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Objective Criticism and Negative Conclusions on Using the Fuzzy SWARA Method in Multi-Criteria Decision Making

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Abstract: The quality of output or decision-making depends on high-quality input data, their adequate evaluation, the application of adequate approaches, and accurate calculation. In this paper, an objective criticism of applying the fuzzy SWARA (step-wise weight assessment ratio analysis) method based on the Chang TFN (triangular fuzzy number) scale is performed. Through research, it has been noticed that a large number of studies use this approach and, as an epilogue, there are wrong decisions based on inconsistent values in relation to the initial assessment of decision-makers (DMs). Seven representative studies (logistics, construction industry, financial performance management, and supply chain) with different parameter structures and decision matrix sizes have been singled out. The main hypothesis has been set, which implies that the application of this approach leads to wrong decisions because the weight values of the criteria are incorrect. A comparative analysis with the improved fuzzy SWARA (IMF SWARA) method has been created and a number of negative conclusions has been reached on using the fuzzy SWARA method and the Chang scale: Primarily, that using such an approach is impossible for two or more criteria to have equal value, that allocating TFN (1,1,1) leads to criteria values that are inconsistent with expert evaluation, that the last-ranked criteria in the fuzzy SWARA method have no influential value on the ranking of alternatives, that there is a great gap between the most significant and last-ranked criteria, and that the most significant criterion has a huge impact on the evaluation of alternative solutions and decision making. As a general conclusion, it is given that this approach is not adequate for application in problems of multi-criteria decision making because it produces inadequate management of processes and activities in various spheres.

Keywords: objective criticism; fuzzy SWARA; IMF SWARA; criteria weights; logistics; management; decision making

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Citation: Stević, Ž.; Das, D.K.; Tešić, R.; Vidas, M.; Vojinović, D. Objective Criticism and Negative Conclusions on Using the Fuzzy SWARA Method in Multi-Criteria Decision Making. *Mathematics* **2022**, *10*, 635. https://doi.org/10.3390/math10040635

Academic Editors: Santoso Wibowo and Michael Li

Received: 31 January 2022
Accepted: 15 February 2022
Published: 18 February 2022

1. Introduction

In today's modern conditions of operating in various fields, adequate decision making is a need on the one hand, and a challenge on the other. There is a need for constant consideration of multi-criteria decision-making (MCDM) problems and evaluation of alternative solutions. If we add to this the increasing presence of uncertainty and the need for more precise decision making, then decision makers are faced with an extremely difficult task. The field of MCDM is one of the most developed areas of operational research which, due to a large number of methods, finds its application every day in various fields:

supply chain management [1,2] construction [3,4], marketing [5,6], logistics [7,8], financial management applications [9,10], and many others [11–13]. In conditions when there is a constant search for better, faster, and more efficient solutions, it is unacceptable to apply approaches that make wrong decisions because, in that way, a chain of negative values is created. Taking into account that MCDM is an area of great importance, applicable in all areas that consider multiple criteria and potential solutions, it is necessary to point out the application of certain inadequate approaches that contribute to incorrect decision making. That is the motivation for writing this paper, which is an objective criticism of applying the fuzzy SWARA method in combination with the Chang scale for assessing the mutual significance of criteria. After reviewing the literature, seven different studies have been selected from different fields (logistics, construction industry, financial performance management, and supply chain) that use the fuzzy SWARA method and Chang scale. This combination represents an approach by which incorrect decisions are made and it gives priority to those alternative solutions that essentially do not deserve it. The biggest problem in applying such an approach is the allocation of TFN (1,1,1) for those criteria that are of equal importance. It is necessary to consider the following situation. At the very beginning of a decision-making process, experts, when comparing criteria, indicate that two criteria are of equal importance, and, at the end of the calculation, the values of these criteria differ. By applying this methodology, it is possible to obtain the value of criterion Cj and the next criterion by importance $Cj - 1$, which have a double difference since Cj is twice as important compared to $Cj - 1$. Based on the above, the main hypothesis of the paper is as follows:

H: The application of the fuzzy SWARA method in combination with the Chang scale for assessing the mutual importance of criteria leads to erroneous decision making. Erroneous decision making is manifested through incorrect weights of criteria obtained by applying such an approach, which causally affect the inadequate ranking of alternative solutions.

In addition to setting the hypothesis, this objective criticism also contains several research questions that will be answered in the conclusion of the paper.

RQ1: Is it possible for criteria to have equal value by applying the fuzzy SWARA method and the Chang scale?

RQ2: Does the allocation of TFN (1,1,1) lead to values of criteria that are inconsistent with expert assessment?

RQ3: Do the last-ranked criteria in the fuzzy SWARA method have any influential value on the ranking of alternatives?

RQ4: Is there a great gap between the most significant and last-ranked criteria?

RQ5: Does the most significant criterion have a huge impact on the evaluation of alternative solutions and decision making?

RQ6: What is the impact of the last-ranked criteria on decision making if it is a large set of criteria on the basis of which a decision is made?

In order to make the best possible objective criticism and obtain valid results that confirm the hypothesis, the improved fuzzy SWARA method developed in the previous year has been applied [14]. So far, it has been applied in several studies: In [15], IMF SWARA, based on the Bonferroni aggregator, was used for the analysis of the healthcare system in Bosnia and Herzegovina. The study [16] applied IMF SWARA with fuzzy MABAC (multi-attributive border approximation area comparison) to evaluate the logistics villages in Turkey, while in [17], it was used to determine the importance of criteria for evaluating companies in the transport of dangerous goods.

Taking this into account, it is necessary to prove, through practical examples, that the application of the fuzzy SWARA and Chang scale leads to erroneous decision making in multi-criteria problems.

The rest of the paper is structured as follows. Section 2 provides preliminaries related to the application of fuzzy number operations, the presentation of the inadequate Chang scale for the fuzzy SWARA method, the presentation of the scale that is an integral part of the IMF SWARA method, and other steps of this method. Section 3 presents the overall

research flow by a methodology diagram. All phases of the research are also described. Section 4 includes objective criticism and proofs obtained from previously published studies and comparative analysis. In Section 5, the discussion of the obtained results and objective criticism is given. Finally, Section 6 outlines negative conclusions as a contribution to objective criticism.

2. Preliminaries

2.1. Preliminaries—Operations with Fuzzy Numbers

The basic operations with TFNs are presented here primarily because of Section 4.6 and two examples in which the following equations have not been complied with. The operational laws of TFN are $\overline{Y} = (l_1, m_1, u_1)$ and $\overline{Y} = (l_2, m_2, u_2)$ [18,19].

Addition:

$$\overline{Y_1} + \overline{Y_2} = (l_1, m_1, u_1) + (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2). \tag{1}$$

Multiplication:

$$\overline{Y_1} \times \overline{Y_2} = (l_1, m_1, u_1) \times (l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \tag{2}$$

$$\overline{Y_1} - \overline{Y_2} = (l_1, m_1, u_1) - (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2). \tag{3}$$

Division:

$$\frac{\overline{Y_1}}{\overline{Y_2}} = \frac{(l_1, m_1, u_1)}{(l_2, m_2, u_2)} = \left(\frac{l_1}{u_2}, \frac{m_1}{m_2}, \frac{u_1}{l_2}\right). \tag{4}$$

Reciprocal:

$$\overline{Y_1}^{-1} = (l_1, m_1, u_1)^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right). \tag{5}$$

2.2. Linguistic Triangular Fuzzy Scales for Criteria Assessment

In this section, two linguistic scales that are the subject of discussion further in the paper are presented and the examples analyzed. The first linguistic scale to be transformed into TFNs is essentially the Chang scale (Table 1) used in the fuzzy AHP (Analytic Hierarchy Process) method. The authors of [20] used the Chang scale [21,22] to compare the significance of criteria when extending the SWARA method with TFNs, which led to studies with incorrect weight values of criteria and incorrect decisions.

Table 1. Inadequate scale for comparing criteria by the fuzzy SWARA method.

Linguistic Scale	Abbreviation	Response Scale
Equally important	EI	(1,1,1)
Moderately less important	MLI	(2/3,1,3/2)
Less important	LI	(2/5,1/2,2/3)
Very less important	VLI	(2/7,1/3,2/5)
Much less important	MLI	(2/9,1/4,2/7)

The difference between the fuzzy AHP procedure and fuzzy SWARA method is obvious, so applying the Chang scale in combination with the fuzzy SWARA method procedure yields erroneous results. It can be improved by applying a slightly different scale shown in Table 2. The authors in [14] have noticed this and created the IMF SWARA method that uses an adequate scale and solves the problems of the previous inadequate assessment scale, which will be proven in this paper.

Table 2. Linguistics and the TFN scale for comparing criteria in the IMF SWARA method.

