sustainability

MDPI

Article

The Location Selection for Roundabout Construction Using Rough BWM-Rough WASPAS Approach Based on a New Rough Hamy Aggregator

Željko Stević [1,*], Dragan Pamučar [2], Marko Subotić [1], Jurgita Antuchevičiene [3] and Edmundas Kazimieras Zavadskas [4]

[1] Faculty of Transport and Traffic Engineering Doboj, University of East Sarajevo, Vojvode Mišića 52, 74000 Doboj, Bosnia and Herzegovina; msubota@gmail.com
[2] Department of Logistics, University of Defence in Belgrade, Pavla Jurisica Sturma 33, 11000 Belgrade, Serbia; dpamucar@gmail.com
[3] Department of Construction Management and Real Estate, Vilnius Gediminas Technical University, LT-10223 Vilnius, Lithuania; jurgita.antucheviciene@vgtu.lt
[4] Institute of Sustainable Construction, Faculty of Civil Engineering, Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania; edmundas.zavadskas@vgtu.lt
* Correspondence: zeljkostevic88@yahoo.com or zeljko.stevic@sf.ues.rs.ba

Received: 2 July 2018; Accepted: 6 August 2018; Published: 8 August 2018

check for updates

Abstract: An adequately functionally located traffic infrastructure is an important factor in the mobility of people because it affects the quality of traffic, safety and efficiency of carrying out transportation activities. Locating a roundabout on an urban network is an imperative for road engineering to address traffic problems such as reduction of traffic congestion, enhancement of security and sustainability, etc. Therefore, this paper evaluates potential locations for roundabout construction using Rough BWM (Best Worst Method) and Rough WASPAS (Weighted Aggregated Sum Product Assessment) models. Determination of relative criterion weights on the basis of which the potential locations were evaluated was carried out using the Rough BWM method. In this paper, in order to enable the most precise consensus for group decision-making, a Rough Hamy aggregator has been developed. The main advantage of the Hamy mean (HM) operator is that it can capture the interrelationships among multi-input arguments and can provide DMs more options. Until now, there is no research based on HM operator for aggregating imprecise and uncertain information. The obtained indicators are described through eight alternatives. The results show that the fifth and sixth alternatives are the locations that should have a priority in the construction of roundabouts from the perspective of sustainable development, which is confirmed throughout changes of parameter k and with comparing to other methods in the sensitivity analysis.

Keywords: Rough Hamy aggregator; sustainable traffic; Rough BWM; Rough WASPAS; construction; roundabout

1. Introduction

Increase in a number of traffic accidents and the development of modern traffic signaling have affected realistic traffic solutions at intersections aimed at constructing roundabouts, which has improved the capacity and safety of traffic participants. Roundabouts have become very attractive for implementation since the last decades of the 20th century [1]. Some states in the USA (Maryland and Florida) introduce contemporary roundabouts into permanent practical application, where for their use and construction, the US Department of Transportation issued a manual in 2000 [2]. In European countries, experts believe that roundabouts reduce a number of accidents and affect capacity increase, resulting in high utilization attractiveness since the 1980s. In the Netherlands, France, Norway, Denmark and other European countries, the number of roundabouts progressively increases. In the Netherlands [3], turbo-roundabouts with 20 to 30% higher speeds of movement in them and with greater safety are introduced. These roundabouts possess a specific central circle (called a cutting tool). This phenomenon requires the introduction of modern circle intersections (MCI), which characterize the smaller diameter of the central island in relation to standard roundabouts [4]. The specificity of MCI installation in the research is conditioned by the appearance of various installations and free urban space, and often the specific requirements of urban environment. At the intersections regulated by light signals, there is a problem of the junction of the flows of pedestrians and vehicles, which adversely affects pedestrians, as a "vulnerable" category. This case is especially striking at Russian light signaling intersections, where drivers often drive under the influence of alcohol or go through a red light [3]. According to the studies [5], the performance of roundabouts was considered based on the criteria of road properties, the capacity and the location. Their study consists of the observation of two types of roundabouts with and without pedestrian crossings and cycling paths. The purpose of their discussion was to analyze the roundabouts with and without cycling paths, according to the given criteria. The trend of roundabout construction has also been transferred to less urban areas, and observing the territory of Bosnia and Herzegovina (B&H) it is possible to notice their constant growth in urban areas. An example of that are the urban areas of Bijeljina, Derventa, Trebinje, Prnjavor, Brčko, Tuzla and others. For the purpose of solving traffic congestion and increasing safety on main roads, the trend is the construction of roundabouts. In the Doboj region of the central part of Bosnia and Herzegovina, a rural network with first-order main roads is notable, with intersections that are not regulated by roundabouts. Considering that the position of the town of Doboj is defined as the intersection zone of primary routes, it is assumed that a number of circle intersections are required in the zone, from the aspect of safety-manageable sustainability. This paper has several aims. The first aim of the paper is to create a new methodology for evaluating potential locations for the construction of roundabouts. The second aim of the paper is the development of a novel Rough Hamy aggregator to achieve a consensus for group decision-making and enhance this field. The main advantage of the Hamy mean (HM) operator is that it can capture the interrelationships among multi-input arguments and can provide DMs more options. Until now, there is no research based on HM operator for aggregating imprecise and uncertain information. So it is necessary to propose some HM operators for rough numbers. In some practical situations, there are interrelationships among attributes and we need to capture the interrelationships among the attribute values to deal with complex decision-making problems. The third aim of the paper is to develop a model for the construction of a roundabout in Doboj applying the integrated Rough Best Worst Method (BWM) and Rough Weighted Aggregated Sum Product Assessment (WASPAS) approach.

Until now, there is no research based on integration Rough BWM and Rough WASPAS methods. This Integrated model based on new Rough Hamy aggregator has significance on academic front because can be used in different areas for solving the various problem. His contribution is related with developing new aggregator which is more precise from other. This is explained in detail in section Materials and methods. Beside that this integrated model has significance on the practical front because was used for solving an important problem which is one of the main prerequisites for sustainability and efficiency development of road engineering.

After introductory considerations describing the importance of the topic and the reasons for its selection, the paper is structured through five other sections. In Section 2, a review of the literature on the application of multi-criteria decision-making for the construction of traffic infrastructure is given. Section 3 presents the methods divided into three parts. In the first part, the Rough BWM algorithm is presented, in the second part, the Rough WASPAS method, and in the third part, the development of a novel Rough Hamy aggregator is shown. Section 4 of the paper is solving a specific case study in the town of Doboj. Subsequently, in Section 5, the sensitivity analysis is performed, and in Section 6, conclusions with guidelines for future research are given.

2. Literature Review

2.1. Review of MCDM Methods in Traffic Engineering

Increasing the capacity of road engineering according to Li et al. [6] has become an important way of solving traffic problems, and roundabouts in addition to a large number of benefits also affect the increase of traffic capacity [7] and greater traffic flow [8]. A roundabout properly constructed according to Prateli et al. [9] can significantly influence the increase in traffic safety, as confirmed by Antov et al. [10] who determine that the construction of roundabouts is an effective way of increasing safety. In order to determine certain parameters on the basis of which certain decisions can be made and analyzes performed, it is necessary to use optimization techniques of operational research. Multi-criteria decision-making can be used as an adequate tool for making valid decisions. Sohn [11] carried out a study in which it was necessary to eliminate unnecessary overpasses that had lost their positive function in the traffic flow and became a burden for the environment. He used the Analytic Hierarchy Process (AHP) to assess the most important criteria for eliminating the overpasses. Podvezko and Sivilevičius [12] applied the same method to determine the influence of traffic factor interaction on the rate of traffic accidents. In order to optimize geometry, traffic efficiency and traffic safety, Pilko et al. [13] created a new multi-criteria and simultaneous multi-objective optimization (MOO) model using the AHP method for evaluating and ranking traffic and geometric elements. Its applicability in the field of traffic engineering, the AHP method also confirms in the paper [14] where it is used for the evaluation of road section design in an urban environment. The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method was used to evaluate locations with roundabouts and noise analysis in them [15]. The multi-criteria approach was also applied in [16] for the identification of priority black spots in order to increase the safety in traffic. It is important to note that the most important criterion in this research is the criterion of a specific location whose integral part is a roundabout. Four types of intersections, among which one alternative is a roundabout, have been evaluated using the AHP method in [17] based on five criteria. The usefulness of applying multi-criteria decision-making methods is also reflected in the analysis of traffic capacity, i.e., evaluation of the variants for the reconstruction of circle intersection. In [18], six variants were evaluated based on eight criteria for roundabout reconstruction in Zagreb. In research in [19], a multi-criteria model was used, which implied the integration of Fuzzy AHP method with WSM (Weighted Sum Method), ELECTRE (ELimination Et Choix Traduisant la REalité) and TOPSIS methods to evaluate alternatives for noise reduction in traffic, i.e., increase traffic sustainability. The Fuzzy AHP method was also applied in [20] in action plans for noise. The research in [21] uses a multi-criteria model that includes the AHP method to evaluate the effectiveness of traffic calming measures. A hybrid multi-criteria model that combines Fuzzy AHP, TOPSIS and gray correlation techniques is presented in [22] for the evaluation of traffic congestion rates. The hybrid fuzzy multi-criteria model is also used in [23] to mitigate congestion at the Ninoy Aquino airport. The model integrates the fuzzy set theory, ANP (Analytic Network Process), DEMATEL (DEcision-MAking Trial and Evaluation Laboratory) and TOPSIS methods. The hybrid model created by the combination of SWARA (Step-wise Weight Assessment Ratio Analysis) and VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) methods in [24] was used for the selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents. PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) method was applied in the Spanish provinces to determine urban road safety [25], while in [26] the authors used different normalization methods for selection of road alignment variants. The AHP method was applied in [27], for ranking various on-road emission mitigation strategies including reduce, avoid, and replace.

2.2. Review of Methods for Location Selection Problems

According to Drezner [28] the study of location selection has a long and extensive history spanning many general research fields including operations research (or management science), industrial engineering, geography, economics, computer science, mathematics, marketing, electrical engineering, urban planning. According to Kahraman et al. [29] evaluation of specific sites in the selected community is commonly termed microanalysis.

The conventional approaches to location selection include heuristics [30], integer programming [31], nonlinear programming [32], multi-objective goal programming [33], analog approach [34], Analytic Hierarchy Process [35], multi-attribute utility method [36], multiple regression analysis [37] and other. According to [29] these approaches can only provide a set of systematic steps for problem solving without considering the relationships between the decisions factors globally. Moreover, the ability and experience of the analyst(s) may also influence significantly the final outcome. In addition, artificial intelligence (AI) techniques, such as expert systems, artificial neural networks (ANNs), and fuzzy set theory are used in location selection.

Depending on the type of location problems, different methods are applied as already shown. In the last decade, MCDM (Multi-criteria Decision Making) methods are widely used to solve location problems [38–42]. Zhao et al. [41] use a combination of AHP and TOPSIS method for construction of a metro-integrated logistics system. Using TOPSIS method they performed the evaluation of the importance of each metro station. Nazari et al. [42] are performed research with the aim to select a suitable site for photovoltaic installation in Iran. Four different locations are evaluated based on TOPSIS method. Samanlioglu and Ayağ, [40] use combination of fuzzy AHP and fuzzy PROMETHEE II for selection the best location for a solar power plant. The integration of single-valued neutrosophic sets and the WASPAS method was used to determine the location problem of a garage for a residential house in [43]. WASPAS was extended in [39] with interval neutrosophic sets for the solar-wind power station location selection problem.

2.3. Summarized Overview of Used MCDM Approaches and a Brief Overview of the Advantages of the Proposed Model

Table 1 gives an overview of the most commonly used MCDM methods with the main topic, approach and results.

Table 1. Overview of the used Multi-criteria Decision Making (MCDM) methods in road engineering and location selection.

