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A NEW CRITERIA IMPORTANCE ASSESSMENT (CIMAS) METHOD IN MULTI-CRITERIA GROUP DECISION-MAKING: CRITERIA EVALUATION FOR SUPPLIER SELECTION

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Abstract. *Decision-making is a challenging task for logistics managers when solving the supplier selection problem. It is usually affected by numerous conflicting criteria that are not equally important to all decision-makers. Criteria evaluation is one of the crucial parts here. The primary purpose of this paper is to propose a novel integrated criteria importance assessment method based on objective judgment and group decision-making. The developed method is applied to the criteria importance evaluation for supplier selection. First, we proposed the criteria importance assessment (CIMAS) method based on the expert's opinion, where the years of experts' experience were given in the form of an expert's weight. Second, the obtained criteria weights are further integrated within the well-known CRITIC method, and the hybrid criteria weights are determined. The input data matrix is based on the experts' criteria evaluation on the one-to-ten-point scale. The data were further analyzed by the novel CIMAS method and were utilized within the CRITIC (objective) method. The paper's main contribution is the proposal of the novel CIMAS method. Another contribution is coupling the subjective (CIMAS) and the objective (CRITIC) methods. The results reveal that the most important criterion for supplier selection is on-time distribution, followed by distribution cost, external image and appearance in public, social responsibility rate, and air pollution, respectively. The sensitivity and comparative analysis were also performed, and the technique confirmed a high level of stability.*

Key words: *Decision-Making, Experts, Supplier Evaluation, CIMAS, CRITIC*

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1. INTRODUCTION

The Multi-Criteria Decision-Making (MCDM) process has always been an intriguing issue for both researchers and managers all around the world. Each decision-making problem in life is affected by many criteria that interact with each other. Only some of the requirements are equally important to each decision-maker. For that reason, it is necessary to assign the proper importance to them. Many methods, that are used to evaluate the criteria, have been suggested by various authors in the MCDM field [1,2]. Two sorts of methods in the criteria weighting exist, the Subjective Weighting Methods (Direct Rating (DR), Simple Multi-Attribute Rating Technique (SMART), Delphi, Full Consistency Method (FUCOM), Best-Worst Method (BWM), Analytic Hierarchy Process (AHP), Stepwise Weight Assessment Ratio Analysis (SWARA), etc.) and the Objective Weighting Methods (Entropy, CRITIC, Standard Deviation, etc.). In this paper, the authors conducted research on the subjective methods that were proposed in the literature. The Web of Science database was this survey's primary source of information. It is noticed from the literature that there are a bunch of publications regarding the criteria evaluation methods. Saaty [3] proposed the AHP method. Diakoulaki [1] developed the CRiteria Importance Through Intercriteria Correlation (CRITIC) method. Gabus and Fontela [4] developed the Decision-making Trial and Evaluation Laboratory (DEMATEL) method. Rezaei [5] developed the BWM. Keršuliene et al. [6] proposed the SWARA method. Pamučar et al. [2] developed the Full Consistency Method (FUCOM).

All the proposed methods found their application in various fields. For instance, Xie et al. [7] applied DEMATEL for the site selection of supermarkets. Ortega et al. [8] used the BWM to find a sustainable park-and-ride location. Kant and Gupta [9] evaluated urban freight strategies using the BWM method. Regarding the AHP method, it is applied in various contexts such, as forest fire hazard modeling [10], risk assessment of metro systems [11], project post-evaluation [12], etc. The SWARA method has applications to various problems such as supplier evaluation [13], road sections ranking [14], risk assessment in coal supply chain management [15], glasshouse location selection [16]. When it comes to the FUCOM method, it has been applied to various branches such as in the manufacturing environment [17], human resources [18], landfill site selection [19], forklift efficiency analysis [20], etc.

Besides MCDM methods for criteria importance assessment, in recent years, the field of MCDM has been growing rapidly. For instance, Bošković et al. [21] developed the AROMAN method to select the best electric vehicle alternative for last-mile delivery. This method has been further developed and applied to cargo bike delivery concept selection by Bošković et al. [22]. In addition, Yalçın et al. [23] developed an Intuitionistic Fuzzy-based AROMAN model for performance evaluation of EcoPorts. Švadlenka et al. [24] developed a picture-fuzzy decision-making approach for sustainable last-mile delivery. Simić et al. [25] developed a neutrosophic LOPCOW-ARAS model for prioritizing industry 4.0-based material handling technologies in smart and sustainable warehouse management systems. Tirkolaee et al. [26] proposed an integrated decision-support framework for resilient supply chain network design. They used the BWM and WASPAS methods that were further integrated within the type-2 neutrosophic fuzzy numbers (T2NN). Čubranić-Dobrodolac et al. [27] proposed a fuzzy-AROMAN-Fuller technique to select a professional driver. On the other hand, Nikolić et al. [28] applied an Interval Type-2 Fuzzy AROMAN Decision-Making method to improve the sustainability of the postal network in rural areas. Pamucar et al. [29]

prioritized sustainable mobility-sharing systems using integrated fuzzy DIBR and fuzzy-rough EDAS models.

