Measurement and Analysis of The Information Performance of Companies in The European Union and Serbia Based on The Fuzzy LMAW and MARCOS Methods

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Information and communication technology is one of the critical factors of the business success of a modern company. Therefore, it is important to investigate the information performance of companies from different angles. In this paper, starting from that, a comparative analysis of the selection and ranking of the information performance of companies in the European Union and Serbia is performed based on the FLMAW and MARCOS methods. The obtained empirical results show that the top five countries in terms of information performance include: Finland, Belgium, Denmark, Sweden and Spain. Germany is in tenth place. France is in sixteenth place. Italy is in nineteenth place. Serbia is in twenty-fifth place. In terms of information performance, Serbia is in a worse position compared to the countries in the region. Slovenia is in twelfth place. Croatia is in twenty-first place. In order to improve information performance in the future, it is necessary to significantly improve information and communication technology. This especially applies, in addition to Serbia, to Romania, Bulgaria, Hungary and Estonia. The effects of this are the improvement of the financial performance and efficiency of the company.
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1 Introduction

The issue of measuring information performance is very current, challenging and significant, considering that information and communication technology is one of the critical factors of the business success of a modern company [6]. [7], [10]. Based on that, the subject of research in this paper is a comparative analysis of the selection and ranking of information performance of European Union and Serbian companies based on the FLMAW-MARCOS method. The aim and purpose of this is to look at the existing situation as realistically as possible in order to improve the company's information performance by improving information and communication technology.

As is known, there is an increasingly rich body of literature devoted to the analysis of the effects of information and communication technology on the financial performance and efficiency of a modern company [2], [5], [8], [9], [13], [16]. This is completely and understandable when you consider the fact that empirical analysis has established that information and communication technology significantly contributes to improving the financial performance and efficiency of companies [1]. All relevant literature [1-17] in this paper serves as a theoretical, methodological and empirical basis for researching the problem treated in this paper.

The main research hypothesis in this paper is based on the fact that information and communication technology is one of the critical factors of the business success of a modern company. Considering that, it is necessary to know as realistically as possible the position of the companies of each country with regard to the development of information and communication technology in order to improve it in the future.

In the methodological sense of the word, multi-criteria decision-making methods, including the FLMAW-MARCOS method, play a significant role in this.

Relevant information society indicators were collected from Eurostat for the analysis of the problem treated in this paper.

2 FUZZY LMAW Method

The logarithmic methodology of additive weights is used to determine weight coefficients and rank alternatives [4], [11]. Fuzzy Logarithm Methodology of Additive Weights (FLMAW) is based on the application of triangular fuzzy numbers [3], [12]. The FLMAW method takes place through six steps [3].

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 $A = \{A_1, A_2, \ldots, A_m\}$in relation to n criteria $C = \{C_1, C_2, \ldots, C_n\}$. So, 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 *e* 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 $E = \{E1, E2, \ldots, Ek\}$.

Step 4.1. Prioritization of criteria.

Based on the value of the predefined fuzzy linguistic scale, the experts determine the priorities of the criteria $C = \{C1, C2, \dots, Cn\}$. 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 $\tilde{P}^e = (\tilde{\gamma}_{C1}^e, \tilde{\gamma}_{C2}^e, \dots, \tilde{\gamma}_{Cn}^e)$, 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: $\tilde{n}_{Cn}^e = \left(\frac{\tilde{\gamma}_{Cn}^e}{\tilde{\gamma}_{AIP}}\right) = \left(\frac{\gamma_{Cn}^{(l)e}}{\gamma_{AIP}^{(r)}}, \frac{\gamma_{Cn}^{(m)e}}{\gamma_{AIp}^{(m)}}, \frac{\gamma_{Cn}^{(r)\,e}}{\gamma_{AIP}^{(l)}}\right)$ (3)

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

Step 4.4. Determining vector weight coefficients $\omega_j^e = (\widetilde{\omega}_1^e, \widetilde{\omega}_2^e, \dots, \widetilde{\omega}_n^e)^T$, especially for each expert.