Ref.	Approach	Purpose of Application
[11]	AHP	elimination of unnecessary overpasses that had lost their positive function in the traffic flow
[12]	AHP	determination of the influence of traffic factor interaction on the rate of traffic accidents
[13]	MOO and AHP	evaluation and ranking traffic and geometric elements
[14]	AHP	evaluation of road section design in an urban environment
[15]	TOPSIS	evaluation of locations with roundabouts and noise analysis in them
[16]	Delphi and TOPSIS	identification of priority black spots in order to increase the safety in traffic
[17]	AHP	evaluation of four types of intersections
[18]	AHP	evaluation of variants for roundabout reconstruction
[19]	Fuzzy AHP, WSM ELECTRE and TOPSIS	evaluation of the alternatives for noise reduction in traffic
[20]	Fuzzy AHP	prioritizing road stretches included in a noise action plans
[21]	AHP	evaluation of the effectiveness of traffic calming measures
[22]	Fuzzy AHP and TOPSIS	evaluation of traffic congestion rates
[23]	ANP, DEMATEL, fuzzy set theory and TOPSIS	mitigation of congestion at the Ninoy Aquino airport

Table 1. *Cont.*

Ref.	Approach	Purpose of Application
[24]	SWARA and VIKOR	selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents
[25]	PROMETHEE	determination of urban road safety
[27]	AHP	ranking various on-road emission mitigation strategies
[39]	WASPAS with interval neutrosophic sets	the solar-wind power station location selection
[40]	Fuzzy AHP and Fuzzy PROMETHEE II	selection the best location for a solar power plant
[41]	AHP and TOPSIS	construction of a metro-integrated logistics system
[42]	TOPSIS	selection of suitable site for photovoltaic installation
[43]	WASPAS with single-valued neutrosophic sets	determination of the location problem of a garage for a residential house

The nature of the problem in this study is different in relation to the above-mentioned research. In relation to research by Zhao et al. [41], we have fewer variables that have influence on problem solving. In the integrated logistic system created in the mentioned paper, the P-median model is also used, because the distribution of goods is considered in which it is necessary to determine the distributions hub. In this paper, the existing traffic infrastructure is a limitation for the formation of a different model. When it comes to the applied methods, the possibility of using the P-median model due to the above is excluded. The application of the proposed Rough BWM-WASPAS model based on rough Hamy aggregator is better option than the application of conventional and exploited MCDM methods such as AHP and TOPSIS.

Fuzzy set theory has serious difficulties in producing valid answers in decision making by fuzzifying judgments. No theorems are available about its workability when it is applied indiscriminately as a number crunching approach to numerical measurements that represent judgment [44]. When judgments are allowed to vary in choice over the values of a fundamental scale, as in the AHP, these judgments are themselves already fuzzy [45]. In addition to increasing the complexity of manipulations, the fuzzification of numbers complicates the computational process and often leads to less desirable instead of more desirable results [46]. In some situations, the fuzzy AHP method can also result in the wrong decision and the choice of the worst criterion (alternative) as the best [45,46]. Compared with research [40] where the authors use a combination of fuzzy AHP and fuzzy PROMETHEE II, our proposed model is better from the reasons which are previously mentioned. The advantage of the proposed model comparing with fuzzy theory is that the integration of rough numbers into the MCDM methods according to Stević et al. [47] exploits the subjectivity and unclear assessment of the experts and avoids assumptions, which is not the case when applying fuzzy theory.

Advantage of the proposed model based on rough Hamy aggregator as follow. As a result, some traditional aggregation operators, such as the Bonferroni mean (BM) [48], Rough Number Averaging (RNA) operator or Rough Number Geometric (RNG), can be applied to reflect interactions among input arguments. However, compared with the ordinary BM, the HM can consider the interrelationship among multi-input arguments whereas the ordinary BM can only capture the interrelationship between two input arguments. On the other hand, the HM is more general than the RNA and RNG, and the RNA and RNG are a special cases of HM operator. Therefore, the HM is more suitable to model interactions among input arguments than the BM, RNA and RNG.

3. Materials and Methods

3.1. Proposed Methodology

Figure 1 shows the methodology for the location selection for roundabout construction; it consists of three phases. Each of these phases and steps are explained in detail.

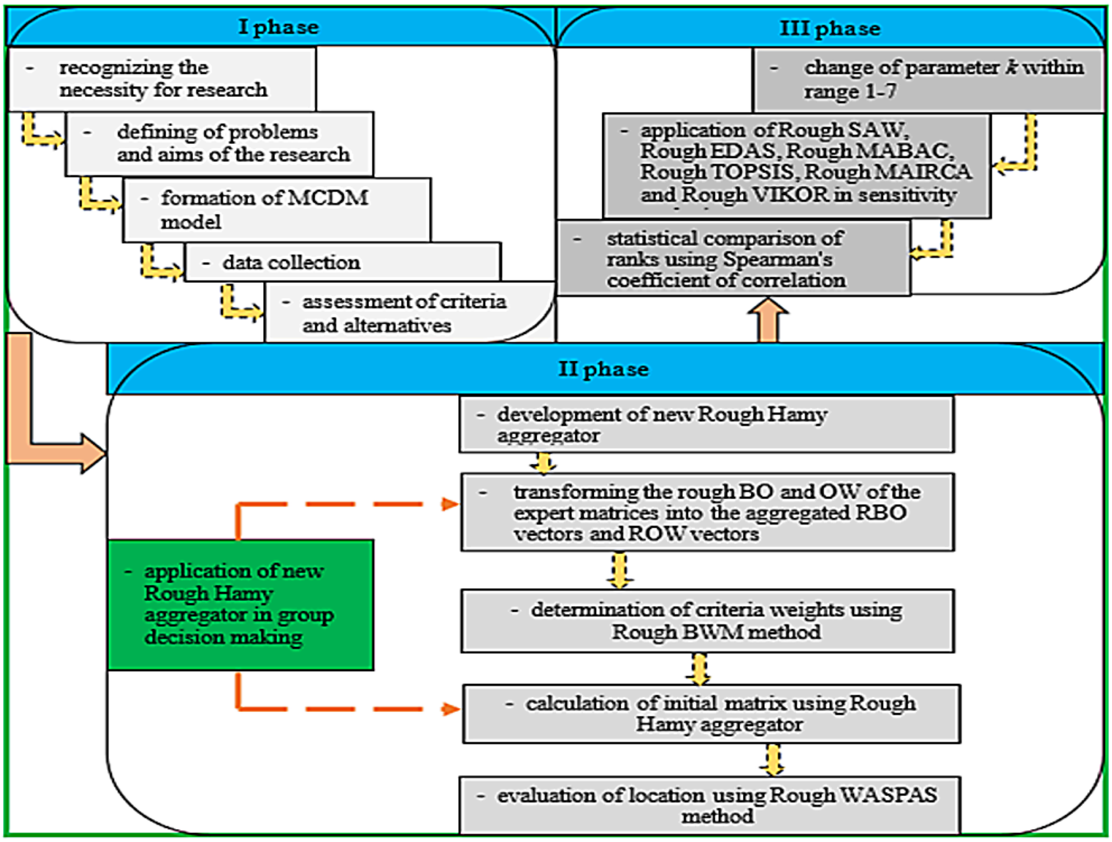

Figure 1. Proposed model for location selection for roundabout construction.

The proposed model for location selection for roundabout construction in Doboj consists of three phases and 13 steps. The first phase consists of five steps, from which the first step recognizing of the necessity for research. In the Doboj region of the central part of Bosnia and Herzegovina, a rural network with first-order main roads is notable, with intersections that are not regulated by roundabouts. The second step represents defining the problems and objectives of the research related to the need for the construction roundabout. In addition, the research objectives also relate to the identification of priority locations and the construction of the roundabout on that locations. In the third step of the first phase, a multi-criteria model was formed which consist of eight criteria, six alternatives, and seven decision-makers (DMs). The next step is collecting data that implies empirical research on the measurement of traffic parameters and the collection of other data from other sources. After the data collection was completed, the evaluation of criteria and alternatives by seven experts was carried out. The second phase involves the development of a new Rough Hamy aggregator, processing, and analysis of the collected data. The first step at this phase is the development of a new Rough Hamy aggregator used to transform rough Best to Other (BO) and Other to Worst (OW) into aggregated vectors in the second step and to calculate the initial decision matrix in the fourth step. The third step is a determination of the criteria weights using Rough BWM, while the fifth step of this phase represents the evaluation of locations using the Rough WASPAS method. The third phase of the proposed model is a sensitivity analysis which consists of three steps. First, a change in the k parameter has been made and a check on its influence on the ranking of the alternative. After that, a comparison was made with six different methods in the second step, while in the third calculated Spearman's coefficient of correlation showing a high level of correlation of ranks.

Advantages of the proposed model are as follow. The main advantage of the Hamy mean (HM) operator is that it can capture the interrelationships among multi-input arguments and can provide DMs more options. Until now, there is no research based on HM operator for aggregating imprecise and uncertain information. So it is necessary to propose some HM operators for rough numbers. In some practical situations, there are interrelationships among attributes and we need to capture the interrelationships among the attribute values to deal with complex decision-making problems. As a result, some traditional aggregation operators, such as the Bonferroni mean (BM) [48], Rough Number Averaging (RNA) operator or Rough Number Geometric (RNG), can be applied to reflect interactions among input arguments. However, compared with the ordinary BM, the HM can consider the interrelationship among multi-input arguments whereas the ordinary BM can only capture the interrelationship between two input arguments. On the other hand, the HM is more general than the RNA and RNG, and the RNA and RNG are a special cases of HM operator. Therefore, the HM is more suitable to model interactions among input arguments than the BM, RNA and RNG.

Determining the significance of criteria is one of the most important stages in the decision-making process [49–51]. Practically doesn't exist the problem of multi-criteria decision-making in which criteria have the equal importance. Taking into account previously said, the methods for determining the weight values are an important factor for making valid decisions. The BWM [52] is one of more recent methods. Some of the advantages of using BWM are as follows: (1) in comparison with the AHP method, which until the establishment of this method was in comparable and most commonly used to determine weight coefficients, it requires a smaller number of pairwise comparisons (in the AHP method, the number of comparisons is $n\ (n-1)/2$, while, for the BWM, the number of comparisons is $2n-3$; (2) weight coefficients determined using the BWM are more reliable, since comparisons in this method are made with a higher degree of consistency compared with the AHP method; (3) with most MCDM models (e.g., AHP), the degree of consistency checks whether the comparison of criteria is consistent or not, while, in BWM, the degree of consistency is used to determine the level of consistency because the outputs from BWM are always consistent; and (4) the BWM for pairwise comparison of the criteria requires only integer values, which is not the case with other MCDM methods (e.g., AHP) which also require fractional numbers [52]. Additionally, the Rough BWM makes it possible to bridge the existing gap that exists in the BWM methodology by applying a new approach in treating imprecision that is based on RN. This approach has been used in several studies in a very short time [53–55], therefore its complete algorithm has not been shown in this paper. The Rough BWM model in [53] is used to determine weight coefficients of the criteria for location selection for wind farms, while in [54], it is used to determine the importance of the criteria for selecting wagons for a logistics company. Interval Rough fuzzy BWM has been applied in [55] to a study of the optimal selection of firefighting helicopters. The Rough BWM is expected to be increasingly used in the future, which is one of the reasons for its application in this paper.

Bearing in mind all the advantages of using rough theory [56,57] in the MCDM to represent ambiguity, vagueness and uncertainty, the authors in the paper [58] made modification of the WASPAS algorithm using rough numbers. According to Stojić et al. [58] in comparison with other concepts, a novel rough WASPAS approach has some advantages that can be described as follows. The first reason is its advantage in comparison with grey theory. Grey relation analysis provides a well-structured analytical framework for a multi-criteria decision-making process, but it lacks the capability to characterize the subjective perceptions of designers in the evaluation process. Rough set theory may help here, because rough sets can facilitate effective representation of vague information or imprecise data. Also, a very important advantage of using rough set theory to handle vagueness and uncertainty is that it expresses vagueness by means of the boundary region of a set instead of membership function. In addition, the integration of rough numbers in MCDM methods gives the possibility to explore subjective and unclear evaluation of the experts and to avoid assumptions, which is not the case when applying fuzzy theory. According to Hashemkhani Zolfani et al. [59], the main advantage of the WASPAS method is its high degree of reliability. Different aggregation parameter and the proportion adjustment parameter facilitate the whole procedures of a dynamic selection. In the paper [39] aggregation parameter setting is based on the requirement of the real application and subjective preference of DMs, which makes the extended WASPAS technique feasible in dealing with the reality which is the case in this research also.

Integration of rough numbers and the WASPAS method with advantages of both concepts presents a very important support in decision-making in everyday conflicting situations. It is important to note that until now, there is no research based on integration Rough BWM and Rough WASPAS methods. This is also one of the advantages of the proposed methodology.

3.2. Novel Rough Hamy Mean Operators and Their Operations

To adequately solve decision-making problems with vague or imprecise information according to Mardani et al. [60], the fuzzy set theory [61] and aggregation operator theory have become powerful tools. In addition to fuzzy logic, the rough set theory [62,63] also adequately fulfills these advantages, so in this paper, a new Rough Hamy aggregator for group decision-making has been developed.