Linguistic Variable	Abbreviation	TFN Scale
Absolutely less significant	ALS	(1,1,1)
Dominantly less significant	DLS	(1/2,2/3,1)
Much less significant	MLS	(2/5,1/2,2/3)
Really less significant	RLS	(1/3,2/5,1/2)
Less significant	LS	(2/7,1/3,2/5)
Moderately less significant	MDLS	(1/4,2/7,1/3)
Weakly less significant	WLS	(2/9,1/4,2/7)
Equally significant	ES	(0,0,0)

2.3. IMF SWARA

Step 1: The criteria was arranged in descending order based on their expected significance.

Step 2: Starting from the previously determined rank, the significance of the criterion (Cj) was determined in relation to the previous one ($Cj-1$), and this was repeated for each subsequent criterion. This relation is marked with $\overline{\varsigma_j}$.

Step 3: The fuzzy coefficient was determined $\overline{\vartheta_j}$:

$$\overline{\vartheta_j} = \begin{cases} (1,1,1) & j = 1 \\ \overline{\varsigma_j} & j > 1 \end{cases}. \tag{6}$$

Step 4: The calculated weights were determined $\overline{\varepsilon_j}$:

$$\overline{\varepsilon_j} = \begin{cases} (1,1,1) & j = 1 \\ \frac{\overline{\varepsilon_{j-1}}}{\overline{\vartheta_j}} & j > 1 \end{cases}. \tag{7}$$

Step 5: The fuzzy weight coefficients were calculated using the following Equation:

$$\overline{w_j} = \frac{\overline{\varepsilon_j}}{\sum_{j=1}^{m} \overline{\varepsilon_j}} \tag{8}$$

where w_j represents the fuzzy relative weight of the criteria j, and m represents the total number of criteria.

3. Methodology

Figure 1 presents a methodology that shows erroneous decision making by applying the fuzzy SWARA method with the Chang scale. The overall procedure with the areas of examples analyzed is defined through three phases.

The first phase of the methodology involves recognizing the need for research and creating such an objective criticism of applying the fuzzy SWARA method in combination with the Chang scale. Then, data are collected through a review of the literature and a selection of several studies containing erroneous decision making. The criterion for the selection of these studies was the availability of data in each study individually in order to be able to compare the fuzzy SWARA and IMF SWARA method. Seven studies in the field of logistics, supply chain management, intermodal transport, construction industry, and financial performance, have been selected and are presented in the second phase of the methodology.

A complete calculation of selected studies and proofs confirming the objective criticism of applying the fuzzy SWARA method are given in the third phase of the methodology. For two studies, the calculation has been performed at two levels of the hierarchical structure because the criteria are classified into several main groups, while for the other studies, there is one level of the hierarchy of criterion classification.

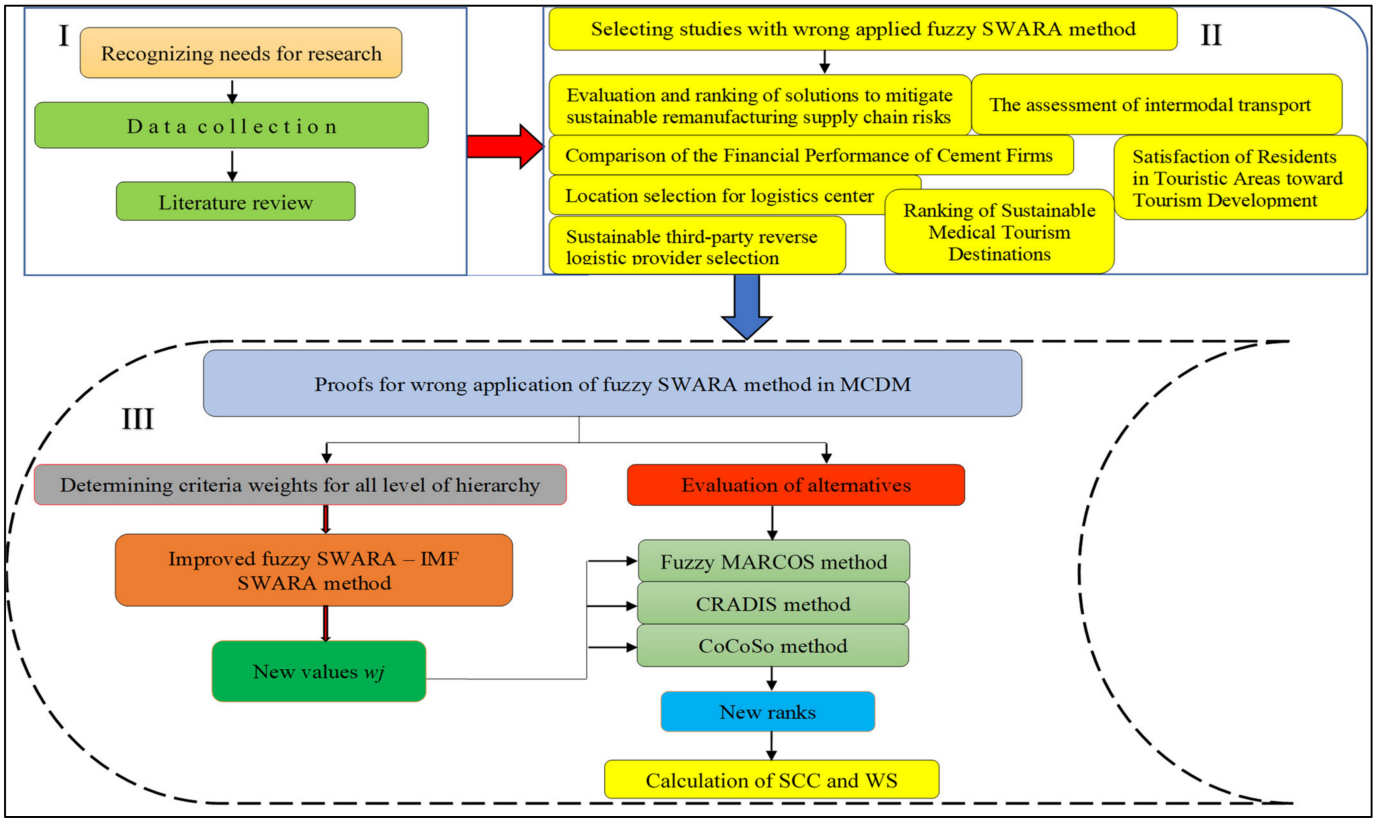


Figure 1. Methodology which proves the wrong application of fuzzy SWARA method in some MCDM studies.

The IMF SWARA method [14] was applied, and new values of all criteria were obtained. In addition to the proofs of changes in the values of weight coefficients, in order to further provide proofs related to objective criticism, the evaluation and ranking of alternative solutions was done. Depending on the availability of data, observing each study individually and the possibility of recreating the model, the fuzzy MARCOS (measurement of alternatives and ranking according to compromise solution) [23], CRADIS (compromise ranking of alternatives from distance to ideal solution) [24], and CoCoSo (combined compromise solution) method were applied [25]. Statistical correlation coefficients SCC (Spearman's correlation coefficient) [26] and WS [27] were calculated for certain examples.

4. Objective Criticism on Using the Fuzzy SWARA Method in Multi-Criteria Decision Making

In this section, a total of seven examples of different studies using the fuzzy SWARA method based on an inadequate linguistic scale are presented. As a result, incorrect decisions are made and priority is given to those alternatives that essentially do not deserve it. The biggest problem with the application of fuzzy SWARA on the basis of inadequate scale is the allocation of a triangular fuzzy number (1,1,1) for those criteria that are of equal importance. Thus, at the very beginning of a decision-making process, experts, when comparing criteria, indicate that two or more criteria have equal importance, and in the end, the values of these criteria show otherwise. Applying this methodology, it is possible to obtain the values of criterion Cj and the next criterion by importance $Cj - 1$, which has a double difference because Cj is twice as important compared to $Cj - 1$, however they should have equal importance. Therefore, it is proved below through examples that the application of inadequate linguistic scale in the fuzzy SWARA method proposed by the authors developing this method contributes to erroneous decision making in multi-criteria problems. Depending on the examples, proving the misapplication of the fuzzy SWARA method has been done in two ways. The first implies that only the criteria with allocated

TFN (1,1,1), Scenario 1 (S1), have been observed, thus these values were transformed into TFN (0,0,0) in order for the criteria to have equal importance. The second involves the application of the IMF SWARA method, i.e., the complete linguistic scale, and based on it, the calculation of weight coefficients.