Fuzzy value of weighting coefficients criteria for e $(1 \le e \le k)$ is obtained by applying the following equation:

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

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 $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \dots, \widetilde{\omega}_n)^T$.

Weight coefficients of the aggregated fuzzy vectors $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \dots, \widetilde{\omega}_n)^T$are determined using the Boneferroni aggregator [17] 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 $\omega_j = (\omega_1, \omega_2, \dots, \omega_3)^T$.

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

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

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

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

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

wherein

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

where it $\tilde{\vartheta}'_j$ represents the elements of the normalized matrix $\sim = \left[\vartheta_{ij}\right]_{mxn}$, the ω_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 on the basis of 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 $\tilde{N} = \left[\tilde{\xi}_{ij}\right]_{mxn}$, *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.

3 MARCOS Method

The MARCOS 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 [14], [15]:

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.

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

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:

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

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

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

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

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:

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

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

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

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

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

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

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

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:

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

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

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:

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

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:

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

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

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.

4 Results and discussion

In the context of the problem treated in this paper, relevant indicators of the information society were chosen as criteria. Alternatives are individual member states of the European Union and Serbia. They are shown in Table 1. for 2021.

Table 1. Information society indicator

		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	Buy cloud computing services used over the internet Percentage of enterprises	Use enterprise's blog or microblogs (e.g. Twitter, Present.ly, etc.) (as of 2014) 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	Enterprises use IoT (interconnected devices or systems that can be monitored or remotely controlled via the internet) (as of 2021) Percentage of enterprises	Enterprises with e-commerce sales of at least 1% turnover Percentage of enterprises	Enterprises' total turnover from e-commerce sales Percentage of turnover
		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	Belgium	57	54	53	15	10	28	31	28
A2	Bulgaria	22	17	13	4	3	15	10	6
A3	Czech Republic	38	18	44	9	4	31	25	30
A4	Denmark	50	42	65	11	24	20	38	28
A5	Germany	38	45	42	8	11	36	20	19
A6	Estonia	23	23	58	7	3	17	19	15
A7	Ireland	24	32	59	22	8	34	34	38
A8	Greece	35	20	22	15	4	22	20	10
A9	Spain	49	40	31	26	8	27	26	19
A10	France	45	32	29	11	7	22	12	22
A11	Croatia	24	20	39	6	9	23	30	15
A12	Italy	32	27	60	7	6	32	13	13
A13	Cyprus	34	39	50	23	3	33	17	4
A14	Latvia	39	18	29	11	4	28	15	10
A15	Lithuania	45	32	34	6	4	28	32	18
A16	Luxembourg	40	35	33	13	13	22	9	17
A17	Hungary	21	15	26	3	3	22	18	21
A18	Malta	39	39	57	20	10	28	27	12
A19	Netherlands	43	52	65	21	13	21	23	19
A20	Austria	45	46	40	13	9	51	23	17
A21	Poland	32	32	29	7	3	19	15	18
A22	Portugal	52	25	35	8	17	23	16	17
A23	Romania	17	17	14	6	1	11	12	9
A24	Slovenia	36	22	43	11	12	49	20	18
A25	Slovakia	31	22	36	8	5	27	14	19
A26	Finland	48	46	75	21	16	40	24	22
A27	Sweden	35	38	75	18	10	40	34	26
A28	Serbia	22	14	29	7	1	20	27	5
	Statistics								
	Mean	36.2857	30.7857	42.3214	12.0357	7.8929	27.4643	21.5714	17.6786
	Std. Error of Mean	2.00387	2.24454	3.21992	1.21333	1.02268	1.79394	1.50785	1.47739
	Median	37.0000	32.0000	39.5000	11.0000	7.5000	27.0000	20.0000	18.0000