The Hamy mean (HM) [64] is used for aggregation of values while simultaneously including mutual correlations among multiple arguments and is defined in the following way:

Definition 1. [64]. *Assume that x_i $(i = 1, 2, \ldots, n)$ represent a set of non-negative real numbers and a parameter $k = 1, 2, \ldots, n$, then HM is defined as:*

$$HM^{(k)}(x_1, x_2, \ldots, x_n) = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{k} x_{i_j} \right)^{1/k}}{\begin{pmatrix} n \\ k \end{pmatrix}}, \tag{1}$$

where $(i_1, i_2, \ldots, i_k)$ includes all k-tuple combinations of $(1, 2, \ldots, n)$ and $\begin{pmatrix} n \\ k \end{pmatrix}$ represents a binomial coefficient calculated as:

$$\begin{pmatrix} n \\ k \end{pmatrix} = \frac{n!}{k!(n-k)!}, \tag{2}$$

Based on the predefined operations on rough numbers (RNs), the next part shows HM operator for averaging RNs. In the forthcoming section, besides performing the RNHM operator, some specific cases of this new operator for RNs are shown.

Definition 2. *Assume that $RN(\varphi_1) = [\underline{Lim}(\varphi_1), \overline{Lim}(\varphi_1)]$ and $RN(\varphi_2) = [\underline{Lim}(\varphi_2), \overline{Lim}(\varphi_2)]$ are two RNs, then RNHM operator is defined as follows:*

$$RNHM^{(k)}\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{k} RN(\varphi_{i_j}) \right)^{1/k}}{\begin{pmatrix} n \\ k \end{pmatrix}}, \tag{3}$$

where $(i_1, i_2, \ldots, i_k)$ *includes all k-tuple combinations of* $(1, 2, \ldots, n)$ *and* $\begin{pmatrix} n \\ k \end{pmatrix}$ *represents a binomial coefficient and* $\begin{pmatrix} n \\ k \end{pmatrix} = \frac{n!}{k!(n-k)!}$.

Theorem 1. *Let* $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$; $(j = 1, 2, \ldots, n)$ *represent a set of RNs in R. The aggregated values of rough numbers from a set R can be determined using the expression (3) and then the next expression:*

$$RNHM^{(k)}\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = [\underline{Lim}(\varphi_{RNHM}), \overline{Lim}(\varphi_{RNHM})] = \\ = \left[\frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{k} \underline{Lim}(\varphi_{i_j}) \right)^{1/k}}{\begin{pmatrix} n \\ k \end{pmatrix}}, \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{k} \overline{Lim}(\varphi_{i_j}) \right)^{1/k}}{\begin{pmatrix} n \\ k \end{pmatrix}} \right], \quad (4)$$

Example 1. *Let* $RN(\varphi_1) = [2, 3]$, $RN(\varphi_2) = [3, 5]$, $RN(\varphi_3) = [1, 3]$ *and* $RN(\varphi_3) = [5, 8]$ *be four RNs, then the shown RNHM operator (assume that k = 2) can be used for their aggregation obtaining the aggregated value* $RNHM^{(k)}\{RN(\varphi_1), RN(\varphi_2), RN(\varphi_3), RN(\varphi_4)\} = [\underline{Lim}(\varphi_\alpha), \overline{Lim}(\varphi_\alpha)]$.

(i). $\frac{1}{\begin{pmatrix} n \\ k \end{pmatrix}} = \frac{k!(n-k)!}{n!} = \frac{2!(4-2)!}{2!} = \frac{1}{6}$

(ii). $\underline{Lim}(\varphi_\alpha) = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le 4} \left(\prod\limits_{j=1}^{2} \underline{Lim}(\varphi_{i_j}) \right)^{1/2}}{\begin{pmatrix} 4 \\ 2 \end{pmatrix}} = \frac{(2\times3)^{1/2}+(2\times1)^{1/2}+(2\times5)^{1/2}+(3\times1)^{1/2}+(3\times5)^{1/2}+(1\times5)^{1/2}}{6} = 2.478$

(iii). $\underline{Lim}(\varphi_\alpha) = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le 4} \left(\prod\limits_{j=1}^{2} \overline{Lim}(\varphi_{i_j}) \right)^{1/2}}{\begin{pmatrix} 4 \\ 2 \end{pmatrix}} = \frac{(3\times5)^{1/2}+(3\times3)^{1/2}+(3\times8)^{1/2}+(5\times3)^{1/2}+(5\times8)^{1/2}+(3\times8)^{1/2}}{6} = 4.478$

In this way, the aggregated value $RNHM^{(2)}\{RN(\varphi_1), RN(\varphi_2), RN(\varphi_3), RN(\varphi_4)\} = [2.478, 4.478]$ is obtained.

Theorem 2. *(Idempotency). If* $RN(\varphi_j) = RN(\varphi) = [\underline{Lim}(\varphi), \overline{Lim}(\varphi)]$ *for all* $(j = 1, 2, \ldots, n)$, *then* $RNHM\{RN(\varphi), RN(\varphi), \ldots, RN(\varphi)\} = RN(\varphi) = [\underline{Lim}(\varphi), \overline{Lim}(\varphi)]$.

Theorem 3. *(Commutativity). Let RN rough set* $(RN(\varphi'_1), RN(\varphi'_2), \ldots, RN(\varphi'_n)$ *be any permutation of* $(RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n))$.

Then $RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = RNHM\{RN(\varphi'_1), RN(\varphi'_2), \ldots, RN(\varphi'_n)\}$.

Theorem 4. *(Boundedness). Let* $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$; $(j = 1, 2, \ldots, n)$, *be a collection of RNs in R, let* $RN(\varphi_j^-) = [\min\{\underline{Lim}(\varphi_j)\}, \min\{\overline{Lim}(\varphi_j)\}]$ *and* $RN(\varphi_j^+) = [\max\{\underline{Lim}(\varphi_j)\}, \max\{\overline{Lim}(\varphi_j)\}]$, *then we have* $RN(\varphi_j^-) \le RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \le RN(\varphi_j^+)$.

Theorem 5. *(Monotonicity). Let* $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$, $RN(\phi_j) = [\underline{Lim}(\phi_j), \overline{Lim}(\phi_j)]$; $(j = 1, 2, \ldots, n)$, *be two collections of RNs, if* $\underline{Lim}(\varphi_j) \le \underline{Lim}(\phi_j)$, $\overline{Lim}(\varphi_j) \le \overline{Lim}(\phi_j)$ *for all j, then* $RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \le RNHM\{RN(\phi_1), RN(\phi_2), \ldots, RN(\phi_n)\}$.

All proofs of theorems are shown in Appendix A. In the next section, a discussion in which some specific cases of RNHM operator depending on the change of parameter k has been presented.

Case 1. *When $k = 1$, then the RNHM operator (4) can be reduced into the RNA (Rough Number Averaging) operator*

$$RNHM^{(1)}\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \left[\frac{\sum\limits_{1 \le i_1 \le n} \left(\prod\limits_{j=1}^{1} \underline{Lim}(\varphi_{i_j}) \right)^{1/1}}{\begin{pmatrix} n \\ 1 \end{pmatrix}}, \frac{\sum\limits_{1 \le i_1 \le n} \left(\prod\limits_{j=1}^{1} \overline{Lim}(\varphi_{i_j}) \right)^{1/1}}{\begin{pmatrix} n \\ 1 \end{pmatrix}} \right]$$

$$= \left[\frac{1}{n} \sum_{1 \le i_1 \le n} \left(\underline{Lim}(\varphi_{i_j}) \right), \frac{1}{n} \sum_{1 \le i_1 \le n} \left(\overline{Lim}(\varphi_{i_j}) \right) \right]; (let\ i_1 = i)$$

$$= \left[\frac{1}{n} \sum_{i=1}^{n} \left(\underline{Lim}(\varphi_{i_j}) \right), \frac{1}{n} \sum_{i=1}^{n} \left(\overline{Lim}(\varphi_{i_j}) \right) \right] = RNA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\}$$

Case 2. *When $k = n$, then the RNHM operator (4) can be reduced into the RNG (Rough Number Geometric) operator:*

$$RNHM^{(n)}\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{n} RN(\varphi_{i_j}) \right)^{1/n}}{\begin{pmatrix} n \\ n \end{pmatrix}}$$

$$= \left[\frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{n} \underline{Lim}(\varphi_{i_j}) \right)^{1/n}}{\begin{pmatrix} n \\ n \end{pmatrix}}, \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le n} \left(\prod\limits_{j=1}^{n} \overline{Lim}(\varphi_{i_j}) \right)^{1/n}}{\begin{pmatrix} n \\ n \end{pmatrix}} \right]$$

$$= \left[\left(\prod_{j=1}^{n} \underline{Lim}(\varphi_{i_j}) \right)^{1/n}, \left(\prod_{j=1}^{n} \overline{Lim}(\varphi_{i_j}) \right)^{1/n} \right]; (let\ i_j = j) = \left[\left(\prod_{j=1}^{n} \underline{Lim}(\varphi_i) \right)^{1/n}, \left(\prod_{j=1}^{n} \overline{Lim}(\varphi_i) \right)^{1/n} \right] = \prod_{j=1}^{n} RN(\varphi_i)^{1/n}$$

4. The Location Selection for Roundabout Construction in Doboj

The location selection for the construction of a roundabout consists of several stages that are described in detail below. The first stage implies the formation of a multi-criteria model based on the real needs of traffic infrastructure in Doboj. The second stage implies collecting data based on performed measurements of traffic indicators and based on other sources such as the Interior Ministry where data on the number of traffic accidents at the locations for roundabout construction were obtained. The third stage refers to the expert evaluation of the importance of criteria as the first step and the determination of the weights of the criteria using the Rough BWM method as the second step. The fourth stage is an interpretation of the application of the developed Rough Hamy aggregator for obtaining the initial decision-making matrix, while the fifth stage represents the evaluation of locations based on the Rough WASPAS method.

4.1. Forming a Multi-Criteria Model

Six locations (Figure 2) of which one is located in the very center of the town, four locations which represent the connection between the streets for the entrance into/exit from the town and the first-order main road, and one location where the first-order main roads intersect are evaluated based on a total of eight criteria presented in Table 2.

Figure 2. Potential locations for roundabout construction.

Table 2. Criteria in a multi-criteria model and their interpretation.

Ord. No.	Criterion	Criterion Description
1	Flow of vehicles	The number of vehicles passing through the observed road intersection in a unit of time in both directions.
2	Flow of pedestrians	The number of pedestrians crossing the observed intersection at the point for pedestrian movement (pedestrian crossing, zebra, etc.) at a given time interval.
3	Traffic safety indicator	The number of traffic accidents on the observed section of the road
4	Costs of construction and exploitation	Cost estimation (construction, exploitation and maintenance)
5	Type of intersection	Three-way or four-way intersections
6	Average vehicle intensity per access arm	The limit intensity is the intensity at the entry arm into the intersection of 360 PA/h
7	Functional criterion of spatial fitting	What is the primary role of the intersection observed? This section analyzes what type of intersection is the most acceptable due to its role in traffic.
8	Public opinion	It implies a survey of local population that have chosen one of the offered locations as a priority for the construction of a roundabout.

Table 2 shows the criteria and a detailed interpretation of their meaning. The criteria are selected according to current needs of the city Doboj and relevant literature which considered the similar researches [65–68]. In all mentioned researches criteria are organized in few categories: traffic criteria, safety, functionality, performance, cost et. The criteria used in this study are the most commonly used criteria in Croatia: functional criterion, spatially-urbanistic criterion, traffic flow criterion, design and technical criterion, traffic safety criterion, capacity criterion, environmental criterion economic criterion, Serbia and Slovenia: functional criterion, capacity criterion, spatial criterion, design and technical criterion, traffic safety criterion and economic criterion [69]. Results that provided in research [70] indicate that public support continued to increase with time, presumably because traffic participants became more informed and comfortable with this form of traffic control. According to that the application of the last criterion in this research have justification.

The second (traffic flows of pedestrians) and the fourth criterion (costs of construction and exploitation) belong to the cost criteria, i.e., they need to be minimized. The fourth (costs of construction and exploitation) and seventh criterion (functionality or criterion of spatial fitting) are qualitative criteria that are not easily measurable and they are evaluated on the basis of experts' forecasts who are familiar with potential locations, current infrastructure, and current intersections. After empirical research where the data for each location was determined, the group of seven experts carried out an assessment of all the criteria and alternatives.

Figure 2 shows potential locations for the construction of roundabouts in Doboj. The first location is the exit from the town onto the M17 main road towards Modriča (left), and towards Sarajevo (right). The second location represents a three-way intersection that is a junction of the M17 and M14 main roads, while the third location is after 300 m and connects the exit from the town with the M17 main road. The fourth location represents a four-way intersection that connects the main street with the M17 main road and the railway station, while the fifth location represents the last exit from the town towards Sarajevo and it is a four-way intersection with an additional side road access. The sixth location is a location in the center of the town.

