

Article

Toward Sustainable Urban Mobility by Using Fuzzy-FUCOM and Fuzzy-CoCoSo Methods: The Case of the SUMP Podgorica

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Abstract: Sustainable urban mobility plans (SUMPs) have become increasingly popular in cities with environmental problems to reduce pollution, often caused by urban transportation. Therefore, this study aims to provide a practical framework for the selection decisions of final measures and policies to be carried out to achieve SUMP workspace goals using a fuzzy multi-criteria decision-making (MCDM) methodology. Alternatives are created with the strategic “pillar”, which was first adopted by the Podgorica city council. With the measurements in this pillar, the main criteria and the recommended measures for these measures create sub-criteria. Secondly, a Fuzzy Full Consistency Method (F-FUCOM) was used to determine the weights of the main and sub-criteria. The Fuzzy Combined Compromise Solution (F-CoCoSo) method was then applied to rank the alternatives. “The implementation and assurance of the SUMP” and “establishing a system for regular data collection, monitoring and evaluation of selected mobility indicators” were decided as the most important main and sub-criteria with weights of 0.286 and 0.1079, respectively. The findings suggest that the comprehensive planning for sustainable urban mobility alternative is first and the valorization of cycling potential alternative is second. A comprehensive sensitivity analysis confirms the validity, robustness, and effectiveness of the proposed framework. The applied methodology has the potential to assist decision makers in the process of developing SUMPs.

Keywords: sustainable urban mobility plan; MCDM; fuzzy method; FUCOM; CoCoSo



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1. Introduction

In the past several decades, the tendency of rapid and unplanned urbanization and human population growth has been identified in all parts of the world. According to the United Nations statistics, more than one-half of the people worldwide reside in urban centers, with expectations of further growth in the future [1]. The disparity between the travel needs and transport infrastructure resulted in a large number of adverse consequences, such as traffic congestion, road accidents, air and noise pollution, inefficient energy consumption, and finally and above all, the impacts on the general living standards of the people [2–4]. Therefore, new strategic transport planning and a design of the cities are essential to achieve sustainable development goals.

By the beginning of the 1980s, the traditional approach to transport planning in many urban communities was characterized by the strong dependence on private cars as the primary travel option, insufficient encouragement of human-powered transport, and the inadequate coordination of transport and urban planning [5]. However, environmental, social, and economic challenges led to a rapid paradigm shift in urban planning practice and the development of a novel approach that is nowadays widely recognized as sustainable urban mobility. The United Nations General Assembly has recently adopted a concluding document known as the 2030 Agenda for Sustainable Development which recognized

the transport sector as an important link in the chain of sustainable development. These initiatives encourage local governments to develop and implement an SUMP to diminish reliance on private individual transport [6]. According to the Eltis plus European Guidelines, an SUMP can be defined as: “a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles” [7,8]. Because of the numerous benefits of the adoption and implementation of this concept in the area of traffic planning, the European Commission promoted it actively [9,10]. The European Commission is supporting local authorities in its communication together toward competitive and resource-efficient urban mobility [11]. To promote sustainable urban mobility, the European Union financed several projects (e.g., CIVITAS, CH4ALLENGE) and adopted numerous strategic documents containing long-term goals for urban mobility [12]. The European Union has adopted the following strategic documents: Green Paper: Towards a new culture for urban mobility [13]; Freight Transport Action Plan [14]; A Sustainable Future for Transport: Towards an Integrated Technology-Led and User-Friendly System [15]; White Paper: Roadmap to a Single European Transport Area—Towards a competitive and resource-efficient transport system [16]; Action Plan on Urban Mobility [17]; and A European Strategy for Low-Emission Mobility [18]. Werland explores how the European Commission promotes the concept of an SUMP among European cities [19] and has revealed supporting evidence of the important role of the commission in urban mobility systems and mobility performance.

A reliable urban transport system is a prerequisite for a strong and successful local economy, as it provides access to services and enables personal urban mobility [20]. At the same time, high volumes of traffic require negative externalities on society, including congestion, accidents, noise pollution, or environmental damage [21]. The good practice of EU cities that have completed the development and implementation of SUMP indicates that this results in economic benefits [22,23], benefits for traffic calming [24], benefits for reducing dependence on cars [25], and benefits for traffic safety as a whole [26], thus achieving the final goal of improving the quality of life for all citizens [27].

The SUMP of the capital city of Podgorica was formally initiated in 2020 to provide an accessible, available, safe, and healthier urban environment for its residents, i.e., road users, with a special focus on susceptible population groups [28]. The SUMP consists of five main strategic pillars: (1) comprehensive planning for sustainable urban mobility; (2) more rational use of passenger cars; (3) modernization and popularization of public urban transport; (4) valorization of cycling potential; and (5) returning to walking as the healthiest mode of mobility. In addition, the SUMP action plan in Podgorica comprises a comprehensive depiction of measures and activities ready to be delivered for years to come. Recently, Vujadinović et al. [29] have described the vision and strategic objectives in sustainable urban mobility development, the key research findings, and conclusions, as well as a procedure of the SUMP development for the city of Podgorica. The authors of this paper are of the opinion that the SUMP Action Plan and the prioritized measures provide space for using the fuzzy multi-criteria decision-making (MCDM) methodology.

In the real world, there may be a partial lack of knowledge or knowledge of the nature of situations or events. In this case, decision makers evaluated attributes using MCDM models based on fuzzy cluster theory, which uses linguistic variables instead of clear data. This study aims to provide an integrated fuzzy methodological framework based on the FUCOM and CoCoSo method and to confirm its effectiveness in the real-world context of adapting it to the SUMP for Podgorica. The theoretical and practical contributions of this study to the existing knowledge are as follows:

- A multi-level decision-making hierarchy structure based on 5 main criteria and 23 sub-criteria was introduced for relevant stakeholders to provide a practical framework for evaluating existing SUMP.
- This hierarchical structure is the first study to present a fuzzy methodological framework based on the FUCOM and CoCoSo method together.

- The case study on Podgorica confirms the effectiveness of its recommended fuzzy model and provides valuable decision-making guidelines.
- Although this study primarily aims to evaluate the existing SUMP sustainability with a fuzzy model, it aims to solve the emerging SUMP-related problems with MCDM.

This research is structured as follows: Section 2 provides an examination of the latest research concerned. Section 3 shows the introduction of the materials and methods of the research and the case study in Podgorica in Section 4. It provides a sensitivity analysis for the accuracy of this study. Section 6 presents the results and shows possible future research directions.

2. Literature Review

Decision makers in local authorities must consider a wide range of different impacts (social, economic, and environmental) resulting from sustainable urban mobility projects or measures, along with their objectives. Investments in urban mobility should deliver maximum economic, social, and environmental benefits, while in times of constrained budgets, the projects' economic viability is often the deciding factor. Decision makers need information on the potential costs, benefits, and overall impacts of sustainable urban mobility measures or projects [30]. In earlier studies, MCDM was applied to facilitate a decision process when there are multiple criteria in the field of sustainable development [31,32]. For example, Stanujkic et al. [31] utilized the MCDM approach to assess the performance of the selected EU countries in terms of accomplishing the sustainable development goals. Furthermore, a hybrid multi-criteria analysis was performed by Zapolskytė et al. [32] to benchmark smart city mobility systems and to estimate the degrees of their smartness. In a similar vein, Garcia-Garcia-Ayllon et al. [33] gave a review of the sustainable urban mobility plans of 47 cities in Spain carried out over 15 years, analyzing both the diagnosis and proposal of solutions and their subsequent implementation. From the results obtained, a new framework based on a structured hybrid methodology was proposed to aid decision making for the evaluation of alternatives in the implementation of proposals in an SUMP. This hybrid methodology applied the two different MCDM methods in different phases to present two rankings of the best alternatives. Regarding the selection of suitable vehicles operating in public transport systems, Romero-Ania et al. [34] applied the MCDM framework in conjunction with the Delphi method. Ruiz Bagueño et al. [35] carried out a state-of-the-art analysis on MCDM and urban mobility and identified a research gap and potential for the further application of the MCDM methods in urban sustainable mobility planning. In addition, Parezanovic et al. [36] used the COPRAS (i.e., Complex Proportional Assessment) method for assessing the mobility measures in line with the selected assessment criteria. Furthermore, Podvezko and Sivilevičius [37] employed the AHP (i.e., Analytic Hierarchy Process) method and examined transport systems through the criteria of traffic safety. In their study, Hickman et al. [38] applied the multi-criteria assessment in exploring the possibilities of developing transport infrastructure in keeping up with different scenarios. Barauskas et al. applied the MCDM methods in specifying locations to implement mobility measures [39]. The TOPSIS (i.e., Technique for Order Preference by Similarity to Ideal Solution) method has been used for determining the distance to the ideal point, whereby the best-selected alternative has the smallest distance to the best decision and the largest distance to the worst decision [40]. The EDAS (i.e., evaluation based on distance from average solution) method has determined that the best alternative is related to the distance from the average decision [41]. The ARAS (i.e., Additive Ratio Assessment) method has indicated the best alternative that is closest to the optimal solution [42]. The Borda [43] and Copeland [44] methods can be used to identify the most significant alternatives computed by employing MCDM techniques. Damidavičius et al. used different MCDM methods (weighted average, Borda, and Copeland) in the biggest Lithuanian cities [45]. Morfoulaki and Papatthanasiou used the PROMETHEE (i.e., the preference ranking organization method for enrichment of evaluations) in Greece's SUMP [46]. Kramar et al. used the FAHP (i.e., the Fuzzy Analytical Hierarchical Process) [47]. Mardani

et al. had a literature discussion about transportation information [48]. Macharis and Bernardini summarized the MCDA assessments of transportation projects [49].

The F-FUCOM (i.e., Fuzzy Full Consistency Method) is a new technique used to weight criteria. The studies were used to solve world problems in different areas. Here are some of the studies with the FUCOM and F-FUCOM:

About improving the quality of logistics services, Prentkovskis et al. [50] implemented Delphi-servqual methods in controversy with the FUCOM. For the installation of solar panels and the selection of the best installer, Cao et al. [51] used the FUCOM and Grey SWARA (i.e., Step-wise Weight Assessment Ratio Analysis). Nouredine and Ristic [52] worked together with the FUCOM on the TOPSIS (i.e., Technique for Order of Preference by Similarity to Ideal Solution) and MABAC (i.e., Multi-attributive Border Approximation Area Comparison) for the best route selection for the transport of hazardous substances. Nenadić [53] used the WASPAS (i.e., Weighted Aggregate Sum Product Assessment method) with the FUCOM to detect and rank dangerous sections on the roads. Road planning for multiple robots in complex and crowded situations worked with Zagradjanin et al.'s [54] FUCOM to identify factors affecting the robot's movement. Stević et al. [55] used the Interval Rough SAW (i.e., Simple Additive Weighting) method with the FUCOM to solve the selection of a sustainable supplier. Pamucar and Ecer [56] fuzzy used the FUCOM to identify factors affecting demand in the transportation sector. Ali et al. [57] fuzzy applied the TOPSIS method with the FUCOM for the solution of the car selection problem. Stević and Brković [58] applied the FUCOM and MARCOS (i.e., Measurement Alternatives and Ranking according to Compromise Solution) method for a transport company's personnel selection and personnel evaluation. Böyükaslan and Ecer [59] worked with the FUCOM-F'B (i.e., Full Consistency Method-Fuzzy-Bonferroni) to spend money to buy cryptocurrencies. Ecer's [60] FUCOM worked on the evaluating factors affecting the choice of location for the wind farm. Ecer [61] used the MAIRCA (i.e., Multi Attributive Ideal-Real Comparative Analysis) with the FUCOM to solve the sustainable supplier selection problem. Pamucar et al. [62] applied the Fuzzy FUCOM and the Fuzzy MARCOS (i.e., Measurement Alternatives and Ranking according to the Compromise Solution) method to solve the selection problem of alternative fuel-consuming vehicles. Ong et al. [63] used the FUCOM and the VIKOR (i.e., VlseKriterijumska Optimizacija I Kompromisno Resenje) method for the development of integrated water systems. Blagojević et al. [64] used the Fuzzy FUCOM, Fuzzy PIPRECIA (i.e., Pivot Pairwise Relative Criteria Importance Assessment), and Fuzzy MARCOS to examine the safety factors at railway crossings.

The F-CoCoSo (i.e., Fuzzy Combined Compromise Solution) is the new technique used to evaluate alternatives. Some of the studies with the CoCoSo and F-CoCoSo follow:

To solve the supplier selection problem, Zolfani et al. [65] used the CoCoSo and BWM (i.e., Best Worst Method). Yazdani et al. [66] utilized the Grey-CoCoSo method. For selecting and evaluating electric vehicles, Biswas et al. [67] applied the CRITIC (i.e., CRiteria Importance Through Intercriteria Correlation) method with the CoCoSo. Wen et al. [68] utilized the Fuzzy CoCoSo to facilitate the decision-making process and choose a suitable tool for decision making. Wen et al. [69] applied the Fuzzy CoCoSo to solve appropriate decision making and make appropriate choices regarding the decisions taken. Karaşan and Bolturk [70] applied the Fuzzy CoCoSo to resolve the problem of choosing the disposal site for waste. Erceg et al. [71] used the FUCOM with the CoCoSo to reduce inventory management costs. Maghsoodi et al. [72] applied the BWM and MULTIMOORA (i.e., Multi-Objective Optimization based on Ratio Analysis plus full multiplicative form) methods with the CoCoSo for phase change material selection in interior building applications. Peng and Smarandache [73] worked with the CoCoSo and CRITIC for the assessment of land industry safety. In the manufacturing industry, Cui et al. [74] used the CoCoSo and Fuzzy SWARA to identify obstacles to the adoption of the internet. Peng and Huang [75] implemented the fuzzy CRITIC method with the Fuzzy CoCoSo in solving the financial risk assessment problem. Liu et al. [76] used the Fuzzy CoCoSo method for evaluating a suitable medical waste processing technology. Deveci et al. [77] applied the Fuzzy CoCoSo to determine the

advantages of real-time traffic management models. Using health indicators, Torkayesh et al. [78] implemented the BWM and LBWA (i.e., Level Based Weight Assessment) method with the CoCoSo to rank the health care performance of countries. Ulutaş et al. [79] used Fuzzy CoCoSo for the transportation company selection.

