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COMPARATIVE ANALYSIS OF TRANSPORT AND STORAGE INFORMATION SYSTEMS OF THE EUROPEAN UNION AND SERBIA USING FUZZY LMAW AND MARCOS METHODS

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Abstract

Information and communication technology is one of the critical factors for the business success of modern transport and storage. Therefore, it is important to research the transport and storage information system from different aspects. In this paper, starting from that, a comparative analysis of the selection and ranking of the information system of transport and storage in the European Union and Serbia is carried out based on the FLMAW - MARCOS method. The obtained empirical results show that the top five countries according to the information system of transport and storage include: Malta, the Netherlands, Lithuania, Spain, and Slovenia. Germany ranked thirteenth, France sixteenth, and Italy eighteenth. Bulgaria (in twenty-fifth place) and Romania (in twenty-sixth place) are in an unenviable position. In the last (twenty-eighth) place is Belgium. Serbia is in twenty-second place and is in a worse position compared to the countries in the region (Slovenia - fifth place and Croatia - fifteenth place). In order to improve the information system in the future, a greater application of information and communication technology in transport and storage is necessary, especially in countries ranked at a lower level. The effects of this are to improve the overall transport and storage performance.

Keywords: *Information system, transport, and storage, European Union, Serbia, FLMAW - MARCOS method*

JEL codes: *D22, L81, M31, M41, P25, O32*

Introduction

The analysis of the information system is very current, challenging, and significant considering that information and communication technology is one of the critical factors of business success in modern transport and storage (Kazakov et al., 2021; Jorgensen et al., 2022). Based on that, the research subject in this paper is a comparative analysis of the transport and storage information system of the European Union and Serbia based on the FLMAW - MARCOS method. Its goal and purpose are to look at the existing situation as realistically as possible in order to improve the information system of transport and storage in the future by improving information and communication technology (Kine et al., 2022; Fazlollahtabar et al., 2019; Setiawan et al., 2022).

Recently, as is known, the problem of researching the effects of the application of information and communication technology on the performance of all entities is becoming more and more challenging (Cano et al., 2021; Chatti, 2021). This means both transport and storage. Considering that, there is an increasingly rich literature devoted to the analysis of the effects of information and communication technology on the overall performance and efficiency of modern transport and storage (Argilés-Bosch et al., 2022; Gu, 2021; Liu, 2022; Lukic et.al., 2016). It is completely and understandable when taking into account the fact that empirical analysis has established that information and communication technology significantly contributes to the improvement of the overall performance and efficiency of transportation and storage (Alam et al., 2022; Jinghui, D. andLiu, Y. ,2022; Chinoracky et al., 2021). This is especially visible in the conditions of the Covid-19 corona virus pandemic (Klein et al., 2022). All relevant literature in this paper serves as a theoretical, methodological, and empirical basis for researching the problem treated in this paper (Lukic $ Hadrović-Zelkic, 2021; Lukic, 2022; Rehman, 2022; Tolstoy, 2022).

The main research hypothesis in this paper is based on the fact that information and communication technology is one of the critical factors of business success in modern transport and storage. Considering that, it is necessary to look at the transport and storage position of each country as realistically as possible regarding the development of information and communication technology in order to improve it in the future. The effects of this are to improve the overall performance of transport and storage (Cano et al., 2021; Chatti, 2021).

In the methodological sense of the word, multi-criteria decision-making methods, including the FLMAW - MARCOS method, play a significant role in this. In addition to the FLMAW-MARCOS method, other multi-criteria decision-making methods can be used to solve the problem treated in this paper. The advantage of the FLMAW-MARCOS target is that it is more suitable for a realistic uncertain environment. The weakness, as with other methods of multi-criteria decision-making, lies in the subjectivity of determining the weighting coefficients of the criteria.

In relation to existing studies, this paper identifies and ranks transport and storage in the countries of the European Union and Serbia according to the development of the information system in order to improve it in the future. Because information and communication technology significantly contributes to the improvement of the functioning of transport and storage and the quality of the provided transport services (Cano et al., 2021; Chinoracky et al., 2021; Lukic and Hadrovic Zekic, 2021; Kine et al., 2022). Relevant indicators of the information society were collected from Eurostat for the purposes of comparative analysis of the information system of transport and storage of the European Union and Serbia.

The problem considered in this paper is the identification and ranking of transport and storage in the member states of the European Union and Serbia according to the development of the information system. It is very successfully solved with the application of FLMAW-MARCOS methods. In further presentations of the treated problem, we will point out their basic characteristics.

FUZZY LMAW Method

The logarithmic methodology of additive weights is used to determine weight coefficients and rank alternatives (Demir, 2022; Pamučar et al., 2021). Fuzzy Logarithm Methodology of Additive Weights (FLMAW) is based on the application of triangular fuzzy numbers (Božanić et al., 2022; Puška 2022). The FLMAW method takes place through six steps (Božanić et al., 2022).

Step 1. Formation of the initial (expert) decision-making matrix $(\tilde{X}^e)$.