4.2. Data Collection

Flow measurement was performed at the sampling level in the period September–November 2017. The data collected for each location based on the established criteria are presented in Table 3.

Table 3. Values of alternatives according to criteria.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	1256	8	2	3	3	419	7	85
A_2	2194	4	2	9	3	731	5	89
A_3	1037	5	4	7	3	346	3	45
A_4	2878	32	3	7	4	720	5	8
A_5	1052	2	4	5	4	263	5	27
A_6	4197	124	1	3	4	1050	7	74

Table 3 shows the values for all the locations according to established criteria. It can be noticed that the highest intensity of traffic flows of vehicles and pedestrians belongs to the sixth location with 4197 vehicles and 124 pedestrians in one hour. Locations 4 and 2 have slightly less intensity regarding vehicle flows, while the intensity of pedestrians is 32 for the fourth, and only four for the second location. The remaining locations have double less intensity than the two previously mentioned locations, and almost four times less than the sixth location. If the sixth and fourth location are excluded, the flows of pedestrians are very small. The reason is that the sixth location is in the town center, and the fourth location represents the connection between entering the town and the railway station. Regarding the number of traffic accidents, the largest number of accidents occurred at locations 3 and 5, four accidents per each, while the lowest number of accidents occurred at the sixth location. The average vehicle intensity per an arm (Table 4) is the largest at the sixth location, 1050, while for the second and fourth location it is almost identical, 731 and 720, respectively. The minimum intensity per an arm is at the fifth location because this location has four arms and an additional arm that is not represented in the paper as an arm, as it represents a side road that is not frequent. Based on the public opinion survey for potential locations, the largest number of citizens have characterized the first two locations as a priority for the construction of a roundabout, and as the third one, they designated the sixth location. The fourth and seventh criterion fall into the qualitative group, so their evaluation is carried out by seven experts, while the other criteria are of quantitative nature.

Table 4. Average intensity of vehicles per the arms at all locations.

Location 1—Exit from the Old Town onto the M17 Main Road

Direction	Bare-Maglaj	Bare-Old Town	Maglaj-Bare	Maglaj-Old Town	Old Town-Bare	Old Town-Maglaj	Σ
Trucks	64	12	64	12	12	24	176
Passenger vehicles	268	84	388	108	160	72	1080

Location 2—The Bridge, So-Called "Japanac", Which Represents the Entrance into the Town from Tuzla

Direction	"Japanac"-Maglaj	"Japanac"-Bare	Maglaj-"Japanac"	Maglaj-Bare	Bare-Maglaj	Bare-"Japanac"	Σ
Trucks	60	52	72	84	112	80	462
Passenger vehicles	200	240	360	380	272	280	1732

Location 3—The Intersection on the M17 Main Road at Flea Market

Direction	Bare-Maglaj	Bare-Town Entrance	Maglaj-Bare	Maglaj-Town Entrance	Town Exit-Bare	Town Exit-Maglaj	Σ
Trucks	76	0	80	0	0	0	156
Passenger vehicles	244	108	384	24	100	24	884

Location 4—Traffic-Light Intersection on the M17 Main Road

Direction	Town-Railwaysstation	Town-Maglaj	Town-Bare	Bare-Maglaj	Bare-Town	Bare-r. Stat.	Maglaj-Bare	Mag.-Town	Mag.-r. Station	R. stat.-Bare	R. Stat.-Maglaj	R. Stat.-Town	Σ
Trucks	9	15	24	90	15	27	96	27	24	30	25	15	397
Passenger vehicles	153	225	240	270	105	135	300	270	120	132	246	285	2481

Location 5—Intersection at the Entrance into/Exit from the Town via Usora

Direction	Bare-Maglaj	Bare-Usora	Maglaj-Bare	Maglaj-Usora	Usora-Bare	Usora-Maglaj	Σ
Trucks	68	0	100	4	0	4	176
Passenger vehicles	232	140	288	152	24	40	876

Location 6—Intersection in the Town at the Junction of Jug Bogdana and Cara Dušana Street

Direction	Church-Vladimirka	Church-Center	Church-Bingo	Vlad.-Church	Vlad.-Center	Vlad.-Bingo	Center-Church	Center-Vlad.	Center-Bingo	Bingo.-Center	Bingo-Church	Bingo-Vlad.	Σ
Trucks	9	15	24	90	15	27	96	27	24	30	25	15	397
Passenger vehicles	569	292	478	507	139	234	222	129	374	403	365	88	3800

4.3. Criteria Weight Calculation Using Rough BWM

Evaluation of the criteria has been carried out using the scale, where 1 signifies insignificant domination, while 9 signifies exceptional domination. Expert comparisons through Best to Other and Other to Worst vectors are shown in Table 5.

Table 5. Best to Other (BO) and Other to Worst (OW) vectors of expert judgment.

	BO							OW						
Criteria	**E_1**	**E_2**	**E_3**	**E_4**	**E_5**	**E_6**	**E_7**	**E_1**	**E_2**	**E_3**	**E_4**	**E_5**	**E_6**	**E_7**
C_1	1	1	2	1	1	1	1	6	6	4	6	8	7	7
C_2	2	3	3	4	4	1	2	5	4	3	3	3	6	5
C_3	1	2	1	2	2	1	1	6	5	5	5	5	6	6
C_4	3	4	4	3	3	4	5	3	3	2	4	4	3	2
C_5	2	3	3	3	5	2	2	4	4	3	4	2	5	5
C_6	4	5	4	4	6	1	5	2	2	2	3	1	6	2
C_7	3	4	4	5	7	5	2	3	3	2	2	1	2	5
C_8	6	6	5	6	8	7	7	1	1	1	1	1	1	1

Using the expressions (1)–(6) in [71], the crisp expert evaluations shown in BO and OW vectors are transformed into RNs (Table 6).

Table 6. Rough Best to Other (BO) and Other to Worst (OW) vectors of expert judgment.

				BO			
Criteria	**E_1**	**E_2**	**E_3**	**E_4**	**E_5**	**E_6**	**E_7**
C_1	[1, 1.14]	[1, 1.16]	[1.16, 2]	[1, 1.02]	[1, 1.04]	[1, 1.04]	[1, 1.04]
C_2	[1.67, 2.96]	[2.34, 3.5]	[2.08, 3.67]	[2.53, 4]	[2.26, 4]	[1, 2.05]	[1.84, 2.32]
C_3	[1, 1.43]	[1.49, 2]	[1, 1.35]	[1.42, 2]	[1.27, 2]	[1, 1.19]	[1, 1.23]
C_4	[3, 3.71]	[3.62, 4.25]	[3.45, 4.33]	[3, 3.62]	[3, 3.68]	[3.46, 4.5]	[3.54, 5]
C_5	[2, 2.86]	[2.64, 3.5]	[2.48, 3.67]	[2.42, 4]	[2.71, 5]	[2, 2.34]	[2, 2.44]
C_6	[3.25, 4.59]	[3.86, 5.33]	[3.06, 4.63]	[3.03, 4.79]	[3.76, 6]	[1, 3.33]	[3.73, 5]
C_7	[2.5, 4.61]	[3.33, 4.88]	[2.83, 5.06]	[3.69, 5.67]	[3.85, 7]	[3.38, 5]	[2, 3.21]
C_8	[5.75, 6.63]	[5.67, 6.74]	[5, 6.45]	[5.81, 6.89]	[6.41, 8]	[6.09, 7]	[6.01, 7]
				OW			
Criteria	**E_1**	**E_2**	**E_3**	**E_4**	**E_5**	**E_6**	**E_7**
C_1	[5.5, 6.61]	[5.33, 6.71]	[4, 6.26]	[5.61, 6.86]	[6.16, 8]	[5.82, 7]	[5.7, 7]
C_2	[3.88, 5.33]	[3.25, 4.79]	[3, 4]	[3, 4.04]	[3, 4.04]	[4.04, 6]	[3.61, 5]
C_3	[5.43, 6]	[5, 5.35]	[5, 5.41]	[5, 5.41]	[5, 5.41]	[5.41, 6]	[5.27, 6]
C_4	[2.67, 3.33]	[2.6, 3.4]	[2, 2.95]	[3.04, 4]	[2.75, 4]	[2.55, 3.01]	[2, 2.58]
C_5	[3.48, 4.4]	[3.37, 4,5]	[2.5, 4.06]	[3.34, 4.67]	[2, 3.6]	[3.79, 5]	[3.36, 5]
C_6	[1.8, 2.8]	[1.75, 2.93]	[1.7, 3.11]	[2.02, 4.5]	[1, 2.4]	[2.55, 6]	[1.65, 2.2]
C_7	[2.22, 3.67]	[2.1, 4]	[1.75, 2.63]	[1.67, 2.65]	[1, 2.38]	[1.81, 2.78]	[2.33, 5]
C_8	[1, 1]	[1, 1]	[1, 1]	[1, 1]	[1, 1]	[1, 1]	[1, 1]

After the transformation of the crisp value into RN, the rough BO and OW of the expert matrices are transformed into the aggregated rough BO vectors and rough OW vectors using rough Hamy aggregator, Table 7.

Table 7. Aggregated Rough BO and Rough OW vectors.

Best: C_1	RN	Worst: C_8	RN
C_1	[1.02, 1.18]	C_1	[5.42, 6.91]
C_2	[2.10, 3.16]	C_2	[3.38, 4.71]
C_3	[1.41, 1.58]	C_3	[5.16, 5.65]
C_4	[3.33, 4.14]	C_4	[2.50, 3.30]
C_5	[2.78, 3.34]	C_5	[3.08, 4.45]
C_6	[3.10, 4.77]	C_6	[1.75, 3.30]
C_7	[3.58, 5.00]	C_7	[1.81, 3.24]
C_8	[6.13, 6.95]	C_8	[1.00, 1.00]

On the basis of rough BO and rough OW vectors, the calculation of optimal values of rough weight coefficients of the criteria is performed. Based on the data in Table 4, a nonlinearly constrained optimization problem is introduced, which is represented by concrete numbers.

$$
\begin{array}{l}
\min \xi \\
s.t. \\
\left\{
\begin{array}{l}
\left|\frac{w_1^L}{w_1^U}-1.18\right| \le \xi; \left|\frac{w_1^L}{w_2^U}-3.16\right| \le \xi; \left|\frac{w_1^L}{w_3^U}-1.58\right| \le \xi; \left|\frac{w_1^L}{w_4^U}-4.14\right| \le \xi; \left|\frac{w_1^L}{w_5^U}-3.34\right| \le \xi; \left|\frac{w_1^L}{w_6^U}-4.77\right| \le \xi; \left|\frac{w_1^L}{w_7^U}-5.00\right| \le \xi; \left|\frac{w_1^L}{w_8^U}-6.95\right| \le \xi; \\
\left|\frac{w_1^U}{w_1^L}-1.02\right| \le \xi; \left|\frac{w_1^U}{w_2^L}-2.10\right| \le \xi; \left|\frac{w_1^U}{w_3^L}-1.41\right| \le \xi; \left|\frac{w_1^U}{w_4^L}-3.33\right| \le \xi; \left|\frac{w_1^U}{w_5^L}-2.78\right| \le \xi; \left|\frac{w_1^U}{w_6^L}-3.10\right| \le \xi; \left|\frac{w_1^U}{w_7^L}-3.58\right| \le \xi; \left|\frac{w_1^U}{w_8^L}-6.13\right| \le \xi; \\
\left|\frac{w_1^L}{w_8^U}-6.91\right| \le \xi; \left|\frac{w_2^L}{w_8^U}-4.71\right| \le \xi; \left|\frac{w_3^L}{w_8^U}-5.65\right| \le \xi; \left|\frac{w_4^L}{w_8^U}-3.30\right| \le \xi; \left|\frac{w_5^L}{w_8^U}-4.45\right| \le \xi; \left|\frac{w_6^L}{w_8^U}-3.30\right| \le \xi; \left|\frac{w_7^L}{w_8^U}-3.24\right| \le \xi; \left|\frac{w_8^L}{w_8^U}-1.00\right| \le \xi; \\
\left|\frac{w_1^U}{w_8^L}-5.42\right| \le \xi; \left|\frac{w_2^U}{w_8^L}-3.38\right| \le \xi; \left|\frac{w_3^U}{w_8^L}-5.16\right| \le \xi; \left|\frac{w_4^U}{w_8^L}-2.50\right| \le \xi; \left|\frac{w_5^U}{w_8^L}-3.08\right| \le \xi; \left|\frac{w_6^U}{w_8^L}-1.75\right| \le \xi; \left|\frac{w_7^U}{w_8^L}-1.81\right| \le \xi; \left|\frac{w_8^U}{w_8^L}-1.00\right| \le \xi; \\
\sum_{j=1}^{8} w_j^L \le 1; \sum_{j=1}^{8} w_j^U \ge 1; \\
w_j^L \le w_j^U, \forall j=1,2,\ldots,8; w_j^L, w_j^U \ge 0, \forall j=1,2,\ldots,8
\end{array}
\right.
\end{array}
$$

By solving the presented model, the optimal values of rough weight coefficients of the criteria were obtained.

$$
\begin{aligned}
RN(w_1) &= [0.240,\ 0.295], \\
RN(w_2) &= [0.131,\ 0.131], \\
RN(w_3) &= [0.165,\ 0.165], \\
RN(w_4) &= [0.055,\ 0.098], \\
RN(w_5) &= [0.121,\ 0.121], \\
RN(w_6) &= [0.057,\ 0.079], \\
RN(w_7) &= [0.051,\ 0.076], \\
RN(w_8) &= [0.037,\ 0.037].
\end{aligned}
$$

By analyzing the rough weight coefficients of the criteria of optimality, we observe that the conditions are satisfied that $\sum_{j=1}^{n} w_j^L \le 1$ and $\sum_{j=1}^{n} w_j^U \ge 1$, since $\sum_{j=1}^{8} w_j^L = 0.854 \le 1$ and $\sum_{j=1}^{8} w_j^U = 1.000 \ge 1$. In addition, the requirement is that $0 \le w_j^L \le w_j^U \le 1$, that is, the general condition that applies to the values of the weight coefficients of the criteria being in the interval $w_j \in [0,1], (j = 1,2,\ldots,8)$.