In this paper, a novel integrated criteria importance assessment method based on objective judgment and group decision-making is developed. First, we proposed the criteria importance assessment (CIMAS) method based on the expert's opinion, where the years of experience of each expert are given in the form of an expert's weight. Thus, the obtained criteria weights are further integrated within the well-known CRITIC method, and the hybrid criteria weights are determined. The authors of this paper followed the logic that the more years of experience one expert has, the more critical his criteria assessment decision is. To assess the criteria, the experts use a one-to-ten-point scale and thus formulate an input data matrix. The proposed integrated approach is to help decision-makers determine the criteria weights in multi-criteria decision-making problems, including a team of experts. The first part of the proposed method belongs to a group of subjective methods since a team of experts assesses the criteria in a decision-making process. The second part integrates the well-known CRITIC method, which belongs to the objective methods. The CRITIC method belongs to the objective methods developed and verified by Diakoulaki et al. in 1995 [1]. The correlation analysis obtains the contrasts among criteria [1].

This paper's main contribution lies in coupling subjective and objective methods to get more precise and accurate criteria assessments that are further used in decision-making. In addition, this paper emphasizes its further contributions: i) The original subjective method (CIMAS) to assess the criteria importance is proposed; ii) The proposed CIMAS method appears for the first time in the literature; iii) The method is general (includes the experts' judgment) and is applicable to assess any criteria in real-life problems. iv) The proposed method is applied to evaluate the criteria for sustainable supplier selection. (v) Coupling the subjective (CIMAS) with the well-known objective (CRITIC) method, an integrated approach gives more precise and confident results.

The rest of the paper is structured as follows: Section 2 thoroughly explains the proposed CIMAS method. In Section 3, the CIMAS method is applied to assess the criteria that affect the supplier selection problem. Sub-section 3.1 is the sensitivity analysis on the CIMAS method, where three scenarios are performed. Sub-section 3.2 is the comparative analysis with the CRITIC method. Sub-section 3.3 describes the hybrid criteria weights based on combining the CIMAS and the CRITIC methods. The main contribution should be found in this sub-section. Section 3.4 gives some managerial recommendations regarding the newly proposed method. Section 4 concludes the paper and gives some future research directions.

2. Criteria Importance Assessment Method

This paper proposes a new approach, the Criteria Importance Assessment (CIMAS), in decision-making. This method should be used to identify the criteria' importance in a decision-making process using experts' assessment. One important fact regarding the expert knowledge and experience is that this method considers the experts' experience in the years spent in the considered field. As mentioned above, the authors of this paper followed the logic that the more years of experience one expert has, the more critical the criteria assessment decision is. The experts' weights are further used in the criteria assessment. The calculated expert weights should be significant later in the decision-making process. In addition, the experts use a one-to-ten-point scale to formulate an input data matrix where the most significant importance of one criterion is denoted by 10. In contrast, the lowest one is denoted by 1. A flowchart of the proposed method is depicted in Fig. 1.

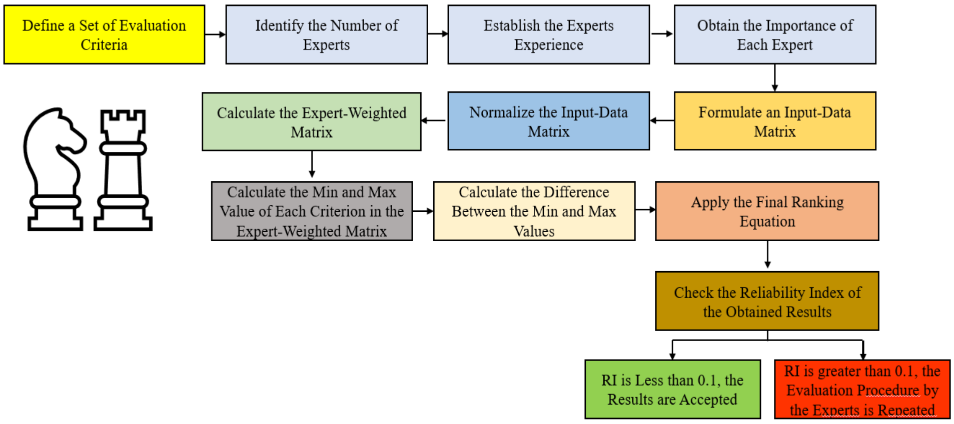

Fig. 1 A flowchart of the proposed method

The CIMAS method is described through the following steps:

Step 1. Define a set of evaluation criteria:

The first step in a decision-making process is to define the criteria by which importance should be assessed. The criteria may be identified either from the literature or by consulting experts.