	Std. Deviation	10.60348	11.87702	17.03820	6.42035	5.41151	9.49262	7.97881	7.81761
	Skewness	-.052	.311	.309	.691	1.096	.844	.318	.432
	Std. Error of Skewness	.441	.441	.441	.441	.441	.441	.441	.441
	Kurtosis	-.804	-1.069	-.679	-.670	1,420	.664	-.837	.545
	Std. Error of Kurtosis	.858	.858	.858	.858	.858	.858	.858	.858
	The minimum	17.00	14.00	13.00	3.00	1.00 am	11.00	9.00	4.00
	Maximum	57.00	54.00	75.00	26.00	24.00	51.00	38.00	38.00

Note: Author's calculation of statistics. Source: Eurostat

The weighting coefficients of the criteria were determined using the FLMAW method. Table 2 shows the fuzzy scale for prioritizing criteria.

Table 2. Fuzzy scale for criteria prioritization

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

FLMAW method is shown below. Table 3 shows the evaluation of the criteria.

Table 3. Evaluation of criteria

KIND	1	1	1	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
P1	**AH**	**L**	**VL**	**E**	**VL**	**VL**	**VL**	**VL**
P2	**AH**	**ML**	**AL**	**H**	**AL**	**VL**	**ML**	**ML**
P3	**AH**	**ML**	**AL**	**MH**	**VL**	**L**	**H**	**ML**
P4	**AH**	**E**	**AL**	**VH**	**AL**	**AL**	**E**	**AL**

ϒAIP	0.5	0.5	0.5

	C1			**C2**			**C3**			**C4**			**C5**			**C6**			**C7**			**C8**		
P1	9	10	10	3	4	5	2	3	4	5	6	7	2	3	4	2	3	4	2	3	4	2	3	4
P2	9	10	10	4	5	6	2	2	2	7	8	9	2	2	2	2	3	4	4	5	6	4	5	6
P3	9	10	10	4	5	6	2	2	2	6	7	8	2	3	4	3	4	5	7	8	9	4	5	6
P4	9	10	10	5	6	7	2	2	2	8	9	10	2	2	2	2	2	2	5	6	7	2	2	2

Table 4 shows the vector weighting coefficients.

Table 4. Weight Coefficients Vector

Weight Coefficients Vector	C1			C2			C3			C4			C5			C6			C7			C8		
W1j	0.172	0.210	0.275	0.086	0.126	0.192	0.054	0.100	0.166	0.126	0.163	0.232	0.054	0.100	0.166	0.054	0.100	0.166	0.054	0.100	0.166	0.054	0.100	0.166
W2j	0.174	0.197	0.222	0.110	0.138	0.173	0.055	0.059	0.067	0.154	0.178	0.212	0.055	0.059	0.067	0.055	0.094	0.134	0.110	0.138	0.173	0.110	0.138	0.173
W3j	0.159	0.181	0.206	0.100	0.126	0.160	0.050	0.054	0.062	0.129	0.153	0.186	0.050	0.086	0.124	0.079	0.109	0.144	0.140	0.163	0.196	0.100	0.126	0.160
W4j	0.195	0.212	0.224	0.143	0.165	0.190	0.062	0.064	0.068	0.185	0.202	0.224	0.062	0.064	0.068	0.062	0.064	0.068	0.143	0.165	0.190	0.062	0.064	0.068

Note: Author's calculation

Table 5 shows the aggregated fuzzy vector.

Table 5. Aggregated Fuzzy Vectors, Aggregated Fuzzy Weight Coefficient Vectors, Final Values of The Weight Coefficients