In this step, each expert (e) from the group of k experts $(1 \leq e \leq k)$ defines a decision matrix by evaluating m alternatives $A = \{A_1, A_2, ..., A_m\}$in relation to n criteria $C = \{C_1, C_2, ..., C_n\}$. Therefore, for each expert, a matrix was obtained $\tilde{X}^e = \left[\tilde{\vartheta}_{ij}^e\right]_{mxn}$, where it $\tilde{\vartheta}_{ij}^e$represents a fuzzy value based on the expert value of the i - *th* alternative in relation to the j -th criterion. The evaluation is based on quantitative indicators or fuzzy linguistic descriptors, depending on the type of criteria.

Step 2. Formation of the initial (aggregate) decision-making matrix $(\tilde{X})$.

Aggregation of the initial (expert) matrices into one aggregated matrix is performed using the Bonferroni aggregator as follows:

$$\tilde{\vartheta}_{ij} = \left(\frac{1}{k(k-1)}\right) \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \tilde{\vartheta}_i^{(e)p} \, \tilde{\vartheta}_j^{(e)q}$$

$$= \left\{ \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(l_e)p} \, \vartheta_j^{(l_e)q} \right)^{\frac{1}{p+q}}, \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(m_e)p} \, \vartheta_j^{(m_e)q} \right)^{\frac{1}{p+q}}, \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(r_e)p} \, \vartheta_j^{(r_e)q} \right)^{\frac{1}{p+q}} \right\} \quad (1)$$

where $\check{\vartheta}_{ij}$represents the aggregated value obtained by applying the Bonferroni aggregator; $p, q \geq 0$stabilization parameters of the Bonferroni aggregator, e e -th expert $1 \leq e \leq k$, l – left distribution of fuzzy number, r – right distribution of fuzzy number, and m – value at which the membership function of the fuzzy number is equal to one. Linguistic criteria are quantified before aggregation.

Step 3. Normalization of elements of the initial matrix.

Normalized matrix $\sim = \left[\tilde{\vartheta}_{ij}\right]_{mxn}$is obtained as follows:

$$\tilde{\vartheta}_{ij} = \begin{cases} 1 + \dfrac{\widetilde{\vartheta_{ij}}}{\widetilde{\vartheta_j^{(+)}}} = \left(1 + \dfrac{\vartheta_{ij}^{(l)}}{\vartheta_j^{(+)}}, 1 + \dfrac{\vartheta_{ij}^{(m)}}{\vartheta_j^{(+)}}, 1 + \dfrac{\vartheta_{ij}^{(r)}}{\vartheta_j^{(+)}}\right) if \in B, \\ 1 + \dfrac{\tilde{\vartheta}_j^-}{\widetilde{\vartheta_{ij}}} = \left(1 + \dfrac{\vartheta_j^-}{\vartheta_{ij}^{(r)}}, 1 + \dfrac{\vartheta_j^-}{\vartheta_{ij}^{(m)}}, 1 + \dfrac{\vartheta_j^-}{\vartheta_{ij}^{(l)}}\right) \quad if \in C \end{cases} \quad (2)$$

where $\tilde{\vartheta}_{ij}$represents the normalized value of the initial decision matrix, where $\vartheta_j^+ = max\left(\tilde{\vartheta}_j^{(r)}\right)$, i $\vartheta_j^- = min\left(\vartheta_j^{(l)}\right)$, *l is the* left distribution of the fuzzy number, *r is* the right distribution of the fuzzy number, and *m* is the value at which the membership function of the fuzzy number is equal to one.

Step 4. Determining the weighting coefficients of the criteria.

In order to determine the weighting coefficients of the criteria, certain experts should be engaged$E = \{E1, E2, ..., Ek\}$.

Step 4.1. Prioritization of criteria.

Based on the value of the predefined fuzzy linguistic scale, the experts determine the priorities of the criteria $C = \{C1, C2, \ldots, Cn\}$.. In that criterion of high importance, a higher value from the fuzzy linguistic scale is assigned, and vice versa. In this way, the priority vectors are defined $\tilde{P}^e = (\tilde{\gamma}_{C1}^e, \tilde{\gamma}_{C2}^e, \ldots, \tilde{\gamma}_{Cn}^e)$, especially for each expert, where it $\tilde{\gamma}_{Cn}^e$ represents the value from the fuzzy linguistic scale that the expert e $(1 \le e \le k)$mark for criterion n .

Step 4.2. Defining the absolute fuzzy anti-ideal point $(\tilde{\gamma}AIP)$.
This value is defined by the decision maker, and is a fuzzy number that is smaller than the smallest value from the set of all priority vectors.

Step 4.3. Defining the fuzzy relational vector $\tilde{R}^e$.
The relationship between the elements of the priority vector and the absolute anti-ideal point $(\gamma AIP)$is determined by applying the following equation:

$$\tilde{n}_{Cn}^e = \left(\frac{\tilde{\gamma}_{Cn}^e}{\tilde{\gamma}_{AIP}}\right) = \left(\frac{\gamma_{Cn}^{(l)e}}{\gamma_{AIP}^{(r)}}, \frac{\gamma_{Cn}^{(m)e}}{\gamma_{AIp}^{(m)}}, \frac{\gamma_{Cn}^{(r)\,e}}{\gamma_{AIP}^{(l)}}\right) \quad (3)$$

By applying this equation, the expert's relational vector $e(1 \le e \le k)$is obtained: $R^e = (\tilde{n}_{C1}^e, \tilde{n}_{C2}^e, \ldots, \tilde{n}_{Cn}^e)$.

