Research Article

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Streamlining possibility of transport-supply logistics when using chosen Operations Research techniques

https://doi.org/10.1515/eng-2021-0023
Received Sep 17, 2020; accepted Nov 08, 2020

Abstract: The subject of this article is to model and streamline processes in the area of the transport-supply logistics in a specific enterprise. The topic of the manuscript was implemented in a particular enterprise with the residence in the city of České Budějovice (South Bohemia region). The aim of the article is to step by step analyze the current state of the supply logistics of the specific subject and propose appropriate measures contributing to optimize the entire process using selected techniques of the Operations Research. By applying the methods of multi-criteria decision analysis (such as Weighted Sum Approach and Technique for Order Preference by Similarity to Ideal Solution), the most attractive option is chosen; i.e. the optimal supplier for the implementation of the transport-supply process that will enhance the effectiveness of specific logistics activities in the operation being examined. The conclusion in detail discusses individual contributions in terms of the suggested ways of modeling and improving the current state with respect to supply processes in the selected enterprise.

Keywords: Transport, supplier, modeling, WSA, TOPSIS

1 Introduction

The sphere of logistics has recently seen an incremental influence. Although generally presumed so, the term itself denotes not only transporting goods from location A to B but also covers a large scale of business processes [1]. Rather than that, it refers to the whole value-creating chain composed not only of corporeal flows, but also energy, human resources and detailed and valuable information. Supplying and stock storage represent the most complex areas of logistics. These activities allow a wide range of possibilities and solutions to optimize and develop methods within the process [2].

Supplying is considered as one of the most important activities of the enterprise. Companies have to get necessary materials to a required amount, quality, within the deadline and for the optimal price [3]. Keeping an adequate stock which would ensure a smooth running of the enterprise currently presents the most important aspect for enterprises. It is at the same time necessary to maintain optimal stock levels since stocks are closely related to the capital [4].

The scientific purpose of this research study will be to compare opted Operations Research methods to identify appropriate wholesaler for providing the entire spectrum of transport-supply processes for the enterprise under investigation. Our scientific manuscript brings value-added to understand an efficient setting of supply chains in the Czech Republic and points to the inevitability of choosing the proper criteria (factors). Hence, it can be stated that no analogous publication has been published yet when applying identical Operations Research methods, same set of criteria, nor addressing an equal subject. And that is right where the novelty of our research lies.

2 Literature review

The issue of supply logistics has been discussed in various publications. For instance, the article [5] focuses on designing an innovative approach regarding the multi-criteria decision analysis which objective is to estimate an independent criteria set deemed to be an option to represent the original criteria decision matrix in terms
of TOPSIS method. The authors of the literature [6] fully disclose sources relating to TOPSIS Technique. These authors provide two scenarios to address a specific type of multi-attribute decision-making issues, while they rank outcomes on the basis of several approaches to depict the usefulness of $\lambda$-approximation spaces. The modified TOPSIS approach implemented in the decision-making problems is also discussed in the publication [7], where the authors enhance current knowledge in the subject being investigated by implementing a supply partner selection framework for continuous-aid procurement. Namely, suggested fuzzy AHP method is applied to quantify criterion weights, and fuzzy TOPSIS is applied to sort considered supply partner variants.

The article (Agarski et al. [8]) compares the performance and safety attributes by means of multi-criteria decision analyses. Specifically, the authors’ research involves examination of multi-criteria techniques to determine working devices in order to streamline performance and occupational safety when utilizing numerous criteria weight quantification methods. To this end, a set of economic, technical and safety criteria were stipulated, as well as a series of weight scenarios were compared. Group decision-making related to choosing suppliers is discussed in the article [9], in which the compilation of a progressive approach of decision-making sustainable supplier determination, when applying modified TOPSIS method under interval-valued Pythagorean fuzzy environment, is discussed.