Step 2. Identify the number of experts:

Decision-maker identifies the number of experts involved in the field and collects information regarding their years of experience.

Step 3. Establish the experts' experience (years):

The experts clarify their experience in the number of years spent in the field, and the decision-maker defines the importance of each expert.

Step 4. Calculate the importance of each expert:

The importance of each expert is calculated by following this logic: let us suppose that "*q*" experts participate in the criteria assessment procedure. Expert 1 has five years of experience in the considered field, Expert 2 has three years of experience, while Expert *q* participates with seven years of experience. The importance of experts' evaluations (the expert weights) should be determined as 5/15 for Expert 1, 3/15 for Expert 2, and 7/15 for Expert *q*. In the general case, the expert's importance can be calculated by Eq. (1).

$$W^{E_i} = \frac{E_i}{\sum_{i=1}^{q} E_i}, i = 1, 2, \ldots, q \quad (1)$$

Step 5. Formulate an input data matrix based on the experts' assessment (1-10 Scale):

In this step, an input decision-making matrix is defined. The experts use a one-to-ten-point scale to formulate an input data matrix where the most significant importance of one criterion is denoted by 10, while the lowest one is denoted by 1. The structure of the input data matrix is presented in Table 1. E_i represents one of the q experts involved in a decision-making, C_j is one of the p considered evaluation criteria, x_{ij} is the expert's number i assessment of criteria number j importance (on a scale of 1-10), and finally, the values from W^{E_1} to W^{E_q} are the experts' weights.

Table 1 Input Data Matrix

Experts/Criteria	C_1	C_2	...	C_j	...	C_p	Experts' Weights
E_1	x_{11}	x_{12}	...	...	...	x_{1p}	W^{E_1}
E_2	x_{21}	x_{22}	...	...	...	x_{2p}	W^{E_2}
E_i	...	...	...	x_{ij}	...	...	...
E_q	x_{q1}	x_{q2}	...	...	...	x_{qp}	W^{E_q}

Step 6. Normalize the input-data matrix:

After the input data matrix is formulated, step 6 is data normalization. It means that the input data are structured in intervals 0 and 1. It further facilitates the decision-making process. In this method, the normalization technique is applied by Eq. (2) and presented in Table 2.

$$x_{ij}^{*}=\frac{x_{ij}}{\sum_{i=1}^{q} x_{ij}},\ i = 1, 2, \dots, q;\ j = 1, 2, \dots, p \tag{2}$$

Table 2 Normalized Input-Data matrix

Experts/Criteria	C_1	C_2	C_j	C_P
E_1	x_{11}^{*}	x_{12}^{*}	...	x_{1p}^{*}
E_2	x_{21}^{*}	x_{22}^{*}	...	x_{2p}^{*}
E_i	...	...	x_{ij}^{*}	...
E_q	x_{q1}^{*}	x_{q2}^{*}	...	x_{qp}^{*}

Step 7. Multiply each value of the normalized input data matrix by the importance of each expert (expert-weighted matrix):

In this step, the normalized input data are multiplied by the experts' weights obtained in Step 4. It is calculated by Eq. (3) and presented in Table 3.

$$\widehat{x^{*}}_{ij} = x_{ij}^{*} \cdot W^{E_i},\ i = 1,2, \dots q; j = 1, 2, \dots, p \tag{3}$$

Table 3 Expert-Weighted Matrix

Experts/Criteria	C_1	C_2	...	C_j	...	C_P
E_1	$\widehat{x^{*}}_{11}$	$\widehat{x^{*}}_{12}$	...	...	...	$\widehat{x^{*}}_{1p}$
E_2	$\widehat{x^{*}}_{21}$	$\widehat{x^{*}}_{22}$	...	...	...	$\widehat{x^{*}}_{2p}$
E_i	...	...	...	$\widehat{x^{*}}_{ij}$	...	...
E_q	$\widehat{x^{*}}_{q1}$	$\widehat{x^{*}}_{q2}$	...	...	...	$\widehat{x^{*}}_{qp}$

Step 8. Identify the maximum and minimum value of each criterion in the expert-weighted matrix:

The primary purpose of this step is to identify the maximum ($R_{j\,max}$) and minimum value ($R_{j\,min}$) of each criterion by columns. It is calculated by Eqs. (4) and (5) and presented in Table 4.

