 0.0955 compared to RAALTRANS. The calculation considering the second type of weights confirmed the results of the AHP method. Trans. EU was confirmed to be a compromise variant, followed by Transpen and with RAALTRANS rated third. In this specific case, 5 criteria were considered.

Based on the results obtained, it can be stated that the application of the AHP and the Base-criterion methods showedTrans.eu to be the most suitable option on the basis of a specified set of factors. It also can be declared that no similar publication that deals with analogous subject as this publication does has been presented yet. The submitted scientific paper adds value to the knowledge of proper determination and selection of transport companies in the Czech Republic and abroad while emphasizing the importance of defining corresponding criteria. The above findings present aspects in which the novelty and innovative solution of this research work lie.

Further research on the presented subject could focus on extending the compared set of criteria or extending the individual criteria by sub-criteria, or the application of other Operations Research methods, with a focus on the aspect of economic evaluation of the benefits achieved, which has not been addressed in our research.

References

1. Aspen, D.M. & Sparrevik, M. Evaluating alternative energy carriers in ferry transportation using a stochastic multi-criteria decision analysis approach. *Transportation Research Part D: Transport and Environment*. 2020. Vol. 86. DOI: 10.1016/j.trd.2020.102383.
2. Yu, B. & Cai, M. & Li, Q. A λ-rough set model and its applications with TOPSIS method to decision making. *Knowledge-Based Systems*. 2019. Vol. 165. P. 420-431. DOI: 10.1016/j.knosys.2018.12.013.
3. Venkatesh, V.G. & Zhang, A. & Deakins, E. & Luthra, S. & Mangla, S. A fuzzy AHP-TOPSIS approach to supply partner selection in continuous aid humanitarian supply chains. *Annals of Operations Research.* 2019. Vol. 283. No. 1-2. P. 1517-1550. DOI: 10.1007/s10479-018-2981-1.
4. Agarski, B. & Hadzistevic, M. & Budak, I. & Moraca, S. & Vukelic, D. Comparison of approaches to weighting of multiple criteria for selecting equipment to optimize performance and safety. *International Journal of Occupational Safety and Ergonomics*. 2019. Vol. 25. No. 2. P. 228-240. DOI: 10.1080/10803548.2017.1341126.
5. Yu, C. & Shao, Y. & Wang, K. & Zhang, L. A group decision making sustainable supplier selection approach using extended TOPSIS under interval-valued Pythagorean fuzzy environment. *Expert Systems with Applications*. 2019. Vol. 121. P. 1-17. DOI: 10.1016/j.eswa.2018.12.010.
6. Dockalikova, I. & Klozikova, J. MCDM Methods in practice: localization suitable places for company by the utilization of AHP and WSA. TOPSIS Method. In: *Conf. on Europ. Manag. Leadersh. and Govern.* Military Academy, Lisbon, Portugal. 2015. P. 543-552.
7. Ližbetin, J. & Černá, L. & Ľoch, M. Model evaluation of suppliers in terms of real company for selected criteri. *Nase More*. 2015. Vol. 62. P. 147-152. DOI: 10.17818/NM/2015/SI11.