Alike to the previous, even the study [10] written by Hruška et al. deals with a possible scenario in relation to desirable supplier selection, however, in that case, using the Analytic Hierarchy Process. In the publication [11], a specific model for solving problems with the routing of supplier shipments by utilizing one of the most used heuristic methods which address tasks of vehicle routing, namely Clarke-Wright algorithm, is rigorously applied. The European Journal of Social Sciences published the study [12] also focusing on TOPSIS and WSA method applications in terms of the multi-criteria decision analysis of economic activity for the EU states and candidate countries assessed by these two techniques. In this view, the system managed through decision-making is analyzed in the research work [13], where the authors introduce expert-opinion criteria to the methodology of managing system obsolescence applying multi-criteria decision-making, specifically the TOPSIS method and Monte Carlo simulations are suggested as a background for the article. The particular case study conducted in their research work was elaborated with a participation of military and civilian experts.

The article [14] refers to several methods of multi-criteria decision analysis in specific examples. Above all, an implementation of the approaches AHP, WSA and TOPSIS into the localization and allocation tasks in practice is outlined. The supplier quality assessment and requirements for a transport system user are discussed in the manuscripts [15, 16], in which the definition of fundamental approaches and guidelines in association with supplier quality assessment is highlighted [15]. The aim of the designed model is to fortify the efficiency of the supply chain management to better respond to newly generated situations regarding the collaboration among logistics companies.

In line with this context, what also constitutes an integral part is an acceptable imposition of requirements of transport system users – these aspects are discussed in the article [16]. The authors emphasize the matter of elementary features affecting the choice of transport mode by a transport infrastructure user. To this end, they propose to use the Saaty pairwise comparison method to calculate weights of significance of individual factors being defined. As far as logistics chains in intermodal transport are concerned, the literature [17] is focused on the ascertainment, analysis as well as classification of restrictive criteria occurred in intermodal transport in order to compare criteria degrees in a variety of scenarios of the logistics chain implementation.

3 Data and methods

The manuscript deals with process streamlining in the area of supply logistics in the selected enterprise. The project consists in choosing the optimal logistics partner. Here, we look for the optimal supplier cargo delivery of the specific company using TOPSIS and WSA methods. Both approaches choose the ideal variant by classifying assessed alternatives according to the proximity to the ideal variant, i.e. depending on decreasing values of the examined indicator [18].

The implementation of the WSA method comprises steps as follows [14, 19]:

A) The first step consists in defining the optimal and basal variant. Ideal alternative $H$ represents the maximal value of the specific indicator, whereas basal alternative $D$ presents the lowest rate for the particular criterion.
B) The next step comprises establishing normalized criteria matrix R by the formula 1:

$$r_{ij} = \frac{g_{ij} - d_j}{h_j - d_j}$$

(1)

Where: $r_{ij}$ – normalized values for $i$ alternative and $j$ criterion, $g_{ij}$ – matrix elements situated in $i^{th}$ line in $j^{th}$ column, $d_j$ – the lowest value in $j^{th}$ matrix column (values of the basal alternative), $h_j$ – the highest value in $j^{th}$ matrix column (values of the ideal alternative). Basal alternative denotes theoretically the worse alternative (artificially indicated) that could exist, it has the worse values determined from each criterion. Ideal alternative entails the opposite, as it has the best values in each criterion. If the ideal alternative indeed exists, it will be the top alternative. In descending order according to calculated values.

C) Third step encompasses calculating the utility function for individual alternatives uses the following formula 2:

$$u = \sum_{j=1}^{n} v_j \cdot r_{ij}$$

(2)

Where: $v_j$ – level of importance, $r_{ij}$ – normalized matrix elements situated in $i^{th}$ line and $j^{th}$ column.

D) The last step comprises resulting variants classified according to the following formula 3 as presented as follows:

$$r_{ij} = \frac{g_{ij}}{\sqrt{\sum_{i=1}^{m} g^2_{ij}}}$$

(3)

Where: $g_{ij}$ – matrix elements situated in $i^{th}$ line in $j^{th}$ column, $g_{ij}$ – all values of the respective column.

B) Calculating normalized weighted criteria matrix (see formula 4):

$$w_{ij} = r_{ij} \cdot v_j$$

(4)

Where: $r_{ij}$ – normalized matrix elements situated in $i^{th}$ line in $j^{th}$ column, $v_j$ – level of importance.