Aggregated Fuzzy Vectors	C1			C2			C3			C4			C5			C6			C7			C8		
W1j	0.008	0.010	0.015	0.003	0.005	0.008	0.001	0.001	0.003	0.005	0.007	0.012	0.001	0.002	0.004	0.001	0.002	0.005	0.002	0.004	0.008	0.001	0.003	0.006
W2j	0.008	0.010	0.013	0.003	0.005	0.008	0.001	0.001	0.002	0.006	0.008	0.011	0.001	0.001	0.002	0.001	0.002	0.004	0.003	0.005	0.008	0.002	0.003	0.006
W3j	0.007	0.009	0.012	0.003	0.005	0.007	0.001	0.001	0.002	0.005	0.007	0.010	0.001	0.002	0.003	0.001	0.002	0.004	0.004	0.005	0.009	0.002	0.003	0.005
W4j	0.008	0.010	0.013	0.004	0.005	0.008	0.001	0.001	0.002	0.006	0.008	0.012	0.001	0.001	0.002	0.001	0.002	0.002	0.004	0.006	0.008	0.001	0.002	0.003
SUM	0.030	0.040	0.053	0.012	0.019	0.032	0.003	0.005	0.008	0.022	0.030	0.045	0.003	0.006	0.011	0.004	0.008	0.016	0.012	0.020	0.033	0.006	0.011	0.019
Aggregated Fuzzy Weight Coefficient Vectors	0.175	0.200	0.231	0.109	0.139	0.178	0.055	0.069	0.087	0.148	0.174	0.213	0.055	0.077	0.103	0.062	0.091	0.126	0.110	0.141	0.181	0.080	0.106	0.139
Final Values Of The Weight Coefficients	**0.201**			**0.140**			**0.069**			**0.176**			**0.078**			**0.092**			**0.142**			**0.107**		

Note: Author's calculation

MARCOS method is shown below. Table 6 shows the initial matrix.

Table 6. Initial Matrix

Initial Matrix								
weights of criteria	0.201	0.14	0.069	0.176	0.078	0.092	0.142	0.107
kind of criteria	1	1	1	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	57	54	53	15	10	28	31	28
A2	22	17	13	4	3	15	10	6
A3	38	18	44	9	4	31	25	30
A4	50	42	65	11	24	20	38	28
A5	38	45	42	8	11	36	20	19
A6	23	23	58	7	3	17	19	15
A7	24	32	59	22	8	34	34	38
A8	35	20	22	15	4	22	20	10
A9	49	40	31	26	8	27	26	19
A10	45	32	29	11	7	22	12	22
A11	24	20	39	6	9	23	30	15
A12	32	27	60	7	6	32	13	13
A13	34	39	50	23	3	33	17	4
A14	39	18	29	11	4	28	15	10
A15	45	32	34	6	4	28	32	18
A16	40	35	33	13	13	22	9	17
A17	21	15	26	3	3	22	18	21

A18	39	39	57	20	10	28	27	12
A19	43	52	65	21	13	21	23	19
A20	45	46	40	13	9	51	23	17
A21	32	32	29	7	3	19	15	18
A22	52	25	35	8	17	23	16	17
A23	17	17	14	6	1	11	12	9
A24	36	22	43	11	12	49	20	18
A25	31	22	36	8	5	27	14	19
A26	48	46	75	21	16	40	24	22
A27	35	38	75	18	10	40	34	26
A28	22	14	29	7	1	20	27	5
MAX	52	54	75	26	24	51	38	38
MIN	17	14	13	3	1	11	9	4

Note: Author's calculation

Table 7 shows the expanded initial matrix.

Table 7. Extended Initial Matrix

Extended Initial Matrix								
weights of criteria	0.201	0.14	0.069	0.176	0.078	0.092	0.142	0.107
kind of criteria	1	1	1	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
AAA	17	14	13	3	1	11	9	4
A1	57	54	53	15	10	28	31	28
A2	22	17	13	4	3	15	10	6
A3	38	18	44	9	4	31	25	30
A4	50	42	65	11	24	20	38	28
A5	38	45	42	8	11	36	20	19
A6	23	23	58	7	3	17	19	15
A7	24	32	59	22	8	34	34	38
A8	35	20	22	15	4	22	20	10
A9	49	40	31	26	8	27	26	19
A10	45	32	29	11	7	22	12	22
A11	24	20	39	6	9	23	30	15
A12	32	27	60	7	6	32	13	13
A13	34	39	50	23	3	33	17	4
A14	39	18	29	11	4	28	15	10
A15	45	32	34	6	4	28	32	18
A16	40	35	33	13	13	22	9	17
A17	21	15	26	3	3	22	18	21
A18	39	39	57	20	10	28	27	12
A19	43	52	65	21	13	21	23	19
A20	45	46	40	13	9	51	23	17
A21	32	32	29	7	3	19	15	18
A22	52	25	35	8	17	23	16	17
A23	17	17	14	6	1	11	12	9
A24	36	22	43	11	12	49	20	18
A25	31	22	36	8	5	27	14	19