As a result of the literature review, no study was found in which the F-FUCOM and F-CoCoSo method were used together, as far as the authors know. There are studies in the literature in which the F-FUCOM and F-CoCoSo method are used separately. The fuzzy versions of both the FUCOM and CoCoSo method were used to use the subjective evaluations of the decision makers. The most important advantages of the FUCOM for decision makers are that it makes fewer pairwise comparisons compared to other weight determination methods, its ease of understanding and application, and the elimination of the problem of inconsistency caused by a large number of pairwise comparisons. High stability, robustness, and reliability in determining the performance of the CoCoSo decision alternatives and being based on the SAW and WEP models are the most important advantages.

3. Materials and Methods

Figure 1 shows the research flow of the methods created to evaluate SUMP. General methodology consists of three stages. Each stage is connected to the next stage for the continuation of the model.

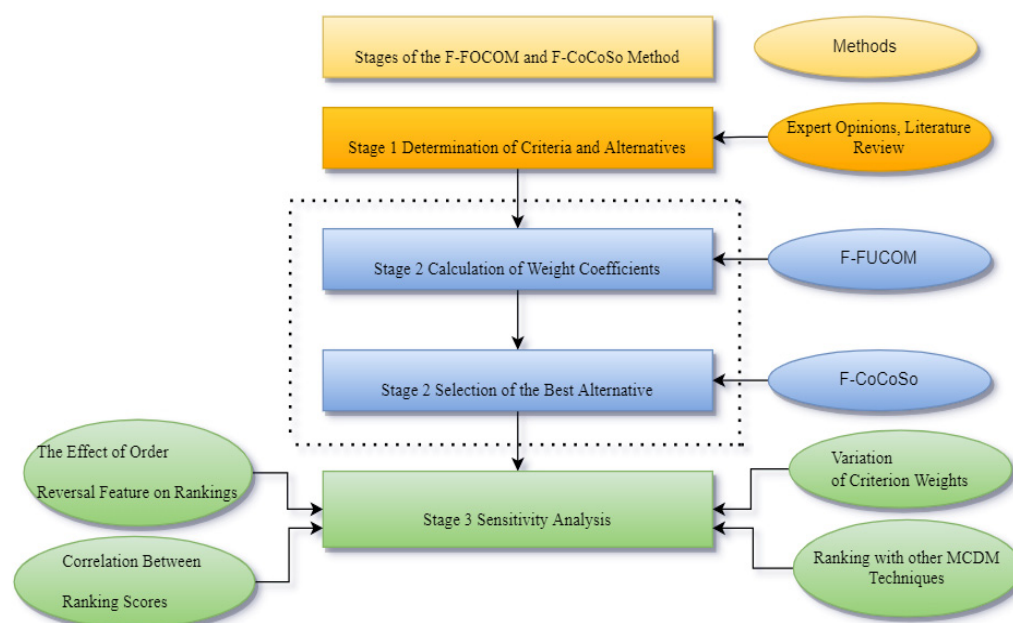


Figure 1. Flowchart of the introduced framework.

3.1. The First Stage

SUMP covers a wide range of measures to regulate parking spaces, modernize public transport, and improve cycling and walking conditions. Podgorica was accepted by the city parliament's first SUMP in February 2020. The capital of Montenegro, which is interested in the issue of the large presence of public transport and the increasing number of cars, encourages walking and cycling. Podgorica is preparing for the fourth phase of SUMP implementation based on participatory process experience and a large network of stakeholders and supporters.

This study has benefited from the plan that aims to solve problems related to urban mobility that covers the city's 2020–2025 period, which is accepted by the city council to assess SUMP in Podgorica. The SUMP Podgorica is organized in such a way that it relies on five main strategic pillars, so the authors selected SUMP pillars for the alternatives (A1:A5):

A1—Comprehensive planning for sustainable urban mobility.

A2—More rational use of passenger cars.

A3—Modernization and popularization of public urban transport.

A4—Valorization of cycling potential.

A5—Return to walking as the healthiest mode of mobility.

Each pillar is organized in such a way that it consists of a package of measures, which will be the main criteria (MCi), while the specific measures in the package of measures will be sub-criteria (Ci). The main criteria (MC1:MC5) and sub-criteria (C1:C23) are given below and are the subject of further research and application of selected methods:

MC1—IMPLEMENTATION AND ASSURANCE OF THE SUMP

C1—*Form a coordination body for SUMP monitoring and implementation.*

C2—*Prepare a balanced mobility budget with a guaranteed minimum annual allocation for each transport mode.*

C3—*Revise SUMP.*

C4—*Develop a new SUMP.*

MC2—MONITORING AND EVALUATION OF THE SUMP

C5—*Establish a system for regular data collection, monitoring, and evaluation of selected mobility indicators.*

C6—*Regularly monitor and evaluate the SUMP and the action plan.*

MC3—STRENGTHENING AND INTEGRATION OF PLANNING SECTORS AND GOVERNANCE LEVELS

C7—*Recruit/appoint a competent person to be responsible for monitoring the SUMP implementation.*

C8—*Regularly participate in EU projects in the field of sustainable mobility.*

C9—*Regularly educate employees responsible for transport, including those in related sectors at the city level, on new approaches and good practices in the field of sustainable transport.*

C10—*Establish an integrated system of sustainable mobility planning and the planning of other sectors and enhancing cooperation among sectors, with a special focus on the spatial planning of compact urban structures of short distances.*

C11—*Prepare technical guidelines for traffic areas where practice does not offer good solutions:*

- Guidelines for car and bicycle parking for new buildings in new urban plans;
- Technical guidelines for pedestrian and cycling infrastructure.

C12—*Assess the impact of new larger structures/buildings on traffic.*

C13—*Integrate SUMP into the curricula of the road transport study program at the Faculty of Mechanical Engineering, University of Montenegro.*

C14—*Establish a specialized portal that will allow every citizen to be a “traffic policeman” and to photograph and send traffic violations.*

C15—*Cooperate with the MTMA to improve road transport legislation and with the MI to improve the road traffic safety legislation.*

MC4—STRENGTHENING AND INTEGRATION OF PLANNING SECTORS AND GOVERNANCE LEVELS

C16—*Revise existing road network hierarchy and prepare a development plan for “superblocks”.*

C17—*Implement pilot “superblocks” (3 to 4 by 2025).*

C18—*Develop mobility plans for key traffic drivers in the city (minimum 4 by 2025):*

- Clinical Hospital Centre complex.
- University of Montenegro.
- City Cemetery, etc.

C19—*Introduce a single city card for payment for parking, public transport, museums, etc.*

MC5—PUBLIC PARTICIPATION AND PROMOTION OF THE SUMP ACHIEVEMENTS

C20—Develop the SUMP Promotion and Public Relations Plan.

C21—Implement the SUMP Promotion and Public Relations Plan.

C22—Introduce a so-called participatory budget, which serves to consider and support citizens' initiatives in the field of sustainable mobility.

C23—Include the topic of sustainable mobility in the existing call for financing NGOs.

The relationship between the alternatives, main criteria, and sub-criteria used in the study is summarized in Figure 2.

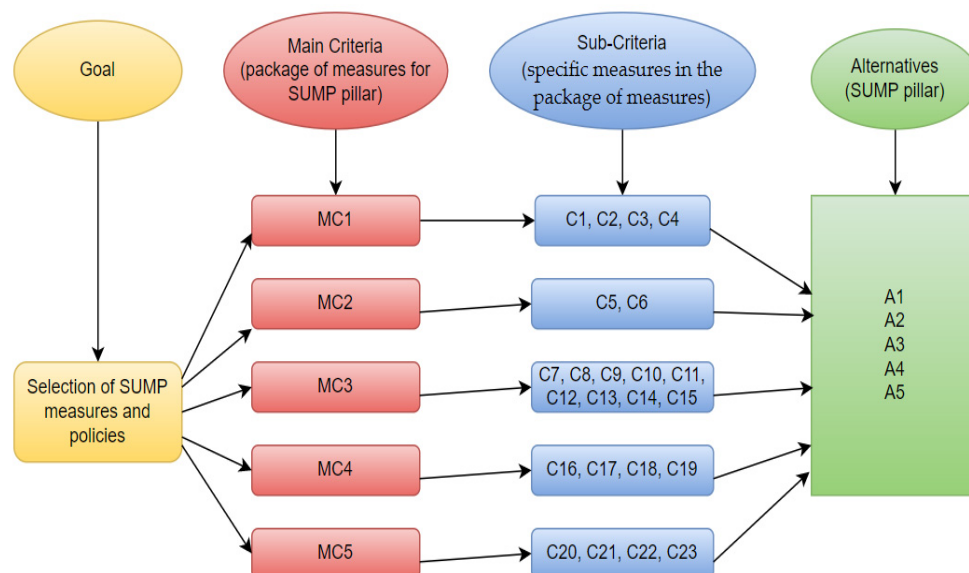


Figure 2. Relationship between alternatives, main criteria, and sub-criteria.

FUCOM and CoCoSo method were integrated by treating the extension of the fuzzy cluster as a methodological framework. The selection decision of these two methods is based on their ability to successfully address MCDM problems. In this context, triangular fuzzy numbers (TFNs), F-FUCOM, and F-CoCoSo are discussed in this section.

3.2. The Second Stage

The second stage consists of two different stages. In the first stage, the weight coefficients of the criteria are calculated using the F-FUCOM model, while in the second stage of the multi-criterion methodology, alternatives are evaluated using the F-CoCoSo model.

3.2.1. F-FUCOM

FUCOM is the MCDM technique that was developed by Pamučar et al. in 2018 [80]. FUCOM is a method that allows the weight coefficients of all elements at a specific hierarchy level and provides consistency conditions for comparison.

FUCOM performs a binary comparison of evaluation criteria not only by using integers but also by using dexterity values. It uses a simple algorithm to determine the weight of the criteria. The criterion requires a smaller number of binary comparisons to decide its weight [62]. The method is preferred in the study due to its usefulness.

There should be n evaluation criteria shown as w_j , $j = 1, 2, \dots, n$ and their weight coefficients should be calculated in an MCDM problem. Subjective models need decision makers to determine the degree of impact of criteria i over criteria j to determine weights based on binary comparison of criteria. The degree of effect of the i criteria on the j criteria is presented as the comparison value (a_{ij}) . The values of the a_{ij} comparison are not based on precise measurements, but based on subjective estimates, existing uncertainties can be expressed in fuzzy numbers. Linguistic scales are most commonly used for the comparison of two factors. Therefore, a fuzzy linguistic scale given in Table 1 is considered to offer the preferences of decision makers (DMs) in F-FUCOM.

Table 1. Fuzzy linguistic scale.

Linguistic Variables	TFN
Equally important (EI)	(1, 1, 1)
Weakly important (WI)	(2/3, 1, 3/2)
Fairly important (FI)	(3/2, 2, 5/2)
Very important (VI)	(5/2, 3, 7/2)
Absolutely important (AI)	(7/2, 4, 9/2)

Source: [81] (p. 29).

The F-FUCOM algorithm is present in four steps in the following section [56] (pp. 7–8).

Step 1. Determination of criteria.

Assume that there are n criteria expressed in the $C_j = \{C_1, C_2, \dots, C_n\}$ and $j = 1, 2, \dots, n$ set.

Step 2. Ranking of criteria.

Let us say that a group of DMs (DM1, DM2,..., DMn) participate in the study. According to DMs, preferences determine the rankings of the criteria. Respectively, the first turn is assigned to the expected criteria to have the highest weight coefficient. The last turn is assigned to the expected criteria to have the lowest value of the weight coefficient. Obtain criterion ranking $C_{j(1)} > C_{j(2)} > \dots > C_{j(k)}$. k represents the order of the observed criterion. If two or more criteria have the same rankings, the “>” sign is put in the “=” sign between the criteria.

Step 3. Comparison of criteria using triangular fuzzy numbers.

Criteria are compared to each other using Table 1. The comparison is performed according to the first order (most important) criteria. Thus, fuzzy criteria signability ($\tilde{\omega}_{C_{j(k)}}$) is obtained for all the criteria listed in Step 2. Since the first criterion is compared to itself (its importance $\tilde{\omega}_{C_{j(1)}}$: equal importance), the remaining criteria ($n - 1$) should be compared. Based on the defined importance of the criteria, the fuzzy comparative importance ($\tilde{\varphi}_{k/(k+1)}$) is determined by applying Equation (1).

$$\tilde{\varphi}_{k/(k+1)} = \frac{\tilde{\omega}_{C_{j(k+1)}}}{\tilde{\omega}_{C_{j(k)}}} = \frac{(\omega_{C_{j(k+1)}}^l, \omega_{C_{j(k+1)}}^m, \omega_{C_{j(k+1)}}^u)}{(\omega_{C_{j(k)}}^l, \omega_{C_{j(k)}}^m, \omega_{C_{j(k)}}^u)} \quad (1)$$

Thus, a fuzzy vector with the comparative importance of evaluation criteria is obtained using Equation (2).

$$\tilde{\Phi} = (\tilde{\varphi}_{1/2}, \tilde{\varphi}_{2/3}, \dots, \tilde{\varphi}_{k/(k+1)}) \quad (2)$$

where $\tilde{\varphi}_{k/(k+1)}$, $C_{j(k)}$ refers to the importance of the next criteria according to the criteria of $C_{j(k+1)}$.