4.1. Study 1—Evaluation and Ranking of Solutions to Mitigate Sustainable Remanufacturing Supply Chain Risks: A Hybrid Fuzzy SWARA-Fuzzy COPRAS Framework Approach

In this example [28], a combination of fuzzy SWARA and fuzzy COPRAS (COmplex PRoportional Assessment) methods was used to evaluate and rank 12 alternative solutions based on 24 criteria arranged by three main criteria: economic (ER), environmental (ENVR), and social (SR). The first group contains 10 sub-criteria, the second contains 6 sub-criteria, and the third contains 8. When applying the fuzzy SWARA method, the main criteria have the following values: ER = (0.478,0.526,0.584), ENVR = (0.191,0.263,0.351), and SR = (0.149,0.211,0.287). When comparing the main criteria, there is no equal importance, therefore we move immediately onto the second scenario, which involves the application of the IMF SWARA method. Instead of the linguistic designation MLI, DLS was assigned because the complete linguistic scale in the IMF SWARA method was reduced to the interval 0–1, as previously stated. The comparison of the second and third criteria remained the same. The results show that there are some changes in the weight values of the main criteria ER = (0.452,0.481,0.529), ENVR = (0.226,0.288,0.353), and SR = (0.176,0.231,0.289), which is not a significant change, however it is important due to further calculation and major changes that occur in sub-criteria, especially in the sub-criteria of the economic and environmental group. Table 3 shows a comparative analysis of the values of the economic group sub-criteria, applying all three previously described scenarios (original fuzzy SWARA, Scenario 1–change of linguistic designation only for criteria assigned with equal importance and the IMF SWARA method).

Table 3. Weights of the sub-criteria of the economic group.

	Original Fuzzy SWARA		**Scenario 1**		**IMF SWARA**	
Criteria	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**
ER01	(0.005,0.012,0.022)	(0.003,0.006,0.013)	(0.007,0.015,0.029)	(0.003,0.008,0.017)	(0.008,0.017,0.03)	(0.004,0.008,0.016)
ER02	(0.009,0.018,0.033)	(0.004,0.01,0.019)	(0.011,0.024,0.044)	(0.005,0.012,0.025)	(0.013,0.026,0.045)	(0.006,0.013,0.024)
ER03	(0.047,0.074,0.106)	(0.023,0.039,0.062)	(0.059,0.095,0.141)	(0.028,0.05,0.082)	(0.07,0.105,0.144)	(0.032,0.05,0.076)
ER04	(0.079,0.111,0.149)	(0.038,0.058,0.087)	(0.099,0.142,0.198)	(0.047,0.075,0.115)	(0.117,0.157,0.202)	(0.053,0.075,0.107)
ER05	(0.198,0.221,0.248)	(0.095,0.116,0.145)	(0.247,0.284,0.329)	(0.118,0.15,0.192)	(0.234,0.262,0.303)	(0.106,0.126,0.161)
ER06	(0.017,0.033,0.054)	(0.008,0.017,0.032)	(0.021,0.042,0.072)	(0.01,0.022,0.042)	(0.025,0.047,0.074)	(0.011,0.022,0.039)
ER07	(0.012,0.025,0.042)	(0.006,0.013,0.025)	(0.015,0.032,0.056)	(0.007,0.017,0.033)	(0.018,0.035,0.057)	(0.008,0.017,0.03)
ER08	(0.396,0.443,0.495)	(0.189,0.233,0.289)	(0.247,0.284,0.329)	(0.118,0.15,0.192)	(0.234,0.262,0.303)	(0.106,0.126,0.161)
ER09	(0.007,0.015,0.027)	(0.003,0.008,0.016)	(0.008,0.019,0.036)	(0.004,0.01,0.021)	(0.01,0.021,0.036)	(0.005,0.01,0.019)
ER10	(0.028,0.049,0.076)	(0.014,0.026,0.044)	(0.036,0.063,0.101)	(0.017,0.033,0.059)	(0.042,0.07,0.103)	(0.019,0.034,0.055)

From Table 3, certain differences can be seen in the weights of criteria that cause erroneous decision making or that potentially give priority to alternatives that do not deserve it, taking into account the aspect of the importance of criteria. In S1, which is also a part of the IMF SWARA method, the linguistic scale EI was changed into ES, while in the application of the IMF SWARA method, MLI was additionally transformed into DLS. Other linguistic values remained unchanged in order to more clearly prove the negative impact of the linguistic scale in the original fuzzy SWARA method. If considering the values of the sub-criteria ER08 and ER05, which the experts have indicated to be of equal importance, it can be seen that this is not the case with the fuzzy SWARA method. On the contrary, ER08 with values of (0.396,0.443,0.495), is twice as important as ER05 = (0.198,0.221,0.248), which was corrected in further analysis. By allocating TFN (0,0,0) instead of (1,1,1), this problem is solved, so in S1 and applying the IMF SWARA method, these criteria have equal importance of (0.247,0.284,0.329) and (0.234,0.262,0.303), respectively. By transforming MLI into DLS,

i.e., (2/3,1,3/2) in (1/2,2/3,1), the difference between the criteria is further reduced. In this case, it has been done with the criterion ER04 and it thus gain more importance.

Table 4 shows the analysis of the values of the social group sub-criteria.

Table 4. Weights of the sub-criteria of social group.

	Original Fuzzy SWARA		Scenario 1		IMF SWARA	
Criteria	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**
SR1	(0.388,0.467,0.562)	(0.058,0.099,0.161)	(0.388,0.467,0.562)	(0.058,0.099,0.161)	(0.348,0.396,0.478)	(0.061,0.091,0.138)
SR2	(0.021,0.047,0.092)	(0.003,0.01,0.026)	(0.021,0.047,0.092)	(0.003,0.01,0.026)	(0.029,0.057,0.097)	(0.005,0.013,0.028)
SR3	(0.155,0.233,0.337)	(0.023,0.049,0.097)	(0.155,0.233,0.337)	(0.023,0.049,0.097)	(0.174,0.238,0.319)	(0.031,0.055,0.092)
SR4	(0.037,0.078,0.145)	(0.006,0.016,0.041)	(0.037,0.078,0.145)	(0.006,0.016,0.041)	(0.052,0.095,0.152)	(0.009,0.022,0.044)
SR5	(0.062,0.117,0.202)	(0.009,0.025,0.058)	(0.062,0.117,0.202)	(0.009,0.025,0.058)	(0.087,0.143,0.213)	(0.015,0.033,0.061)
SR6	(0.027,0.058,0.112)	(0.004,0.012,0.032)	(0.027,0.058,0.112)	(0.004,0.012,0.032)	(0.037,0.071,0.118)	(0.007,0.016,0.034)

In this example, the sub-criteria of the social group have the least sensitivity to changes since, according to experts, no criterion has been assigned the linguistic designated EI, i.e., there are no criteria that are of equal importance. This is the reason for the same values of the sub-criteria of this group in the original fuzzy SWARA and Scenario 1. When applying the IMF SWARA method, the difference between SR3 and SR5 was reduced because of the transformation of MLI into DLS, i.e., (2/3,1,3/2) in (1/2,2/3,1).

Table 5 shows the analysis of the values of the environmental group sub-criteria.

Table 5. Weights of the sub-criteria of the environmental group.

	Original Fuzzy SWARA		Scenario 1		IMF SWARA	
Criteria	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**
ENVR1	(0.429,0.479,0.528)	(0.082,0.126,0.185)	(0.273,0.315,0.359)	(0.052,0.083,0.126)	(0.252,0.28,0.322)	(0.057,0.081,0.114)
ENVR2	(0.215,0.239,0.264)	(0.041,0.063,0.093)	(0.273,0.315,0.359)	(0.052,0.083,0.126)	(0.252,0.28,0.322)	(0.057,0.081,0.114)
ENVR3	(0.034,0.06,0.095)	(0.007,0.016,0.033)	(0.044,0.079,0.129)	(0.008,0.021,0.045)	(0.063,0.101,0.143)	(0.014,0.029,0.051)
ENVR4	(0.086,0.12,0.158)	(0.016,0.031,0.056)	(0.109,0.157,0.215)	(0.021,0.041,0.076)	(0.126,0.168,0.215)	(0.028,0.048,0.076)
ENVR5	(0.007,0.016,0.031)	(0.001,0.004,0.011)	(0.009,0.021,0.042)	(0.002,0.006,0.015)	(0.013,0.027,0.046)	(0.003,0.008,0.016)
ENVR6	(0.009,0.02,0.038)	(0.002,0.005,0.013)	(0.011,0.026,0.051)	(0.002,0.007,0.018)	(0.016,0.034,0.057)	(0.004,0.01,0.02)
ENVR7	(0.012,0.027,0.048)	(0.002,0.007,0.017)	(0.016,0.035,0.066)	(0.003,0.009,0.023)	(0.023,0.045,0.073)	(0.005,0.013,0.026)
ENVR8	(0.021,0.04,0.068)	(0.004,0.01,0.024)	(0.026,0.052,0.092)	(0.005,0.014,0.032)	(0.038,0.067,0.102)	(0.009,0.019,0.036)

From Table 5, certain differences in significance and values can be noticed if the values of the sub-criteria ENVR1 and ENVR2 are observed. For these sub-criteria, experts have indicated that they are of equal importance, which certainly is not the case with the fuzzy SWARA method. As in all other cases where TFN (1,1,1) has been incorrectly allocated, one sub-criterion has twice the value compared to the other. In this case, these are the criteria ENVR1 and ENVR2 with values of (0.429,0.479,0.528) and (0.215,0.239,0.264), respectively. By allocating TFN (0,0,0) instead of (1,1,1), this problem is solved, thus in S1 and using the IMF SWARA method, these criteria have equal importance of (0.273,0.315,0.359) and (0.252,0.28,0.322), respectively. By transforming MLI into DLS, i.e., (2/3,1,3/2) in (1/2,2/3,1), the difference between the criteria is further reduced. In this case, it has been done with the sub-criteria ENVR4 and ENVR3 and they thus obtain higher values.