$$R_{j\,max} = \max_{i} \widehat{x^*}_{ij}, j = 1, 2, \ldots, p, \tag{4}$$

$$R_{j\,min} = \min_{i} \widehat{x^*}_{ij}, j = 1, 2, \ldots, p. \tag{5}$$

Table 4 Maximum and Minimum Value of Each Criterion in the Expert-Weighted Matrix

Experts/Criteria	C_1	C_2	…	C_j	…	C_p
E_1	$\widehat{x^*}_{11}$	$\widehat{x^*}_{12}$	…	…	…	$\widehat{x^*}_{1p}$
E_2	$\widehat{x^*}_{21}$	$\widehat{x^*}_{22}$	…	…	…	$\widehat{x^*}_{2p}$
E_i	…	…	…	$\widehat{x^*}_{ij}$	…	…
E_q	$\widehat{x^*}_{q1}$	$\widehat{x^*}_{q2}$	…	…	…	$\widehat{x^*}_{qp}$
$R_{j\,max}$	$R_{1\,max}$	$R_{2\,max}$	…	$R_{j\,max}$	…	$R_{p\,max}$
$R_{j\,min}$	$R_{1\,min}$	$R_{2\,min}$	…	$R_{j\,min}$	…	$R_{p\,min}$

Step 9. Calculate the difference between minimum and maximum values:

This step calculates the difference (B_j) between the minimum and maximum values from the previous step by applying Eq. (6).

$$B_j = R_{j\,max} - R_{j\,min}, j = 1, 2, \ldots, p \tag{6}$$

Step 10. Apply the final ranking formula:

This step obtains the criteria importance (L_j) by using the final ranking equation, i.e. Eq. (7).

$$L_j = \frac{B_j}{\sum_{j=1}^{p} B_j}, j = 1, 2, \ldots, p \tag{7}$$

2.1. Checking Reliability Index (RI)

When it comes to subjective methods, which in this case is the CIMAS method, an important issue is measuring the reliability of the collected answers by the experts. In the AHP method, the authors proposed a well-known approach to measure the inconsistency rate. In that case, the inconsistency rate should be less than 0.1 to consider the results reliable. In the case of CIMAS, this approach cannot be utilized. In the case of CIMAS, the authors applied another approach [27] for measuring the reliability index (RI). The procedure implies a second round of interviewing the experts, where they do not know the results of the first round regarding the criteria assessed. In the second round, the experts are asked to consider the criteria on a scale from 0 to 100 % and thus determine the percentage importance of each criterion. The experts should be careful that the evaluation for all *"n"* criteria must give the sum of 100 %. Finally, the results from both rounds are compared and they lead to the conclusion regarding the reliability of the results. If we denote the answers from the second round of the interview by P_j and previously obtained CIMAS weights by L_j, then the reliability index (RI) can be calculated by Eq. (8).

$$RI = \frac{\sum_{j=1}^{n} |L_j * 100 - P_j|}{100} \tag{8}$$

If the *RI* is less than 0.1, the results should be considered reliable. Contrary, the experts should repeat the criteria assessment procedure.

3. Results and Discussion

This section demonstrates the applicability of a newly proposed CIMAS method in the case of the criteria assessment for the supplier selection process. Five criteria have been identified from the literature: two Economic (distribution costs [30-33], and on-time distribution [30, 31,34, 35]), one Environmental (air pollution [30, 33, 34, 36, 37]), and two Social (external image and appearance in public [30, 31, 33, 34] and social responsibility rate [30, 31, 33, 34]). The criteria assessment problem is depicted in Fig. 2.

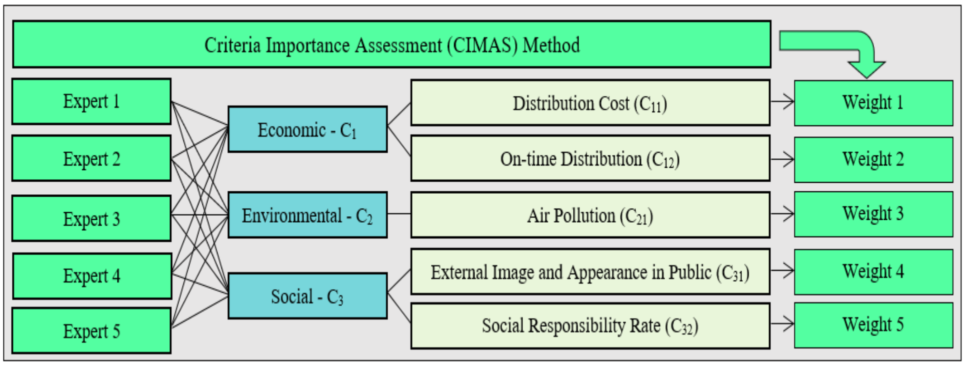

Fig. 2 Illustration of the problem

The first economic criterion is distribution cost. It is the cost that possible suppliers would request from the company for the distribution process. The second economic criterion is on-time distribution, which means whether the supplier respects the promised timeframes. The third criterion is air pollution which belongs to the environmental pillar. The fourth social criterion is the external image and appearance in public. It presents the general impression of possible suppliers in public, such as their building, transport fleet, logo, behavior toward customers, etc. The fifth and last social criterion is the social responsibility rate.