A26	48	46	75	21	16	40	24	22
A27	35	38	75	18	10	40	34	26
A28	22	14	29	7	1	20	27	5
AI	52	54	75	26	24	51	38	38

Note: Author's calculation

Table 8 shows the normalized matrix.

Table 8. Normalized Matrix

Normalized Matrix								
weights of criteria	0.201	0.14	0.069	0.176	0.078	0.092	0.142	0.107
kind of criteria	1	1	1	1	1	1	1	1
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
AAA	0.326923	0.259259	0.173333	0.115385	0.041667	0.215686	0.236842	0.105263
A1	1.0962	1.0000	0.7067	0.5769	0.4167	0.5490	0.8158	0.7368
A2	0.4231	0.3148	0.1733	0.1538	0.1250	0.2941	0.2632	0.1579
A3	0.7308	0.3333	0.5867	0.3462	0.1667	0.6078	0.6579	0.7895
A4	0.9615	0.7778	0.8667	0.4231	1.0000	0.3922	1.0000	0.7368
A5	0.7308	0.8333	0.5600	0.3077	0.4583	0.7059	0.5263	0.5000
A6	0.4423	0.4259	0.7733	0.2692	0.1250	0.3333	0.5000	0.3947
A7	0.4615	0.5926	0.7867	0.8462	0.3333	0.6667	0.8947	1.0000
A8	0.6731	0.3704	0.2933	0.5769	0.1667	0.4314	0.5263	0.2632
A9	0.9423	0.7407	0.4133	1.0000	0.3333	0.5294	0.6842	0.5000
A10	0.8654	0.5926	0.3867	0.4231	0.2917	0.4314	0.3158	0.5789
A11	0.4615	0.3704	0.5200	0.2308	0.3750	0.4510	0.7895	0.3947
A12	0.6154	0.5000	0.8000	0.2692	0.2500	0.6275	0.3421	0.3421
A13	0.6538	0.7222	0.6667	0.8846	0.1250	0.6471	0.4474	0.1053
A14	0.7500	0.3333	0.3867	0.4231	0.1667	0.5490	0.3947	0.2632
A15	0.8654	0.5926	0.4533	0.2308	0.1667	0.5490	0.8421	0.4737
A16	0.7692	0.6481	0.4400	0.5000	0.5417	0.4314	0.2368	0.4474
A17	0.4038	0.2778	0.3467	0.1154	0.1250	0.4314	0.4737	0.5526
A18	0.7500	0.7222	0.7600	0.7692	0.4167	0.5490	0.7105	0.3158
A19	0.8269	0.9630	0.8667	0.8077	0.5417	0.4118	0.6053	0.5000
A20	0.8654	0.8519	0.5333	0.5000	0.3750	1.0000	0.6053	0.4474
A21	0.6154	0.5926	0.3867	0.2692	0.1250	0.3725	0.3947	0.4737
A22	1.0000	0.4630	0.4667	0.3077	0.7083	0.4510	0.4211	0.4474
A23	0.3269	0.3148	0.1867	0.2308	0.0417	0.2157	0.3158	0.2368
A24	0.6923	0.4074	0.5733	0.4231	0.5000	0.9608	0.5263	0.4737
A25	0.5962	0.4074	0.4800	0.3077	0.2083	0.5294	0.3684	0.5000
A26	0.9231	0.8519	1.0000	0.8077	0.6667	0.7843	0.6316	0.5789
A27	0.6731	0.7037	1.0000	0.6923	0.4167	0.7843	0.8947	0.6842
A28	0.4231	0.2593	0.3867	0.2692	0.0417	0.3922	0.7105	0.1316
AI	1	1	1	1	1	1	1	1

Note: Author's calculation

Table 9 shows the weighted normalized matrix.