Through a previous comparative analysis, it has been proven that the application of the fuzzy SWARA method based on the linguistic Chang scale leads to erroneous results in terms of criterion values. If experts or any other decision makers have indicated that two criteria are of equal importance, then their values must be identical too. The question further arises as to how these weights affect decision making, i.e., the evaluation and ranking of a set of alternative solutions. Since studies usually (it is the case here too) do not provide enough data to recreate the model, a new MCDM model was formed in which

all previous weights were included in order to clearly identify the difference. A set of 10 alternatives was formed and the fuzzy MARCOS method was applied to rank them. Table 6 shows the results obtained.

Table 6. Results obtained by applying the fuzzy MARCOS method with different weights of criteria.

Alternatives	Original Fuzzy SWARA		S1		IMF SWARA	
A1	0.736	9	0.764	9	0.723	9
A2	0.882	3	0.943	2	0.888	2
A3	0.827	5	0.878	3	0.829	4
A4	0.916	1	0.987	1	0.931	1
A5	0.667	10	0.739	10	0.693	10
A6	0.756	8	0.814	8	0.769	8
A7	0.781	7	0.871	7	0.831	3
A8	0.822	6	0.873	6	0.821	5
A9	0.864	4	0.874	5	0.810	6
A10	0.907	2	0.876	4	0.800	7

As can be seen from Table 6, there are significant changes in the ranking of alternatives in relation to the application of weights obtained with the fuzzy SWARA method. Only four of the 10 alternatives retain their original rankings, while the ranking of the alternative A10 changes by as many as five places. When the original weights of the criteria obtained by the SWARA method are included in fuzzy MARCOS, A10 takes a high second place, while when applying the IMF SWARA method, it takes a low seventh place. It implies the inadequacy of the application of the fuzzy SWARA method in combination with the linguistic Chang scale. Since there were changes in the rankings, the statistical correlation test was calculated using the WS and Spearman's correlation coefficient of 0.790 and 0.709, respectively, when observing the fuzzy SWARA and IMF SWARA method.

4.2. Study 2—Comparison of the Financial Performance of Turkish Cement Firms with Fuzzy SWARA-COPRASMAUT Methods

In this example [29], a combination of the fuzzy SWARA, COPRAS, and MAUT (Multi-attribute utility theory) method was used to evaluate and rank 12 companies in the construction industry based on 10 criteria. The aim of the study was to determine the ranking of companies based on financial performances, such as market value, book value, profit and sales ratios, capital, etc.

When applying fuzzy SWARA to compare financial performances, decision makers have estimated that a large number of criteria should be of equal importance. The criteria in pairs are F03 and F04, F05 and F06, F07 and F08, and F09 and F10, however the former always has twice the value due to the inadequate linguistic scale that is transformed into TFNs. Table 7 shows a comparative analysis for financial performances used as criteria in the study.

Table 7. Weights of 10 financial performances.

Criteria	Original Fuzzy SWARA	S1	IMF SWARA
F01	(0.348,0.383,0.425)	(0.234,0.276,0.329)	(0.218,0.247,0.294)
F02	(0.248,0.287,0.331)	(0.167,0.207,0.256)	(0.156,0.185,0.229)
F03	(0.099,0.144,0.198)	(0.067,0.103,0.154)	(0.078,0.111,0.153)
F04	(0.05,0.072,0.099)	(0.067,0.103,0.154)	(0.078,0.111,0.153)
F05	(0.035,0.054,0.077)	(0.048,0.078,0.12)	(0.056,0.083,0.119)
F06	(0.018,0.027,0.039)	(0.048,0.078,0.12)	(0.056,0.083,0.119)
F07	(0.011,0.018,0.028)	(0.029,0.052,0.085)	(0.033,0.056,0.085)
F08	(0.005,0.009,0.014)	(0.029,0.052,0.085)	(0.033,0.056,0.085)
F09	(0.002,0.004,0.008)	(0.011,0.026,0.051)	(0.017,0.033,0.057)
F10	(0.001,0.002,0.004)	(0.011,0.026,0.051)	(0.017,0.033,0.057)

From Table 7, it can be noted that there are quite large differences in the weights of financial performances since a large number of criteria in pairs should have the same value because the decision maker indicated so in the initial evaluation, however unfortunately the calculation is completely different. In S1, which is also a part of the IMF SWARA method, the linguistic scale EI was changed into ES for F09, F08, F04, and F06, while when applying the IMF SWARA method, MLI was additionally transformed into DLS for F10 and F05. Other linguistic values have remained unchanged. If considering financial performances in pairs that should have the same values, F03 and F04, F05 and F06, F07 and F08, and F09 and F10, the following values can be noticed: (0.099,0.144,0.198) and (0.05,0.072,0.099), (0.035,0.054,0.077) and (0.018,0.027,0.039), (0.011,0.018,0.028) and (0.005,0.009,0.014), and (0.002,0.004,0.008) and (0.001,0.002,0.004), respectively. Forming S1 and applying the IMF SWARA method, these financial performances in pairs have the same values as necessary, based on the initial assessment of decision makers: F03 = F04 = (0.078,0.111,0.153), F05 = F06 = (0.056,0.083,0.119), F07 = F08 = (0.033,0.056,0.085), and F09 = F10 = (0.017,0.033,0.057).

By transforming MLI into DLS, i.e., (2/3,1,3/2) in (1/2,2/3,1), the difference between the criteria is further reduced. In this case, this has been done with the financial performances F05 and F010 and they thus gain higher values. An MCDM model was formed in which previous weights were included in order to clearly identify the difference. A set of a total of 10 alternatives was formed and the CRADIS method was applied to rank them. The CRADIS method was applied in a crisp form because in [29], after the calculation of weight coefficients for financial performances, classical averaging was performed using the average value instead of equations for defuzzification. Therefore, even after the application of the IMF SWARA method, averaging was performed in order to consistently determine the differences in the methods for determining the weights of criteria. Table 8 shows the results obtained using the CRADIS method.

Table 8. Results obtained by applying the CRADIS method with different weights of criteria.

Alternatives	Original Fuzzy SWARA		S1		IMF SWARA	
A1	0.537	10	0.517	9	0.508	9
A2	0.630	8	0.614	5	0.603	6
A3	0.538	9	0.513	10	0.505	10
A4	0.645	6	0.609	7	0.594	7
A5	0.804	2	0.779	2	0.766	2
A6	0.669	4	0.637	4	0.627	4
A7	0.648	5	0.613	6	0.607	5
A8	0.638	7	0.603	8	0.591	8
A9	0.693	3	0.667	3	0.660	3
A10	0.822	1	0.813	1	0.803	1

As can be seen from Table 8, there are significant differences in the ranking of alternatives compared to the application of the original model with weights included from the fuzzy SWARA method. Only the first four alternatives out of a total of 10 retain their original rank, while the rank of alternative A2 changes by three positions. When the original weights of the criteria obtained by the SWARA method are included in CRADIS, A2 takes eighth place, however takes the sixth place by applying the IMF SWARA method, and fifth place in S1. It also implies the inadequacy of the application of the fuzzy SWARA method in combination with the linguistic Chang scale.

4.3. Study 3—Location Selection for a Logistics Center with Fuzzy SWARA and CoCoSo Methods

In [30], a combination of the fuzzy SWARA and CoCoSo method was used to evaluate and rank 12 locations for a logistics center in the Sivas province based on 11 criteria. Therefore, the multi-criteria model involves the calculation of weight coefficients using the fuzzy SWARA method, then defuzzification of weights and their implementation in the CoCoSo method to determine the best location of the logistics center.

When applying fuzzy SWARA to compare the criteria for the location of the logistics center, decision makers have estimated that a large number of criteria should be of equal importance. The criteria in the pairs are proximity to highway (PH), proximity to railway (PR), and proximity to airport (PA), then distance to settlement area (DSA) and cost of land (CL), distance to population density (DPD), and distance to forest area (DFA), however the former always has twice the value as a result of the inadequate linguistic scale that is transformed into TFNs. It is in the case when two consecutive criteria are of equal importance, however when three criteria are of equal importance as is the case with PH, PR, and PA using the fuzzy SWARA method, the first PH has four times the value of PA. Table 9 shows a comparative analysis for the criteria for selecting the location of a logistics center.

Table 9. Weights of 11 criteria for selecting the location of a logistics center.