Step 4.4. Determining vector weight coefficients $\omega_j^e = (\widetilde{\omega}_1^e, \widetilde{\omega}_2^e, \ldots, \widetilde{\omega}_n^e)^T$, especially for each expert. Fuzzy value of weighting coefficients criteria for e $(1 \le e \le k)$is obtained by applying the following equation:

$$\widetilde{\omega}_j^e = \left(\frac{ln(\tilde{n}_{Cn}^e)}{ln\left(\prod_{j=1}^n \tilde{n}_{Cn}^e\right)}\right) = \left(\frac{ln\left(n_{Cn}^{(l)e}\right)}{ln\left(\prod_{j=1}^n n_{Cn}^{(r)e}\right)}, \frac{ln\left(n_{Cn}^{(m)e}\right)}{ln\left(\prod_{j=1}^n n_{Cn}^{(m)e}\right)}, \frac{ln\left(n_{Cn}^{(r)e}\right)}{ln\left(\prod_{j=1}^n n_{Cn}^{(l)e}\right)}\right) \quad (4)$$

where $\tilde{n}_{Cn}^e$represents the element of the relational vector R^e, the $n_{Cn}^{(l)e}$left distribution of the fuzzy priority vector, the $n_{Cn}^{(r)e}$right distribution of the fuzzy priority vector, and $n_{Cn}^{(m)e}m$the value at which the membership function of the fuzzy priority vector is equal to one.

Step 4.5. Calculation of weight coefficients of aggregated fuzzy vectors $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \ldots, \widetilde{\omega}_n)^T$.
Weight coefficients of the aggregated fuzzy vectors $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \ldots, \widetilde{\omega}_n)^T$are determined using the Boneferroni aggregator (Yager, 2009) as follows:

$$\widetilde{\omega}_j = \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \ne j}}^{k} \widetilde{\omega}_i^{(e)p} \widetilde{\omega}_j^{(e)q}\right)^{\frac{1}{p+q}}$$

$$= \left\{\left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \ne j}}^{k} \widetilde{\omega}_i^{(l_e)p} \widetilde{\omega}_j^{(l_e)q}\right)^{\frac{1}{p+q}}, \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \ne j}}^{k} \widetilde{\omega}_i^{(m_e)p} \widetilde{\omega}_j^{(m_e)q}\right)^{\frac{1}{p+q}}, \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \ne j}}^{k} \widetilde{\omega}_i^{(r_e)p} \widetilde{\omega}_j^{(r_e)q}\right)^{\frac{1}{p+q}}\right\} \quad (5)$$

where it $p, q \ge 0$represents the stabilization parameters of the Bonoferroni aggregator, the weighting $\widetilde{\omega}_j^e$coefficients obtained on the basis of the evaluation of the e -th expert $1 \le e \le k$, the $\omega_j^{(l_e)}$left distribution of fuzzy weighting coefficients $\widetilde{\omega}_j^e$, $\omega_j^{(r_e)}$the right distribution of fuzzy weighting coefficients $\widetilde{\omega}_j^e$, and $\omega_j^{(m_e)}$the right value at which the fuzzy weighting coefficient function is $\widetilde{\omega}_j^e$equal to one.

Step 4.6. Calculation of final values of weighting coefficients $\omega_j = (\omega_1, \omega_2, \ldots, \omega_3)^T$.

The calculation of the final value of the weight coefficients of the criteria is performed by defuzzification as follows:

$$\omega_j = \frac{l + 4m + r}{6} \qquad (6)$$

Step 5. Calculation of the weight matrix (*N*).

The elements of the weight matrix $N = [\tilde{\xi}_{ij}]_{mxn}$ were obtained as follows:

$$\tilde{\xi}_{ij} = \frac{2\tilde{\varphi}_{ij}^{\omega_j}}{(2-\tilde{\varphi}_{ij})^{w_j} + \tilde{\varphi}_{ij}^{\omega_j}} = \left(\frac{2\varphi_j^{(l)^{\omega_j}}}{\left(2-\varphi_j^{(r)}\right)^{\omega_j} + \phi_j^{(r)^{\omega_j}}}, \frac{2\varphi_j^{(m)^{\omega_j}}}{\left(2-\varphi_j^{(m)}\right)^{\omega_j} + \phi_j^{(m)^{\omega_j}}}, \frac{2\varphi_j^{(r)^{\omega_j}}}{\left(2-\varphi_j^{(l)}\right)^{\omega_j} + \phi_j^{(l)^{\omega_j}}} \right) \quad (7)$$

wherein

$$\tilde{\varphi}_{ij} = \frac{ln(\tilde{\vartheta}_{ij}^{'})}{ln(\prod_{i=1}^{m}\tilde{\vartheta}_{ij}^{'})} = \left(\frac{ln\left(\vartheta_{ij}^{'(l)}\right)}{ln\left(\prod_{i=1}^{m}\vartheta_{ij}^{'(r)}\right)}, \frac{ln\left(\vartheta_{ij}^{'(m)}\right)}{ln\left(\prod_{i=1}^{m}\vartheta_{ij}^{'(m)}\right)}, \frac{ln\left(\vartheta_{ij}^{'(r)}\right)}{ln\left(\prod_{i=1}^{m}\vartheta_{ij}^{'(l)}\right)} \right) \quad (8)$$

where it $\tilde{\vartheta}_j^{'}$represents the elements of the normalized matrix ~ = $[\vartheta_{ij}]_{mxn}$, the $\omega_j$weight elements of the criteria, *l* – the left distribution of the fuzzy number, *r* – the right distribution of the fuzzy number, and *m* is the value at which the membership function of the fuzzy number is equal to one.