Table 9. Weighted Normalized Matrix

Weighted Normalized Matrix								
0	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
AAA	0.065712	0.036296	0.01196	0.020308	0.00325	0.019843	0.033632	0.011263
A1	0.2203	0.1400	0.0488	0.1015	0.0325	0.0505	0.1158	0.0788
A2	0.0850	0.0441	0.0120	0.0271	0.0098	0.0271	0.0374	0.0169
A3	0.1469	0.0467	0.0405	0.0609	0.0130	0.0559	0.0934	0.0845
A4	0.1933	0.1089	0.0598	0.0745	0.0780	0.0361	0.1420	0.0788
A5	0.1469	0.1167	0.0386	0.0542	0.0358	0.0649	0.0747	0.0535
A6	0.0889	0.0596	0.0534	0.0474	0.0098	0.0307	0.0710	0.0422
A7	0.0928	0.0830	0.0543	0.1489	0.0260	0.0613	0.1271	0.1070
A8	0.1353	0.0519	0.0202	0.1015	0.0130	0.0397	0.0747	0.0282
A9	0.1894	0.1037	0.0285	0.1760	0.0260	0.0487	0.0972	0.0535
A10	0.1739	0.0830	0.0267	0.0745	0.0228	0.0397	0.0448	0.0619
A11	0.0928	0.0519	0.0359	0.0406	0.0293	0.0415	0.1121	0.0422
A12	0.1237	0.0700	0.0552	0.0474	0.0195	0.0577	0.0486	0.0366
A13	0.1314	0.1011	0.0460	0.1557	0.0098	0.0595	0.0635	0.0113
A14	0.1508	0.0467	0.0267	0.0745	0.0130	0.0505	0.0561	0.0282
A15	0.1739	0.0830	0.0313	0.0406	0.0130	0.0505	0.1196	0.0507
A16	0.1546	0.0907	0.0304	0.0880	0.0423	0.0397	0.0336	0.0479
A17	0.0812	0.0389	0.0239	0.0203	0.0098	0.0397	0.0673	0.0591
A18	0.1508	0.1011	0.0524	0.1354	0.0325	0.0505	0.1009	0.0338
A19	0.1662	0.1348	0.0598	0.1422	0.0423	0.0379	0.0859	0.0535
A20	0.1739	0.1193	0.0368	0.0880	0.0293	0.0920	0.0859	0.0479
A21	0.1237	0.0830	0.0267	0.0474	0.0098	0.0343	0.0561	0.0507
A22	0.2010	0.0648	0.0322	0.0542	0.0553	0.0415	0.0598	0.0479
A23	0.0657	0.0441	0.0129	0.0406	0.0033	0.0198	0.0448	0.0253
A24	0.1392	0.0570	0.0396	0.0745	0.0390	0.0884	0.0747	0.0507
A25	0.1198	0.0570	0.0331	0.0542	0.0163	0.0487	0.0523	0.0535
A26	0.1855	0.1193	0.0690	0.1422	0.0520	0.0722	0.0897	0.0619
A27	0.1353	0.0985	0.0690	0.1218	0.0325	0.0722	0.1271	0.0732
A28	0.0850	0.0363	0.0267	0.0474	0.0033	0.0361	0.1009	0.0141
AI	0.201	0.14	0.069	0.176	0.078	0.092	0.142	0.107