C) This step determines the optimal and basal variant with respect to matrix values W. The ideal variant is represented by letter H and the basal one by letter D. In other words, it specifies the ideal and negative-ideal solution. Let $H = (H_1, H_2, \ldots, H_n)$, where $H_j$ denotes the optimal value of any $a_j$ with respect to $C_i$. Let $D = (D_1, D_2, \ldots, D_n)$, where $D_j$ denotes the least optimal performance of any $a_j$ with respect to $C_i$. $H^+$ is the positive-ideal solution, while $D^-$ is the negative-ideal solution.

D) Determining the distance from the basal variant (see formula 5):

$$d_i^C = \sqrt{\sum_{j=1}^{r} (w_{ij} - D_j)^2}$$

(5)

Where: $d_i^C$ – distance from the basal variant, $w_{ij}$ – individual elements in $i$ matrix line, $D_j$ – the lowest values in $j$ matrix columns.

E) Determining the distance from the ideal variant (see formula 6):

$$d_i^C = \sqrt{\sum_{j=1}^{r} (w_{ij} - H_j)^2}$$

(6)

Where: $d_i^C$ – distance from the ideal variant, $w_{ij}$ – individual elements in $i$ matrix line, $H_j$ – the highest values in $j$ matrix columns.

F) This step determines the indicator of the relative distance from the basal variant $C_i$ according to the following formula 7:

$$c_i = \frac{d_i^C}{d_i^C + d_i^H}$$

(7)

Where: $c_i$ – indicator of the relative distance from the basal variant, $d_i^C$ – individual resulting distances from the basal variant, $d_i^H$ – individual resulting distance from the ideal variant.

G) The last step classifies the variants according to decreasing values.

First of all, it is necessary to determine a list of assessed options relating to suppliers [19]. This case involves following companies operating in the gastronomic industry in the territory of the enterprise being investigated:
These are wholesalers offering a wide range of food and non-food products, but especially supply and wholesale activities in the field of complex gastronomy. These companies offer transport of goods directly to restaurants and other facilities. They have built their own network of retail discount stores throughout the Czech Republic, and have launched the concept (logistics technology) of Cash & Carry stores. Hence, it can be stated that they provide their customers high-quality logistics and additional services associated with the process of modern supply and sale.

Thereafter, the crucial aspect is to identify attributes according to which the variants will be assessed [20]. For this study, the following factors were defined (if applicable, separate units are included) [21]:

- **C1** – Carriage charges (€/1 carriage),
- **C2** – Goods quality (-),
- **C3** – Delivery times (-),
- **C4** – Communication (-).

Table 1 summarizes all the input data – individual variants with specific criteria/factors and their respective values for the follow-up calculation (provided with the factor nature and levels of importance quantified according to expert’s opinions from the particular field of research). Maximizing criteria are assessed by scale 1-5 where 1 represents the worst possible result, whereas 5 refers to the best possible assessment.

<table>
<thead>
<tr>
<th>Variant</th>
<th>Carriage charges (€/1 import)</th>
<th>Goods quality (scale 1-5)</th>
<th>Delivery times (scale 1-5)</th>
<th>Communication (scale 1-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>150</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>JIP</td>
<td>250</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>200</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Exver Food</td>
<td>350</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Levels of importance</strong></td>
<td></td>
<td><strong>MIN</strong></td>
<td><strong>MAX</strong></td>
<td><strong>MAX</strong></td>
</tr>
<tr>
<td>Source: authors</td>
<td></td>
<td>0.11</td>
<td>0.54</td>
<td>0.28</td>
</tr>
</tbody>
</table>

A very important factor. All participants who evaluated individual criteria among each other agreed that the goods quality always comes first. Quality significantly affects the selection of the desired assortment.

- **C3** – this factor was chosen by restaurant owners mainly by the way in which the considered suppliers are able to respond quickly and promptly to changes in supply operations.
- **C4** – restaurant owners prefer a quick agreement in regard to ordering the goods, as well as the helpfulness of sales representatives of wholesale centers.