By solving the model, the value ξ^*, which amounts to $\xi^* = 1.148$, was obtained. The value ξ^* was used to determine the consistency ratio. Since we obtain the value $\overline{a}_{BW}$, i.e., a_{BW}^U on the basis of aggregated experts' decisions, it is not possible to define in advance the values of the consistency index ξ. Reference [52] defined the values of the consistency index (ξ) for crisp BWM. Because this relates to RBWM, for the value $a_{BW}^U = 6.95$, the value $CI(\max\xi) = 3.595$ is defined and the value $CR = 0.319$ is obtained. Based on [52], the obtained CR value was assessed as satisfactory.

4.4. Aggregation of an Initial Matrix on the Basis of the Developed Rough Hamy Aggregator

Table 8 shows the evaluation of locations according to all criteria based on the evaluation of seven experts in the field of traffic. The evaluation was performed in the period November 2017–February 2018.

Table 8. Evaluation of locations according to criteria by seven experts.

				A_1							**A_2**							**A_3**			
C_1	3	3	5	3	3	3	1	5	5	7	5	5	5	3	1	1	3	3	3	3	1
C_2	5	3	3	3	3	3	1	3	1	3	1	3	1	1	3	1	3	3	3	1	1
C_3	5	3	1	5	3	3	3	5	3	1	5	3	3	3	9	7	5	9	7	5	7
C_4	5	3	5	3	1	3	3	7	1	7	5	5	7	9	5	1	5	3	3	7	7
C_5	7	5	7	7	5	7	5	7	5	7	7	5	7	5	7	5	7	7	5	7	5
C_6	5	5	3	5	3	5	3	7	7	5	7	5	7	5	3	5	1	5	3	3	1
C_7	7	7	9	7	9	7	7	9	9	7	7	7	7	5	5	7	5	5	7	7	3
C_8	9	7	9	7	9	7	9	9	7	9	7	9	7	9	5	5	5	5	5	5	5
				A_4							**A_5**							**A_6**			
C_1	7	5	7	5	5	5	5	1	1	3	3	3	3	1	9	7	9	7	9	7	7
C_2	7	7	5	5	7	5	5	1	1	1	1	1	1	1	9	9	7	9	9	9	9
C_3	7	5	3	7	5	3	5	9	7	5	9	7	5	7	1	1	1	3	1	1	1
C_4	5	3	7	5	3	3	7	3	1	3	5	3	3	5	5	1	3	3	3	1	3
C_5	9	7	9	9	7	9	7	9	7	9	9	7	9	7	9	7	9	9	7	9	7
C_6	7	7	5	7	5	7	5	1	3	1	3	3	1	1	9	9	7	9	9	9	7
C_7	5	7	5	3	3	7	5	7	7	7	5	5	9	5	5	9	5	7	7	7	7
C_8	1	3	1	1	1	1	1	3	3	3	5	3	5	3	7	7	7	5	7	5	7

After the transformation of experts' evaluations into rough numbers, seven rough matrices are obtained that are aggregated into the aggregated rough matrix using the RNHM operator (3). Using the expression (3), the transformation of experts' individual rough matrices into RGM is performed. Thus, for example, in position A_1–C_1, we obtain the following values in expert correspondent matrices: $RN(x_{11}^{E1}) = [2.67, 3.33]$, $RN(x_{11}^{E2}) = [2.67, 3.33]$, $RN(x_{11}^{E3}) = [3.00, 5.00]$, $RN(x_{11}^{E4}) = [2.67, 3.33]$, $RN(x_{11}^{E5}) = [2.67, 3.33]$, $RN(x_{11}^{E6}) = [2.67, 3.33]$ and $RN(x_{11}^{E7}) = [1.00, 3.00]$. Based on the proposed values, the expression (3) and taking that $k = 2$, in position A_1-C_1, the aggregation of values is performed:

(a) $$\frac{1}{\begin{pmatrix} n \\ k \end{pmatrix}} = \frac{k!(n-k)!}{n!} = \frac{2!(7-2)!}{7!} = \frac{1}{21}$$

(b) $$\underline{Lim}(x_{11}) = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le 7} \left(\prod\limits_{j=1}^{2} \underline{Lim}(x_{i_j}) \right)^{1/2}}{\begin{pmatrix} 7 \\ 2 \end{pmatrix}} =$$
$$= \frac{(2.67 \times 2.67)^{1/2} + (2.67 \times 3)^{1/2} + (2.67 \times 3)^{1/2} + (2.67 \times 2.67)^{1/2} + \ldots + (2.67 \times 1)^{1/2} + (2.67 \times 1)^{1/2}}{21} = 2.417$$

(c) $$\underline{Lim}(x_{11}) = \frac{\sum\limits_{1 \le i_1 < \ldots < i_k \le 7} \left(\prod\limits_{j=1}^{2} \overline{Lim}(\varphi_{i_j}) \right)^{1/2}}{\begin{pmatrix} 7 \\ 2 \end{pmatrix}} =$$
$$= \frac{(3.33 \times 3.33)^{1/2} + (3.33 \times 5)^{1/2} + (2 \times 5)^{1/2} + (3.33 \times 3.33)^{1/2} + \ldots + (3.33 \times 3)^{1/2} + (3.33 \times 3)^{1/2}}{21} = 3.494$$

In this way, we obtain the aggregated value $RNHM^{(2)}\{RN(x_{11}^{1}), RN(x_{11}^{2}), RN(x_{11}^{3}), \ldots, RN(x_{11}^{7})\} = [2.417, 3.494]$. As for the k = 2 values used in this paper, it was selected for a better display of the value aggregation using the Hamy aggregator and since it is a recommendation to use k = 2 for the initial aggregation in the papers [72,73]. An additional analysis of the change in the value of the parameter k showed that there were no changes in the ranks, and hence the decision to select the values $k = 2$ was confirmed. Similarly, we obtain the remaining elements of RGM, Table 9.

Table 9. Group rough matrix obtained using the Rough Hamy aggregator.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	[2.42, 3.49]	[2.42, 3.49]	[2.49, 3.97]	[2.49, 3.97]	[5.63, 6.62]	[3.63, 4.62]	[7.16, 7.96]	[7.64, 8.63]
A2	[4.45, 5.5]	[1.33, 2.31]	[2.49, 3.97]	[4.07, 7.21]	[5.63, 6.62]	[5.63, 6.62]	[6.54, 7.98]	[7.64, 8.63]
A3	[1.59, 2.61]	[1.59, 2.61]	[6.06, 7.89]	[2.89, 5.73]	[5.63, 6.62]	[1.99, 3.87]	[4.69, 6.35]	[5, 5]
A4	[5.16, 5.96]	[5.36, 6.33]	[4.04, 5.89]	[3.68, 5.69]	[7.64, 8.63]	[5.63, 6.62]	[4.04, 5.89]	[1.04, 1.48]
A5	[1.59, 2.61]	[1, 1]	[6.06, 7.89]	[2.49, 3.97]	[7.64, 8.63]	[1.33, 2.31]	[5.62, 7.23]	[3.16, 3.95]
A6	[7.36, 8.34]	[8.45, 8.96]	[1.04, 1.48]	[1.93, 3.39]	[7.64, 8.63]	[8.01, 8.83]	[5.98, 7.41]	[6, 6.83]

4.5. Evaluation of Locations Using Rough WASPAS Methods

After all previous calculations and obtaining the averaging Rough Hamy initial matrix, it is necessary to apply the Equations (8) and (9) from [58] o normalize the initial matrix. An example of normalization for the criteria belonging to the benefit group is:

$$n_{21} = \left[\frac{x_{ij}^{L}}{x_{ij}^{+U}}; \frac{x_{ij}^{U}}{x_{ij}^{+L}}\right] = \left[\frac{x_{21}^{L}}{x_{61}^{+U}}; \frac{x_{21}^{U}}{x_{61}^{+L}}\right] = \left[\frac{4.45}{8.34}; \frac{5.50}{7.36}\right] = [0.53, 0.75],$$

and for the criteria belonging to the cost group:

$$n_{12} = \left[\frac{x_{ij}^{-L}}{x_{ij}^{U}}; \frac{x_{ij}^{-U}}{x_{ij}^{L}}\right] = \left[\frac{x_{15}^{L}}{x_{12}^{U}}; \frac{x_{15}^{U}}{x_{12}^{L}}\right] = \left[\frac{1.00}{3.49}; \frac{1.00}{2.42}\right] = [0.29, 0.41],$$

In the same way, all the elements of the normalized matrix should be calculated, Table 10:

Table 10. Normalized matrix.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	[0.29, 0.47]	[0.29, 0.41]	[0.32, 0.65]	[0.49, 1.36]	[0.65, 0.87]	[0.41, 0.58]	[0.9, 1.11]	[0.89, 1.13]
A2	[0.53, 0.75]	[0.43, 0.75]	[0.32, 0.65]	[0.27, 0.83]	[0.65, 0.87]	[0.64, 0.83]	[0.82, 1.11]	[0.89, 1.13]
A3	[0.19, 0.35]	[0.38, 0.63]	[0.77, 1.3]	[0.34, 1.17]	[0.65, 0.87]	[0.23, 0.48]	[0.59, 0.89]	[0.58, 0.65]
A4	[0.62, 0.81]	[0.16, 0.19]	[0.51, 0.97]	[0.34, 0.92]	[0.89, 1.13]	[0.64, 0.83]	[0.51, 0.82]	[0.12, 0.19]
A5	[0.19, 0.35]	[1, 1]	[0.77, 1.3]	[0.49, 1.36]	[0.89, 1.13]	[0.15, 0.29]	[0.7, 1.01]	[0.37, 0.52]
A6	[0.88, 1.13]	[0.11, 0.12]	[0.13, 0.24]	[0.57, 1.76]	[0.89, 1.13]	[0.91, 1.1]	[0.75, 1.04]	[0.7, 0.89]

The next step is weighting the normalized matrix with the weights of criteria obtained by using the Rough BWM method. In order to obtain the weighted normalized matrix shown in Table 11, the Equation (11) from [58] should be applied.

Table 11. Weighted normalized matrix.

	C1	C2	C3	C4	C5	C6	C7	C8
A1	[0.07, 0.14]	[0.04, 0.05]	[0.05, 0.11]	[0.03, 0.13]	[0.08, 0.10]	[0.02, 0.05]	[0.05, 0.08]	[0.03, 0.04]
A2	[0.13, 0.22]	[0.06, 0.10]	[0.05, 0.11]	[0.01, 0.08]	[0.08, 0.10]	[0.04, 0.07]	[0.04, 0.09]	[0.03, 0.04]
A3	[0.05, 0.10]	[0.05, 0.08]	[0.13, 0.21]	[0.02, 0.02]	[0.08, 0.10]	[0.01, 0.04]	[0.03, 0.07]	[0.02, 0.02]
A4	[0.15, 0.24]	[0.02, 0.02]	[0.08, 0.16]	[0.02, 0.09]	[0.11, 0.14]	[0.04, 0.07]	[0.03, 0.06]	[0, 0.01]
A5	[0.05, 0.10]	[0.13, 0.13]	[0.13, 0.21]	[0.03, 0.13]	[0.11, 0.14]	[0.01, 0.02]	[0.04, 0.08]	[0.01, 0.02]
A6	[0.21, 0.33]	[0.01, 0.02]	[0.02, 0.04]	[0.03, 0.17]	[0.11, 0.14]	[0.05, 0.09]	[0.04, 0.08]	[0.03, 0.03]

The seventh step summarizes the values by the rows and the matrix Q_i. is obtained. Applying the Equation (13) from step 8 from [58], the following matrix is obtained:

$$Q_i \begin{bmatrix} [0.366, 0.712] \\ [0.440, 0.804] \\ [0.383, 0.751] \\ [0.445, 0.785] \\ [0.493, 0.838] \\ [0.501, 0.987] \end{bmatrix} P_i \begin{bmatrix} [0.449, 0.656] \\ [0.542, 0.795] \\ [0.446, 0.667] \\ [0.508, 0.692] \\ [0.518, 0.713] \\ [0.483, 0.673] \end{bmatrix}$$

The relative values of the alternatives (Table 12) are calculated in the ninth step by applying the Equation (14), while λ is obtained by applying the Equation (15) [58] and it is:

$$\lambda = [0.828, 1.253]$$

Table 12. Determining relative value alternatives and ranking.