Note: Author's calculation

Table 10 and Figure 1 show 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	0.2023							
Belgium	**A1**	0.7883	3.8975	0.7844	0.1675	0.8325	0.7588	0.7588	**2**
Bulgaria	**A2**	0.2592	1.2816	0.2579	0.1675	0.8325	0.2495	0.2495	**27**

Czech Republic	**A3**	0.5418	2.6785	0.5391	0.1675	0.8325	0.5215	0.5215	**15**
Denmark	**A4**	0.7713	3.8135	0.7675	0.1675	0.8325	0.7425	0.7425	**3**
Germany	**A5**	0.5853	2.8936	0.5824	0.1675	0.8325	0.5634	0.5634	**10**
Estonia	**A6**	0.4029	1.9921	0.4009	0.1675	0.8325	0.3878	0.3878	**24**
Ireland	**A7**	0.7003	3.4624	0.6968	0.1675	0.8325	0.6741	0.6741	**7**
Greece	**A8**	0.4645	2.2965	0.4622	0.1675	0.8325	0.4471	0.4471	**18**
Spain	**A9**	0.7230	3.5745	0.7194	0.1675	0.8325	0.6959	0.6959	**5**
France	**A10**	0.5273	2.6069	0.5246	0.1675	0.8325	0.5075	0.5075	**16**
Croatia	**A11**	0.4462	2.2060	0.4440	0.1675	0.8325	0.4295	0.4295	**21**
Italy	**A12**	0.4587	2.2678	0.4564	0.1675	0.8325	0.4415	0.4415	**19**
Cyprus	**A13**	0.5783	2.8591	0.5754	0.1675	0.8325	0.5566	0.5566	**11**
Latvia	**A14**	0.4463	2.2064	0.4441	0.1675	0.8325	0.4296	0.4296	**20**
Lithuania	**A15**	0.5626	2.7814	0.5598	0.1675	0.8325	0.5415	0.5415	**13**
Luxembourg	**A16**	0.5272	2.6063	0.5245	0.1675	0.8325	0.5074	0.5074	**17**
Hungary	**A17**	0.3401	1.6816	0.3384	0.1675	0.8325	0.3274	0.3274	**26**
Malta	**A18**	0.6574	3.2501	0.6541	0.1675	0.8325	0.6328	0.6328	**9**
Netherlands	**A19**	0.7226	3.5724	0.7190	0.1675	0.8325	0.6955	0.6955	**6**
Austria	**A20**	0.6731	3.3277	0.6697	0.1675	0.8325	0.6479	0.6479	**8**
Poland	**A21**	0.4315	2.1333	0.4293	0.1675	0.8325	0.4153	0.4153	**23**
Portugal	**A22**	0.5566	2.7517	0.5538	0.1675	0.8325	0.5357	0.5357	**14**
Romania	**A23**	0.2566	1.2684	0.2553	0.1675	0.8325	0.2470	0.2470	**28**
Slovenia	**A24**	0.5630	2.7836	0.5602	0.1675	0.8325	0.5420	0.5420	**12**
Slovakia	**A25**	0.4349	2.1502	0.4327	0.1675	0.8325	0.4186	0.4186	**22**
Finland	**A26**	0.7917	3.9144	0.7878	0.1675	0.8325	0.7621	0.7621	**1**
Sweden	**A27**	0.7296	3.6070	0.7259	0.1675	0.8325	0.7023	0.7023	**4**
Serbia	**A28**	0.3497	1.7289	0.3480	0.1675	0.8325	0.3366	0.3366	**25**
	AI	1.0050							