Step 6 . Calculation of the final ranking index of alternatives (Q_i).

The final ranking of the alternatives is defined based on value Q_i, whereby the alternative with a higher value is ranked better Q_i. The value Q_i was obtained with the defuzzification of the value $\tilde{Q}_i$using equation (6). The value $\tilde{Q}_i$is calculated using the following equation:

$$\tilde{Q}_i = \sum_{j=1}^{n}\tilde{\xi}_{ij} = \left(\sum_{j=1}^{n}\xi_{ij}^{(l)}, \sum_{j=1}^{n}\xi_{ij}^{(m)}, \sum_{j=1}^{n}\xi_{ij}^{(r)}\right) \quad (9)$$

where $\tilde{\xi}_{ij}$represents the elements of the weight matrix $\tilde{N} = [\tilde{\xi}_{ij}]_{mxn}$, *l* – the left distribution of the fuzzy number, *r* – the right distribution of the fuzzy number, and *m* is the value at which the value of belonging to the fuzzy number is equal to one.

MARCOS Method

The MARCOS (Measurement of Alternatives and Ranking according to the Compromise Solution) method is based on defining the relationship between alternatives and reference values (ideal and anti-ideal alternatives). Based on the defined relationships, the utility functions of the alternatives are determined, and a compromise ranking is made in relation to ideal and anti-ideal solutions. Decision preferences are defined based on a utility function. Utility functions represent the position of alternatives in relation to ideal and anti-ideal solutions. The best alternative is the one that is closest to the ideal and at the same time furthest from the anti-deal reference point. The MARCOS method proceeds procedurally through the following steps (Stević, 2020a, b):

Step 1: Formation of the initial decision-making matrix.

A multi-criteria model involves defining a set of *n* criteria and *m* alternatives. In the case of group decision-making, a set of *r* experts is formed who evaluate the alternatives in relation to the criteria. In that case, the expert evaluation matrices are aggregated into the initial group decision matrices.

Step 2: Forming the expanded initial matrix.

In this step, the expansion initial matrix is defined with ideal (*AI*) and anti-ideal (*AAI*) solutions.

$$X = \begin{matrix} AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ AI \end{matrix} \overset{\begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix}}{\begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix}} \quad (10)$$

Anti-ideal solution (*AAI*) is the worst alternative. The ideal solution (*AI*) is, on the contrary, the alternative with the best characteristics. Depending on the nature of the criteria, *AAI* and *AI* are defined by applying the following equations:

$$AAI = \min_i x_{ij} \ \ if \ j \in B \ and \ \max_i x_{ij} \ \ if \ j \in C \qquad (11)$$

$$AI = \max_i x_{ij} \ \ if \ j \in B \ and \ \min_i x_{ij} \ \ if \ j \in C \qquad (12)$$

where *B* represents a benefit and *C a* cost group of criteria.

Step 3: Normalization of the expanded initial matrix (*X*).

The elements of the normalized matrix $N = [n_{ij}]_{mxn}$ are obtained by applying the following equations:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \ if \ j \in C \qquad (13)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \ if \ j \in B \qquad (14)$$

where the elements x_{ij} and x_{ai} represent the elements of the matrix *X*.

Step 4: Defining the weight matrix $V = [v_{ij}]_{mxn}$.

The weighting matrix *V* is obtained by multiplying the normalized matrix *N* with the weighting coefficients of the criterion w_j using the following equation:

$$v_{ij} = n_{ij} x v_j \qquad (15)$$

Step 5: Determining the degree of utility of alternatives K_i .

The degree of usefulness of alternatives in relation to anti-ideal and ideal solutions is determined using the following equations:

$$K_i^- = \frac{S_i}{S_{aai}} \qquad (16)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \qquad (17)$$

where S_i (*i=1,2,..,m*) represents the sum of the elements of the weight matrix *V* , shown in the following equation:

$$S_i = \sum_{i=1}^{n} v_{ij} \qquad (18)$$

Step 6: Determining the utility function of alternatives *f(K ᵢ)* .

The utility function is the compromise of the observed alternative in relation to ideal and anti-ideal solutions. The utility function of alternatives is defined by the following equation:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}}; \qquad (19)$$

where $f(K_i^-)$represents the utility function in relation to the anti-ideal solution and $f(K_i^+)$represents the utility function in relation to the ideal solution.
Utility functions in relation to ideal and anti-ideal solutions are determined using the following equations:

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \qquad (20)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \qquad (21)$$

Step 7: Ranking of alternatives. The ranking of alternatives is based on the final value of the utility function.