	$\lambda \times Q_i$	$(1-\lambda) \times P_i$	A_i	Rank
A_1	[0.303, 0.891]	[−0.113, 0.113]	[0.189, 1.004]	6
A_2	[0.364, 1.007]	[−0.137, 0.137]	[0.227, 1.144]	3
A_3	[0.317, 0.940]	[−0.113, 0.115]	[0.205, 1.055]	5
A_4	[0.369, 0.983]	[−0.128, 0.119]	[0.240, 1.102]	4
A_5	[0.409, 1.050]	[−0.131, 0.123]	[0.278, 1.172]	2
A_6	[0.415, 1.124]	[−0.122, 0.116]	[0.293, 1.240]	1

Based on the presented calculation it can be noticed that the location under the rank number 6 is the best and is a priority for the construction of a roundabout. Since it is the location that has the largest traffic flow of pedestrians, the alternative solution for this location is the installation of a traffic light at this intersection, as it is well-known that if there is a high rate of pedestrians for the roundabout, alternative solutions are used. The intensity of pedestrians at this location for the period of one hour is 124 and, according to the authors' opinion, it is not a limitation for the roundabout construction. Location 6 represents the location in the town center. The second location for the construction of a roundabout is location 5 representing the last exit from the town towards Sarajevo and which is a four-way intersection with an additional side road. There is often traffic congestion at this intersection with town streets being its arms, so there is often a situation where drivers carelessly merge onto a main road, as evidenced by a number of accidents. Considering the above, the priority for the construction of a roundabout at this location is justified. Table 12 shows the results for all the locations and their ranks.

5. Sensitivity Analysis

In order to discuss the influence of the parameter k, we can adopt different values of parameter k in our proposed method to rank the alternatives, and the results are listed in Table 13. As we can see from Table 13 and Figure 3, the ranking orders are same with the parameter k changes in this example.

Table 13. Ranking results by utilizing the different *k*.

Alte.	*k* = 1	*k* = 2	*k* = 3	*k* = 4	*k* = 5	*k* = 6	*k* = 7
A1	0.595	0.597	0.599	0.669	0.679	0.681	0.682
A2	0.702	0.686	0.685	0.739	0.746	0.747	0.748
A3	0.638	0.630	0.631	0.694	0.703	0.704	0.705
A4	0.684	0.671	0.669	0.718	0.726	0.727	0.728
A5	0.734	0.725	0.726	0.749	0.754	0.755	0.756
A6	0.767	0.766	0.768	0.774	0.778	0.778	0.779
Ranking	A6 > A5 > A2 > A4 > A3 > A1	A6 > A5 > A2 > A4 > A3 > A1	A6 > A5 > A2 > A4 > A3 > A1	A6 > A5 > A2 > A4 > A3 > A1	A6 > A5 > A2 > A4 > A3 > A1	A6 > A5 > A2 > A4 > A3 > A1	A6 > A5 > A2 > A4 > A3 > A1

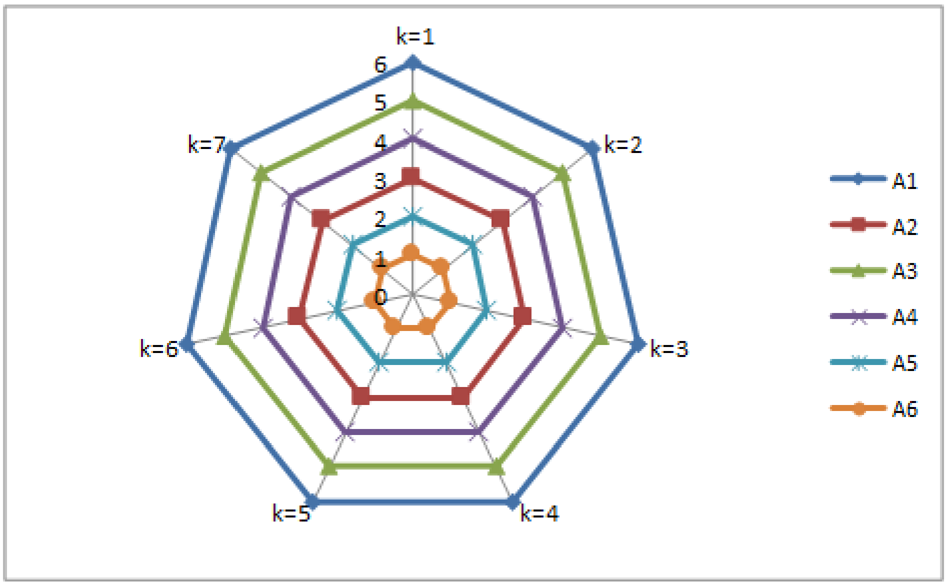

Figure 3. Results of sensitivity analysis.

For all changes of parameter *k* the ranking results are same, i.e., A6 > A5 > A2 > A4 > A3 > A1. This verifies that the proposed method based on the RNHM can provide more flexibility and adaptability in information aggregation and take full advantage of parameter change to solve MCDM problems in which there are interrelationships between the attributes. In real-world decision-making situations, DMs can choose the appropriate value in accordance with their risk preferences. That is, it is more effective for DMs to select adaptive value of the parameter *k* according to their risk attitude. If the DM favors risk, he/she can take the parameter as small as possible; if the DM dislikes risk, he can take the parameter as large as possible. Therefore, the proposed method provides a general and flexible way to express the DMs' preference and/or real requirements by utilizing the different parameter *k* in the decision process.

In the sensitivity analysis, a multi-criteria problem was calculated by applying other rough methods to verify the validity of the model, i.e., the results obtained. For this purpose, the following methods were used: Rough SAW (Simple Additive Weighting) [54], Rough EDAS (Evaluation based on Distance from Average Solution) [47], Rough MABAC (Multi-Attributive Border Approximation Area Comparison) [74] and Rough TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) [75], Rough MAIRCA (Multi-Attributive Ideal-Real Comparative Analysis) [76] and Rough VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) [77].

From Figure 4 it can be seen that the sixth location is the best solution in all formed scenarios, i.e., by applying all other methods mentioned above. Location 5 is in the second position three times, using Rough WASPAS, Rough EDAS and Rough SAW, while by applying Rough VIKOR and Rough TOPSIS it is in the fourth place, which is a consequence of similarity in the methodology of these two methods. The fourth location is in the second position four times, while in other scenarios it is twice in the third and twice in the fourth position. The alternative 2 is in the third or fourth place in all scenarios, while the third and the first alternative exchange their ranks in the fifth, i.e., sixth place. Since there is a change in the ranking of alternatives, it is necessary to perform a statistical comparison of ranks, i.e., to determine their correlation. Table 14 shows Spearman's coefficient of correlation.

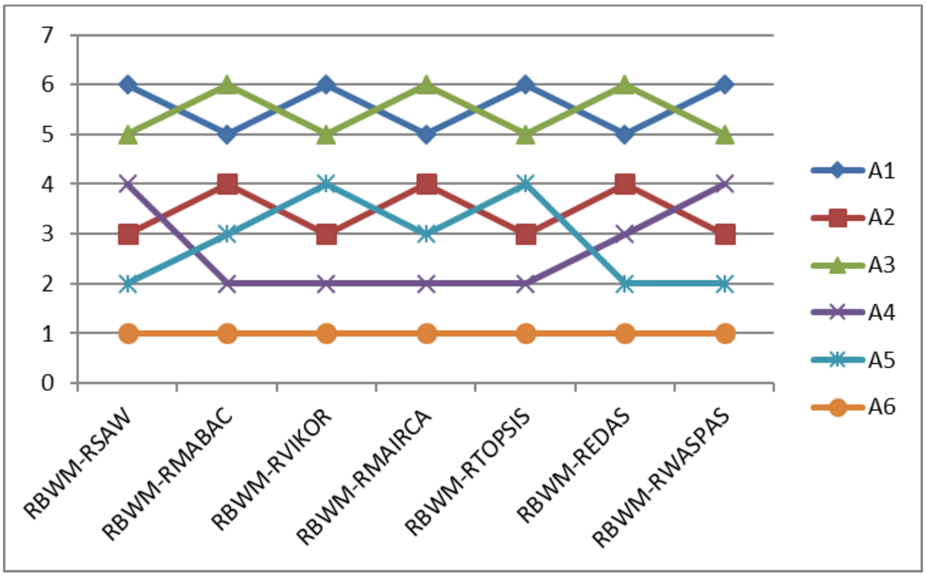

Figure 4. Ranking alternatives using different methods.

Table 14. Spearman's coefficient of correlation for rank location using different methods.

Methods	RBWM-RWASPAS	RBWM-RSAW	RBWM-RMABAC	RBWM-RVIKOR	RBWM-RMAIRCA	RBWM-RTOPSIS	RBWM-REDAS	Average
RBWM-RWASPAS	1.000	1.000	0.771	0.771	0.771	0.771	0.886	0.853
RBWM-RSAW	-	1.000	0.771	0.771	0.771	0.771	0.886	0.828
RBWM-RMABAC	-	-	1.000	0.886	1.000	0.886	0.943	0.943
RBWM-RVIKOR	-	-	-	1.000	0.886	1.000	0.771	0.914
RBWM-RMAIRCA	-	-	-	-	1.000	0.886	0.943	0.943
RBWM-RTOPSIS	-	-	-	-	-	1.000	0.771	0.886
RBWM-REDAS	-	-	-	-	-	-	1.000	1.000
			Overall average					0.910

Based on the total calculated statistical correlation coefficient (0.910) it can be concluded that the ranks are in high correlation in all the created scenarios. Regarding rank correlation of Rough WASPAS with other methods, the highest correlation is with Rough SAW where the ranks are in total correlation, i.e., SCC is 1.00. It has a slightly lower correlation with Rough EDAS (0.886), while with others, it has a correlation of 0.771. As it has already been said, Rough SAW and Rough WASPAS have total correlation, hence the Rough SAW has the same correlation with other approaches as Rough WASPAS. Rough MABAC and Rough MAIRCA also have total correlation of ranks, as well as Rough VIKOR and Rough TOPSIS. The correlation coefficient of Rough MABAC, i.e., Rough MAIRCA with Rough EDAS is high and is 0.943, while the correlation coefficient of Rough VIKOR and Rough TOPSIS with Rough EDAS is 0.771. Considering the overall ranks and correlation coefficients, it can be concluded that the model obtained is very stable and the ranks are in high correlation, since all values higher than 0.80 according to Keshavarz Ghorabaee et al. [78] represent a very high correlation of ranks.

6. Conclusions

In this paper, a novel Rough Hamy aggregator has been developed to achieve a more favorable consensus for group decision-making, which is one of the key contributions of the paper.

The development of a new aggregator and the formation of an integrated Rough BWM-Rough WASPAS model further enrich the area of multi-criteria decision-making. Observing the advantages of the complete model, it is possible to make decisions that are more precise because an initial matrix has more accurate values, eliminates subjectivity and reduces uncertainty in a decision-making process.

The developed model was applied to a case study of the location selection for the construction of roundabout in the town of Doboj, which is one of the essential factors for increasing the mobility and functional sustainability of the town. Taking into account the geographic position of Doboj, there is an imperative for the construction of a roundabout on the territory covered by this urban area. The position itself causes significant share of transit flows, increasing negative externalities to the sustainability of traffic. The solution is certainly the construction of roundabouts that significantly eliminate or reduce the current negative effects. In the paper, six potential locations evaluated by using the Rough BWM-Rough WASPAS model are considered.