Step 4. Calculating optimum fuzzy weights.

The final values of the fuzzy weight coefficients of the criteria are calculated $(\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)^T$. The final values of weight coefficients must meet the conditions specified by Equations (3) and (4).

$$\frac{\tilde{w}_k}{\tilde{w}_{k+1}} = \tilde{\varphi}_{k/(k+1)} \quad (3)$$

$$\frac{\tilde{w}_k}{\tilde{w}_{(k+2)}} = \tilde{\varphi}_{k/(k+1)} \otimes \tilde{\varphi}_{(k+1)/(k+2)} \quad (4)$$

For the conditions to be met, the values of the weight coefficients $((\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)^T)$ must meet the $\left| \frac{\tilde{w}_k}{\tilde{w}_{k+1}} - \tilde{\varphi}_{k/(k+1)} \right| \leq \chi$ and $\left| \frac{\tilde{w}_k}{\tilde{w}_{(k+2)}} - \tilde{\varphi}_{k/(k+1)} \otimes \tilde{\varphi}_{(k+1)/(k+2)} \right| \leq \chi$ states by

minimizing the value of χ . In this way, the maximum consistency requirement is fulfilled. Based on the defined settings, the final nonlinear model can be demonstrated by Equation (5) to determine the optimal fuzzy values of the weight coefficients $(\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n)^T$ of the evaluation criteria.

Min χ
s.t.

$$\begin{aligned} & \left| \frac{\tilde{w}_k}{\tilde{w}_{k+1}} - \tilde{\varphi}_{k/(k+1)} \right| \leq \chi, \forall_j \\ & \left| \frac{\tilde{w}_k}{\tilde{w}_{(k+2)}} - \tilde{\varphi}_{k/(k+1)} \otimes \tilde{\varphi}_{(k+1)/(k+2)} \right| \leq \chi, \forall_j \\ & \sum_{j=1}^n \tilde{w}_j = 1, \forall_j \\ & w_j^l \leq w_j^m \leq w_j^u \\ & w_j^l \geq 0 \forall_j \\ & j = 1, 2, \dots, n \end{aligned} \quad (5)$$

where it is in the form of $\tilde{w}_j = (w_j^l, w_j^m, w_j^u)$ and $\tilde{\varphi}_{k/(k+1)} = (\varphi_{k/(k+1)}^l, \varphi_{k/(k+1)}^m, \varphi_{k/(k+1)}^u)$.

3.2.2. F-CoCoSo Method

The CoCoSo method is based on a combination of SAW and WEP methods. This method can be considered a summary of other consensus solutions [82]. The addition of a new alternative to analysis or the removal of an alternative in the analysis is less than the final rankings obtained by this method according to other MCDM methods. There is high stability, robustness, and reliability in the sorting of alternatives [82–85]. The method is preferred due to these strengths. A fuzzy linguistic scale given in Table 2 is considered to offer DMs preferences in F-CoCoSo.

Table 2. Fuzzy linguistic scale.

Linguistic Variables	TFN
Absolutely less significant (ALS)	(0.222, 0.250, 0.286)
Dominantly less significant (DLS)	(0.250, 0.286, 0.333)
Much less significant (MLS)	(0.286, 0.333, 0.400)
Really less significant (RLS)	(0.333, 0.400, 0.500)
Less significant (LS)	(0.400, 0.500, 0.667)
Moderately less significant (MoLS)	(0.500, 0.667, 1.000)
Weakly less significant (WLS)	(0.667, 1.000, 1.000)

Source: [86] (p. 7).

The process steps of the method used to sort alternatives according to their performance are described as follows [79] (pp. 1235–1237):

Step 1. Create the fuzzy decision matrix (\tilde{Z}).

$$\tilde{Z} = [\tilde{z}_{ij}]_{k \times n} = \begin{bmatrix} \tilde{z}_{11} & \dots & \tilde{z}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{k1} & \dots & \tilde{z}_{kn} \end{bmatrix} \quad (6)$$

Equation (6) $\tilde{z}_{ij} = (z_{ij}^l, z_{ij}^m, z_{ij}^u)$ is the fuzzy value of the i . alternative to the j . criteria.

Step 2. Create normalized fuzzy decision matrix (\tilde{R}).

This matrix is obtained as follows by using Equation (7) (for non-useful criteria) and Equation (8) (for useful criteria).

$$\begin{aligned}\tilde{R} = [\tilde{r}_{ij}]_{k \times n} = \tilde{r}_{ij} &= (r_{ij}^l, r_{ij}^m, r_{ij}^u) = \frac{\max(\tilde{z}_{ij}) - \tilde{z}_{ij}}{\max(\tilde{z}_{ij}) - \min(\tilde{z}_{ij})} \\ &= \left(\frac{\max(z_{ij}^u) - z_{ij}^u}{\max(z_{ij}^u) - \min(z_{ij}^l)}, \frac{\max(z_{ij}^u) - z_{ij}^m}{\max(z_{ij}^u) - \min(z_{ij}^l)}, \frac{\max(z_{ij}^u) - z_{ij}^l}{\max(z_{ij}^u) - \min(z_{ij}^l)} \right)\end{aligned}\quad (7)$$

$$\begin{aligned}\tilde{R} = [\tilde{r}_{ij}]_{k \times n} = \tilde{r}_{ij} &= (r_{ij}^l, r_{ij}^m, r_{ij}^u) = \frac{\tilde{z}_{ij} - \min(\tilde{z}_{ij})}{\max(\tilde{z}_{ij}) - \min(\tilde{z}_{ij})} \\ &= \left(\frac{z_{ij}^l - \min(z_{ij}^l)}{\max(z_{ij}^u) - \min(z_{ij}^l)}, \frac{z_{ij}^m - \min(z_{ij}^l)}{\max(z_{ij}^u) - \min(z_{ij}^l)}, \frac{z_{ij}^u - \min(z_{ij}^l)}{\max(z_{ij}^u) - \min(z_{ij}^l)} \right)\end{aligned}\quad (8)$$

Step 3. Calculate the sum of comparability arrays (\tilde{S}_i) and the sum of power weights (\tilde{P}_i) of the comparability arrays.

Comparability is achieved by Equation (9) for the sum of arrays and Equation (10) for the sum of power weights of comparability arrays as follows.

$$\tilde{S}_i = (S_i^l, S_i^m, S_i^u) = \sum_{j=1}^n \tilde{w}_{jc} \tilde{r}_{ij} = \left(\sum_{j=1}^n w_{jc}^l r_{ij}^l, \sum_{j=1}^n w_{jc}^m r_{ij}^m, \sum_{j=1}^n w_{jc}^u r_{ij}^u \right) \quad (9)$$

$$\tilde{P}_i = (P_i^l, P_i^m, P_i^u) = \sum_{j=1}^n (\tilde{r}_{ij})^{\tilde{w}_{jc}} = \left(\sum_{j=1}^n (r_{ij}^l)^{w_{jc}^u}, \sum_{j=1}^n (r_{ij}^m)^{w_{jc}^m}, \sum_{j=1}^n (r_{ij}^u)^{w_{jc}^l} \right) \quad (10)$$

Step 4. Calculate three fuzzy evaluation scores (\tilde{f}_{ia} , \tilde{f}_{ib} , \tilde{f}_{ic}).

Three collection strategies given in Equations (11)–(13) are applied to achieve three fuzzy evaluation scores.

$$\tilde{f}_{ia} = (f_{ia}^l, f_{ia}^m, f_{ia}^u) = \frac{\tilde{P}_i + \tilde{S}_i}{\sum_{i=1}^k (\tilde{P}_i + \tilde{S}_i)} = \left(\frac{P_i^l + S_i^l}{\sum_{i=1}^k (P_i^u + S_i^u)}, \frac{P_i^m + S_i^m}{\sum_{i=1}^k (P_i^m + S_i^m)}, \frac{P_i^u + S_i^u}{\sum_{i=1}^k (P_i^l + S_i^l)} \right) \quad (11)$$

$$\tilde{f}_{ib} = (f_{ib}^l, f_{ib}^m, f_{ib}^u) = \frac{\tilde{S}_i}{\min(\tilde{S}_i)} + \frac{\tilde{P}_i}{\min(\tilde{P}_i)} = \left(\frac{S_i^l}{\min(S_i^l)} + \frac{P_i^l}{\min(P_i^l)}, \frac{S_i^m}{\min(S_i^l)} + \frac{P_i^m}{\min(P_i^l)}, \frac{S_i^u}{\min(S_i^l)} + \frac{P_i^u}{\min(P_i^l)} \right) \quad (12)$$

$$\begin{aligned}\tilde{f}_{ic} &= (f_{ic}^l, f_{ic}^m, f_{ic}^u) = \frac{\lambda(\tilde{S}_i) + (1-\lambda)(\tilde{P}_i)}{\lambda \max(\tilde{S}_i) + (1-\lambda) \max(\tilde{P}_i)} \\ &= \left(\frac{\lambda(S_i^l) + (1-\lambda)(P_i^l)}{\lambda \max(S_i^u) + (1-\lambda) \max(P_i^u)}, \frac{\lambda(S_i^m) + (1-\lambda)(P_i^m)}{\lambda \max(S_i^u) + (1-\lambda) \max(P_i^u)}, \frac{\lambda(S_i^u) + (1-\lambda)(P_i^u)}{\lambda \max(S_i^u) + (1-\lambda) \max(P_i^u)} \right)\end{aligned}\quad (13)$$

In Equation (13), λ is usually taken as 0.5. Decision makers also determine this value.

Step 5. Obtain the net assessment scores.

Fuzzy assessment scores (\tilde{f}_{ia} , \tilde{f}_{ib} , \tilde{f}_{ic}) are converted to net evaluation scores (f_{ia} , f_{ib} , f_{ic}) using Equations (14)–(16).

$$f_{ia} = \frac{f_{ia}^l + f_{ia}^m + f_{ia}^u}{3} \quad (14)$$

$$f_{ib} = \frac{f_{ib}^l + f_{ib}^m + f_{ib}^u}{3} \quad (15)$$

$$f_{ic} = \frac{f_{ic}^l + f_{ic}^m + f_{ic}^u}{3} \quad (16)$$

Step 6. Calculate crips evaluation scores.

Crips assessment scores are combined to achieve the final score (f_i) for each alternative using Equation (17).

$$f_i = (f_{ia} f_{ib} f_{ic})^{1/3} + \left(\frac{f_{ia} + f_{ib} + f_{ic}}{3} \right) \quad (17)$$

The alternative with the highest score is the best.

3.3. The Third Stage

Sensitivity analysis is performed to check the extent to which the sequence obtained by an MCDM method can vary according to small changes, thereby determining the stability of the results. To investigate the capacity to compromise and the uncertainty of the recommended MCDM model, three different sensitivity analyses have been proposed to investigate the effect of different parameters on the final rankings of the alternatives.

- Sensitivity analysis based on the variation of the criteria.
- Sensitivity analysis based on the row reversing feature.
- Sensitivity analysis based on different sorting methodologies.

3.3.1. Sensitivity Analysis Based on the Variation of Criterion Weight

After determining the “most important criterion” based on the estimated weights using the criterion weighting method, weight sensitivity analysis can be performed by changing the weight of the “most important criterion” to observe the effect of the proposed model on the ranking performance [83] (pp. 2512–2516), [87] (pp. 163–164). New weights are obtained using Equation (18) [88].

$$\tilde{W}_{n\beta} = (1 - \tilde{W}_{n\alpha}) \frac{\tilde{w}_{\beta}}{(1 - \tilde{W}_n)} \quad (18)$$

3.3.2. Sensitivity Analysis Based on the Row Reversing Feature

One way to check the stability of MCDM methods is to add new alternatives to the original cluster or remove weak alternatives from the cluster. In such cases, the MCDM method is expected not to show any significant change in the order of alternatives. This phenomenon is called the “popular sequence reversing problem” and it was highly noticeable in the literature [89,90]. One of the ways to test the validity of the results obtained from the model for decision making is to create dynamic matrices and then analyze the solutions that the model offers under newly created conditions.

3.3.3. Sensitivity Analysis of Ranking Stability Based on Different Ranking Methodologies

In many complex decisions, comparing the result of a model by other present and well-structured methods, the susceptibility analysis of the sorting points and reliability of the alternatives are examined. It is clarified that different MCDM anatomies can generate similar or different sort scores.

In addition, the high correlation coefficient between ranking scores can also provide a pragmatic verification and a way to negotiate. This can also be considered a global strategy for comparing the decision results of applications in practice.

4. Case Study—SUMP Podgorica

The authors of this paper did not find a relevant literature source with an integrated approach of the F-FUCOM and F-CoCoSo applied to sustainable urban mobility plans. It is the aim that the approach presented in the study will contribute to the SUMP literature in the field of fuzzy multi-criteria decision making by taking into account incomplete or unclear information during the evaluation activity. To realize this purpose, it is used by the SUMP Podgorica official document, prepared by experts, and accepted by experts in creating alternatives and criteria.

In the first stage of the study, expert opinions and the creation of criteria and alternatives as a result of the literature review are found. The second stage consists of two different stages. In the first stage, the weight coefficients of the criteria are calculated using the F-FUCOM model, while in the second stage of the multi-criterion methodology, alternatives are evaluated using the F-CoCoSo model.