The alternative that has the highest possible value of the utility function is preferred.

Results and discussion

Numerous indicators of the information society have been developed. The most important indicators of the information society were used as criteria for the research of the treated problem in this work by applying the given methodology. They are particularly highlighted in Eurostat statistics. Because they are a good measure of the development of the information system. Alternatives are some member states of the European Union and Serbia. They, as well as the relevant initial data, are shown in Table 1 for 2021.

Table 1: Transportation and storage (10 or more employees and self-employed persons)

		Enterprises with e-commerce sales; Percentage of enterprises	Enterprises with a website; Percentage of enterprises	Enterprises who have an ERP software package to share information between different functional areas; Percentage of enterprises	Enterprises using software solutions like Customer Relationship Management (CRM); Percentage of enterprises	Enterprises use at least one of the AI technologies: AI_TTM, AI_TSR, AI_TNLG, AI_TIR, AI_TML, AI_TPA, AI_TAR; Percentage of enterprises
		C1	**C2**	**C3**	**C4**	**C5**
A1	Belgium	25	0	0	0	6
A2	Bulgaria	5	41	16	16	2
A3	Czech Republic	14	67	22	9	3
A4	Denmark	36	0	35	29	21
A5	Germany	11	73	23	30	6
A6	Estonia	15	0	15	17	2
A7	Ireland	34	77	17	23	5

A8	Greece	12	61	54	27	2
A9	Spain	23	65	48	35	9
A10	France	11	55	42	23	4
A11	Croatia	44	0	21	16	8
A12	Italy	10	62	20	18	3
A13	Cyprus	7	79	37	37	7
A14	Latvia	6	49	40	17	3
A15	Lithuania	44	65	44	29	4
A16	Luxembourg	16	65	33	34	10
A17	Hungary	19	49	14	9	3
A18	Malta	37	90	42	39	15
A19	Netherlands	26	87	33	36	11
A20	Austria	31	77	31	24	7
A21	Poland	9	56	24	25	2
A22	Portugal	18	0	0	26	15
A23	Romania	8	42	12	12	0
A24	Slovenia	51	68	22	12	13
A25	Slovakia	9	67	23	11	6
A26	Finland	19	87	29	19	6
A27	Sweden	29	74	22	16	4
A28	Serbia	19	58	16	11	1
	Statistics					
	Mean	21.0000	54.0714	26.2500	21.4286	6.3571
	Std. Error of Mean	2.43541	5.38122	2.53475	1.88241	.93607
	Median	18.5000	63.5000	23.0000	21.0000	5.5000
	Std. Deviation	12.88697	28.47472	13.41261	9.96077	4.95322
	Skewness	.784	-1.055	.072	.012	1,300
	Std. Error of Skewness	.441	.441	.441	.441	.441
	Kurtosis	-.346	.026	-.275	-.670	1.576
	Std. Error of Kurtosis	.858	.858	.858	.858	.858
	The minimum	5.00	.00	.00	.00	.00
	Maximum	51.00	90.00	54.00	39.00	21.00

Note: Author's calculation of statistics

Source: Eurostat

The weight coefficients of the criteria were determined using the FLMAW method. In Table 2, for these purposes, the fuzzy scale of prioritization of criteria is presented.

Table 2: Fuzzy criteria prioritization scale

Fuzzy scale for criteria prioritization				
Fuzzy Linguistic Descriptor	**Abbreviation**	**Fuzzy Number**		
Absolutely Low	**AL**	1	1	1
Very Low	**VL**	1	1.5	2
Low	**L**	1.5	2	2.5
Medium Low	**ML**	2	2.5	3
Equal	**E**	2.5	3	3.5
Medium High	**MH**	3	3.5	4
High	**H**	3.5	4	4.5

Very High	**VH**	4	4.5	5
Absolutely High	**AH**	4.5	5	5

Table 3 shows the evaluation by experts of the criteria.

Table 3: Evaluation of criteria

KIND	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**
P1	**AH**	**L**	**VL**	**E**	**VL**
P2	**AH**	**ML**	**AL**	**H**	**AL**
P3	**AH**	**ML**	**AL**	**MH**	**VL**
P4	**AH**	**E**	**AL**	**VH**	**AL**

YAIP	0.5	0.5	0.5

	C1			**C2**			**C3**			**C4**			**C5**		
P1	9	10	10	3	4	5	2	3	4	5	6	7	2	3	4
P2	9	10	10	4	5	6	2	2	2	7	8	9	2	2	2
P3	9	10	10	4	5	6	2	2	2	6	7	8	2	3	4
P4	9	10	10	5	6	7	2	2	2	8	9	10	2	2	2

Note: Author's calculation

Table 4 shows the vector weight coefficients.