Based on the obtained results it can be concluded that the sixth location is the best from the aspect of the defined optimization criterion and is a priority for the construction of a roundabout. Location 6 represents the location that is in the town center. The second location priority for the construction of a roundabout is the location 5 representing the last exit from the town towards Sarajevo and a four-way intersection with an additional side road. There is very often traffic congestion at this intersection with town streets being its arms. Taking into account the above, the priority for the construction of a roundabout at the mentioned locations is considered as justified. Through the sensitivity analysis, in which the scenarios were created by applying different approaches, the model stability was verified.

Future research with respect to this paper are in relation to the development of a model that will enable the measurement of parameters that enhance traffic sustainability and the possibility of developing new approaches in the area of multi-criteria decision-making.

Author Contributions: Each author has participated and contributed sufficiently to take public responsibility for appropriate portions of the content.

Funding: This research received no external funding.

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

Appendix A

Proof of the Theorem 1. Based on the operations with RN:

(1) $\prod_{j=1}^{k} RN(\varphi_{i_j}) = \left[\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}), \prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j})\right]$,

(2) $\left(\prod_{j=1}^{k} RN(\varphi_{i_j})\right)^{1/k} = \left[\left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j})\right)^{1/k}, \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j})\right)^{1/k}\right]$,

(3) $\sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} RN(\varphi_{i_j})\right)^{1/k} = \left[\sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j})\right)^{1/k}, \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j})\right)^{1/k}\right]$,

(4) $\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} RN(\varphi_{i_j})\right)^{1/k} = \left[\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j})\right)^{1/k}, \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j})\right)^{1/k}\right]$.

Besides, since

$$0 \le \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}) \right)^{1/k} \le \underline{Lim}(\varphi_{RNHM}),$$

$$\underline{Lim}(\varphi_{RNHM}) \le \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j}) \right)^{1/k} \le \overline{Lim}(\varphi_{RNHM})$$

then $\left[\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}) \right)^{1/k}, \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j}) \right)^{1/k} \right]$ represents RN, so that Theorem 1 has been proved. □

Proof of the Theorem 2. Since $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)] = RN(\varphi)$; $(j = 1, 2, \ldots, n)$, then using Theorem 1, the following calculations are obtained:

$$RNHM^{(k)}\{RN(\varphi), RN(\varphi), \ldots, RN(\varphi)\} = \left[\underline{Lim}(\varphi), \overline{Lim}(\varphi)\right] =$$
$$= \left[\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}) \right)^{1/k}, \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j}) \right)^{1/k} \right]$$
$$= \left[\frac{1}{\binom{n}{k}} \left(\underline{Lim}(\varphi_{i_j}) \right), \frac{1}{\binom{n}{k}} \left(\overline{Lim}(\varphi_{i_j}) \right) \right] = \left[\underline{Lim}(\varphi), \overline{Lim}(\varphi)\right] = RN(\varphi)$$

□

Proof of the Theorem 3. Based on Definition 2, the conclusion is obvious:

$$RNHM^{(k)}\{RN(\varphi'_1), RN(\varphi'_2), \ldots, RN(\varphi'_n)\} = \left[\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi'_{i_j}) \right)^{1/k}, \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j}) \right)^{1/k} \right] =$$
$$= \left[\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}) \right)^{1/k}, \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \overline{Lim}(\varphi_{i_j}) \right)^{1/k} \right] = RNHM^{(k)}\left\{RN(\varphi_{i_j}), RN(\varphi_{i_j}), \ldots, RN(\varphi_{i_j})\right\}$$

□

Proof of the Theorem 4. Let $RN(\varphi_j^-) = \min\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \left[\underline{Lim}(\varphi_j^-), \overline{Lim}(\varphi_j^-)\right]$ and $RN(\varphi_j^+) = \max\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \left[\underline{Lim}(\varphi_j^+), \overline{Lim}(\varphi_j^+)\right]$. Then we have $\underline{Lim}(\varphi_j^-) = \min_j\left\{\underline{Lim}(\varphi_j)\right\}$, $\overline{Lim}(\varphi_j^-) = \min_j\left\{\overline{Lim}(\varphi_j)\right\}$, $\underline{Lim}(\varphi_j^+) = \max_j\left\{\underline{Lim}(\varphi_j)\right\}$ and $\overline{Lim}(\varphi_j^+) = \max_j\left\{\overline{Lim}(\varphi_j)\right\}$. Based on that, we have that

$$\frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}^-) \right)^{1/k} \le \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}) \right)^{1/k} \le \frac{1}{\binom{n}{k}} \sum_{1 \le i_1 < \ldots < i_k \le n} \left(\prod_{j=1}^{k} \underline{Lim}(\varphi_{i_j}^+) \right)^{1/k}$$

$$\frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\varphi_{i_j}^-)\right)^{1/k} \le \frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\varphi_{i_j})\right)^{1/k} \le \frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\varphi_{i_j}^+)\right)^{1/k}$$

According to the inequalities shown above, we can conclude that $RN(\varphi_j^-) \le RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \le RN(\varphi_j^+)$. □

Proof of the Theorem 5. Since $0 \le \underline{Lim}(\varphi_j) \le \underline{Lim}(\phi_j)$, $0 \le \overline{Lim}(\varphi_j) \le \overline{Lim}(\phi_j)$, then based on Theorem 1 it is obtained that

$$\frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\underline{Lim}(\varphi_{i_j})\right)^{1/k} \le \frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\underline{Lim}(\phi_{i_j})\right)^{1/k}$$

$$\frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\varphi_{i_j})\right)^{1/k} \le \frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\phi_{i_j})\right)^{1/k}$$

Let $RN(\varphi) = RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\}$ and $RN(\phi) = RNHM\{RN(\phi_1), RN(\phi_2), \ldots, RN(\phi_n)\}$ be two RNs, then:

(1) If $\underline{Lim}(\varphi) \le \underline{Lim}(\phi)$ and $\overline{Lim}(\varphi) \le \overline{Lim}(\phi)$, then it is obtained that $RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \le RNHM\{RN(\phi_1), RN(\phi_2), \ldots, RN(\phi_n)\}$;
(2) If $\underline{Lim}(\varphi) = \underline{Lim}(\phi)$ and $\overline{Lim}(\varphi) = \overline{Lim}(\phi)$, then it can be concluded that there are the following equalities:

$$\frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\underline{Lim}(\varphi_{i_j})\right)^{1/k} = \frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\underline{Lim}(\phi_{i_j})\right)^{1/k}$$

$$\frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\varphi_{i_j})\right)^{1/k} = \frac{1}{\binom{n}{k}}\sum_{1\le i_1<\ldots<i_k\le n}\left(\prod_{j=1}^{k}\overline{Lim}(\phi_{i_j})\right)^{1/k}$$

Finally, it can be concluded that there is the following inequality: $RNHM\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \le RNHM\{RN(\phi_1), RN(\phi_2), \ldots, RN(\phi_n)\}$. □

References

1. Brown, M. *The Design of Roundabouts*; TRL State of the Art Review; Her Majesty Stationary Office: London, UK, 1995.
2. Hels, T.; Orozova-Bekkevold, I. The effect of roundabout design features on cyclist accident rate. *Accid. Anal. Prev.* **2007**, *39*, 300–307. [CrossRef] [PubMed]
3. Vasilyeva, E.; Sazonova, T. Justification of the Expediency of Creating Circular Intersections in Modern Cities. *Earth Environ. Sci.* **2017**, *90*, 012116. [CrossRef]
4. Mottaeva, A. Innovative Aspects of Ecological and Economic Management of Investment and Construction Activities for the Sustainable Development of the Region. *MATEC Web Conf.* **2016**, *73*, 07020. [CrossRef]
5. Møller, M.; Hels, T. Cyclists' perception of risk in roundabouts. *Accid. Anal. Prev.* **2008**, *40*, 1055–1062. [CrossRef] [PubMed]
6. Li, Y.; Zhao, L.; Suo, J. Comprehensive assessment on sustainable development of highway transportation capacity based on entropy weight and TOPSIS. *Sustainability* **2014**, *6*, 4685–4693. [CrossRef]

7. Pratelli, A. Design of modern roundabouts in urban traffic systems. *WIT Trans. Built Environ.* **2006**, *89*, 11.
8. Retting, R.A.; Mandavilli, S.; McCartt, A.T.; Russell, E.R. Roundabouts, traffic flow and public opinion. *Traffic Eng. Control* **2006**, *47*, 268–272.
9. Pratelli, A.; Sechi, P.; Roy Souleyrette, R. Upgrading Traffic Circles to Modern Roundabouts to Improve Safety and Efficiency–Case Studies from Italy. *Promet-Traffic Transp.* **2018**, *30*, 217–229. [CrossRef]
10. Antov, D.; Abel, K.; Sürje, P.; Rouk, H.; Roivas, T. Speed reduction effects of urban roundabouts. *Balt. J. Road Bridge Eng.* **2009**, *4*. [CrossRef]
11. Sohn, K. A systematic decision criterion for the elimination of useless overpasses. *Transp. Res. Part A Policy Pract.* **2008**, *42*, 1043–1055. [CrossRef]
12. Podvezko, V.; Sivilevičius, H. The use of AHP and rank correlation methods for determining the significance of the interaction between the elements of a transport system having a strong influence on traffic safety. *Transport* **2013**, *28*, 389–403. [CrossRef]
13. Pilko, H.; Mandžuka, S.; Barić, D. Urban single-lane roundabouts: A new analytical approach using multi-criteria and simultaneous multi-objective optimization of geometry design, efficiency and safety. *Transp. Res. Part C Emerg. Technol.* **2017**, *80*, 257–271. [CrossRef]
14. Barić, D.; Pilko, H.; Strujić, J. An analytic hierarchy process model to evaluate road section design. *Transport* **2016**, *31*, 312–321. [CrossRef]
15. Singh, T.P.; Nigam, S.P.; Singh, D.G.; Agrawal, V.P. Analysis and Validation of Traffic Noise under Dynamic Condition Near Roundabout Using Madm Approach. Ph.D. Thesis, LM Thapar School of Management, Behra, India, 2013.
16. Pirdavani, A.; Brijs, T.; Wets, G. A Multiple Criteria Decision-Making Approach for Prioritizing Accident Hotspots in the Absence of Crash Data. *Transp. Rev.* **2010**, *30*, 97–113. [CrossRef]
17. Murat, Y.S.; Arslan, T.; Cakici, Z.; Akçam, C. Analytical Hierarchy Process (AHP) based Decision Support System for Urban Intersections in Transportation Planning. In *Using Decision Support Systems for Transportation Planning Efficiency*; IGI Global: Hershey, PA, USA, 2016; pp. 203–222.
18. Legac, I.; Pilko, H.; Brcic, D. Analysis of traffic capacity and design for the reconstruction of a large roundabout in the city of Zagreb. *Intersec. Control Saf.* **2013**, *66*, 17.
19. Ruiz-Padillo, A.; Ruiz, D.P.; Torija, A.J.; Ramos-Ridao, Á. Selection of suitable alternatives to reduce the environmental impact of road traffic noise using a fuzzy multi-criteria decision model. *Environ. Impact Assess. Rev.* **2016**, *61*, 8–18. [CrossRef]
20. Ruiz-Padillo, A.; Torija, A.J.; Ramos-Ridao, A.F.; Ruiz, D.P. Application of the fuzzy analytic hierarchy process in multi-criteria decision in noise action plans: Prioritizing road stretches. *Environ. Model. Softw.* **2016**, *81*, 45–55. [CrossRef]
21. Joo, S.; Lee, G.; Oh, C. A multi-criteria analysis framework including environmental and health impacts for evaluating traffic calming measures at the road network level. *Int. J. Sustain. Transp.* **2017**, 1–9. [CrossRef]
22. Hao, N.; Feng, Y.; Zhang, K.; Tian, G.; Zhang, L.; Jia, H. Evaluation of traffic congestion degree: An integrated approach. *Int. J. Distrib. Sens. Netw.* **2017**, *13*. [CrossRef]
23. Bongo, M.F.; Ocampo, L.A. A hybrid fuzzy MCDM approach for mitigating airport congestion: A case in Ninoy Aquino International Airport. *J. Air Transp. Manag.* **2017**, *63*, 1–16. [CrossRef]
24. Hashemkhani Zolfani, S.; Esfahani, M.H.; Bitarafan, M.; Zavadskas, E.K.; Arefi, S.L. Developing a new hybrid MCDM method for selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents. *Transport* **2013**, *28*, 89–96. [CrossRef]
25. Castro-Nuño, M.; Arévalo-Quijada, M.T. Assessing urban road safety through multidimensional indexes: Application of multicriteria decision making analysis to rank the Spanish provinces. *Transp. Policy* **2018**, *68*, 118–129. [CrossRef]
26. Gardziejczyk, W.; Zabicki, P. Normalization and variant assessment methods in selection of road alignment variants–case study. *J. Civ. Eng. Manag.* **2017**, *23*, 510–523. [CrossRef]
27. Javid, R.J.; Nejat, A.; Hayhoe, K. Selection of CO_2 mitigation strategies for road transportation in the United States using a multi-criteria approach. *Renew. Sustain. Energy Rev.* **2014**, *38*, 960–972. [CrossRef]
28. Drezner, Z. *Facility Location: A Survey of Applications and Methods*; Springer: New York, NY, USA, 1995.
29. Kahraman, C.; Ruan, D.; Doğan, I. Fuzzy group decision-making for facility location selection. *Inf. Sci.* **2003**, *157*, 135–153. [CrossRef]