A decision-making team was created in Podgorica to evaluate the criteria and alternatives. The views of the eight decision makers (DMs) were used to be closely related to the SUMP. Four of the DMs are professors in road traffic studies, while the other four are master students in this program. These graduate students were selected because they had many years of experience in traffic secretaries in the cities where they came from. Using the linguistic values in Table 1, each decision maker was asked to rank the main criteria and sub-criteria in order of importance. According to Table 1, linguistic values were converted into triangular numbers by giving triangular value to the most important criterion (1,1,1). According to Table 2, the linguistic values and importance of each alternative according to the main criteria were expressed by the decision makers. Then, it was converted to triangular numbers. In the next section, the recommended two-step models are offered for the application of the high criteria methodology.

Phase I—Determination of criteria weights using the F-FUCOM model

Podgorica has been used to attribute both the evaluation criteria of the created DMs and to score the criteria for each criterion. Scoring with linguistic variables using Table 1 by DMs for both the main criteria and sub-criteria through the F-FUCOM, the solution is performed by defining the following six models:

Model 1—Determination of local weights of MC1, MC2, MC3, MC4, and MC5.

Model 2—Determination of local weights in MC1.

Model 3—Determination of local weights in MC2.

Model 4—Determination of local weights in MC3.

Model 5—Determination of local weights in MC4.

Model 6—Determination of local weights in MC5.

As mentioned above, the F-FUCOM is used to calculate the weights of relative criteria due to their obvious superiority. According to DM1's opinion, linguistic variables of the comparative importance of criteria are determined as shown in Table 3. The opinions of other decision makers are presented in Table 3 and in Appendix A.

Table 3. Linguistic evaluations of the main criteria/sub-criteria.

Main Criteria/Sub-Criteria		DM1
Main Criteria (MC1–MC5)	R C	MC1 > MC2 > MC4 > MC3 > MC5 EI, VI, FI, WI, WI
MC1—Sub-Criteria (C1–C4)	R C	C1 > C2 > C3 > C4 EI, VI, FI, WI
MC2—Sub-Criteria (C5–C6)	R C	C5 > C6 EI, VI
MC3—Sub-Criteria (C7–C15)	R C	C10 > C7 > C11 > C12 > C13 > C8 > C9 > C15 > C14 EI, VI, VI, VI, VI, FI, FI, FI, WI
MC4—Sub-Criteria (C16–C19)	R C	C18 > C19 > C16 > C17 EI, EI, FI, WI
MC5—Sub-Criteria (C20–C23)	R C	C20 > C21 > C22 > C23 EI, EI, WI, WI
R—Rank; C—Comparisons		

To clarify the F-FUCOM, Model 1 is solved in this section. By using Equation (1), the comparative importance of the main criteria is defined as follows.

$$\tilde{\varphi}_{MC1/MC2} = \tilde{w}_{MC1}/\tilde{w}_{MC2} = (5/2, 3, 7/2)/(1, 1, 1) = (2.5, 3, 3.5)$$

$$\tilde{\varphi}_{MC2/MC4} = \tilde{w}_{MC2}/\tilde{w}_{MC4} = (3/2, 2, 5/2)/(5/2, 3, 7/2) = (0.43, 0.67, 1)$$

$$\tilde{\varphi}_{MC4/MC3} = \tilde{w}_{MC4}/\tilde{w}_{MC3} = (2/3, 1, 3/2)/(3/2, 2, 5/2) = (0.27, 0.5, 1)$$

$$\tilde{\varphi}_{MC3/MC5} = \tilde{w}_{MC3}/\tilde{w}_{MC5} = (2/3, 1, 3/2)/(2/3, 1, 3/2) = (0.44, 1, 2.25)$$

Therefore, a vector of comparative importance is defined as follows:

$$\tilde{\Phi} = ((2.5, 3, 3.5), (0.43, 0.67, 1), (0.27, 0.5, 1), (0.44, 1, 2.25))$$

Considering Equation (4), the relationship is obtained from three restrictions caused by the transitive conditions.

$$\tilde{w}_{MC1}/\tilde{w}_{MC4} = (2.5, 3, 3.5) \otimes (0.43, 0.67, 1) = (1.08, 2.01, 3.5)$$

$$\tilde{w}_{MC2}/\tilde{w}_{MC3} = (0.43, 0.67, 1) \otimes (0.27, 0.5, 1) = (0.12, 0.34, 1)$$

$$\tilde{w}_{MC4}/\tilde{w}_{MC5} = (0.27, 0.5, 1) \otimes (0.44, 1, 2.25) = (0.12, 0.5, 2.25)$$

The restrictions for the remaining sub-criteria are identified in the same way. Based on the specified constraints, models have been created to determine the local values of the weight coefficients of the main criteria/sub-criteria. In the following section, nonlinear models are presented to determine the local fuzzy values of the weight coefficients of the criteria. Other models for determining the weight coefficients of the sub-criteria are presented as Models (2–6) in Appendix B. l , m , and u triangles in the model established with the DM1 evaluations for the calculation of the main criteria below represent the lower, middle, and upper values of the fuzzy number.

$$\begin{array}{lll} \text{DM1 (MC1–MC5)} \rightarrow \min \chi & \text{DM8 (MC1–MC5)} \rightarrow \min \chi & \text{Model 1} \\ \text{s.t.} & \text{s.t.} & \end{array}$$

$$\left\{ \begin{array}{l} \left| \frac{w_1^l}{w_2^l} - 2.5 \right| \leq \chi; \left| \frac{w_1^m}{w_2^m} - 3 \right| \leq \chi; \left| \frac{w_1^u}{w_2^u} - 3.5 \right| \leq \chi; \\ \left| \frac{w_2^l}{w_4^l} - 0.43 \right| \leq \chi; \left| \frac{w_2^m}{w_4^m} - 0.67 \right| \leq \chi; \left| \frac{w_2^u}{w_4^u} - 1 \right| \leq \chi \\ \left| \frac{w_4^l}{w_3^l} - 0.27 \right| \leq \chi; \left| \frac{w_4^m}{w_3^m} - 0.5 \right| \leq \chi; \left| \frac{w_4^u}{w_3^u} - 1 \right| \leq \chi \\ \left| \frac{w_5^l}{w_5^l} - 0.44 \right| \leq \chi; \left| \frac{w_5^m}{w_5^m} - 1 \right| \leq \chi; \left| \frac{w_5^u}{w_5^u} - 2.25 \right| \leq \chi \\ \left| \frac{w_1^l}{w_4^l} - 1.08 \right| \leq \chi; \left| \frac{w_1^m}{w_4^m} - 2.01 \right| \leq \chi; \left| \frac{w_1^u}{w_4^u} - 3.5 \right| \leq \chi \\ \left| \frac{w_2^l}{w_3^l} - 0.12 \right| \leq \chi; \left| \frac{w_2^m}{w_3^m} - 0.34 \right| \leq \chi; \left| \frac{w_2^u}{w_3^u} - 1 \right| \leq \chi \\ \left| \frac{w_4^l}{w_5^l} - 0.12 \right| \leq \chi; \left| \frac{w_4^m}{w_5^m} - 0.5 \right| \leq \chi; \left| \frac{w_4^u}{w_5^u} - 2.25 \right| \leq \chi \\ ((w_1^l + 4w_1^m + w_1^u) + (w_2^l + 4w_2^m + w_2^u) + (w_3^l + 4w_3^m + w_3^u) \\ + (w_4^l + 4w_4^m + w_4^u) + (w_5^l + 4w_5^m + w_5^u))/6; \\ w_j^l \leq w_j^m \leq w_j^u; j = 1, \dots, 5 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 1, \dots, 5 \end{array} \right. \quad \dots \quad \left\{ \begin{array}{l} \left| \frac{w_1^l}{w_2^l} - 2.5 \right| \leq \chi; \left| \frac{w_1^m}{w_2^m} - 3 \right| \leq \chi; \left| \frac{w_1^u}{w_2^u} - 3.5 \right| \leq \chi; \\ \left| \frac{w_2^l}{w_5^l} - 0.71 \right| \leq \chi; \left| \frac{w_2^m}{w_5^m} - 1 \right| \leq \chi; \left| \frac{w_2^u}{w_5^u} - 1.4 \right| \leq \chi \\ \left| \frac{w_5^l}{w_4^l} - 0.43 \right| \leq \chi; \left| \frac{w_5^m}{w_4^m} - 0.67 \right| \leq \chi; \left| \frac{w_5^u}{w_4^u} - 1 \right| \leq \chi \\ \left| \frac{w_4^l}{w_3^l} - 0.27 \right| \leq \chi; \left| \frac{w_4^m}{w_3^m} - 0.5 \right| \leq \chi; \left| \frac{w_4^u}{w_3^u} - 1 \right| \leq \chi \\ \left| \frac{w_1^l}{w_5^l} - 1.78 \right| \leq \chi; \left| \frac{w_1^m}{w_5^m} - 3 \right| \leq \chi; \left| \frac{w_1^u}{w_5^u} - 4.9 \right| \leq \chi \\ \left| \frac{w_2^l}{w_4^l} - 0.31 \right| \leq \chi; \left| \frac{w_2^m}{w_4^m} - 0.67 \right| \leq \chi; \left| \frac{w_2^u}{w_4^u} - 1.4 \right| \leq \chi \\ \left| \frac{w_5^l}{w_3^l} - 0.12 \right| \leq \chi; \left| \frac{w_5^m}{w_3^m} - 0.34 \right| \leq \chi; \left| \frac{w_5^u}{w_3^u} - 1 \right| \leq \chi \\ ((w_1^l + 4w_1^m + w_1^u) + (w_2^l + 4w_2^m + w_2^u) + (w_3^l + 4w_3^m + w_3^u) \\ + (w_4^l + 4w_4^m + w_4^u) + (w_5^l + 4w_5^m + w_5^u))/6; \\ w_j^l \leq w_j^m \leq w_j^u; j = 1, \dots, 5 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 1, \dots, 5 \end{array} \right.$$

The offered models are solving the local values of the weight coefficients by DMS. When the models are solved using the LINGO 19.0 software, the blurred weights of the main criteria are calculated separately to each DM and are given in Table 4.

The fuzzy weights of the main criteria are obtained with an average of $\chi = 0.003$. This shows the high consistency of the values obtained from the criterion weights. Then, the fuzzy weights obtained for all decision makers were defuzzified, and the geometric averages of the weight obtained were taken as well as the net weight of the main criteria (0.286, 0.149, 0.191, 0.152, 0.2222). Models 2–6 were solved with similar steps, resulting in both net weights and local weights. The global weights of the criteria are obtained by multiplying the net weights of the main criteria and the local weights of the sub-criteria.

Table 5 provides local and global weights of all of the SUMP evaluation criteria and their rankings by global weights.

Table 4. Fuzzy weights of the main criteria.

MC1–MC5	DM1	DM2	DM3	DM4
MC1	(0.224, 0.265, 0.265)	(0.330, 0.320, 0.370)	(0.235, 0.297, 0.297)	(0.111, 0.194, 0.200)
MC2	(0.066, 0.100, 0.105)	(0.128, 0.208, 0.208)	(0.093, 0.169, 0.169)	(0.095, 0.184, 0.184)
MC3	(0.141, 0.248, 0.248)	(0.076, 0.099, 0.102)	(0.078, 0.104, 0.104)	(0.256, 0.350, 0.350)
MC4	(0.084, 0.150, 0.177)	(0.088, 0.132, 0.155)	(0.066, 0.107, 0.118)	(0.088, 0.119, 0.119)
MC5	(0.094, 0.284, 0.401)	(0.109, 0.234, 0.258)	(0.143, 0.388, 0.437)	(0.086, 0.225, 0.225)
χ	0.004	0.002	0.002	0.004
MC1–MC5	DM5	DM6	DM7	DM8
MC1	(0.235, 0.297, 0.297)	(0.261, 0.328, 0.376)	(0.111, 0.194, 0.200)	(0.255, 0.207, 0.297)
MC2	(0.093, 0.169, 0.169)	(0.097, 0.097, 0.120)	(0.095, 0.184, 0.184)	(0.077, 0.104, 0.104)
MC3	(0.078, 0.104, 0.104)	(0.088, 0.088, 0.202)	(0.256, 0.350, 0.350)	(0.143, 0.388, 0.437)
MC4	(0.066, 0.107, 0.118)	(0.164, 0.397, 0.464)	(0.088, 0.119, 0.119)	(0.093, 0.169, 0.169)
MC5	(0.143, 0.388, 0.437)	(0.085, 0.097, 0.129)	(0.086, 0.225, 0.225)	(0.066, 0.107, 0.118)
χ	0.002	0.003	0.004	0.003

Table 5. Final weights of criteria.

Main Criteria	Sub-Criteria	Local Weights	Global Weights	Rank
MC1 (0.286)	C1	0.202	0.0578	6
	C2	0.247	0.0706	4
	C3	0.189	0.0541	7
	C4	0.362	0.1035	2
MC2 (0.149)	C5	0.724	0.1079	1
	C6	0.276	0.0411	13
MC3 (0.191)	C7	0.078	0.0149	21
	C8	0.100	0.0191	17
	C9	0.091	0.0174	18
	C10	0.225	0.0430	12
	C11	0.080	0.0153	20
	C12	0.078	0.0149	21
	C13	0.068	0.0130	23
	C14	0.199	0.0380	14
MC4 (0.152)	C15	0.083	0.0158	19
	C16	0.299	0.0454	9
	C17	0.213	0.0324	15
	C18	0.192	0.0292	16
MC5 (0.222)	C19	0.296	0.0450	11
	C20	0.266	0.0591	5
	C21	0.203	0.0451	10
	C22	0.325	0.0722	3
	C23	0.206	0.0457	8

According to Table 5, the most important main criterion (28.6%) was MC1, followed by MC5 (22.2%), MC3 (19.1%), MC4 (15.2%), and MC2 (14.9%). In addition, C4 was first in the MC1 main criterion, while C3 was last. The C5 sub-criterion for the MC2 main criterion was first and C6 was last. In the MC3 main criteria, C10 ranked first and the C13 sub-criterion was last. C16 was first in the MC4 main criteria and C18 was last. C22 was first in the MC5 main criteria and C21 was last. Based on the global weights determined in this study, it is seen that the most important sub-criterion for the SUMP evaluation is C5 with a weight of 0.1079.