Five experts participated in the criteria assessment. All these experts belong to the logistics field with various years of experience (Table 5). Experts 1 to 3 are the CEOs of the logistics companies in the Czech Republic. Experts 4 and 5 are the CEOs of the middle-sized logistics companies in Slovakia. The names of the companies are not mentioned because of their internal policy. The experts were interviewed by telephone due to the ongoing COVID-19 crisis. They were asked to give the importance of each criterion by following the one-to-ten-point scale, where the highest priority of one criterion is denoted by 10. At the same time, the lowest one is represented by 1. In addition, the experts' weights are determined based on their experience in the field. Therefore, the data were generated from the experts' criteria assessments for this case study. According to the CIMAS method, the following results are obtained (Table 5 - Table 7). The criteria rank is depicted in Fig. 3.

Table 5 Input Data Matrix

	Distribution Cost	On-time Distribution	Air Pollution	External Image and Appearance in Public	Social Responsibility Rate	Expert – Years of Experience	Expert-Weights
E_1	9	6	6	6	4	2	W^{E_1} =0.0909
E_2	8	8	7	9	6	4	W^{E_2} =0.1818
E_3	10	9	6	7	7	1	W^{E_3} =0.0455
E_4	9	6	8	9	8	5	W^{E_4} =0.2273
E_5	10	9	6	8	6	10	W^{E_5} =0.4545
						∑=22	

Table 6 Normalized input data matrix

	Distribution Cost	On-time Distribution	Air Pollution	External Image and Appearance in Public	Social Responsibility Rate
E_1	0.1957	0.1579	0.1818	0.1538	0.1290
E_2	0.1739	0.2105	0.2121	0.2308	0.1935
E_3	0.2174	0.2368	0.1818	0.1795	0.2258
E_4	0.1957	0.1579	0.2424	0.2308	0.2581
E_5	0.2174	0.2368	0.1818	0.2051	0.1935

The results of the criteria assessment for supplier selection are given in the following ranking order: the highest importance was assigned to the distribution on time, followed by the cost of distribution, external image, and appearance in public, social responsibility rate, and air pollution, respectively. To check the reliability of the obtained results, we interviewed the experts in the second round to collect information about the percentage distribution of criteria importance. The results are shown in Table 8. As it can be concluded, the rate of inconsistency is below 0.1 (RI = 0.06445), which means that reliability is satisfactory.

Table 7 The maximum and minimum value of each criterion, its difference obtained final weights.

	Distribution Cost	On-time Distribution	Air Pollution	External Image and Appearance in Public	Social Responsibility Rate	
E_1	0.0178	0.0144	0.0165	0.0140	0.0117	
E_2	0.0316	0.0383	0.0386	0.0420	0.0352	
E_3	0.0099	0.0108	0.0083	0.0082	0.0103	
E_4	0.0445	0.0359	0.0551	0.0524	0.0587	
E_5	0.0988	0.1077	0.0826	0.0932	0.0880	
$R_{j\,max}$	0.0988	0.1077	0.0826	0.0932	0.0880	
$R_{j\,min}$	0.0099	0.0108	0.0083	0.0082	0.0103	
B_j	0.0889	0.0969	0.0744	0.0851	0.0777	∑=0.4230
L_j	0.2102	0.2291	0.1758	0.2011	0.1837	

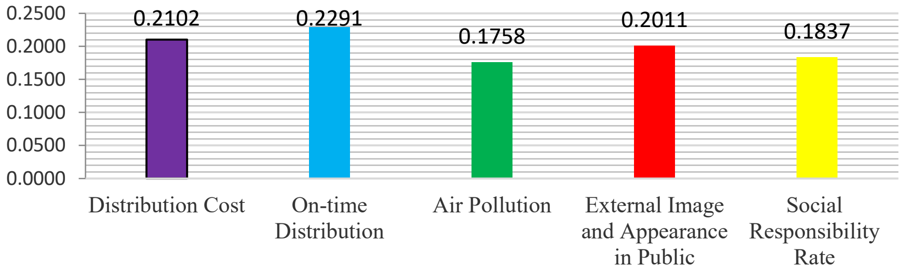

Fig. 3 Criteria Ranking

Table 8 Calculation of the reliability index (RI)