30. Berman, O.; Drezner, Z.; Wesolowsky, G.O. Location of facilities on a network with groups of demand points. *IIE Trans.* **2001**, *33*, 637–648. [CrossRef]
31. Melkote, S.; Daskin, M.S. Capacitated facility location/network design problems. *Eur. J. Oper. Res.* **2001**, *129*, 481–495. [CrossRef]
32. Nanthavanij, S.; Yenradee, P. Predicting the optimum number, location, and signal sound level of auditory warning devices for manufacturing facilities. *Int. J. Ind. Ergon.* **1999**, *24*, 569–578. [CrossRef]
33. Badri, M.A. Combining the analytic hierarchy process and goal programming for global facility location-allocation problem. *Int. J. Prod. Econ.* **1999**, *62*, 237–248. [CrossRef]
34. Applebaum, W. The analog method for estimating potential store sales. *Guid. Stor. Locat. Res.* **1968**, *3*, 127–144.
35. Stević, Ž.; Vesković, S.; Vasiljević, M.; Tepić, G. The selection of the logistics center location using AHP method. In Proceedings of the 2nd Logistics International Conference, Belgrade, Serbia, 21–23 May 2015; pp. 86–91.
36. Benjamin, C.O.; Chi, S.C.; Gaber, T.; Riordan, C.A. Comparing BP and ART II neural network classifiers for facility location. *Comput. Ind. Eng.* **1995**, *28*, 43–50. [CrossRef]
37. Satani, N.; Uchida, A.; Deguchi, A.; Ohgai, A.; Sato, S.; Hagishima, S. Commercial facility location model using multiple regression analysis. *Comput. Environ. Urban Syst.* **1998**, *22*, 219–240. [CrossRef]
38. Chauhan, A.; Singh, A. A hybrid multi-criteria decision making method approach for selecting a sustainable location of healthcare waste disposal facility. *J. Clean. Prod.* **2016**, *139*, 1001–1010. [CrossRef]
39. Nie, R.X.; Wang, J.Q.; Zhang, H.Y. Solving solar-wind power station location problem using an extended weighted aggregated sum product assessment (WASPAS) technique with interval neutrosophic sets. *Symmetry* **2017**, *9*, 106. [CrossRef]
40. Samanlioglu, F.; Ayağ, Z. A fuzzy AHP-PROMETHEE II approach for evaluation of solar power plant location alternatives in Turkey. *J. Intell. Fuzzy Syst.* **2017**, *33*, 859–871. [CrossRef]
41. Zhao, L.; Li, H.; Li, M.; Sun, Y.; Hu, Q.; Mao, S.; Li, J.; Xue, J. Location selection of intra-city distribution hubs in the metro-integrated logistics system. *Tunn. Undergr. Space Technol.* **2018**, *80*, 246–256. [CrossRef]
42. Nazari, M.A.; Aslani, A.; Ghasempour, R. Analysis of solar farm site selection based on TOPSIS approach. *Int. J. Soc. Ecol. Sustain. Dev.* **2018**, *9*, 12–25. [CrossRef]
43. Baušys, R.; Juodagalvienė, B. Garage location selection for residential house by WASPAS-SVNS method. *J. Civ. Eng. Manag.* **2017**, *23*, 421–429. [CrossRef]
44. Pamučar, D.; Stević, Ž.; Zavadskas, E.K. Integration of interval rough AHP and interval rough MABAC methods for evaluating university web pages. *Appl. Soft Comput.* **2018**, *67*, 141–163. [CrossRef]
45. Saaty, T.L.; Tran, L.T. On the invalidity of fuzzifying numerical judgments in the Analytic Hierarchy Process. *Math. Comput. Model.* **2007**, *46*, 962–975. [CrossRef]
46. Wang, Y.M.; Luo, Y.; Hua, Z. On the extent analysis method for fuzzy AHP and its applications. *Eur. J. Oper. Res.* **2008**, *186*, 735–747. [CrossRef]
47. Stević, Ž.; Pamučar, D.; Vasiljević, M.; Stojić, G.; Korica, S. Novel Integrated Multi-Criteria Model for Supplier Selection: Case Study Construction Company. *Symmetry* **2017**, *9*, 279. [CrossRef]
48. Yager, R.R. On generalized Bonferroni mean operators for multi-criteria aggregation. *Int. J. Approx. Reason.* **2009**, *50*, 1279–1286. [CrossRef]
49. Petrović, G.S.; Madić, M.; Antucheviciene, J. An approach for robust decision making rule generation: Solving transport and logistics decision making problems. *Expert Syst. Appl.* **2018**, *106*, 263–276. [CrossRef]
50. Stefanovic-Marinovic, J.; Troha, S.; Milovančevic, M. An Application of Multicriteria Optimization to the Two-Carrier Two-Speed Planetary Gear Trains. *Facta Univ. Ser. Mech. Eng.* **2017**, *15*, 85–95. [CrossRef]
51. Chatterjee, P.; Mondal, S.; Boral, S.; Banerjee, A.; Chakraborty, S. A novel hybrid method for non-traditional machining process selection using factor relationship and multi-attributive border approximation method. *Facta Univ. Ser. Mech. Eng.* **2017**, *15*, 439–456. [CrossRef]
52. Rezaei, J. Best-worst multi-criteria decision-making method. *Omega* **2015**, *53*, 49–57. [CrossRef]
53. Pamučar, D.; Gigović, L.; Bajić, Z.; Janošević, M. Location selection for wind farms using GIS multi-criteria hybrid model: An approach based on fuzzy and rough numbers. *Sustainability* **2017**, *9*, 1315. [CrossRef]
54. Stević, Ž.; Pamučar, D.; Zavadskas, E.K.; Ćirović, G.; Prentkovskis, O. The Selection of Wagons for the Internal Transport of a Logistics Company: A Novel Approach Based on Rough BWM and Rough SAW Methods. *Symmetry* **2017**, *9*, 264. [CrossRef]

55. Pamučar, D.; Petrović, I.; Ćirović, G. Modification of the Best–Worst and MABAC methods: A novel approach based on interval-valued fuzzy-rough numbers. *Expert Syst. Appl.* **2018**, *91*, 89–106. [CrossRef]
56. Pawlak, Z. *Rough Sets: Theoretical Aspects of Reasoning about Data*; Springer: Berlin, Germany, 1991.
57. Pawlak, Z. Anatomy of conflicts. *Bull. Eur. Assoc. Theor. Comput. Sci.* **1993**, *50*, 234–247.
58. Stojić, G.; Stević, Ž.; Antuchevičienė, J.; Pamučar, D.; Vasiljević, M. A Novel Rough WASPAS Approach for Supplier Selection in a Company Manufacturing PVC Carpentry Products. *Information* **2018**, *9*, 121. [CrossRef]
59. Hashemkhani Zolfani, S.; Aghdaie, M.H.; Derakhti, A.; Zavadskas, E.K.; Varzandeh, M.H.M. Decision making on business issues with foresight perspective; an application of new hybrid MCDM model in shopping mall locating. *Expert Syst. Appl.* **2013**, *40*, 7111–7121. [CrossRef]
60. Mardani, A.; Nilashi, M.; Zavadskas, E.K.; Awang, S.R.; Zare, H.; Jamal, N.M. Decision making methods based on fuzzy aggregation operators: Three decades review from 1986 to 2017. *Int. J. Inf. Technol. Decis. Mak.* **2018**, *17*, 391–466. [CrossRef]
61. Božanić, D.; Tešić, D.; Milićević, J. A hybrid fuzzy AHP-MABAC model: Application in the Serbian Army—The selection of the location for deep wading as a technique of crossing the river by tanks. *Decis. Mak. Appl. Manag. Eng.* **2018**, *1*, 143–164. [CrossRef]
62. Roy, J.; Adhikary, K.; Kar, S.; Pamučar, D. A rough strength relational DEMATEL model for analysing the key success factors of hospital service quality. *Decis. Mak. Appl. Manag. Eng.* **2018**, *1*, 121–142. [CrossRef]
63. Vasiljevic, M.; Fazlollahtabar, H.; Stevic, Z.; Veskovic, S. A rough multicriteria approach for evaluation of the supplier criteria in automotive industry. *Decis. Mak. Appl. Manag. Eng.* **2018**, *1*, 82–96. [CrossRef]
64. Hara, T.; Uchiyama, M.; Takahasi, S.E. A refinement of various mean inequalities. *J. Inequal. Appl.* **1998**, *2*, 387–395. [CrossRef]
65. Day, C.M.; Hainen, A.M.; Bullock, D.M. *Best Practices for Roundabouts on State Highways*; Publication Joint Transportation Research Program, Indiana Department of Transportation and Purdue University: West Lafayette, Indiana, 2013.
66. Benekohal, R.F.; Atluri, V. *Roundabout Evaluation and Design: A Site Selection Procedure*; Illinois Center for Transportation (ICT): Rantoul, IL, USA, 2009.
67. Deluka-Tibljaš, A.; Babić, S.; Cuculić, M.; Šurdonja, S. Possible reconstructions of intersections in urban areas by using roundabouts. In Proceedings of the The First International Conference on Road and Rail Infrastructure (CETRA 2010), Road and Rail Infrastructure, Opatija, Croatia, 17–18 May 2010; pp. 171–178.
68. Steiner, R.L.; Washburn, S.; Elefteriadou, L.; Gan, A.; Alluri, P.; Michalaka, D.; Xu, R.; Rachmat, S.; Lytle, B.; Cavaretta, A. *Roundabouts and Access Management*; State of Florida Department of Transportation: Florida, FL, USA, 2014.
69. Kozić, M.; Šurdonja, S.; Deluka-Tibljaš, A.; Karleuša, B.; Cuculić, M. Criteria for urban traffic infrastructure analyses–case study of implementation of Croatian Guidelines for Rounabouts on State Roads. In Proceedings of the 4th International Conference on Road and Rail Infrastructure, Šibenik, Croatia, 23–25 May 2016.
70. Retting, R.; Kyrychenko, S.; McCartt, A. Long-term trends in public opinion following construction of roundabouts. *Transp. Res. Rec. J. Transp. Res. Board* **2007**, *2019*, 219–224. [CrossRef]
71. Zavadskas, E.K.; Stević, Ž.; Tanackov, I.; Prentkovskis, O. A Novel Multicriteria Approach–Rough Step-Wise Weight Assessment Ratio Analysis Method (R-SWARA) and Its Application in Logistics. *Stud. Inf. Control* **2018**, *27*, 97–106. [CrossRef]
72. Qin, J. Interval type-2 fuzzy Hamy mean operators and their application in multiple criteria decision making. *Granul. Comput.* **2017**, *2*, 249–269. [CrossRef]
73. Liu, P.; You, X. Some linguistic neutrosophic Hamy mean operators and their application to multi-attribute group decision making. *PLoS ONE* **2018**, *13*, e0193027. [CrossRef] [PubMed]
74. Roy, J.; Chatterjee, K.; Bandhopadhyay, A.; Kar, S. Evaluation and selection of Medical Tourism sites: A rough AHP based MABAC approach. *arXiv*, 2016.
75. Song, W.; Ming, X.; Wu, Z.; Zhu, B. A rough TOPSIS approach for failure mode and effects analysis in uncertain environments. *Qual. Reliab. Eng. Int.* **2014**, *30*, 473–486. [CrossRef]
76. Pamučar, D.; Mihajlović, M.; Obradović, R.; Atanasković, P. Novel approach to group multi-criteria decision making based on interval rough numbers: Hybrid DEMATEL-ANP-MAIRCA model. *Expert Syst. Appl.* **2017**, *88*, 58–80. [CrossRef]

77. Zhu, G.N.; Hu, J.; Qi, J.; Gu, C.C.; Peng, Y.H. An integrated AHP and VIKOR for design concept evaluation based on rough number. *Adv. Eng. Inf.* **2015**, *29*, 408–418. [CrossRef]
78. Keshavarz Ghorabaee, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making. *Econ. Comput. Econ. Cybern. Stud. Res.* **2016**, *50*, 25–44.