After the weights of the criteria were calculated, these weights were used in the F-CoCoSo model to obtain the ranking results of the alternatives.

Phase II—Evaluation of alternatives using the F-CoCoSo model

Eight DMs participated in the presented research (DM_i , $i = 1, 2, \dots, 8$). The DMs assessed five alternatives (A_i , $i = 1, \dots, 5$) about five main criteria. The assessments obtained using the language scale presented in Table 2 are presented in Table 6.

Table 6. DMs' correspondent matrices.

Criteria	A1	A2	A3	A4	A5
MC1	WLS, WLS, WLS, MoLS, MoLS, LS, LS, WLS	MoLS, LS, LS, RLS, LS, LS, RLS, MoLS	LS, RLS, RLS, MLS, MLS, LS, LS, MoLS	MoLS, LS, LS, LS, LS, RLS, RLS, RLS	MLS, MLS, DLS, RLS, DLS, DLS, DLS, ALS
MC2	MoLS, MoLS, MLS, WLS, LS, RLS, MoLS, RLS	LS, RLS, RLS, RLS, LS, MLS, RLS, MLS	MoLS, LS, LS, RLS, RLS, RLS, MLS, MLS	MoLS, LS, MoLS, MoLS, LS, LS, MoLS, LS	DLS, DLS, ALS, ALS, MLS, ALS, DLS, DLS
MC3	MoLS, RLS, LS, LS, MoLS, LS, WLS, LS	RLS, LS, LS, MoLS, MoLS, LS, RLS, RLS	MLS, LS, RLS, LS, LS, MoLS, LS, LS	LS, RLS, RLS, RLS, MoLS, LS, MoLS, LS	DLS, RLS, LS, MLS, RLS, DLS, MLS, DLS
MC4	WLS, WLS, WLS, MoLS, WLS, MoLS, MoLS, MoLS	WLS, LS, LS, RLS, RLS, LS, LS, LS	MLS, LS, RLS, LS, LS, MoLS, MoLS, LS	MoLS, RLS, RLS, RLS, RLS, RLS, LS, MoLS	ALS, RLS, MLS, MLS, MLS, DLS, DLS, RLS
MC5	WLS, WLS, MoLS, WLS, LS, MoLS, MoLS, LS	RLS, RLS, MoLS, LS, LS, RLS, MLS, RLS	LS, RLS, RLS, RLS, MLS, LS, LS, MoLS	MLS, LS, LS, MoLS, MoLS, LS, MoLS, MLS	DLS, RLS, ALS, DLS, ALS, DLS, DLS, LS

Then, the arithmetic average of the matrices corresponding to the evaluations of the decision makers was obtained by obtaining the initial (aggregated) decision matrix and is given in Table 7.

Table 7. Aggregated decision matrix.

	A1	A2	A3	A4	A5
MC1	(0.559, 0.792, 0.917)	(0.408, 0.517, 0.709)	(0.367, 0.496, 0.600)	(0.387, 0.483, 0.646)	(0.266, 0.308, 0.365)
MC2	(0.439, 0.579, 0.758)	(0.338, 0.408, 0.542)	(0.359, 0.442, 0.579)	(0.450, 0.584, 0.834)	(0.244, 0.278, 0.324)
MC3	(0.450, 0.529, 0.771)	(0.400, 0.504, 0.688)	(0.389, 0.488, 0.654)	(0.400, 0.504, 0.688)	(0.299, 0.353, 0.433)
MC4	(0.584, 0.834, 1.000)	(0.446, 0.583, 0.750)	(0.438, 0.508, 0.729)	(0.383, 0.479, 0.646)	(0.281, 0.328, 0.394)
MC5	(0.475, 0.813, 0.918)	(0.365, 0.450, 0.592)	(0.373, 0.463, 0.613)	(0.409, 0.438, 0.600)	(0.272, 0.318, 0.384)

Using Equations (8)–(10), the power weight of the weighted comparison fuzzy sum (\tilde{S}_i) and the comparative sequences (\tilde{P}_i) for each alternative were calculated. These values are specified in Table 8.

Table 8. The fuzzy sum of weighted comparability and power weight.

\tilde{S}_i	\tilde{P}_i
(0.3100, 0.6974, 0.9180)	(4.3300, 4.6820, 4.9170)
(0.2402, 0.4762, 0.6888)	(4.1130, 4.3590, 4.7560)
(0.2324, 0.4643, 0.6587)	(4.0950, 4.3420, 4.7250)
(0.2449, 0.4747, 0.7006)	(4.1400, 4.3600, 4.7650)
(0.1660, 0.3064, 0.3985)	(3.8180, 4.0100, 4.4460)

Using Equations (11)–(13), three fuzzy evaluation scores (\tilde{f}_{ia} , \tilde{f}_{ib} , \tilde{f}_{ic}) were obtained for each alternative. Evaluation scores are shown in Table 9.

These fuzzy appraisal scores (\tilde{f}_{ia} , \tilde{f}_{ib} , \tilde{f}_{ic}) were converted into crisp appraisal scores (f_{ia} , f_{ib} , f_{ic}) by using Equations (14)–(17). These crisp scores are presented in Table 10.

The Podgorica SUMP assessment ranks alternatives in the last column of Table 10. Based on the obtained values, it is seen that A1 is the first of the alternatives using the F-FUCOM and the F-CoCoSo model. $A1 \succ A4 \succ A2 \succ A3 \succ A5$ (" \succ " means "superior") sorting in the form.

Table 9. The fuzzy appraisal scores.

\tilde{f}_{ia}	\tilde{f}_{ib}	\tilde{f}_{ic}
(0.1720, 0.2226, 0.2690)	(3.0019, 5.4287, 6.8195)	(0.7952, 0.9220, 1.000)
(0.1614, 0.2000, 0.2510)	(2.5245, 4.0111, 5.3964)	(0.7460, 0.8287, 0.9331)
(0.1604, 0.1988, 0.2482)	(2.4726, 3.9351, 5.2068)	(0.7415, 0.8236, 0.9227)
(0.1626, 0.2000, 0.2520)	(2.5598, 4.0020, 5.4694)	(0.7514, 0.8285, 0.9367)
(0.1477, 0.1786, 0.2234)	(2.0000, 2.8963, 3.5656)	(0.6828, 0.7397, 0.8303)

Table 10. Crisp appraisal scores and rankings.

	f_{ia}	f_{ib}	f_{ic}	f_i	Ranking
A1	0.2212	5.0834	0.9057	3.0762	1
A2	0.2042	3.9773	0.8359	2.5513	3
A3	0.2025	3.8715	0.8293	2.5007	4
A4	0.2048	4.0104	0.8389	2.5680	2
A5	0.1832	2.8206	0.7509	1.9810	5

5. Sensitivity Analysis

Four approaches have been used to verify the results of the analysis. First, criteria weights were changed to see if there was a difference in the ranking. Then, the last alternatives were eliminated and sensitivity analysis was performed based on the difference in the order reversal feature. Then, a comparison analysis was performed with other MCDM methods. Finally, the correlation coefficient was calculated based on the obtained rankings and the reliability analysis of the model was performed.

5.1. Sensitivity Analysis Based on Variation of Criteria Weight

In the first phase of the verification test, the effect of replacing the most important main criterion MC1 on the ranking results was analyzed. A total of 20 scenarios were created using Equation (18). If Equation (18) is observed, $\tilde{W}_{n\beta}$ represents the fuzzy corrected value of the MC2, MC3, MC4, and MC5 criteria by groups, respectively. $\tilde{W}_{n\alpha}$ represents the reduced fuzzy value of the MC1 criterion, the original fuzzy value of the criterion taken into account in the \tilde{w}_{β} , and the original fuzzy value of the criteria that are reduced in \tilde{W}_n , in this case, the MC1 value.

In the first scenario, the fuzzy value of the MC1 criterion was reduced by 5%, while the values of the remaining criteria were corrected proportionally by applying Equation (18). In each subsequent scenario, the value of the MC1 criterion was reduced, while the values of the remaining criteria were corrected, thus meeting the condition $\sum_{j=1}^n w_j^m = 1$.

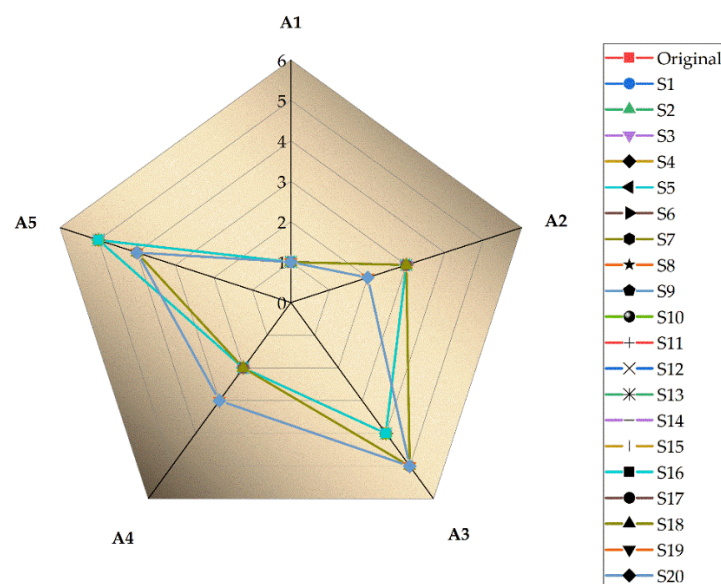
As a result of these changes, 20 new vectors of the weight coefficients of the criteria were created and given in Table 11.

These 20 different scenarios were analyzed individually in the F-CoCoSo method, and the order of the alternatives was re-determined. The results of the resulting ranking are given in Figure 3.

Figure 3 shows the sequences of the alternatives obtained and how the initial results compare with the results in S1–S20. The weights obtained by changing the criteria weights were changed according to the rankings obtained by using the F-CoCoSo method one by one. The change in weight of the most important criterion appears to have a slight effect on the SUMP sequences. The A1, A4, and A2 alternatives again came first, second, and third in all scenarios. With the elimination of the importance of the first criterion, the weight of the weight was 0.0267, 0.0166, and 0.0066, and there have been changes for the A3 and A5 alternatives. It can be said that the model is sensitive to changes in weight coefficients.

Table 11. New values of criteria in 20 different scenarios.

	MC1	MC2	MC3	MC4	MC5
Original	(0.2070, 0.2740, 0.2810)	(0.0920, 0.1460, 0.1510)	(0.1230, 0.1800, 0.2040)	(0.0890, 0.1470, 0.1600)	(0.0980, 0.2190, 0.2490)
S1	(0.1976, 0.2603, 0.2670)	(0.0920, 0.1488, 0.1540)	(0.1230, 0.1834, 0.2080)	(0.0890, 0.1498, 0.1631)	(0.0980, 0.2231, 0.2539)
S2	(0.1867, 0.2343, 0.2403)	(0.0944, 0.1540, 0.1596)	(0.1262, 0.1899, 0.2156)	(0.0913, 0.1550, 0.1691)	(0.1005, 0.2310, 0.2631)
S3	(0.1767, 0.2108, 0.2162)	(0.0955, 0.1587, 0.1646)	(0.1277, 0.1957, 0.2224)	(0.0924, 0.1598, 0.1744)	(0.1018, 0.2381, 0.2714)
S4	(0.1667, 0.1898, 0.1946)	(0.0967, 0.1629, 0.1691)	(0.1293, 0.2009, 0.2285)	(0.0935, 0.1641, 0.1792)	(0.1030, 0.2444, 0.2789)
S5	(0.1567, 0.1708, 0.1751)	(0.0978, 0.1668, 0.1732)	(0.1308, 0.2056, 0.2340)	(0.0947, 0.1679, 0.1836)	(0.1042, 0.2501, 0.2857)
S6	(0.1467, 0.1537, 0.1576)	(0.0990, 0.1702, 0.1769)	(0.1324, 0.2098, 0.2390)	(0.0958, 0.1714, 0.1875)	(0.1055, 0.2553, 0.2917)
S7	(0.1367, 0.1383, 0.1419)	(0.1002, 0.1733, 0.1802)	(0.1339, 0.2136, 0.2435)	(0.0969, 0.1745, 0.1910)	(0.1067, 0.2599, 0.2972)
S8	(0.1267, 0.1245, 0.1277)	(0.1013, 0.1761, 0.1832)	(0.1355, 0.2171, 0.2475)	(0.0980, 0.1773, 0.1941)	(0.1079, 0.2641, 0.3021)
S9	(0.1167, 0.1121, 0.1149)	(0.1025, 0.1786, 0.1859)	(0.1370, 0.2202, 0.2511)	(0.0991, 0.1798, 0.1970)	(0.1092, 0.2679, 0.3065)
S10	(0.1067, 0.1008, 0.1034)	(0.1036, 0.1808, 0.1883)	(0.1386, 0.2229, 0.2544)	(0.1003, 0.1821, 0.1995)	(0.1104, 0.2712, 0.3105)
S11	(0.0966, 0.0908, 0.0931)	(0.1048, 0.1828, 0.1905)	(0.1401, 0.2254, 0.2573)	(0.1014, 0.1841, 0.2018)	(0.1116, 0.2743, 0.3141)
S12	(0.0866, 0.0817, 0.0838)	(0.1060, 0.1847, 0.1924)	(0.1417, 0.2277, 0.2600)	(0.1025, 0.1859, 0.2039)	(0.1129, 0.2770, 0.3173)
S13	(0.0767, 0.0735, 0.0754)	(0.1071, 0.1863, 0.1942)	(0.1432, 0.2297, 0.2623)	(0.1036, 0.1876, 0.2058)	(0.1141, 0.2795, 0.3202)
S14	(0.0667, 0.0662, 0.0679)	(0.1083, 0.1878, 0.1958)	(0.1448, 0.2315, 0.2645)	(0.1048, 0.1891, 0.2074)	(0.1153, 0.2817, 0.3228)
S15	(0.0567, 0.0595, 0.0611)	(0.1094, 0.1891, 0.1972)	(0.1463, 0.2332, 0.2664)	(0.1059, 0.1904, 0.2089)	(0.1166, 0.2837, 0.3252)
S16	(0.0467, 0.0536, 0.0550)	(0.1106, 0.1903, 0.1985)	(0.1479, 0.2346, 0.2681)	(0.1070, 0.1916, 0.2103)	(0.1178, 0.2855, 0.3273)
S17	(0.0367, 0.0482, 0.0495)	(0.1118, 0.1914, 0.1996)	(0.1494, 0.2360, 0.2697)	(0.1081, 0.1927, 0.2115)	(0.1191, 0.2871, 0.3292)
S18	(0.0267, 0.0434, 0.0445)	(0.1129, 0.1924, 0.2007)	(0.1510, 0.2372, 0.2711)	(0.1092, 0.1937, 0.2126)	(0.1203, 0.2886, 0.3309)
S19	(0.0166, 0.0391, 0.0401)	(0.1141, 0.1932, 0.2016)	(0.1525, 0.2382, 0.2724)	(0.1104, 0.1946, 0.2136)	(0.1215, 0.2899, 0.3324)
S20	(0.0066, 0.0352, 0.0361)	(0.1152, 0.1940, 0.2024)	(0.1541, 0.2392, 0.2735)	(0.1115, 0.1954, 0.2145)	(0.1228, 0.2910, 0.3338)