	L_j	E_1 (%)	E_2 (%)	E_3 (%)	E_4 (%)	E_5 (%)	*Average* P_j	$\lvert W_j*100-P_j\rvert$	RI_j
Distribution Cost	0.2102	25	30	15	15	15	20	1.0244473	0.010244
On-Time Distribution	0.2291	30	25	20	20	35	26	3.0944179	0.030944
Air Pollution	0.1758	25	5	15	30	5	16	1.5840832	0.015841
External Image and Appearance in Public	0.2011	15	15	35	25	10	20	0.1139869	0.00114
Social Responsibility Rate	0.1837	15	25	15	5	35	19	0.6280995	0.006281
									0.06445

3.1. Sensitivity Analysis

In this section, the sensitivity analysis is performed to check the deviations of the CIMAS method. The sensitivity analysis is performed in a way that the most experienced experts were excluded from the model to observe how the rank of criteria will change. In our case, we examined three scenarios. Scenario 1, where the high-experienced expert (Expert 5) was excluded. Scenario 2, where the second most experienced expert (Expert 4) was excluded, and Scenario 3, where an inexperienced expert (Expert 1) was excluded. The results of the sensitivity analysis are presented in Fig. 4.

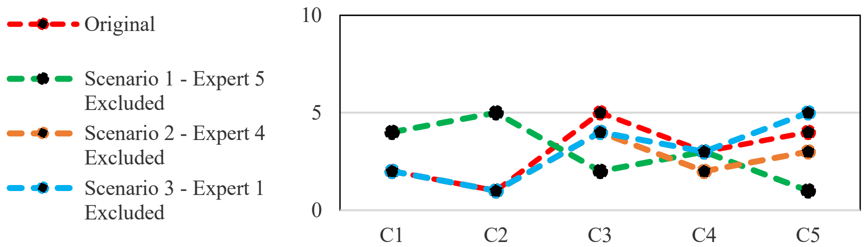

Fig. 4 Sensitivity Analysis

The sensitivity analysis results revealed that when the most experienced expert (Expert 5) was excluded from decision-making, there was a significant change in criteria ranking. The other two scenarios had better compatibility with the original state. However, when the least experienced expert (Expert 1) was excluded, this did not significantly affect the ranking order. It may be concluded that the more experienced experts significantly influence the criteria to rank more than those inexperienced.

3.2. Comparative Analysis with the CRITIC method

In this sub-section, the newly proposed CIMAS method was compared to the well-known CRITIC method proposed by Diakoulaki et al. [1]. The CRITIC method, as mentioned at the beginning of the paper, belongs to the objective methods used to obtain the criteria weights. The authors of this paper utilized the same input data (in the CRITIC method) obtained from the five experts, and the results of the comparative analysis are depicted in Fig. 5.

It may be noticed from Fig. 5 that both the CRITIC and the CIMAS methods ranked the on-time distribution (C_2) criterion with the highest importance. On the other hand, the CRITIC method ranked the Distribution Cost (C_1) as the second best, while the CIMAS ranked the C_1 as the third best. In the next section, given the noticeable similarity between the two methods, the paper's authors coupled the newly proposed method with the CRITIC one to obtain hybrid criteria weights that should be utilized further in decision-making.

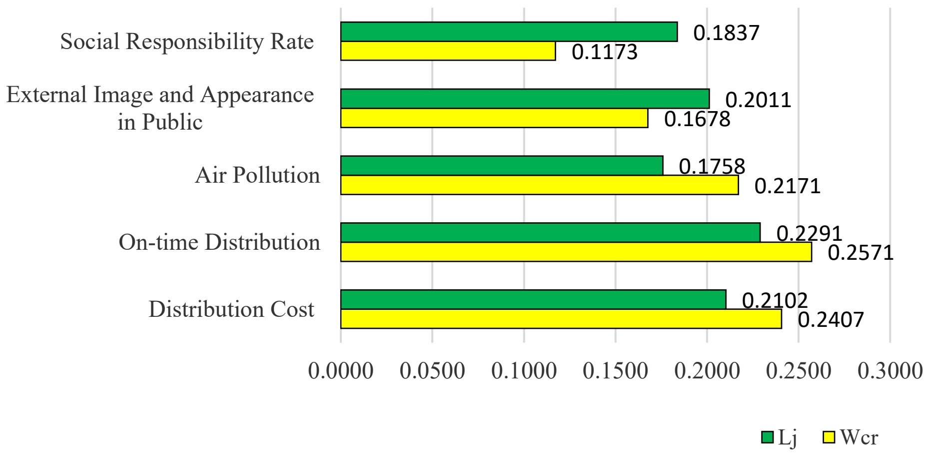

Fig. **5** Comparative analysis between the CRITIC and the CIMAS methods

3.3. Hybrid weights based on the integration of the CRITIC and CIMAS methods

In this sub-section, the obtained criteria weights from the CIMAS and CRITIC methods are effectively coupled, and the hybrid criteria weights are obtained. The hybrid criteria weights are calculated by applying the equation of an arithmetic mean:

$$W_j^{hybrid} = \frac{W_j^{CR} + L_j}{2}, \; j = 1, 2, \ldots, p \qquad (9)$$

where: W_j^{CR} are the criteria importance obtained by the CRITIC method, while L_j are the criteria obtained by the CIMAS method. The obtained hybrid criteria weights are presented in Table 9 and Fig. 6.

Table 9 Hybrid criteria weights

	W_j^{CR}	L_j	W_j^{hybrid}
Distribution Cost	0.2407	0.2102	0.2255
On-time Distribution	0.2571	0.2291	0.2431
Air Pollution	0.2171	0.1758	0.1965
External Image and Appearance in Public	0.1678	0.2011	0.1844
Social Responsibility Rate	0.1173	0.1837	0.1505

Fig. 6 shows that the obtained hybrid criteria weights (the red line) are in between the CRITIC and newly proposed CIMAS method, which may indicate more accurate results in the decision-making process. This should be seen as a powerful technique that combines objective and subjective criteria weights for better decisions.

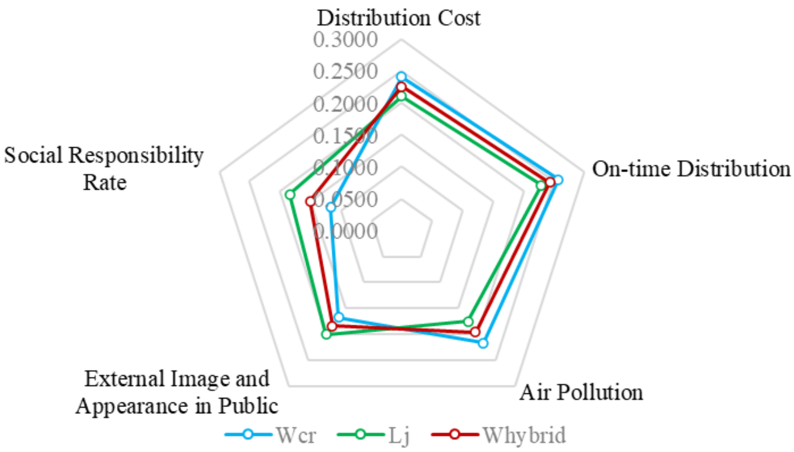

Fig. 6 Hybrid Criteria Weights

3.3.1. Sensitivity analysis of the integrated model

The sensitivity analysis is proposed to prove the robustness of the newly proposed framework with the hybrid criteria weights. The authors introduced the parameter λ (between the intervals 0 and 1) and tested the robustness of the hybrid CRITIC-CIMAS model. The robustness of the model was tested by applying Eq. (10). The results are presented in Fig. 7.

$$W_j^{Hybrid\ (\lambda)} = \frac{\lambda W_j^{CR} + (1-\lambda)L_j}{2}, j = 1, 2, \ldots, p \quad (10)$$