Levels of importance (i.e. vector of criteria weights) refer to criteria preference values and these were assigned to each factor by using the modified pairwise comparison method – Saaty method (see Table 3), which takes into account only 3 relevant values (1, 3 and 5).

In our case, quantifying the weights of criteria was conducted by the following procedure [14, 16]:

1. First, a relation between each criterion pair being assessed needs to be specified, in which a degree of importance is calculated within a point scope of 1–5. All input values in terms of criteria weights can be obtained by executing a survey; i.e. experts’ opinion examination in our case. Undoubtedly, specification of an adequate set of decision-making factors in relation to supply logistics is regarded highly delicate process, wherein a wide array of experts focused on particular topics of logistics are demanded to assign individual evaluation values. In order to secure as high objectivity as possible, ten experts dealing with topics encompassing supply chain management were demanded to assign importance values among each pair of factors. The following Table 2 describes the expert representatives who participated in a research of defining a set of factors as well as evaluating their weights.
Table 2: A list of experts cooperating within a process of determining the weights of criteria

<table>
<thead>
<tr>
<th>Name of the expert</th>
<th>Expertise</th>
<th>Date of evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD. Marin Marinov</td>
<td>Simulation modeling; transport and logistics; rail freight; freight logistics; urban freight</td>
<td>November 14, 2019</td>
</tr>
<tr>
<td>PhD. Petr Nachtigall</td>
<td>Road transport and forwarding; combined transport and logistics; integrated transport systems</td>
<td>November 25, 2019</td>
</tr>
<tr>
<td>Prof. Larisa M. Kapustina</td>
<td>Supply chain management; Operations Research in logistics; road and urban transport</td>
<td>November 27, 2019</td>
</tr>
<tr>
<td>Assoc. Prof. Stefano Ricci</td>
<td>Transport engineering; urban transport planning; supply logistics; transport management and scheduling</td>
<td>December 3, 2019</td>
</tr>
<tr>
<td>Assoc. Prof. Milos Hitka</td>
<td>Personal management in transport and logistics</td>
<td>January 12, 2020</td>
</tr>
<tr>
<td>Prof. Pawel Droździel</td>
<td>Automotive engineering; Operations Research in transport; public passenger transport</td>
<td>January 12, 2020</td>
</tr>
<tr>
<td>Assoc. Prof. Ádám Török</td>
<td>Sustainable transport development; urban planning; automotive engineering</td>
<td>February 1, 2020</td>
</tr>
<tr>
<td>Prof. Borna Abramović</td>
<td>Supply chain management; transport planning and management; transport engineering and logistics</td>
<td>February 9, 2020</td>
</tr>
<tr>
<td>prof. Gabriel Fedorko</td>
<td>Industrial logistics; structural analysis and dynamics; computational mechanics; simulation modeling</td>
<td>February 11, 2020</td>
</tr>
<tr>
<td>Prof. Jozef Gašparík</td>
<td>Rail transportation planning and modeling; traffic engineering; supply logistics; accident analysis</td>
<td>February 26, 2020</td>
</tr>
</tbody>
</table>

Source: authors

Table 3: Calculation of the vector of criteria weights by the modified Saaty method

<table>
<thead>
<tr>
<th>Criterion</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>Geometric mean</th>
<th>Vector of criteria weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>1/5</td>
<td>1/5</td>
<td>3</td>
<td>0.59</td>
<td>0.11</td>
</tr>
<tr>
<td>C2</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2.94</td>
<td>0.54</td>
</tr>
<tr>
<td>C3</td>
<td>5</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>1.49</td>
<td>0.28</td>
</tr>
<tr>
<td>C4</td>
<td>1/3</td>
<td>1/5</td>
<td>1/3</td>
<td>1</td>
<td>0.38</td>
<td>0.07</td>
</tr>
<tr>
<td>Sum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.4</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: authors

(2) As for the Saaty matrix, scoring of factors being evaluated by the experts were performed, and thereafter, arithmetic means out of all the partial matrix values were counted.