Criteria	Original Fuzzy SWARA	S1	IMF SWARA
Proximity to industrial area (PIA)	(0.435,0.489,0.554)	(0.242,0.298,0.369)	(0.214,0.248,0.306)
Proximity to highway (PH)	(0.174,0.245,0.332)	(0.097,0.149,0.221)	(0.107,0.149,0.204)
Proximity to railway (PR)	(0.087,0.122,0.166)	(0.097,0.149,0.221)	(0.107,0.149,0.204)
Proximity to airport (PA	(0.044,0.061,0.083)	(0.097,0.149,0.221)	(0.107,0.149,0.204)
Slope of land (SL)	(0.026,0.041,0.059)	(0.058,0.099,0.158)	(0.064,0.099,0.146)
Distance to settlement area (DSA)	(0.01,0.02,0.036)	(0.023,0.05,0.095)	(0.032,0.059,0.097)
Cost of land (CL)	(0.005,0.01,0.018)	(0.023,0.05,0.095)	(0.032,0.059,0.097)
Distance to disaster center (DDC)	(0.002,0.005,0.011)	(0.009,0.025,0.057)	(0.016,0.036,0.065)
Distance to surface water (DSW)	(0.001,0.003,0.008)	(0.006,0.017,0.041)	(0.01,0.024,0.046)
Distance to population density (DPD)	(0.001,0.002,0.005)	(0.002,0.008,0.024)	(0.005,0.014,0.031)
Distance to forest area (DFA)	(0,0.001,0.002)	(0.002,0.008,0.024)	(0.005,0.014,0.031)

From Table 9, note the large differences in the weights of the criteria for selecting the location of a logistics center and although a large number of criteria in pairs should have the same value due to the initial evaluation, however, the calculation is completely different. In S1, which is also a part of the IMF SWARA method, the linguistic scale EI was changed into ES for PR, PA, CL, and DFA, while by applying the IMF SWARA method, MLI was additionally transformed into DLS for PH, DSA, DDC, and DPD. The other two linguistic values remained unchanged. If observing the logistic criteria in pairs that should have the same values, PH, PR, and PA, then DSA and CL, DPD, and DFA, the following values can be noticed: PH = (0.174,0.245,0.332), PR = (0.087,0.122,0.166) and PA = (0.044,0.061,0.083), DSA = (0.01,0.02,0.036) and CL = (0.005,0.01,0.018), DPD = (0.001,0.002,0.005), and DFA = (0,0.001,0.002). Forming S1 and applying the IMF SWARA method, these logistical criteria in pairs have the same values as necessary based on the initial assessment of decision makers: PH = PR = PA = (0.107,0.149,0.204), DSA = CL = (0.032,0.059,0.097), and DPD = DFA = (0.005,0.014,0.031). By transforming MLI into DLS, i.e., (2/3,1,3/2) in (1/2,2/3,1), the difference between the criteria is further reduced. In this case, it has been done with the logistical criteria PH in relation to PIA, DSA in relation to SL, DDC in relation to CL, and DPD in relation to DSW and they thus gain a higher value. Since in the analyzed example [30], there is enough data to recreate the model, then the same methodology was applied, more precisely the CoCoSo method for evaluating the locations of a logistics center. After the calculation of weight coefficients for the logistic criteria, transformation into crisp values was done. Therefore, even after the application of the IMF SWARA method, such a transformation was performed in order to consistently determine the differences in the methods for determining the weights of criteria. Figure 2 shows the results obtained using the CoCoSo method.

As can be seen from Figure 2, there are significant differences in the ranking of alternatives compared to the application of the original model with weights included from the fuzzy SWARA method. Only the first-placed alternative LC4, out of a total of 12, retained its original ranking, while the ranking of other alternatives changed by even a few positions, e.g., LC2 and LC5 by four positions. From this, the inadequacy of the application of the fuzzy SWARA method in combination with the linguistic Chang scale can be seen.

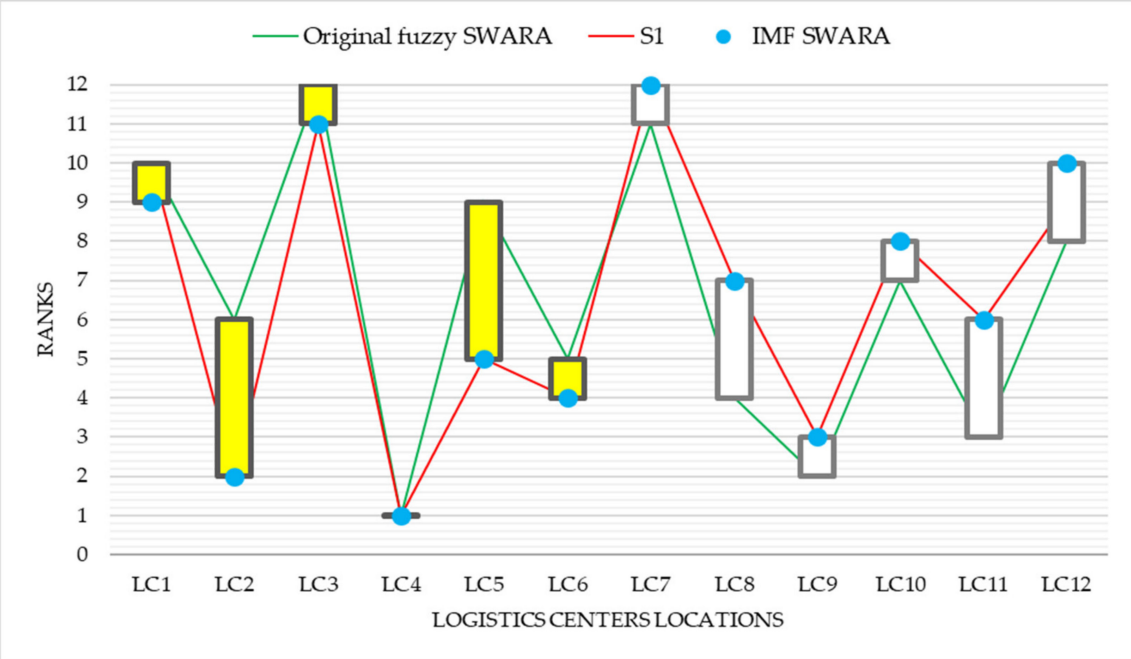


Figure 2. Results obtained by applying the CoCoSo method.

4.4. Study 4—Sustainable Third-Party Reverse Logistic Provider Selection with Fuzzy SWARA and Fuzzy MOORA in Plastic Industry

In the paper [20], the fuzzy SWARA method for third-party reverse logistic provider selection is developed and applied for the first time. It is integrated with the fuzzy MOORA method in order to evaluate and rank nine alternative solutions based on 23 criteria distributed through four main criteria: economic, environmental, social, and risk. The first group contains eight sub-criteria, the second and third contains six sub-criteria, and the fourth three. When applying the fuzzy SWARA method, the main criteria have the following values: EC = (0.377,0.405,0.444), ENV = (0.226,0.27,0.317), SC = (0.176,0.216,0.259), and R = (0.07,0.108,0.156). When comparing the main criteria, there is no equal importance, thus it has been immediately moved onto the second scenario, which involves the application of the complete IMF SWARA method. Instead of the linguistic designation MLI, DLS was assigned for the relation of C3 and C4, while the comparison of the first and second criterion remained the same. The results show that there were some changes in the weight values of the main criteria, EC = (0.372,0.397,0.435), ENV = (0.223,0.265,0.311), SC = (0.174,0.212,0.254), and R = (0.087,0.127,0.169), which is not a great change, however it is important due to further calculation and considerable changes that occur in the sub-criteria. Table 10 shows a comparative analysis of the values of economic group sub-criteria using the fuzzy SWARA and IMF SWARA method.

Table 10. The weights of the sub-criteria of economic group for selecting a logistics provider.