8. Kampf, R. & Lizbetin, J. & Lizbetinova, L. Requirements of a transport system user. *Komunikacie*. 2012. Vol. 14. No. 4. P. 106-108.
9. Chen, X. & Ding, Y. & Cory, C.A. & Hu, Y. & Wu, K. & Feng, X. A decision support model for subcontractor selection using a hybrid approach of QFD and AHP-improved grey correlation analysis. *Engineering, Construction and Architectural Management*. 2020. DOI: 10.1108/ECAM-12-2019-0715.
10. Ikram, M. & Sroufe, R. & Zhang, Q. Prioritizing and overcoming barriers to integrated management system (IMS) implementation using AHP and G-TOPSIS. *Journal of Cleaner Production*. 2020. Vol. 254. No. 120121.
11. Roy, P.K. & Shaw, K. A credit scoring model for SMEs using AHP and TOPSIS. *International Journal of Finance and Economics*. 2021. DOI:10.1002/ijfe.2425.
12. Yadav, S. & Garg, D. & Luthra, S. Selection of third-party logistics services for internet of things-based agriculture supply chain management. *International Journal of Logistics Systems and Management.* 2020. Vol. 35. No. 2. P. 204-230. DOI: 10.1504/IJLSM.2020.104780.
13. Phruksaphanrat, B. & Borisutiyanee, M. Ranking barriers and solutions of supply chain information technology adoption in Thai industrial sector by AHP and fuzzy TOPSIS. *International Journal of Integrated Supply Management*. 2019. Vol. 12. No. 3. P. 230-258. DOI:10.1504/IJISM.2019.099719.
14. Droździel, P. & Wińska, M. & Madleňák, R. & Szumski, P. Optimization of the position of the local distribution centre of the regional post logistics network. *Transport Problems*. 2017. Vol. 12. No. 3. P. 43-50. DOI: 10.20858/tp.2017.12.3.4.
15. Dinçer, S.E. Multi-criteria analysis of economic activity for European Union member states and candidate countries: TOPSIS and WSA applications. *European Journal of Social Science*s. 2011. Vol. 21. No. 4. P. 563-572.
16. Houska, M. Reply to the paper 'Multi-criteria analysis of economic activity for European Union member states and candidate countries: TOPSIS and WSA applications' by S.E. Dincer. *European Journal of Social Sciences*. 2012. Vol. 30. No. 2. P. 290-295.
17. Duleba, S. & Moslem, S. Examining Pareto optimality in analytic hierarchy process on real Data: An application in public transport service development. *Expert Systems with Applications.* 2019. Vol. 116. P. 21-30. DOI: 10.1016/j.eswa.2018.08.049.
18. Kauf, S. & Tłuczak, A. Allocation of logistic risk-investment in public-private-partnership – Use of fuzzy TOPSIS method. *MATEC Web of Conferences*. 2019. Vol. 184. DOI: 10.1051/matecconf/201818404025.
19. Adetunji, O. & Bischoff, J. & Willy, C.J. Managing system obsolescence via multicriteria decision making. *Systems Engineering*. 2018. Vol. 21. No. 4. P. 307-321. DOI: 10.1002/sys.21436.
20. Čarný, Š. & Šperka, A. & Zitrický, V. Multi-criteria Evaluation of Railway Transport Using Evaluation Method. *LOGI – Scientific Journal on Transport and Logistics*. 2020. Vol. 11. No. 2. P. 88-99. DOI: 10.2478/logi-2020-0018.
21. Pelegrina, G.D. & Duarte, L.T. & Romano, J.M.T. Application of independent component analysis and TOPSIS to deal with dependent criteria in multicriteria decision problems. *Expert Systems with Applications*. 2016. Vol. 122. P. 262-280. DOI: 10.1016/j.eswa.2019.01.008.
22. Antuchevičiene, J. & Zavadskas, E.K. & Zakarevičius, A. Multiple criteria construction management decisions considering relations between criteria. *Technological and Economic Development of Economy*. 2010. Vol. 16. No. 1. P. 109-125. DOI: 10.3846/tede.2010.07.
23. Chovancová, M. & Klapita, V. Modeling the supply process using the application of selected methods of operational analysis. *Open Engineering*. 2017. Vol. 7. No. 1. P. 50-54. DOI: 10.1515/eng-2017-0009.
24. Behzadian, M. & Khanmohammadi Otaghsara, S. & Yazdani, M. & Ignatius, J. A state-of the-art survey of TOPSIS applications. *Expert Systems with Applications*. 2012. Vol. 39. No. 17. P. 13051-13069. DOI: 10.1016/j.eswa.2012.05.056.
25. Ejem, E.A. & Uka, C.M. & Dike, D.N. & Ikeogu, C.C. & Igboanusi, C.C. & Chukwu, O.E. Evaluation and selection of Nigerian third-party logistics service providers using multi-criteria

decision models. *LOGI – Scientific Journal on Transport and Logistics*. 2021. Vol. 12. No. 1. P. 135-146. DOI: 10.2478/logi-2021-0013.

26. Simić, V. & Lazarević, D. & Dobrodolac, M. Picture fuzzy WASPAS method for selecting last-mile delivery mode: A case study of Belgrade. *European Transport Research Review*. 2021. Vol. 13. No. 1. DOI: 10.1186/s12544-021-00501-6.

27. Cables, E. & García-Cascales, M.S. & Lamata, M.T. The LTOPSIS: An alternative to TOPSIS decision-making approach for linguistic variables. *Expert Systems with Applications*. 2012. Vol. 39. No. 2. P. 2119-2126. DOI:10.1016/j.eswa.2011.07.119.

The list of acronyms

AHP	*Analytic Hierarchy Process*
FT	*Fuller triangle (Fuller pairwise comparison method)*
g_i	*geometric mean*
h	*number of experts*
I_S	*consistency of the Saaty matrix S*
K	*criterion*
l_{max}	*the largest eigenvalue of the Saaty matrix*
m	*number of variants*
N	*number of comparisons of the criteria*
n	*number of criteria*
P_1-P_3	*designation of the provider (variant) evaluated*
S	*the Saaty matrix*
S_{ij}	*values of the Saaty matrix*
SM	*Saaty method of quantitative pairwise comparison*
u_j	*partial evaluation of the criterion*
u(x)	*overall evaluation of the variant*
v_j	*weights of criteria*
v_F	*resulting weights of criteria calculated using the Fuller method*
v_S	*resulting weights of criteria calculated using the Saaty method*
x	*vector*
x_m^b	*base-criterion selected as a vector of the best or predetermined values of the criteria in the set*