(3) Consequently, individual values of the Saaty matrix were implemented in a sequential quantification process; i.e. geometric mean determination, calculation of the final vector of criteria weights; see Table 3.

The whole quantification process along with all the necessary formulas related to the Saaty method are summarized, for example, in the literature [16].

Scoring of factors being evaluated by the experts was performed as follows:
1 – given factors are equally important,
3 – the first factor is slightly more important than the second one,
5 – the first factor is flagrantly more important than the second one.

4 Choosing the ideal variant of a supplier by the TOPSIS method

TOPSIS method minimizes distances from the ideal variant while maximizing spans from the basal alternative. The multi-criteria analysis allows the examined enterprise to pick the optimal variant from the suggested suppliers [22].

Table 4 demonstrates three maximizing and one minimizing criterion. The minimizing model, particularly carriage charges, must be converted to a maximizing principle by subtracting all column values from the largest number...
Table 4: Conversion of minimizing criteria to maximizing ones

<table>
<thead>
<tr>
<th>Variant</th>
<th>Carriage charges (€/1 import)</th>
<th>Goods quality (scale 1-5)</th>
<th>Delivery times (scale 1-5)</th>
<th>Communication (scale 1-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>200</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>JIP</td>
<td>100</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>150</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Exver Food</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Levels of importance</td>
<td>0.11</td>
<td>0.54</td>
<td>0.28</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: authors

Table 5: Normalized criteria matrix by the TOPSIS method

<table>
<thead>
<tr>
<th>Variant</th>
<th>Carriage charges</th>
<th>Goods quality</th>
<th>Delivery times</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>0.743</td>
<td>0.596</td>
<td>0.615</td>
<td>0.577</td>
</tr>
<tr>
<td>JIP</td>
<td>0.371</td>
<td>0.298</td>
<td>0.369</td>
<td>0.462</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>0.557</td>
<td>0.447</td>
<td>0.492</td>
<td>0.577</td>
</tr>
<tr>
<td>Exver Food</td>
<td>0</td>
<td>0.596</td>
<td>0.492</td>
<td>0.346</td>
</tr>
<tr>
<td>Levels of importance</td>
<td>0.11</td>
<td>0.54</td>
<td>0.28</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: authors

Table 6: Weighted normalized criteria matrix

<table>
<thead>
<tr>
<th>Variant</th>
<th>Carriage charges</th>
<th>Goods quality</th>
<th>Delivery times</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>0.082</td>
<td>0.322</td>
<td>0.172</td>
<td>0.040</td>
</tr>
<tr>
<td>JIP</td>
<td>0.041</td>
<td>0.161</td>
<td>0.103</td>
<td>0.032</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>0.061</td>
<td>0.241</td>
<td>0.138</td>
<td>0.040</td>
</tr>
<tr>
<td>Exver Food</td>
<td>0</td>
<td>0.322</td>
<td>0.138</td>
<td>0.024</td>
</tr>
<tr>
<td>Levels of importance</td>
<td>0.11</td>
<td>0.54</td>
<td>0.28</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: authors

in the respective line. The following Table 4 shows the conversion of minimizing criteria to maximizing ones [23, 24].

The next step comprises creating a normalized criteria matrix using formula 3 (see Table 5).

The table suggested above depicts the resulting normalized criteria matrix. The next step encompasses structuring a weighted normalized criteria matrix [25]. The weighted normalized criteria matrix entails the normalized matrix multiplied by individual criteria using formula 4 (see Table 6 below) [26].

Next, we determine ideal $H$ (the variant highest values according to specific criteria) and basal $D$ alternatives (the variant lowest values according to specific criteria):

$H = \{0.082; 0.322; 0.172; 0.040\}$

$D = \{0; 0.161; 0.103; 0.024\}$

The next step involves determining the distance from the ideal variant through formula 5.