	Original Fuzzy SWARA		IMF SWARA	
Criteria	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**
C1	(0.292,0.319,0.351)	(0.11,0.129,0.156)	(0.261,0.287,0.325)	(0.097,0.114,0.141)
C2	(0.209,0.239,0.273)	(0.079,0.097,0.121)	(0.186,0.215,0.253)	(0.069,0.085,0.11)
C3	(0.162,0.191,0.223)	(0.061,0.078,0.099)	(0.145,0.172,0.207)	(0.054,0.068,0.09)
C4	(0.097,0.127,0.16)	(0.037,0.052,0.071)	(0.087,0.115,0.148)	(0.032,0.046,0.064)
C5	(0.039,0.064,0.096)	(0.015,0.026,0.042)	(0.043,0.069,0.098)	(0.016,0.027,0.043)
C6	(0.019,0.032,0.048)	(0.007,0.013,0.021)	(0.043,0.069,0.098)	(0.016,0.027,0.043)
C7	(0.008,0.016,0.029)	(0.003,0.006,0.013)	(0.022,0.041,0.066)	(0.008,0.016,0.029)
C8	(0.006,0.012,0.022)	(0.002,0.005,0.01)	(0.016,0.031,0.051)	(0.006,0.012,0.022)

From Table 10, certain differences can be noticed in the weights of criteria that cause erroneous decision making, or potentially give priority to alternatives that do not deserve it, in terms of the importance of criteria. When applying the IMF SWARA method, MLI was transformed into DLS for criterion C5 in relation to C4 and C7 in relation to C6, while for the relation of C6 and C5, the conversion of TFN (1,1,1) to (0,0,0) was done. Other linguistic values have remained unchanged. If observing the values of sub-criteria C5 and C6, which the experts have indicated to be of equal importance, it can be seen that this is not the case with the fuzzy SWARA method. On the contrary, C5 with a value of (0.039,0.064,0.096) is twice as important as C6 = (0.019,0.032,0.048), which was corrected in further analysis. By allocating TFN (0,0,0) instead of (1,1,1), this problem is solved, so by applying the IMF SWARA method, these criteria are of equal importance (0.043,0.069,0.098). By transforming MLI into DLS, i.e., (2/3,1,3/2) in (1/2,2/3,1), the difference between the criteria is further reduced. In this case, it has been done for criterion C5 in relation to C4 and C7 in relation to C6, and they gain more importance.

Table 11 shows the analysis of the value of the environmental group sub-criteria.

Table 11. The weights of the sub-criteria of environmental group for selecting a logistics provider.

	Original Fuzzy SWARA		IMF SWARA	
Criteria	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**
C1	(0.341,0.354,0.372)	(0.077,0.096,0.118)	(0.247,0.26,0.278)	(0.055,0.069,0.086)
C2	(0.266,0.283,0.304)	(0.06,0.077,0.096)	(0.192,0.208,0.227)	(0.043,0.055,0.071)
C3	(0.133,0.142,0.152)	(0.03,0.038,0.048)	(0.192,0.208,0.227)	(0.043,0.055,0.071)
C4	(0.08,0.094,0.109)	(0.018,0.026,0.034)	(0.115,0.139,0.162)	(0.026,0.037,0.05)
C5	(0.062,0.076,0.089)	(0.014,0.02,0.028)	(0.09,0.111,0.133)	(0.02,0.029,0.041)
C6	(0.037,0.05,0.063)	(0.008,0.014,0.02)	(0.054,0.074,0.095)	(0.012,0.02,0.029)

From Table 11, certain differences in the weights of the criteria can be seen. When applying the IMF SWARA method, the conversion of TFN (1,1,1) into (0,0,0) for the relation of C2 and C3 was done. Other linguistic values have remained unchanged. If observing the values of sub-criteria C2 and C3 with the values (0.266,0.283,0.304) and (0.133,0.142,0.152), respectively, it can be noticed that C2 is twice as important in relation to C3. By allocating TFN (0,0,0) instead of (1,1,1), this problem is solved, so by applying the IMF SWARA method these criteria are of equal importance (0.192,0.208,0.227).

Table 12 shows the analysis of the values of social group sub-criteria.

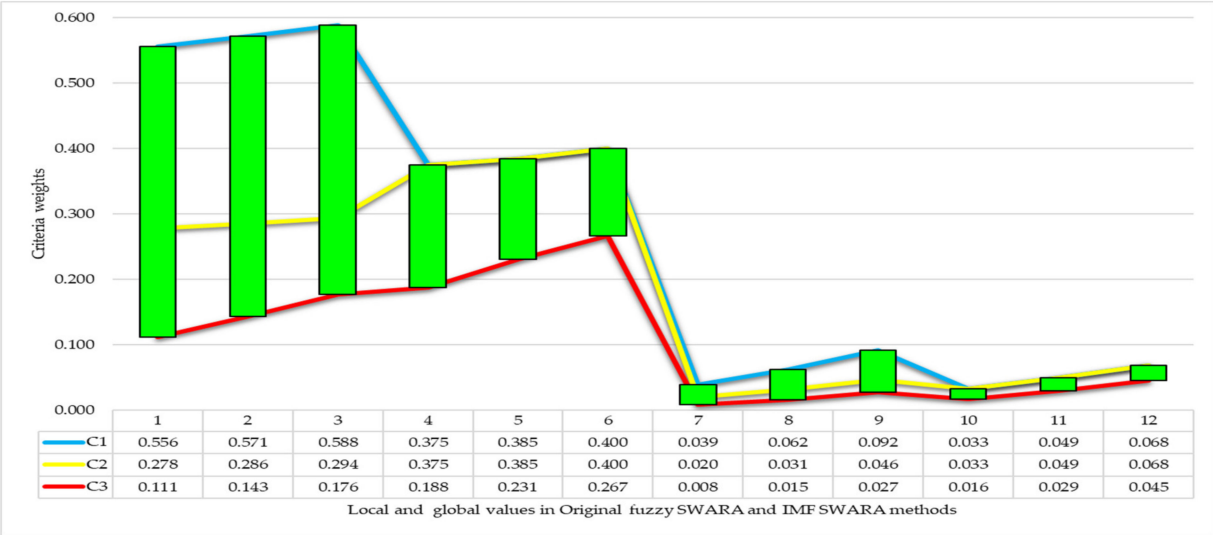
Table 12. The weight of the sub-criteria of social group for selecting a logistics provider.

	Original Fuzzy SWARA		IMF SWARA	
Criteria	**Local w_j**	**Global w_j**	**Local w_j**	**Global w_j**
C1	(0.349,0.38,0.416)	(0.061,0.082,0.108)	(0.278,0.301,0.338)	(0.048,0.064,0.086)
C2	(0.271,0.304,0.34)	(0.048,0.066,0.088)	(0.216,0.241,0.277)	(0.037,0.051,0.07)
C3	(0.109,0.152,0.204)	(0.019,0.033,0.053)	(0.108,0.145,0.185)	(0.019,0.031,0.047)
C4	(0.054,0.076,0.102)	(0.01,0.016,0.026)	(0.108,0.145,0.185)	(0.019,0.031,0.047)
C5	(0.033,0.051,0.073)	(0.006,0.011,0.019)	(0.065,0.096,0.132)	(0.011,0.02,0.033)
C6	(0.023,0.038,0.057)	(0.004,0.008,0.015)	(0.046,0.072,0.103)	(0.008,0.015,0.026)

From Table 12, certain differences in significance and values can be noticed if the values of sub-criteria C3 and C4 are observed. For these sub-criteria, experts have indicated that they are of equal importance, which is not the case with the fuzzy SWARA method. As in all other cases where TFN (1,1,1) has been incorrectly allocated, one sub-criterion has twice the value compared to the other. In this case, these are criteria C3 and C4 with values of (0.109,0.152,0.204) and (0.054,0.076,0.102), respectively. By allocating TFN (0,0,0) instead of (1,1,1), this problem is solved, so by applying the IMF SWARA method, these criteria have equal importance of (0.108,0.145,0.185). By transforming MLI into DLS, i.e.,

(2/3,1,3/2) in (1/2,2/3,1), the difference between the criteria is further reduced. In this case, this has been done with sub-criterion C3 in relation to sub-criterion C2.

Figure 3 shows the analysis of the value of risk group sub-criteria.



	1	2	3	4	5	6	7	8	9	10	11	12
C1	0.556	0.571	0.588	0.375	0.385	0.400	0.039	0.062	0.092	0.033	0.049	0.068
C2	0.278	0.286	0.294	0.375	0.385	0.400	0.020	0.031	0.046	0.033	0.049	0.068
C3	0.111	0.143	0.176	0.188	0.231	0.267	0.008	0.015	0.027	0.016	0.029	0.045

Figure 3. The weights of the sub-criteria of risk group for selecting a logistics provider.

From Figure 3, certain differences in values can be noticed when it comes to all three sub-criteria. Figure 3 shows the local and global weights of the three sub-criteria belonging to the risk group using the fuzzy SWARA and IMF SWARA method. For sub-criteria C1 and C2, experts have indicated that they have equal significance, which is not the case with the fuzzy SWARA method. In this case, sub-criterion C1 with a value of (0.556,0.571,0.588) has a double advantage over sub-criterion C2 (0.278,0.286,0.294). By allocating TFN (0,0,0) instead of (1,1,1), this problem is solved, so these criteria have equal importance of (0.375,0.385,0.400) by applying the IMF SWARA method. By transforming MLI into DLS, i.e., (2/3,1,3/2) in (1/2,2/3,1), the difference between sub-criteria C2 and C3 is further reduced.

Since studies usually (it is the case here too) do not have enough data to recreate the model, a new MCDM model was formed in which all previous weights were included in order to clearly identify the difference. A set of 10 alternatives was formed and the fuzzy MARCOS method was applied to rank them. Figure 4 shows the results obtained.

As can be seen from Figure 4, there are differences in the rankings of alternatives. Four out of 10 alternatives change their original ranking, while the other rankings of the alternatives do not change. Alternatives that change their ranks do so by only one position, so they are not large changes, which is partially due to a large set of criteria.