Note: Author's calculation

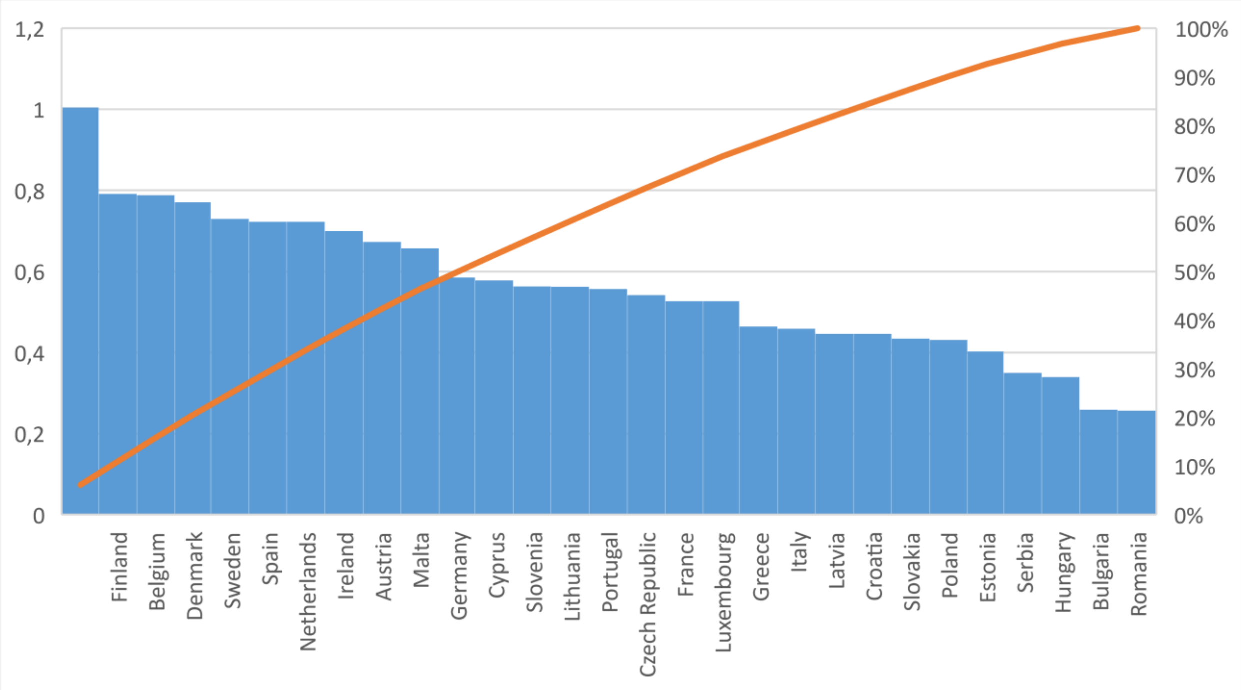

Fig. 1. Ranking of alternatives
Source: Author's picture

According to the results of the Fuzzy LMAW and MARCOS method, the ranking situation is as follows: The top five countries in terms of information performance therefore include: Finland, Belgium, Denmark, Sweden and Spain. Germany is in tenth place. France is in sixteenth place. Italy is in nineteenth place.
Serbia is in twenty -fifth place. In terms of information performance, Serbia is in a worse position compared to the countries in the region. Slovenia is in twelfth place. Croatia is in twenty-first place.
In order to improve information performance in the future, it is necessary to significantly improve information and communication technology. This especially applies, in addition to Serbia, to Romania, Bulgaria, Hungary and Estonia. The effects of this are a significant improvement in the financial performance and efficiency of the company. Information and communication technology have significantly mitigated the negative effect of the COVID-19 corona virus pandemic on the efficiency of business operations.

5 Conclusions

Empirical research conducted in this paper using the given methodology (Fuzzy LMAW and MARCOS method) shows that the top five countries in terms of information performance include: Finland, Belgium, Denmark, Sweden and Spain. The leading countries of the European Union are positioned: Germany in tenth place, France in sixteenth place and Italy in nineteenth place. Serbia is in twenty-fifth place. Serbia is in twenty-fifth place. It is therefore worse positioned than Croatia (twenty-first place) and Slovenia (twelfth place).
Information and communication technology is one of the important factors of efficiency and financial performance of companies. The improvement of information and communication technology has a positive effect on the efficiency and financial performance of companies.

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