Table 4: Weight Coefficients Vector

Weight Coefficients Vector	**C1**			**C2**			**C3**			**C4**			**C5**		
W1j	0.255	0.300	0.366	0.127	0.181	0.256	0.080	0.143	0.220	0.186	0.233	0.309	0.080	0.143	0.220
W2j	0.286	0.312	0.333	0.181	0.218	0.259	0.090	0.094	0.100	0.253	0.282	0.318	0.090	0.094	0.100
W3j	0.266	0.301	0.341	0.168	0.210	0.265	0.084	0.091	0.103	0.217	0.254	0.308	0.084	0.144	0.205
W4j	0.277	0.300	0.317	0.203	0.233	0.268	0.087	0.090	0.095	0.262	0.286	0.317	0.087	0.090	0.095

Note: Author's calculation

Table 5 shows the aggregated fuzzy vector, the aggregated fuzzy weighting coefficients of the vector and the final value of the weighting coefficients.

Table 5: Aggregated fuzzy vector, aggregated fuzzy vector weight coefficients and final value of weight coefficients.

Aggregated Fuzzy Vectors	**C1**			**C2**			**C3**			**C4**			**C5**		
W1j	0.018	0.023	0.030	0.006	0.010	0.017	0.002	0.003	0.005	0.011	0.016	0.024	0.002	0.004	0.007

W2j	0.019	0.023	0.028	0.007	0.011	0.017	0.002	0.003	0.003	0.014	0.018	0.025	0.002	0.003	0.004
W3j	0.018	0.023	0.029	0.007	0.011	0.017	0.002	0.002	0.004	0.013	0.017	0.024	0.002	0.004	0.007
W4j	0.019	0.023	0.027	0.008	0.012	0.017	0.002	0.002	0.003	0.014	0.018	0.025	0.002	0.003	0.004
SUM	0.073	0.092	0.115	0.029	0.044	0.069	0.007	0.011	0.016	0.052	0.070	0.098	0.007	0.014	0.023
Aggregated Fuzzy Weight Coefficient Vectors	0.271	0.303	0.339	0.169	0.210	0.262	0.085	0.104	0.126	0.229	0.264	0.313	0.085	0.117	0.152
Final Values Of The Weight Coefficients	**0.304**			**0.212**			**0.104**			**0.266**			**0.117**		

Note: Author's calculation

Judging by the obtained weight coefficients of the criteria, the most important criterion is Enterprises with e-commerce sales. This means, in other words, that with the increase of Enterprises with e-commerce sales, the improvement of the information system of transport and storage in the countries of the European Union and Serbia can be significantly influenced.

Table 6 shows the initial matrix.

Table 6: Initial Matrix

Initial Matrix					
weights of criteria	0.304	0.212	0.104	0.266	0.117
kind of criteria	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**
A1	25	0	0	0	6
A2	5	41	16	16	2
A3	14	67	22	9	3
A4	36	0	35	29	21
A5	11	73	23	30	6
A6	15	0	15	17	2
A7	34	77	17	23	5
A8	12	61	54	27	2
A9	23	65	48	35	9
A10	11	55	42	23	4
A11	44	0	21	16	8
A12	10	62	20	18	3
A13	7	79	37	37	7
A14	6	49	40	17	3
A15	44	65	44	29	4
A16	16	65	33	34	10
A17	19	49	14	9	3
A18	37	90	42	39	15
A19	26	87	33	36	11
A20	31	77	31	24	7

A21	9	56	24	25	2
A22	18	0	0	26	15
A23	8	42	12	12	0
A24	51	68	22	12	13
A25	9	67	23	11	6
A26	19	87	29	19	6
A27	29	74	22	16	4
A28	19	58	16	11	1
MAX	51	90	54	39	21
MIN	5	0	0	0	0

Note: Author's calculation

Table 7 shows the expanded initial matrix.

Table 7: Expanded Initial Matrix

Extended Initial Matrix					
weights of criteria	0.304	0.212	0.104	0.266	0.117
kind of criteria	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**
AAA	5	0	0	0	0
A1	25	0	0	0	6
A2	5	41	16	16	2
A3	14	67	22	9	3
A4	36	0	35	29	21
A5	11	73	23	30	6
A6	15	0	15	17	2
A7	34	77	17	23	5
A8	12	61	54	27	2
A9	23	65	48	35	9
A10	11	55	42	23	4
A11	44	0	21	16	8
A12	10	62	20	18	3
A13	7	79	37	37	7
A14	6	49	40	17	3
A15	44	65	44	29	4
A16	16	65	33	34	10
A17	19	49	14	9	3
A18	37	90	42	39	15
A19	26	87	33	36	11
A20	31	77	31	24	7
A21	9	56	24	25	2
A22	18	0	0	26	15
A23	8	42	12	12	0
A24	51	68	22	12	13

A25	9	67	23	11	6
A26	19	87	29	19	6
A27	29	74	22	16	4
A28	19	58	16	11	1
AI	51	90	54	39	21

Note: Author's calculation

Table 8 shows the normalized matrix.