4.5. Study 5—The Assessment of Intermodal Transport in Countries of the Danube Region

In [31], the integration of the fuzzy SWARA and fuzzy MARCOS method was performed in order to assess the status of the countries of the Danube region in terms of intermodal transport. Therefore, a total of 14 countries were evaluated that represent alternatives based on a total of seven criteria from the aspect of neutral, service users, and service providers. The following is an example based on data related to service users.

When applying fuzzy SWARA to compare the criteria for assessing the status of countries in terms of intermodal transport, service users have estimated that the following criteria, C7, C1, and C4, i.e., C2 and C3 should be of equal importance to each other. Here there is a similar situation as in example 4.3 since three criteria should be at the same level in terms of significance. As stated, the former always has twice the value due to the inadequate linguistic scale that is transformed into TFNs. It is in the case when two consecutive criteria are of equal importance, and in the case of three criteria of equal

importance as is the case with C7, C1, and C4 using the fuzzy SWARA method, the first C7 has four times the value of C4.

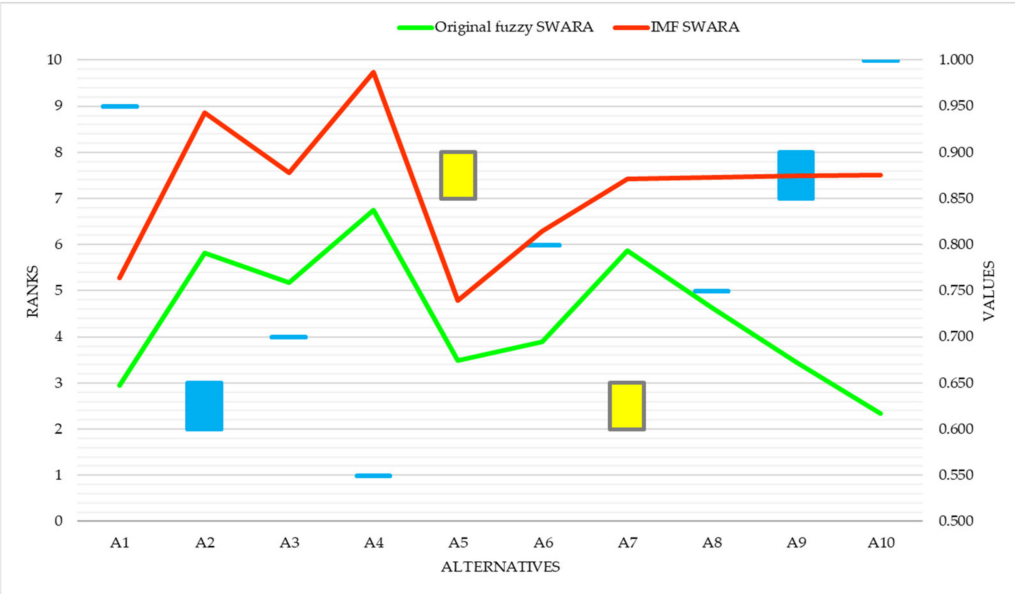


Figure 4. Results by applying the fuzzy MARCOS method with different weights of criteria for selecting a logistics provider.

Table 13 shows a comparative analysis of the criteria for assessing countries from the aspect of intermodal transport.

Table 13. Weights of seven criteria for assessing the status of intermodal transport.

Criteria	Original Fuzzy SWARA	S1	IMF SWARA
C1	(0.088,0.122,0.164)	(0.103,0.15,0.216)	(0.119,0.158,0.206)
C2	(0.019,0.03,0.046)	(0.044,0.075,0.12)	(0.051,0.079,0.115)
C3	(0.009,0.015,0.023)	(0.044,0.075,0.12)	(0.051,0.079,0.115)
C4	(0.044,0.061,0.082)	(0.103,0.15,0.216)	(0.119,0.158,0.206)
C5	(0.026,0.041,0.059)	(0.062,0.1,0.154)	(0.071,0.105,0.147)
C6	(0.438,0.487,0.548)	(0.257,0.3,0.359)	(0.237,0.263,0.31)
C7	(0.175,0.244,0.329)	(0.103,0.15,0.216)	(0.119,0.158,0.206)

From Table 13, certain differences in the weights of criteria for assessing the status of intermodal transport in the Danube region can be noticed since a large number of criteria in pairs should have the same value due to the initial assessment, however the results show otherwise. In S1, which is also a part of the IMF SWARA method, the linguistic scale EI was changed into ES for C7, C1, and C4 as one set and C2 and C3 as another set, while when applying the IMF SWARA method, MLI was additionally transformed into DLS for C7 in relation to C6. Other linguistic values have remained unchanged. If observing the criteria in pairs that should have the same values, C7, C1, and C4, it can be noticed the following values of C7 = (0.175,0.244,0.329), C1 = (0.088,0.122,0.164), and C4 = (0.044,0.061,0.082), identify twice or three times a higher value of C7 in relation to C1 and C4. Furthermore, C2 = (0.009,0.015,0.023) and C3 = (0.009,0.015,0.023). Forming S1 and applying the IMF SWARA method, these logistical criteria in pairs have the same values as necessary based on the initial assessment of decision makers: C7 = C1 = C4 = (0.119,0.158,0.206), C2 = C3 = (0.051,0.079,0.115). By transforming MLI into DLS, i.e., (2/3,1,3/2) in (1/ 2,2/3,1), the difference between criterion C7 in relation to C6 is further reduced. Since there is not enough data in the analyzed example [31] to recreate the model, the same methodology

was applied, however in a novel MCDM example. Figure 5 shows the results obtained using the fuzzy MARCOS method for assessing the status of intermodal transport.

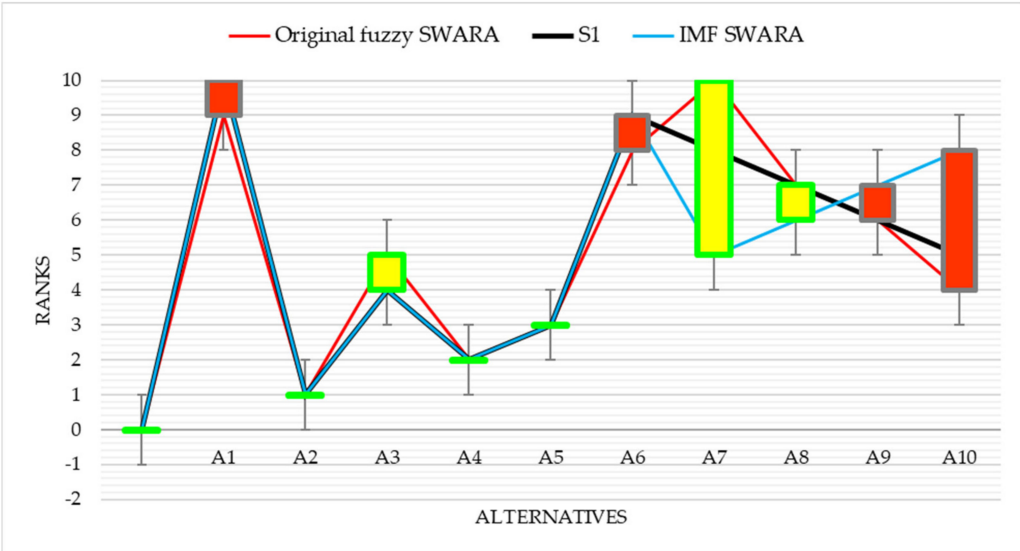


Figure 5. Results obtained by applying the fuzzy MARCOS method to assess the status of intermodal transport.

As can be seen from Figure 5, there are certain differences in the ranking of alternatives compared to the application of the original model with weights included from the fuzzy SWARA method. These are usually rank changes by one or two positions. When it comes to alternatives A7 and A10, there are considerable changes, by five, i.e., four places, respectively. Therefore, in this case, the influence of the fuzzy SWARA method on decision making is evident, too.

4.6. Study 6—A New Hybrid Fuzzy Model: Satisfaction of Residents in Touristic Areas toward Tourism Development and Study 7—Ranking of Sustainable Medical Tourism Destinations in Iran: An Integrated Approach Using Fuzzy SWARA-PROMETHEE

In [32], the authors applied a combination of the fuzzy SWARA and fuzzy EDAS method to assess 16 touristic areas in Iran based on 42 sub-criteria classified into six main criteria. In [33], the authors evaluated countries for medical tourism from the perspective of Iranians based on five main and 20 sub-criteria. They applied a combination of the fuzzy SWARA and PROMETHEE (Preference Ranking for Organization Method for. Enrichment Evaluation) method. For both examples, there were no calculations with the IMF SWARA method. The reason for this is that the authors not only misapplied the fuzzy SWARA method based on an inadequate scale, but also made other substantial errors that are presented below.