**Figure 3.** Comparison of original results with S1–S20 scenarios.

5.2. Sensitivity Analysis Based on Row Reversing Feature

If the ranking of alternatives shows some logical contradictions expressed in the form of undesirable changes, the concern can be expressed that there is a problem with the mathematical mechanism of the applied method. For this purpose, a test was carried out in which the resistance of the model to the problem of inversion was taken into account. In the test, four scenarios were created in which the change in the elements of the decision matrix was simulated. As a rule, four scenarios must be created (one less than the total number of alternatives). In the first scenario, after the F-CoCoSo method is applied (shown in the original order), the sort is performed. In the next scenario (S1), the last-place alternative is eliminated. After that, the remaining four alternatives are reordered. Thus, a total of four scenarios (S1–S4) are created, so that the rankings obtained by elimination of the worst-ranked alternative from the cluster in each subsequent scenario are given in Figure 4.

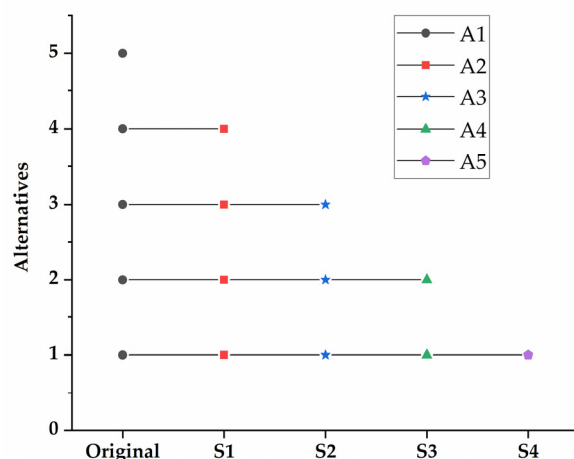


Figure 4. Results of order reversal analysis.

In the four scenarios used, the last-place alternative was removed and reordered. It can be noted from Figure 4 that the F-CoCoSo model provides valid results in a dynamic environment and the model's resistance to the problem of inversion is strong. In all scenarios, the advantages of the first ranking are maintained.

5.3. Sensitivity Analysis of Ranking Stability Based on Different Ranking Methodologies

A comparative analysis can also be performed with MCDM methods based on different sorting methodologies to see the stability of the ranking for the accuracy of the analysis results. In this application, also known as comparison analysis, the robustness and reliability of the ranking scores of the alternatives are examined by comparing the result of one model with other existing and built-in methods in many complex decision environments. A similar ranking comparison was made with some commonly used methods, such as the F-TOPSIS, F-COPRAS, F-ARAS, and F-MOORA, to choose the best alternative and explain the reliability of the proposed F-FUCOM-based F-CoCoSo model. These methods are chosen because of their various advantages, wide application, and potential to efficiently sort alternatives in a multi-criterion selection environment. The ranking results are given in Figure 5.

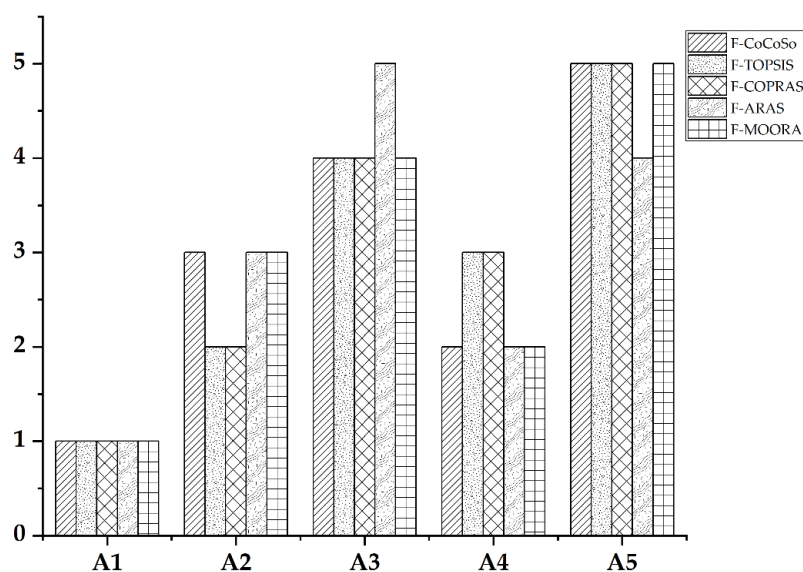


Figure 5. Ranking alternatives by different MCDM methods.

According to Figure 5, the A1 alternative used in the evaluation of the Podgorica SUMP has always been at the forefront of all methods. The A2 alternative came third in the F-TOPSIS and F-COPRAS methods in other methods. The A3 alternative came fourth with the F-ARAS method and fifth with other methods. The A4 alternative came second in the F-TOPSIS and F-COPRAS methods in the third method. The A5 alternative came fifth in the F-ARAS method compared to the four other methods.

Finally, the theoretical analysis is confirmed by the statistical correlation of the rankings made using Spearman's correlation coefficient. The Spearman correlation coefficients were calculated with SPSS 26. Table 12 provides a comparison of the values of Spearman's coefficient with the results from different MCDM models.

Table 12. The values of Spearman's coefficient.

	F-CoCoSo	F-ARAS	F-TOPSIS	F-COPRAS	F-MOORA
F-CoCoSo	1	0.900	0.900	0.900	1.000
F-ARAS		1	0.800	0.800	0.900
F-TOPSIS			1	1.000	0.900
F-COPRAS				1	0.900
F-MOORA					1

Spearman's coefficient of sequence correlation of the strategies considered is considered to be a very high correlation in the range [0.667, 1]. It can be said that the ranking obtained with an average correlation value of 0.925 between the other four MCDM techniques of the proposed model and the F-CoCoSo approach used is approved and reliable.

6. Discussion

The main objective of this paper was to introduce a hybrid MCDM model based on the Fuzzy FUCOM and the Fuzzy CoCoSo method for the assessment of sustainable urban mobility plans. A three-step approach has been proposed. In the first stage, criteria and alternatives were created based on the literature review and the opinions of experts. In the second stage, the weights of the criteria and the order of the alternatives were created using multi-criterion decision-making techniques and linguistic data converted into blurred triangular numbers for further operations. The city of Podgorica is preferred for the numerical application. Podgorica benefits from the SUMP prepared by the city council. Five sustainable strategic pillars are evaluated: comprehensive planning for sustainable urban mobility in the city center, enabling more rational use of passenger cars, modernizing and popularizing public urban transport, valuing cycling potential, and returning to walking as the healthiest mode of mobility. The results of the research show that the best alternative is necessary to make comprehensive planning for sustainable urban mobility in Podgorica's city center. The appreciation of the bicycling potential, more rational use of passenger cars, the modernization and popularization of public urban transport, and the healthiest mobility mode are listed according to importance.

While the main criterion of implementation and assurance of the SUMP (MC1) was the most important criterion with a weight of 0.286, developing a new SUMP (C4) was the most important sub-criterion with a weight of 0.1035 from the sub-criteria in this group. The monitoring and evaluation of the SUMP (MC2) is the main criterion with a weight of 0.149, while establishing a system for regular data collection, monitoring, and evaluation of selected mobility indicators (C5) is an important sub-criterion with a weight of 0.1079 from the lower criteria in this group. The strengthening and integration of planning sectors and governance levels (MC3) ranked third with a net of 0.191, while an integrated system of sustainable mobility planning and the planning of other sectors and enhancing cooperation among sectors, with a special focus on the spatial planning of urban structures of short distances (C10), was the most important lower criterion with a weight of 0.0430. The strengthening and integration of planning sectors and governance levels (MC4) ranked fourth with a weight of 0.152, while revising the existing road network

hierarchy and preparing a development plan for “superblocks” (C16) were the e-criteria with a weight of 0.0454. The main criterion for public participation and promotion of the SUMP achievements (MC5) was second with a weight of 0.222, while introducing a so-called participatory budget, which serves to consider and support citizens’ initiatives in the field of sustainable mobility (C22), was the most important criterion with a weight of 0.0722.

Comprehensive planning for the SUMP for the city of Podgorica (A1) depends on the implementation and assurance of this planning (MC1).

In the paper, sensitivity analysis was conducted with four different approaches to test the reliability and strength of the proposed model. It was observed that the first proposed model is sensitive to changes in weight coefficients. The second approach is resistant to the problem of inversion and has a very high correlation with the results of other MCDM methods used in the literature with the third and fourth approaches. These results show that the proposed model produces consistent and robust ranking results.

The proposed model has strengths such as being able to perform SUMP evaluations without quantitative knowledge and involving multiple decision makers in the decision-making process. The limited number of decision makers included in the study from the same point of view is the limitation of the study. The limitation of the proposed model is that the selected experts operate in the same field. Another limitation is the models used in both the weighting of the criteria and the ranking of the alternatives.

7. Conclusions

In the current study, the F-FUCOM and F-CoCoSo integrated approach was applied with a real case study to evaluate the SUMP for the first time in the literature. First, the F-FUCOM is considered to decide the weights of the five main criteria and twenty-three sub-criteria. Secondly, the F-CoCoSo method is applied to sort the SUMP alternatives. In addition, a detailed sensitivity analysis is carried out to verify the obtained results.

The empirical findings, on the one hand, demonstrate that the implementation and assurance of the SUMP, public participation and promotion of the SUMP achievements, the strengthening and integration of planning sectors and governance levels, implementation of integrated measures in the field of mobility SUMP, and monitoring and evaluation of the SUMP are important, respectively. In addition, developing a new SUMP; introducing a so-called participatory budget, which serves to consider and support citizens’ initiatives in the field of sustainable mobility; establishing an integrated system of sustainable mobility planning and the planning of other sectors and enhancing cooperation among sectors, with a special focus on the spatial planning of compact urban structures of short distances; revising the existing road network hierarchy and preparing a development plan for “superblocks”; and establishing a system for regular data collection, monitoring, and evaluation of selected mobility indicators sub-criteria are the most important measures. The findings suggest that the alternative to comprehensive planning for sustainable urban mobility is first, while the valorization of the cycling potential alternative is second. The comprehensive sensitivity analysis confirms the validity, robustness, and effectiveness of the proposed framework.

Since the proposed methodology is structured with the evaluations of decision makers, it is possible to strengthen the SUMP with the ideas of experts and stakeholders in different fields. SUMP can help improve the implementation of new tools in both the diagnostic and solution proposal stages. When dealing with a large number of alternatives to be implemented in a planning tool such as an SUMP, it is common for some to come before others. For example, comprehensive planning for sustainable urban mobility comes before the assessment of cycling potential. The proposed approach has been effective in a medium-sized city like Podgorica, where the number and interactions of variables are reasonably manageable. However, future research lines will be interesting to assess the ability to optimize processes for solution proposals in urban mobility planning tools in larger and more complex cities, such as Paris or London.

It can be a potential research topic for future studies, as there may be different evaluation criteria or different MCDM methods (WASPAS, CODAS, WISP, etc.) and various extensions of them (global fuzzy sets, Pythagorean fuzzy sets, intuitive fuzzy sets, etc.) that could be a potential research topic in the future. In any country, different criteria can be observed in the solution of the SUMP evaluation problem. The proposed scientific methodology can be easily applied to different cities.

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

Appendix A

Table A1. Linguistic evaluations of the criteria/sub-criteria.