$$d_i^+ = \sqrt{A} = 0$$

where:

$$A = (0.082 - 0.082)^2 + (0.322 - 0.322)^2 + (0.172 - 0.172)^2 + (0.040 - 0.040)^2$$

$$d_i^- = \sqrt{B} = 0.180$$

where:

$$B = (0.041 - 0.082)^2 + (0.161 - 0.322)^2 + (0.103 - 0.172)^2 + (0.032 - 0.040)^2$$

$$d_i^0 = \sqrt{C} = 0.090$$
where:

\[
C = (0.061 - 0.082)^2 + (0.241 - 0.322)^2 \\
+ (0.138 - 0.172)^2 + (0.040 - 0.040)^2
\]

\[d_i^c = \sqrt{C} = 0.090\]

where:

\[
D = (0 - 0.082)^2 + (0, 322 - 0.322)^2 \\
+ (0.138 - 0.172)^2 + (0.024 - 0.040)^2
\]

Subsequently, formula 6 determines the distance from the basal variant.

\[d_i^f = \sqrt{D} = 0.090\]

where:

\[
A = (0.082 - 0)^2 + (0.322 - 0.161)^2 \\
+ (0.172 - 0.103)^2 + (0.040 - 0.024)^2
\]

\[d_i^2 = \sqrt{A} = 0.194\]

where:

\[
B = (0.041 - 0)^2 + (0.161 - 0.161)^2 \\
+ (0.103 - 0.0103)^2 + (0.032 - 0.024)^2
\]

\[d_i^3 = \sqrt{B} = 0.042\]

where:

\[
C = (0.061 - 0)^2 + (0.241 - 0.161)^2 \\
+ (0.138 - 0.103)^2 + (0.040 - 0.024)^2
\]

\[d_i^4 = \sqrt{C} = 0.108\]

where:

\[
D = (0 - 0)^2 + (0.322 - 0.161)^2 \\
+ (0.138 - 0.103)^2 + (0.024 - 0.024)^2
\]

The next step resolves indicators of relative distance from the basal variant according to formula 7.

\[c_1 = \frac{0.194}{0 + 0.194} = 1\]

\[c_2 = \frac{0.042}{0.180 + 0.042} = 0.189\]

\[c_3 = \frac{0.108}{0.090 + 0.108} = 0.546\]

\[c_4 = \frac{0.165}{0.090 + 0.165} = 0.647\]

The following Table 7 summarizes the findings in relation to the final variant order specification [27]. The first place is held by Makro Cash & Carry wholesale store.

The above-mentioned table shows that according to the resulting values, the first place is occupied by Makro Cash & Carry wholesale store. The next places (2nd – 4th), in descending order, are held by suppliers as follows: Exver Food, Astur & Qanto and JIP.

Table 7: The resulting variant order

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>1</td>
</tr>
<tr>
<td>Exver Food</td>
<td>0.647</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>0.546</td>
</tr>
<tr>
<td>JIP</td>
<td>0.189</td>
</tr>
</tbody>
</table>

Source: authors

5 Choosing the ideal variant of a supplier by the WSA method

The multi-criteria analysis provides for the enterprise being examined the optimal variant from the suggested suppliers. Firstly, a maximizing matrix must be determined (see Table 4). The next step embraces setting values of ideal (H) and basal (D) variant, which must be considered in the following step [28].

\[H = \{200; 4; 5; 5\}\]

\[D = \{0; 2; 3; 3\}\]

Separate steps are calculated through the normalized matrix and provided by the formula 1 [29]. Table 8 suggests results of the normalized criteria matrix.

The subsequent step involves quantifying the utility function for individual variants according to formula 2.

\[u_1 = 0.11 * 1 + 0.54 * 1 + 0.28 * 1 + 0.07 * 1 = 1\]

\[u_2 = 0.11 * 0.5 + 0.54 * 0 + 0.28 * 0 + 0.07 * 0.5 = 0.09\]

\[u_3 = 0.11 * 0.75 + 0.54 * 0.5 + 0.28 * 0.5 + 0.07 * 1 = 0.56\]

Streamlining possibility of transport-supply logistics
Table 8: Normalized criteria matrix by the WSA method

<table>
<thead>
<tr>
<th>Variant</th>
<th>Carriage charges</th>
<th>Goods quality</th>
<th>Delivery times</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>JIP</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>0.75</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Exver Food</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Levels of importance</td>
<td>0.11</td>
<td>0.54</td>
<td>0.28</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Source: authors

\[ u_a = 0.11 \times 0 + 0.54 \times 1 + 0.28 \times 0.5 + 0.07 \times 0 = 0.68 \]

The last step encompasses the classification of resulting variants in descending order according to the very quantification (see Table 9).