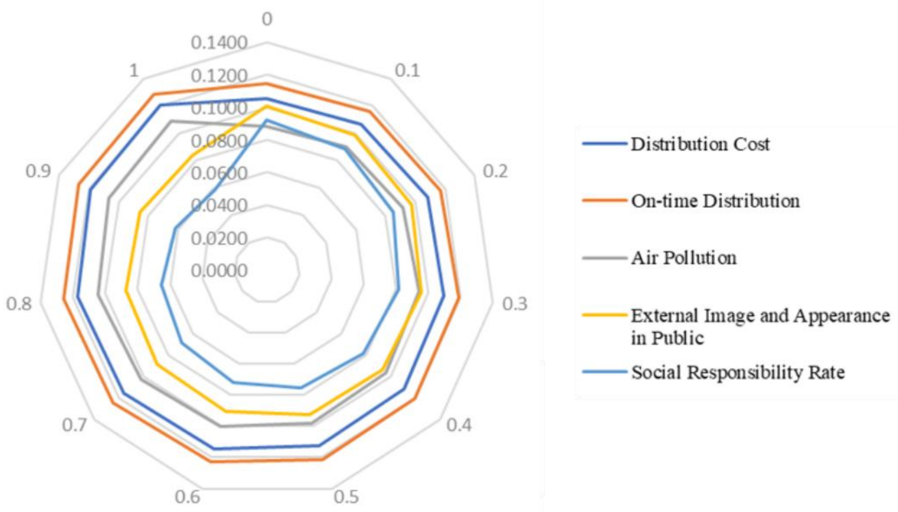

Fig. 7 Sensitivity analysis on the hybrid criteria weights

Applying Eq. 10 allows two scenarios where different methods were used. In the first one, when λ=0, only the criteria weights obtained by the CIMAS method ($\frac{L_j}{2}$) are considered. In the second one, when λ=1, only the criteria weights obtained by the CRITIC method ($\frac{W_j^{CR}}{2}$) are considered. Both criteria weights are considered in all other cases, λ = (0.1-0.9). It may be noticed from Fig. 7 that the criteria weights are stable when λ is between 0.4 and 1. In the rest, minimal overlaps are noticed. It can be concluded that the criteria ranks are very stable to variations in the operational parameter λ.

3.4. Managerial Implications

The evaluating criteria weights for an effective supplier selection process is an initial phase and crucial to all logistics decision-makers. The criteria weights may be determined differently since many multi-criteria decision-making methods were developed. Sometimes, the criteria weights may be obtained either by objective or subjective methods. To reduce the level of uncertainty and boost more precise final ranking decisions, we developed an integrated criteria importance assessment method based on objective judgment and group decision-making. This integrated approach may serve managers to assess the criteria efficiently and effectively. One of the possibilities of this approach is that the managers may choose either to apply the CIMAS method or the CRITIC one to find the criteria's importance. The recommendation to managers may be to use an integrated approach due to its high level of robustness. Apart from the logistics industry, the integrated approach may be applied by managers to assess the criteria in other branches of industry such as supply chain, medicine, education, automotive, construction, etc. One of the advantages of the integrated approach is its simplicity of implementation, which leads to the expectation that managers worldwide would be able to apply it to solve their decision-making problems.

4. Conclusions

The primary aim of this paper was to propose a novel Criteria Importance Assessment (CIMAS) method to help decision-makers assess the criteria when dealing with complex MCDM problems. As its name suggests, the novel method should be suitable in cases when multiple criteria affect the decision on the best alternative. The main advantage of the proposed method is to help managers and decision-makers identify the weights of each criterion and rank them in descending order. The experts' knowledge and experience are essential to the newly proposed method. The final rank of the criteria exclusively depends on the experts' knowledge and experience, which sometimes could be a disadvantage if the decision is made by an inexperienced expert. The paper's authors performed the sensitivity analysis to observe how the criteria to rank would change if some experts were excluded from the criteria evaluation (Fig. 4). The sensitivity analysis results revealed that the most experienced expert significantly impacted decision-making if his knowledge and experience had been omitted from decision-making. On the contrary, if the least experienced expert had been excluded, that did not significantly affect the criteria ranking order.

The secondary aim of this paper was to integrate the newly proposed CIMAS method within objective one (CRITIC) and thus obtain more accurate hybrid criteria weights. The proposed integrated approach was applied to evaluate the hybrid criteria weights affecting supplier selection. The obtained results within the integrated approach presented the following hybrid ranking order (Table 10, Fig. 6): the highest importance was assigned to the on-time distribution, followed by the cost of distribution, air pollution, external image and appearance in public, and social responsibility, respectively. In addition, the sensitivity analysis was performed to check the stability of the newly integrated approach where the criteria rank presented a high level of robustness (Fig. 7).

This paper highlights its significant contributions: i) The original MCDM method, named the Criteria Importance Assessment (CIMAS), is proposed; ii) The CIMAS method belongs to the subjective methods and is presented for the first time in the literature; iii) The method is general (includes the expert-knowledge and experience) and applies to any other multi-criteria decision-making problem in many branches of industry; iv) The application of the CIMAS method is demonstrated in evaluating the criteria which are further used for the supplier selection process. v) Coupling the subjective (CIMAS) with the well-known objective (CRITIC) method, an integrated approach gives a more precise and confident criteria rank which was confirmed by the sensitivity analysis. Besides contributions, there is a limitation of the proposed CIMAS method. The method uses only the crisp values, and its application is not suitable in an uncertain environment.

The possible future research directions of this paper should be: 1) to extend the methodology on fuzzy sets; 2) to apply the methodology to many different fields; 3) to couple the CIMAS method with some of the existing MCDM methods to obtain criteria weights; 4) Sustainable supplier selection as a crucial part of the whole supply chain should also be further addressed. In this regard, it is essential to carefully monitor and identify the most relevant criteria, evaluate them as most appropriate according to the chosen alternatives, and obtain the best possible ranking alternative order.

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