Table 8: Normalized Matrix

Normalized Matrix					
weights of criteria	0.304	0.212	0.104	0.266	0.117
kind of criteria	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**
AAA	0.098039	0	0	0	0
A1	0.4902	0.0000	0.0000	0.0000	0.2857
A2	0.0980	0.4556	0.2963	0.4103	0.0952
A3	0.2745	0.7444	0.4074	0.2308	0.1429
A4	0.7059	0.0000	0.6481	0.7436	1.0000
A5	0.2157	0.8111	0.4259	0.7692	0.2857
A6	0.2941	0.0000	0.2778	0.4359	0.0952
A7	0.6667	0.8556	0.3148	0.5897	0.2381
A8	0.2353	0.6778	1.0000	0.6923	0.0952
A9	0.4510	0.7222	0.8889	0.8974	0.4286
A10	0.2157	0.6111	0.7778	0.5897	0.1905
A11	0.8627	0.0000	0.3889	0.4103	0.3810
A12	0.1961	0.6889	0.3704	0.4615	0.1429
A13	0.1373	0.8778	0.6852	0.9487	0.3333
A14	0.1176	0.5444	0.7407	0.4359	0.1429
A15	0.8627	0.7222	0.8148	0.7436	0.1905
A16	0.3137	0.7222	0.6111	0.8718	0.4762
A17	0.3725	0.5444	0.2593	0.2308	0.1429
A18	0.7255	1.0000	0.7778	1.0000	0.7143
A19	0.5098	0.9667	0.6111	0.9231	0.5238
A20	0.6078	0.8556	0.5741	0.6154	0.3333
A21	0.1765	0.6222	0.4444	0.6410	0.0952
A22	0.3529	0.0000	0.0000	0.6667	0.7143
A23	0.1569	0.4667	0.2222	0.3077	0.0000
A24	1.0000	0.7556	0.4074	0.3077	0.6190
A25	0.1765	0.7444	0.4259	0.2821	0.2857
A26	0.3725	0.9667	0.5370	0.4872	0.2857
A27	0.5686	0.8222	0.4074	0.4103	0.1905
A28	0.3725	0.6444	0.2963	0.2821	0.0476
AI	1	1	1	1	1

Note: Author's calculation

Table 9 shows the weight-normalized matrix.

Table 9: Weight-normalized matrix

Weighted Normalized Matrix					
	C1	**C2**	**C3**	**C4**	**C5**
AAA	0.029804	0	0	0	0
A1	0.1490	0.0000	0.0000	0.0000	0.0334
A2	0.0298	0.0966	0.0308	0.1091	0.0111
A3	0.0835	0.1578	0.0424	0.0614	0.0167
A4	0.2146	0.0000	0.0674	0.1978	0.1170
A5	0.0656	0.1720	0.0443	0.2046	0.0334
A6	0.0894	0.0000	0.0289	0.1159	0.0111
A7	0.2027	0.1814	0.0327	0.1569	0.0279
A8	0.0715	0.1437	0.1040	0.1842	0.0111
A9	0.1371	0.1531	0.0924	0.2387	0.0501
A10	0.0656	0.1296	0.0809	0.1569	0.0223
A11	0.2623	0.0000	0.0404	0.1091	0.0446
A12	0.0596	0.1460	0.0385	0.1228	0.0167
A13	0.0417	0.1861	0.0713	0.2524	0.0390
A14	0.0358	0.1154	0.0770	0.1159	0.0167
A15	0.2623	0.1531	0.0847	0.1978	0.0223
A16	0.0954	0.1531	0.0636	0.2319	0.0557
A17	0.1133	0.1154	0.0270	0.0614	0.0167
A18	0.2205	0.2120	0.0809	0.2660	0.0836
A19	0.1550	0.2049	0.0636	0.2455	0.0613
A20	0.1848	0.1814	0.0597	0.1637	0.0390
A21	0.0536	0.1319	0.0462	0.1705	0.0111
A22	0.1073	0.0000	0.0000	0.1773	0.0836
A23	0.0477	0.0989	0.0231	0.0818	0.0000
A24	0.3040	0.1602	0.0424	0.0818	0.0724
A25	0.0536	0.1578	0.0443	0.0750	0.0334
A26	0.1133	0.2049	0.0559	0.1296	0.0334
A27	0.1729	0.1743	0.0424	0.1091	0.0223
A28	0.1133	0.1366	0.0308	0.0750	0.0056
AI	0.304	0.212	0.104	0.266	0.117

Note: Author's calculation

Table 10 shows the results of the MARCOS method.

Table 10: Results of the MARCOS method

	Results of the MARCOS Method							
		Si	**Ki-**	**Ki+**	**f(K-)**	**f(K+)**	**f(K)**	**Ranking**
	AAA	0.0298						