Main Criteria/Sub-Criteria		DM1	DM2	DM3	DM4
Main Criteria MC1–MC5	R C	MC1 > MC2 > MC4 > MC3 > MC5 EI, VI, FI, WI, WI	MC1 > MC3 > MC4 > MC2 > MC5 EI, AI, VI, FI, FI	MC1 > MC3 > MC4 > MC2 > MC5 EI, VI, VI, FI, WI	MC3 > MC4 > MC1 > MC2 > MC5 EI, VI, FI, FI, FI
MC1—Sub-Criteria C1–C4	R C	C1 > C2 > C3 > C4 EI, VI, FI, WI	C1 > C2 > C3 > C4 EI, AI, FI, FI	C2 > C1 > C3 > C4 EI, VI, FI, WI	C2 > C1 > C3 > C4 EI, FI, FI, WI
MC2—Sub-Criteria C5–C6	R C	C5 > C6 EI, VI	C5 > C6 EI, FI	C5 > C6 EI, FI	C5 > C6 EI, VI
MC3—Sub-Criteria C7–C15	R C	C10 > C7 > C11 > C12 > C13 > C8 > C9 > C15 > C14 EI, VI, VI, VI, VI, FI, FI, FI, WI	C12 > C10 > C7 > C11 > C8 > C9 > C13 > C14 > C15 EI, VI, VI, VI, FI, FI, FI, FI, FI	C11 > C9 > C15 > C7 > C13 > C10 > C12 > C14 > C8 EI, AI, AI, VI, VI, FI, WI, WI, WI	C10 > C7 > C13 > C15 > C9 > C11 > C14 > C8 > C12 EI, AI, AI, AI, VI, VI, FI, WI, WI
MC4—Sub-Criteria C16–C19	R C	C18 > C19 > C16 > C17 EI, EI, FI, WI	C16 > C18 > C17 > C19 EI, VI, FI, WI	C16 > C17 > C18 > C19 EI, VI, VI, VI	C16 > C17 > C18 > C19 EI, VI, VI, VI
MC5—Sub-Criteria C20–C23	R C	C20 > C21 > C22 > C23 EI, EI, WI, WI	C22 > C20 > C21 > C23 EI, WI, WI, WI	C22 > C23 > C20 > C21 EI, VI, FI, FI	C22 > C23 > C20 > C21 EI, VI, FI, FI

Table A1. Cont.

Main Criteria/Sub-Criteria		DM5	DM6	DM7	DM8
Main Criteria MC1–MC5	R C	MC1 > MC3 > MC4 > MC2 > MC5 EI, VI, VI, FI, WI	MC1 > MC2 > MC5 > MC3 > MC4 EI, VI, VI, FI, WI	MC3 > MC4 > MC1 > MC2 > MC5 EI, VI, FI, FI, FI	MC1 > MC2 > MC5 > MC4 > MC3 EI, VI, VI, FI, WI
MC1—Sub-Criteria C1–C4	R C	C2 > C1 > C3 > C4 EI, VI, FI, WI	C2 > C1 > C3 > C4 EI, VI, FI, WI	C2 > C3 > C1 > C4 EI, VI, FI, FI	C1 > C2 > C3 > C4 EI, VI, FI, WI
MC2—Sub-Criteria C5–C6	R C	C5 > C6 EI, FI	C5 > C6 EI, VI	C5 > C6 EI, VI	C5 > C6 EI, AI
MC3—Sub-Criteria C7–C15	R C	C9 > C11 > C15 > C7 > C13 > C10 > C14 > C12 > C8 EI, AI, AI, VI, VI, FI, FI, WI, WI	C7 > C8 > C9 > C12 > C10 > C11 > C14 > C15 > C13 EI, VI, VI, VI, FI, FI, WI, WI, WI	C7 > C9 > C13 > C15 > C10 > C11 > C8 > C12 > C14 EI, AI, AI, AI, VI, VI, FI, FI, FI	C7 > C10 > C12 > C8 > C9 > C11 > C14 > C13 > C15 EI, VI, VI, FI, FI, WI, WI, WI, WI
MC4—Sub-Criteria C16–C19	R C	C16 > C17 > C18 > C19 EI, VI, VI, VI	C19 > C18 > C16 > C17 EI, VI, FI, FI	C18 > C16 > C17 > C19 EI, VI, FI, FI	C19 > C18 > C16 > C17 EI, VI, FI, FI
MC5—Sub-Criteria C20–C23	R C	C22 > C23 > C20 > C21 EI, VI, FI, FI	C20 > C21 > C22 > C23 EI, AI, FI, WI	C22 > C23 > C20 > C21 EI, VI, FI, FI	C20 > C21 > C22 > C23 EI, VI, FI, FI

R—Rank; C—Comparisons.

Appendix B

DM1 (C1–C4) $\rightarrow \min \chi$
s.t.DM8 (C1–C4) $\rightarrow \min \chi$
s.t.

Model 2

$$\left\{ \begin{array}{l} \left| \frac{w_1^l}{w_2^u} - 2.5 \right| \leq \chi; \left| \frac{w_1^m}{w_2^m} - 3 \right| \leq \chi; \left| \frac{w_1^u}{w_2^u} - 3.5 \right| \leq \chi; \\ \left| \frac{w_2^l}{w_3^u} - 0.43 \right| \leq \chi; \left| \frac{w_2^m}{w_3^m} - 0.67 \right| \leq \chi; \left| \frac{w_2^u}{w_3^u} - 1 \right| \leq \chi \\ \left| \frac{w_3^l}{w_4^u} - 0.27 \right| \leq \chi; \left| \frac{w_3^m}{w_4^m} - 0.5 \right| \leq \chi; \left| \frac{w_3^u}{w_4^u} - 1 \right| \leq \chi \\ \left| \frac{w_1^l}{w_3^u} - 1.08 \right| \leq \chi; \left| \frac{w_1^m}{w_3^m} - 2.01 \right| \leq \chi; \left| \frac{w_1^u}{w_3^u} - 3.5 \right| \leq \chi \\ \left| \frac{w_2^l}{w_4^u} - 0.12 \right| \leq \chi; \left| \frac{w_2^m}{w_4^m} - 0.34 \right| \leq \chi; \left| \frac{w_2^u}{w_4^u} - 1 \right| \leq \chi \\ \left((w_1^l + 4w_1^m + w_1^u) + (w_2^l + 4w_2^m + w_2^u) \right) \\ + (w_3^l + 4w_3^m + w_3^u) + (w_4^l + 4w_4^m + w_4^u) / 6; \\ w_j^l \leq w_j^m \leq w_j^u; j = 1, \dots, 4 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 1, \dots, 4 \end{array} \right. \quad \dots \quad \left\{ \begin{array}{l} \left| \frac{w_1^l}{w_2^u} - 2.5 \right| \leq \chi; \left| \frac{w_1^m}{w_2^m} - 3 \right| \leq \chi; \left| \frac{w_1^u}{w_2^u} - 3.5 \right| \leq \chi; \\ \left| \frac{w_2^l}{w_3^u} - 0.43 \right| \leq \chi; \left| \frac{w_2^m}{w_3^m} - 0.67 \right| \leq \chi; \left| \frac{w_2^u}{w_3^u} - 1 \right| \leq \chi \\ \left| \frac{w_3^l}{w_4^u} - 0.27 \right| \leq \chi; \left| \frac{w_3^m}{w_4^m} - 0.5 \right| \leq \chi; \left| \frac{w_3^u}{w_4^u} - 1 \right| \leq \chi \\ \left| \frac{w_1^l}{w_3^u} - 1.08 \right| \leq \chi; \left| \frac{w_1^m}{w_3^m} - 2.01 \right| \leq \chi; \left| \frac{w_1^u}{w_3^u} - 3.5 \right| \leq \chi \\ \left| \frac{w_2^l}{w_4^u} - 0.12 \right| \leq \chi; \left| \frac{w_2^m}{w_4^m} - 0.34 \right| \leq \chi; \left| \frac{w_2^u}{w_4^u} - 1 \right| \leq \chi \\ \left((w_1^l + 4w_1^m + w_1^u) + (w_2^l + 4w_2^m + w_2^u) \right) \\ + (w_3^l + 4w_3^m + w_3^u) + (w_4^l + 4w_4^m + w_4^u) / 6; \\ w_j^l \leq w_j^m \leq w_j^u; j = 1, \dots, 4 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 1, \dots, 4 \end{array} \right.$$

DM1 (C5–C6) $\rightarrow \min \chi$
s.t.DM8 (C5–C6) $\rightarrow \min \chi$
s.t.

Model 3

$$\left\{ \begin{array}{l} \left| \frac{w_5^l}{w_6^u} - 2.5 \right| \leq \chi; \left| \frac{w_5^m}{w_6^m} - 3 \right| \leq \chi; \left| \frac{w_5^u}{w_6^u} - 3.5 \right| \leq \chi; \\ \left((w_5^l + 4w_5^m + w_5^u) + (w_6^l + 4w_6^m + w_6^u) \right) / 6 \\ w_j^l \leq w_j^m \leq w_j^u; j = 5, 6 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 5, 6 \end{array} \right. \quad \dots \quad \left\{ \begin{array}{l} \left| \frac{w_5^l}{w_6^u} - 3.5 \right| \leq \chi; \left| \frac{w_5^m}{w_6^m} - 4 \right| \leq \chi; \left| \frac{w_5^u}{w_6^u} - 4.5 \right| \leq \chi; \\ \left((w_5^l + 4w_5^m + w_5^u) + (w_6^l + 4w_6^m + w_6^u) \right) / 6 \\ w_j^l \leq w_j^m \leq w_j^u; j = 5, 6 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 5, 6 \end{array} \right.$$

DM1 (C7–C15) $\rightarrow \min \chi$
s.t.DM8 (C7–C15) $\rightarrow \min \chi$
s.t.