Table 9 illustrates the findings containing individual utility function values sorted in the descending order [30]. Analogously to the TOPSIS method, the highest value is allocated to Makro Cash & Carry even according to the WSA method.

Table 9: Resulting variant order

<table>
<thead>
<tr>
<th>Variant</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makro</td>
<td>1</td>
</tr>
<tr>
<td>Exver Food</td>
<td>0.68</td>
</tr>
<tr>
<td>Astur &amp; Qanto</td>
<td>0.56</td>
</tr>
<tr>
<td>JIP</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Source: authors

6 Evaluation of findings

The application of the Operations Research methods allowed adopting effective measures contributing to effectively model the transport-supply process of the enterprise being investigated. In particular, four scenarios to efficiently supply the enterprise were designed. The variants were represented by suppliers who may positively influence the whole enterprise transport-supply system. To choose the ideal scenario, fresh approaches of the Operations Research (TOPSIS and WSA) were adopted, showing that Makro Cash & Carry Company appears to be the ideal option for the enterprise supplier, followed by the wholesalers Exver Food and Astur & Qanto, and the worst result was assigned to JIP.

The owner of the examined company has had long experience of buying goods in the above-mentioned wholesale store. This way of transport-supply process appears to be the optimal approach with respect to the quality, price and transport costs. The new way of transport-supply operation ensures goods delivery in the prescribed amount, for the required price and just-in-time. The designated wholesale store keeps customers satisfied, having favorable feedback from its subscribers.

The enterprise is currently supplied in-house each separate weekday; i.e. a new supplier would sufficiently supply the goods twice a week.

7 Conclusion

On the basis of the elaborated literature review, executed calculations, obtaining the final results, and following the evaluation of individual scenarios by using the specific Operations Research techniques, wholesaler 1 (i.e. Makro Cash & Carry Company) is recommended to be the optimal supplier for the implementation of the transport-supply process that will enhance the effectiveness of specific logistics activities in the operation being examined.

Based on the existing criteria set, variant 1 achieved the best possible results by both methods, especially due to the fact that it demonstrated a strong relationship with high-weight-value factor C2 (goods quality) as well as C3 (delivery times). Of course, the recommended wholesaler can differ depending on the kind and range of defined factors, as well as the Operations Research technique implemented in each step of the process of multi-criteria evaluation. The research findings entail valuable data for optimizing specific activities of suppliers, not only those who were compared in this particular study, but such outcomes may even represent the very principle for ranking suppliers’ priorities in order to provide optimal conditions and quality of supply logistics.

The crucial objective of this research study was to compare two Operations Research techniques in order to select the optimal wholesaler to ensure the complex transport-supply process. For this purpose, four enterprises provid-
As TOPSIS, the wholesaler 1 is regarded the most appropriate variant based on the specified set of factors. It also can be concluded that no similar publication has been published yet by implementing analogous Operations Research techniques, same set of factors, nor dealing with the similar topic when determining identical publication objective. Our scientific work adds value to knowledge of the proper functioning of supply chains in the Czech Republic and points out the importance to define corresponding criteria. And just this fact represents an aspect in which the novelty and innovative solution of this work lies.

The subject of further research may consist in an extension of the criteria set being compared or an extension of individual criteria by sub-criteria.

Acknowledgement: This manuscript was supported within solving the research project entitled "Autonomous mobility in the context of regional development LTC19009" of the INTER-EXCELLENCE program, the VES 19 INTER-COST subprogram.

Manuscript is also the result of the project VEGA No. 1/0128/20: Research on the Economic Efficiency of Variant Transport Modes in the Car Transport in the Slovak Republic with emphasis on sustainability and environmental impact, Faculty of Operation and Economics of Transport and Communications: University of Žilina, 2020-2022.

References