Belgium	**A1**	0.1824	6.1216	0.1819	0.0289	0.9711	0.1817	0.1817	**28**
Bulgaria	**A2**	0.2775	9.3098	0.2766	0.0289	0.9711	0.2764	0.2764	**25**
Czech Republic	**A3**	0.3617	12.1374	0.3607	0.0289	0.9711	0.3604	0.3604	**21**
Denmark	**A4**	0.5968	20.0239	0.5950	0.0289	0.9711	0.5945	0.5945	**9**
Germany	**A5**	0.5199	17.4428	0.5183	0.0289	0.9711	0.5179	0.5179	**13**
Estonia	**A6**	0.2454	8.2336	0.2447	0.0289	0.9711	0.2444	0.2444	**27**
Ireland	**A7**	0.6015	20.1824	0.5997	0.0289	0.9711	0.5992	0.5992	**7**
Greece	**A8**	0.5145	17.2633	0.5130	0.0289	0.9711	0.5125	0.5125	**14**
Spain	**A9**	0.6715	22.5311	0.6695	0.0289	0.9711	0.6689	0.6689	**4**
France	**A10**	0.4552	15.2722	0.4538	0.0289	0.9711	0.4534	0.4534	**16**
Croatia	**A11**	0.4564	15.3140	0.4551	0.0289	0.9711	0.4547	0.4547	**15**
Italy	**A12**	0.3837	12.8726	0.3825	0.0289	0.9711	0.3822	0.3822	**18**
Cyprus	**A13**	0.5904	19.8106	0.5887	0.0289	0.9711	0.5882	0.5882	**10**
Latvia	**A14**	0.3609	12.1087	0.3598	0.0289	0.9711	0.3595	0.3595	**23**
Lithuania	**A15**	0.7202	24.1648	0.7181	0.0289	0.9711	0.7174	0.7174	**3**
Luxembourg	**A16**	0.5997	20.1199	0.5979	0.0289	0.9711	0.5973	0.5973	**8**
Hungary	**A17**	0.3337	11.1978	0.3327	0.0289	0.9711	0.3325	0.3325	**24**
Malta	**A18**	0.8630	28.9562	0.8604	0.0289	0.9711	0.8597	0.8597	**1**
Netherlands	**A19**	0.7303	24.5033	0.7281	0.0289	0.9711	0.7275	0.7275	**2**
Austria	**A20**	0.6286	21.0898	0.6267	0.0289	0.9711	0.6261	0.6261	**6**
Poland	**A21**	0.4134	13.8719	0.4122	0.0289	0.9711	0.4118	0.4118	**17**
Portugal	**A22**	0.3682	12.3540	0.3671	0.0289	0.9711	0.3668	0.3668	**19**
Romania	**A23**	0.2516	8.4411	0.2508	0.0289	0.9711	0.2506	0.2506	**26**
Slovenia	**A24**	0.6608	22.1723	0.6588	0.0289	0.9711	0.6583	0.6583	**5**
Slovakia	**A25**	0.3642	12.2205	0.3631	0.0289	0.9711	0.3628	0.3628	**20**
Finland	**A26**	0.5371	18.0197	0.5355	0.0289	0.9711	0.5350	0.5350	**11**
Sweden	**A27**	0.5210	17.4795	0.5194	0.0289	0.9711	0.5190	0.5190	**12**
Serbia	**A28**	0.3613	12.1222	0.3602	0.0289	0.9711	0.3599	0.3599	**22**
	AI	1.0030							

Note: Author's calculation

The obtained empirical results of the selection and ranking of the member states of the European Union and Serbia according to the development of information and communication technology in transport and storage based on the FLMAW - MARCOS method show that the top five countries include: Malta, the Netherlands, Lithuania, Spain, and Slovenia. Germany took the thirteenth place. France is in sixteenth place. Italy took eighteenth place. Bulgaria (in twenty-fifth place) and Romania (in twenty-sixth place) are in an unenviable position. In the last (twenty-eighth) place is Belgium.

Serbia is in twenty-second place. It is in a worse position compared to the countries in the region (Slovenia and Croatia). Slovenia is in fifth place and Croatia is in fifteenth place.

In the informational sense of the word, knowing the position of each member country of the European Union and Serbia in terms of the development of the information system of transport and storage is very significant in itself because it indicates that certain measures should be taken in order to improve it. This is especially true for weakly positioned countries, such as: Belgium, Estonia, Romania and others. Improvement is necessary, especially before the information system significantly affects the efficient functioning of transport and storage and the provision of quality transport services.

All in all, in order to improve the information system in the future, a greater application of information and communication technology in transport and storage is necessary. This is especially true for weakly positioned countries. The effects of this are to improve the overall transport and storage performance.

Conclusion

Based on the obtained empirical results of the ranking of the member states of the European Union and Serbia according to the application of information and communication technology in transport and storage using the FLMAW - MARCOS method, it can be concluded:

1. The top five countries include: Malta, the Netherlands, Lithuania, Spain, and Slovenia. Germany took the thirteenth place. France is in sixteenth place. Italy took eighteenth place. Bulgaria (in twenty-fifth place) and Romania (in twenty-sixth place) are in an unenviable position. In the last (twenty-eighth) place is Belgium.
2. Serbia is in twenty-second place. It is in a worse position compared to the countries in the region (Slovenia and Croatia). Slovenia is in fifth place and Croatia is in fifteenth place.

In order to improve the information system in the future, it is necessary to significantly speed up the development of information and communication technology in transport and storage, especially in poorly positioned countries. The effects of this are to improve the overall transport and storage performance.

The main goals for the introduction of digitization are to improve the functioning of transport and storage and the quality of service provided to users. The digitization of the entire business in transport and storage is increasing. In recent times, the digitalization of the entire transport and storage business is one of the critical factors of business success. For these reasons, the digitization of transport and storage is receiving increasing attention.

It is recommended that, due to its importance, the development, and effects of the application of information and communication technology in transport and storage should be continuously monitored by the comparative use of various multi-criteria decision-making methods with the aim of comparative analysis of the obtained results.

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