1. Incorrect interpretation of TFN. If TFN is $\overline{Y} = (l, m, u)$, then the following condition $l < m < u$ must be met. In both examples, the condition is not met since it is often the case that m has the highest value, as e.g., (0.23,1.5,0.465), that $m < l$ as e.g., (0.42,0.373,0.5), that u has the smallest instead of the highest value as e.g., (0.53,1.74,0.37), etc.
2. Incorrect operations with TFN since the operation of division is present in the procedure of the fuzzy SWARA method, so it is necessary to apply Equation (4). The authors performed the division operations as if they were crisp numbers, not following the rules of operations with TFNs. For example, in the first example for the second sub-criterion of the economic group, the value for q_j = (0.714,0.666,0.599) is obtained

as follows: $\left(\frac{1}{1.4}, \frac{1}{1.5}, \frac{1}{1.667}\right)$. Following the rules of operations with TFNs and applying Equation (4), it should be that $\left(\frac{1}{1.667}, \frac{1}{1.5}, \frac{1}{1.4}\right) = (0.599, 0.666, 0.714)$.

3. An inadequate scale for assessing mutual importance, which was previously explained in detail.

5. Discussion

In the previous section, an objective criticism of applying the fuzzy SWARA method in combination with the Chang scale for mutual comparison of criteria was presented. It has been singled out a total of seven different studies in which this combination was used. Observing the selected studies with this combination applied, there is a prioritization of alternative solutions that do not deserve it according to the performances of the initial decision matrix. The biggest problem with the application of fuzzy SWARA on the basis of inadequate scale is the allocation of TFN (1,1,1) for criteria that are of mutually equal importance. If observing the beginning of a decision-making process, DMs, when comparing criteria, indicate that two or more criteria are of equal importance. However, applying the fuzzy SWARA method with an inadequate scale, the values of these criteria show twice the value of one criterion compared to the other. If there is a situation where DMs have indicated that three criteria have the same significance, then the first is four times more significant than the third, and the second is twice as important as the third. The results of objective criticism have been presented in the previous section, and will be further discussed here. Depending on the example, proving the misapplication of the fuzzy SWARA method was done in two ways. The first implies that the criteria with allocated TFN (1,1,1), Scenario 1 (S1) were only observed, so these values were transformed into (0,0,0) in order for the criteria to really have equal importance. The second involves the application of the IMF SWARA method, i.e., a complete linguistic scale, and, based on it, the calculation of weight coefficients.

If experts or any other decision makers have indicated that two criteria are of equal importance, then their values must be identical. The question further arises as to how these weights affect decision making, i.e., the evaluation and ranking of a set of alternative solutions. This has been covered in the previous section and the results have been shown. In the first example, there are considerable changes in the values of the criteria, which causally affects significant changes in the ranks of alternatives. We will only discuss the differences between the fuzzy SWARA and IMF SWARA method, not considering Scenario 1. In this example, six out of 10 alternatives change their position as follows:

$$(A2) = 3 \to 2, (A3) = 5 \to 4, (A7) = 7 \to 3, (A8) = 6 \to 5, (A9) = 4 \to 6, (A10) = 2 \to 7.$$

In the second example (including Scenario 1), six out of 10 alternatives also change their positions by several places, as is the case in the previous example. The following is an overview of these changes:

$$(A1) = 10 \to 9, (A2) = 8 \to 6, (A3) = 9 \to 10, (A4) = 6 \to 7, (A8) = 7 \to 8.$$

In the third example, huge changes in the weights of criteria were proved. When it comes to three criteria of equal importance as in the case of PH, PR, and PA using the fuzzy SWARA method, the first PH has a higher value four times that of PA, which greatly affects the final ranking of alternatives. In this example, the ranking of alternatives changes in 11 alternatives out of a total of 12:

$$\begin{aligned}&(A1) = 10 \to 9, (A2) = 6 \to 2, (A3) = 12 \to 11, (A5) = 9 \to 5, (A6) = 5 \to 4, (A7) = 11 \to 12,\\ &(A8) = 4 \to 7, (A9) = 2 \to 3, (A10) = 7 \to 8, (A11) = 3 \to 6, (A12) = 8 \to 10\end{aligned}.$$

The fourth study includes a large set of criteria where their values change. As this is a large set of criteria, the changes should be of a minor nature. However, despite a large set of criteria, there is a change of ranking for four alternatives:

$$(A2) = 3 \rightarrow 2, (A5) = 7 \rightarrow 8, (A7) = 2 \rightarrow 3, (A9) = 8 \rightarrow 7.$$

In the fifth example, there are large changes in the weights of criteria, however the changes in the ranks are not too significant. When it comes to three criteria of equal importance as is the case with C7, C1, and C4 using the fuzzy SWARA method, the first C7 has four times the value compared to C4. In this case, the changes in the ranks of seven alternative solutions are:

$$(A1) = 9 \rightarrow 10, (A3) = 5 \rightarrow 4, (A6) = 8 \rightarrow 9, (A7) = 10 \rightarrow 5, (A8) = 7 \rightarrow 6, (A9) = 6 \rightarrow 7, (A10) = 5 \rightarrow 8.$$

In the last two examples, we consider the incorrect application of operations with triangular fuzzy numbers, so the application of the fuzzy SWARA method in these two papers has no purpose.

If experts or any other decision makers have indicated that two criteria are of equal importance, then their values must be identical. The question further arises as to how these weights affect decision making, i.e., the evaluation and ranking of a set of alternative solutions.

Through previous comparative analysis, it has been proven that the application of the fuzzy SWARA method based on the linguistic Chang scale leads to erroneous results in terms of criterion values. Certainly, these values of criteria, when further included in one of the methods for evaluating alternative solutions, also lead to erroneous results that are not in line with the opinions of DMs. Priority is given to some alternatives that do not really deserve it because the values of criteria affect the final rank of alternative solutions.

6. Conclusions

After an overall analysis of a defined sample of several examples, the hypothesis can be confirmed. The application of the fuzzy SWARA method in combination with the Chang scale for assessing the mutual importance of criteria leads to erroneous decision making. This is manifested through the inaccurate weights of criteria obtained by applying such an approach, which causally affect the inadequate ranking of alternative solutions.

After an objective criticism of applying the fuzzy SWARA method in combination with the Chang scale for assessing the mutual importance of criteria, the following negative conclusions can be drawn.

(1) Impossibility to calculate equal values of criteria. If decision makers have defined that two criteria have equal significance, by applying this approach, criterion Cj has twice the value in relation to the next ranked criterion, i.e., the next criterion by importance $Cj - 1$. If DMs have defined that three consecutive criteria have equal significance, then, by applying the fuzzy SWAR and Chang scale, Cj in relation to $Cj - 2$ has four times a higher value, which is unacceptable.

(2) Inadequate marks for criteria of equal importance. The allocation of TFN (1,1,1) instead of TFN (0,0,0) (IMF SWARA) leads to values of criteria that do not comply with the evaluation of experts, which has been explained in the previous conclusion.

(3) Low value of the last-ranked criterion or criteria. By applying an inadequate approach in many cases, the last criterion, or several of them (if it is a large set of criteria), has a very low value, and therefore a small impact on the evaluation of alternative solutions.

(4) The great gap between the first (most significant) and the last-ranked criteria. This is especially evident in cases where TFN occurs (1,1,1). In these cases, there is a situation that the first criterion tends toward a defuzzified value of up to 0.500, and the worst-ranked have very low values.

(5) Great influence of the most significant criterion. Given the fact described in the previous conclusion that the first criterion (in terms of importance) has a very high

value, then the alternative that has the best performance according to that criterion is automatically preferred.

(6) If there is a large set of criteria, the last ranked tends toward zero, which means that there is no impact on decision making.

(7) In previous sections, it has been proven through examples that the application of inadequate linguistic scale in the fuzzy SWARA method proposed by the authors in the development of this method contributes to erroneous decision making in multi-criteria problems, because there are large changes in alternative ranks.

It is important to note that the application of fuzzy SWARA and other appropriate scales can give good results.

Decision making is a very important process for all areas of profession, science, and other spheres of life and management, therefore the application of MCDM methods should contribute to the selection of the best solution from a given set of considered alternatives. If IMF SWARA is applied instead of the previously described inadequate approach, negative conclusions and shortcomings could be eliminated. It is especially important for managers who very often need quick and successful decision making on which they base further management strategies. In that way, quality management should be significantly improved and managers could achieve better results in their fields.

Future research related to the promotion to use the IMF SWARA method or the original SWARA method is required with some appropriate scales to avoid wrong decision making. Using less utilized methods such as SPOTIS [34], SIMUS [35], COMET [36,37] could also be part of future research. In addition, some objective criticism should be performed for some similar problems in the literature.

Author Contributions: Conceptualization, Ž.S. and D.K.D.; methodology, Ž.S.; data curation, R.T. and M.V.; writing—original draft preparation, Ž.S., M.V. and D.V.; writing—review and editing, D.K.D. and R.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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