Model 4

$$\left\{ \begin{array}{l}
\left| \frac{w_{10}^l}{w_7^m} - 2.5 \right| \leq \chi; \left| \frac{w_{10}^m}{w_7^m} - 3 \right| \leq \chi; \left| \frac{w_{10}^u}{w_7^m} - 3.5 \right| \leq \chi; \\
\left| \frac{w_{11}^l}{w_{11}^m} - 0.71 \right| \leq \chi; \left| \frac{w_{11}^m}{w_{11}^m} - 1 \right| \leq \chi; \left| \frac{w_{11}^u}{w_{11}^m} - 1.4 \right| \leq \chi \\
\left| \frac{w_{12}^l}{w_{12}^m} - 0.71 \right| \leq \chi; \left| \frac{w_{12}^m}{w_{12}^m} - 1 \right| \leq \chi; \left| \frac{w_{12}^u}{w_{12}^m} - 1.4 \right| \leq \chi \\
\left| \frac{w_{13}^l}{w_{13}^m} - 0.71 \right| \leq \chi; \left| \frac{w_{13}^m}{w_{13}^m} - 1 \right| \leq \chi; \left| \frac{w_{13}^u}{w_{13}^m} - 1.4 \right| \leq \chi \\
\left| \frac{w_{13}^l}{w_8^m} - 0.43 \right| \leq \chi; \left| \frac{w_{13}^m}{w_8^m} - 0.67 \right| \leq \chi; \left| \frac{w_{13}^u}{w_8^m} - 1 \right| \leq \chi \\
\left| \frac{w_8^l}{w_9^m} - 0.6 \right| \leq \chi; \left| \frac{w_8^m}{w_9^m} - 1 \right| \leq \chi; \left| \frac{w_8^u}{w_9^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_9^l}{w_{15}^m} - 0.6 \right| \leq \chi; \left| \frac{w_9^m}{w_{15}^m} - 1 \right| \leq \chi; \left| \frac{w_9^u}{w_{15}^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_{15}^l}{w_{14}^m} - 0.27 \right| \leq \chi; \left| \frac{w_{15}^m}{w_{14}^m} - 0.5 \right| \leq \chi; \left| \frac{w_{15}^u}{w_{14}^m} - 1 \right| \leq \chi \\
\left| \frac{w_{10}^l}{w_{11}^m} - 1.78 \right| \leq \chi; \left| \frac{w_{10}^m}{w_{11}^m} - 3 \right| \leq \chi; \left| \frac{w_{10}^u}{w_{11}^m} - 4.9 \right| \leq \chi \\
\left| \frac{w_7^l}{w_{12}^m} - 0.5 \right| \leq \chi; \left| \frac{w_7^m}{w_{12}^m} - 1 \right| \leq \chi; \left| \frac{w_7^u}{w_{12}^m} - 1.96 \right| \leq \chi \\
\left| \frac{w_{11}^l}{w_{13}^m} - 0.5 \right| \leq \chi; \left| \frac{w_{11}^m}{w_{13}^m} - 1 \right| \leq \chi; \left| \frac{w_{11}^u}{w_{13}^m} - 1.96 \right| \leq \chi \\
\left| \frac{w_{12}^l}{w_8^m} - 0.31 \right| \leq \chi; \left| \frac{w_{12}^m}{w_8^m} - 0.67 \right| \leq \chi; \left| \frac{w_{12}^u}{w_8^m} - 1.4 \right| \leq \chi \\
\left| \frac{w_{13}^l}{w_9^m} - 0.26 \right| \leq \chi; \left| \frac{w_{13}^m}{w_9^m} - 0.67 \right| \leq \chi; \left| \frac{w_{13}^u}{w_9^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_8^l}{w_{15}^m} - 0.36 \right| \leq \chi; \left| \frac{w_8^m}{w_{15}^m} - 1 \right| \leq \chi; \left| \frac{w_8^u}{w_{15}^m} - 2.79 \right| \leq \chi \\
\left| \frac{w_9^l}{w_{14}^m} - 0.16 \right| \leq \chi; \left| \frac{w_9^m}{w_{14}^m} - 0.5 \right| \leq \chi; \left| \frac{w_9^u}{w_{14}^m} - 1.67 \right| \leq \chi \\
\left((w_7^l + 4w_7^m + w_7^u) + (w_8^l + 4w_8^m + w_8^u) + \dots \right. \\
\left. + (w_{14}^l + 4w_{14}^m + w_{14}^u) + (w_{15}^l + 4w_{15}^m + w_{15}^u) \right) / 6; \\
w_j^l \leq w_j^m \leq w_j^u; j = 7, \dots, 15 \\
w_j^l, w_j^m, w_j^u \geq 0; j = 7, \dots, 15
\end{array} \right. \quad \dots \quad \left\{ \begin{array}{l}
\left| \frac{w_{10}^l}{w_7^m} - 2.5 \right| \leq \chi; \left| \frac{w_{10}^m}{w_7^m} - 3 \right| \leq \chi; \left| \frac{w_{10}^u}{w_7^m} - 3.5 \right| \leq \chi; \\
\left| \frac{w_{10}^l}{w_{12}^m} - 0.71 \right| \leq \chi; \left| \frac{w_{10}^m}{w_{12}^m} - 1 \right| \leq \chi; \left| \frac{w_{10}^u}{w_{12}^m} - 1.4 \right| \leq \chi \\
\left| \frac{w_{12}^l}{w_8^m} - 0.43 \right| \leq \chi; \left| \frac{w_{12}^m}{w_8^m} - 0.67 \right| \leq \chi; \left| \frac{w_{12}^u}{w_8^m} - 1 \right| \leq \chi \\
\left| \frac{w_8^l}{w_9^m} - 0.6 \right| \leq \chi; \left| \frac{w_8^m}{w_9^m} - 1 \right| \leq \chi; \left| \frac{w_8^u}{w_9^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_{11}^l}{w_{11}^m} - 0.26 \right| \leq \chi; \left| \frac{w_{11}^m}{w_{11}^m} - 0.5 \right| \leq \chi; \left| \frac{w_{11}^u}{w_{11}^m} - 1 \right| \leq \chi \\
\left| \frac{w_{14}^l}{w_{14}^m} - 0.44 \right| \leq \chi; \left| \frac{w_{14}^m}{w_{14}^m} - 1 \right| \leq \chi; \left| \frac{w_{14}^u}{w_{14}^m} - 2.25 \right| \leq \chi \\
\left| \frac{w_{13}^l}{w_{13}^m} - 0.44 \right| \leq \chi; \left| \frac{w_{13}^m}{w_{13}^m} - 1 \right| \leq \chi; \left| \frac{w_{13}^u}{w_{13}^m} - 2.25 \right| \leq \chi \\
\left| \frac{w_{15}^l}{w_{15}^m} - 0.44 \right| \leq \chi; \left| \frac{w_{15}^m}{w_{15}^m} - 1 \right| \leq \chi; \left| \frac{w_{15}^u}{w_{15}^m} - 2.25 \right| \leq \chi \\
\left| \frac{w_7^l}{w_{12}^m} - 1.78 \right| \leq \chi; \left| \frac{w_7^m}{w_{12}^m} - 3 \right| \leq \chi; \left| \frac{w_7^u}{w_{12}^m} - 4.9 \right| \leq \chi \\
\left| \frac{w_{10}^l}{w_8^m} - 0.31 \right| \leq \chi; \left| \frac{w_{10}^m}{w_8^m} - 0.67 \right| \leq \chi; \left| \frac{w_{10}^u}{w_8^m} - 1.4 \right| \leq \chi \\
\left| \frac{w_{12}^l}{w_9^m} - 0.26 \right| \leq \chi; \left| \frac{w_{12}^m}{w_9^m} - 0.67 \right| \leq \chi; \left| \frac{w_{12}^u}{w_9^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_8^l}{w_{11}^m} - 0.16 \right| \leq \chi; \left| \frac{w_8^m}{w_{11}^m} - 0.5 \right| \leq \chi; \left| \frac{w_8^u}{w_{11}^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_9^l}{w_{14}^m} - 0.11 \right| \leq \chi; \left| \frac{w_9^m}{w_{14}^m} - 0.5 \right| \leq \chi; \left| \frac{w_9^u}{w_{14}^m} - 2.25 \right| \leq \chi \\
\left| \frac{w_{11}^l}{w_{13}^m} - 0.19 \right| \leq \chi; \left| \frac{w_{11}^m}{w_{13}^m} - 1 \right| \leq \chi; \left| \frac{w_{11}^u}{w_{13}^m} - 5.06 \right| \leq \chi \\
\left| \frac{w_{14}^l}{w_{15}^m} - 0.19 \right| \leq \chi; \left| \frac{w_{14}^m}{w_{15}^m} - 1 \right| \leq \chi; \left| \frac{w_{14}^u}{w_{15}^m} - 5.06 \right| \leq \chi \\
\left((w_7^l + 4w_7^m + w_7^u) + (w_8^l + 4w_8^m + w_8^u) + \dots \right. \\
\left. + (w_{14}^l + 4w_{14}^m + w_{14}^u) + (w_{15}^l + 4w_{15}^m + w_{15}^u) \right) / 6; \\
w_j^l \leq w_j^m \leq w_j^u; j = 7, \dots, 15 \\
w_j^l, w_j^m, w_j^u \geq 0; j = 7, \dots, 15
\end{array} \right.$$

DM1 (C16–C19) $\rightarrow \min \chi$
s.t.

DM8 (C16–C19) $\rightarrow \min \chi$
s.t.

Model 5

$$\left\{ \begin{array}{l}
\left| \frac{w_{18}^l}{w_{19}^m} - 1 \right| \leq \chi; \left| \frac{w_{18}^m}{w_{19}^m} - 1 \right| \leq \chi; \left| \frac{w_{18}^u}{w_{19}^m} - 1 \right| \leq \chi; \\
\left| \frac{w_{19}^l}{w_{16}^m} - 0.15 \right| \leq \chi; \left| \frac{w_{19}^m}{w_{16}^m} - 2 \right| \leq \chi; \left| \frac{w_{19}^u}{w_{16}^m} - 2.5 \right| \leq \chi \\
\left| \frac{w_{16}^l}{w_{17}^m} - 0.27 \right| \leq \chi; \left| \frac{w_{16}^m}{w_{17}^m} - 0.5 \right| \leq \chi; \left| \frac{w_{16}^u}{w_{17}^m} - 1 \right| \leq \chi \\
\left| \frac{w_{18}^l}{w_{16}^m} - 1.5 \right| \leq \chi; \left| \frac{w_{18}^m}{w_{16}^m} - 2 \right| \leq \chi; \left| \frac{w_{18}^u}{w_{16}^m} - 2.5 \right| \leq \chi \\
\left| \frac{w_{19}^l}{w_{17}^m} - 0.41 \right| \leq \chi; \left| \frac{w_{19}^m}{w_{17}^m} - 1 \right| \leq \chi; \left| \frac{w_{19}^u}{w_{17}^m} - 2.5 \right| \leq \chi \\
\left((w_{16}^l + 4w_{16}^m + w_{16}^u) + (w_{17}^l + 4w_{17}^m + w_{17}^u) \right. \\
\left. + (w_{18}^l + 4w_{18}^m + w_{18}^u) + (w_{19}^l + 4w_{19}^m + w_{19}^u) \right) / 6; \\
w_j^l \leq w_j^m \leq w_j^u; j = 16, \dots, 19 \\
w_j^l, w_j^m, w_j^u \geq 0; j = 16, \dots, 19
\end{array} \right. \quad \dots \quad \left\{ \begin{array}{l}
\left| \frac{w_{19}^l}{w_{18}^m} - 2.5 \right| \leq \chi; \left| \frac{w_{19}^m}{w_{18}^m} - 3 \right| \leq \chi; \left| \frac{w_{19}^u}{w_{18}^m} - 3.5 \right| \leq \chi; \\
\left| \frac{w_{18}^l}{w_{16}^m} - 0.43 \right| \leq \chi; \left| \frac{w_{18}^m}{w_{16}^m} - 0.67 \right| \leq \chi; \left| \frac{w_{18}^u}{w_{16}^m} - 1 \right| \leq \chi \\
\left| \frac{w_{16}^l}{w_{17}^m} - 0.6 \right| \leq \chi; \left| \frac{w_{16}^m}{w_{17}^m} - 1 \right| \leq \chi; \left| \frac{w_{16}^u}{w_{17}^m} - 1.67 \right| \leq \chi \\
\left| \frac{w_{19}^l}{w_{16}^m} - 1.08 \right| \leq \chi; \left| \frac{w_{19}^m}{w_{16}^m} - 2.01 \right| \leq \chi; \left| \frac{w_{19}^u}{w_{16}^m} - 3.5 \right| \leq \chi \\
\left| \frac{w_{18}^l}{w_{17}^m} - 0.26 \right| \leq \chi; \left| \frac{w_{18}^m}{w_{17}^m} - 0.67 \right| \leq \chi; \left| \frac{w_{18}^u}{w_{17}^m} - 1.67 \right| \leq \chi \\
\left((w_{16}^l + 4w_{16}^m + w_{16}^u) + (w_{17}^l + 4w_{17}^m + w_{17}^u) \right. \\
\left. + (w_{18}^l + 4w_{18}^m + w_{18}^u) + (w_{19}^l + 4w_{19}^m + w_{19}^u) \right) / 6; \\
w_j^l \leq w_j^m \leq w_j^u; j = 16, \dots, 19 \\
w_j^l, w_j^m, w_j^u \geq 0; j = 16, \dots, 19
\end{array} \right.$$

DM1 (C20–C23) $\rightarrow \min \chi$
s.t.

DM8 (C20–C23) $\rightarrow \min \chi$
s.t.

Model 6

$$\left\{ \begin{array}{l} \left| \frac{w_{20}^l}{w_{21}^u} - 1 \right| \leq \chi; \left| \frac{w_{20}^m}{w_{21}^m} - 1 \right| \leq \chi; \left| \frac{w_{20}^u}{w_{21}^u} - 1 \right| \leq \chi; \\ \left| \frac{w_{21}^l}{w_{22}^u} - 0.67 \right| \leq \chi; \left| \frac{w_{21}^m}{w_{22}^m} - 1 \right| \leq \chi; \left| \frac{w_{21}^u}{w_{22}^u} - 1.5 \right| \leq \chi \\ \left| \frac{w_{22}^l}{w_{23}^u} - 0.44 \right| \leq \chi; \left| \frac{w_{22}^m}{w_{23}^m} - 1 \right| \leq \chi; \left| \frac{w_{22}^u}{w_{23}^u} - 2.25 \right| \leq \chi \\ \left| \frac{w_{20}^l}{w_{22}^u} - 0.67 \right| \leq \chi; \left| \frac{w_{20}^m}{w_{22}^m} - 1 \right| \leq \chi; \left| \frac{w_{20}^u}{w_{22}^u} - 1.5 \right| \leq \chi \\ \left| \frac{w_{21}^l}{w_{23}^u} - 0.27 \right| \leq \chi; \left| \frac{w_{21}^m}{w_{23}^m} - 1 \right| \leq \chi; \left| \frac{w_{21}^u}{w_{23}^u} - 3.38 \right| \leq \chi \\ \left((w_{20}^l + 4w_{20}^m + w_{20}^u) + (w_{21}^l + 4w_{21}^m + w_{21}^u) \right. \\ \left. + (w_{22}^l + 4w_{22}^m + w_{22}^u) + (w_{23}^l + 4w_{23}^m + w_{23}^u) \right) / 6; \\ w_j^l \leq w_j^m \leq w_j^u; j = 20, \dots, 23 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 20, \dots, 23 \end{array} \right. \quad \dots \quad \left\{ \begin{array}{l} \left| \frac{w_{20}^l}{w_{21}^u} - 2.25 \right| \leq \chi; \left| \frac{w_{20}^m}{w_{21}^m} - 3 \right| \leq \chi; \left| \frac{w_{20}^u}{w_{21}^u} - 3.5 \right| \leq \chi; \\ \left| \frac{w_{21}^l}{w_{22}^u} - 0.43 \right| \leq \chi; \left| \frac{w_{21}^m}{w_{22}^m} - 0.67 \right| \leq \chi; \left| \frac{w_{21}^u}{w_{22}^u} - 1 \right| \leq \chi \\ \left| \frac{w_{22}^l}{w_{23}^u} - 0.6 \right| \leq \chi; \left| \frac{w_{22}^m}{w_{23}^m} - 1 \right| \leq \chi; \left| \frac{w_{22}^u}{w_{23}^u} - 1.67 \right| \leq \chi \\ \left| \frac{w_{20}^l}{w_{22}^u} - 1.08 \right| \leq \chi; \left| \frac{w_{20}^m}{w_{22}^m} - 2.01 \right| \leq \chi; \left| \frac{w_{20}^u}{w_{22}^u} - 3.5 \right| \leq \chi \\ \left| \frac{w_{21}^l}{w_{23}^u} - 0.26 \right| \leq \chi; \left| \frac{w_{21}^m}{w_{23}^m} - 0.67 \right| \leq \chi; \left| \frac{w_{21}^u}{w_{23}^u} - 1.67 \right| \leq \chi \\ \left((w_{20}^l + 4w_{20}^m + w_{20}^u) + (w_{21}^l + 4w_{21}^m + w_{21}^u) \right. \\ \left. + (w_{22}^l + 4w_{22}^m + w_{22}^u) + (w_{23}^l + 4w_{23}^m + w_{23}^u) \right) / 6; \\ w_j^l \leq w_j^m \leq w_j^u; j = 20, \dots, 23 \\ w_j^l, w_j^m, w_j^u \geq 0; j = 20, \dots, 23 \end{array} \right.$$

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