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Evaluation of a Third-Party Logistics (3PL) Provider Using a Rough SWARA–WASPAS Model Based on a New Rough Dombi Aggregator

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Abstract: For companies active in various sectors, the implementation of transport services and other logistics activities has become one of the key factors of efficiency in the total supply chain. Logistics outsourcing is becoming more and more important, and there is an increasing number of third party logistics providers. In this paper, logistics providers were evaluated using the Rough SWARA (Step-Wise Weight Assessment Ratio Analysis) and Rough WASPAS (Weighted Aggregated Sum Product Assessment) models. The significance of the eight criteria on the basis of which evaluation was carried out was determined using the Rough SWARA method. In order to allow for a more precise consensus in group decision-making, the Rough Dombi aggregator was developed in order to determine the initial rough matrix of multi-criteria decision-making. A total of 10 logistics providers dealing with the transport of dangerous goods for chemical industry companies were evaluated using the Rough WASPAS approach. The obtained results demonstrate that the first logistics provider is also the best one, a conclusion confirmed by a sensitivity analysis comprised of three parts. In the first part, parameter ρ was altered through 10 scenarios in which only alternatives four and five change their ranks. In the second part of the sensitivity analysis, a calculation was performed using the following approaches: Rough SAW (Simple Additive Weighting), Rough EDAS (Evaluation Based on Distance from Average Solution), Rough MABAC (MultiAttributive Border Approximation Area Comparison), and Rough TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution). They showed a high correlation of ranks determined by applying Spearman's correlation coefficient in the third part of the sensitivity analysis.

Keywords: rough Dombi aggregator; rough SWARA; rough WASPAS; third-party logistics provider; dangerous goods

1. Introduction

Modern market demands lead to an increase in the volume of dangerous goods production at a global level. As a result, the number of transport requests for relocating this specific type of good inevitably increases. The basic difference in relation to the transport of classic types of goods is that, in the transport of dangerous materials, participants are faced with additional safety requirements. This type of transport is specific because of the risks that present themselves during the realization of this logistics process [1], which, due to the dangerous properties of the transported matter and potential reactions, can endanger the life and health of people, the environment, and material resources [2]. That is why the domain of hazardous substances is, at both the national and international levels, one of the most regulated areas in terms of set directives, which are tailored for each type of transport.

The United Nations Economic Commission for Europe (UNECE) has formulated and adopted the European Agreement concerning the International Carriage of Dangerous Goods by Road—ADR. This agreement was confirmed in 48 countries. As the ADR is an agreement between states, there is no prevailing authority regarding its application. In practice, control over roads is overseen by the contracting parties, and non-compliance with the regulations can result in legal measures against offenders enforced by the competent national authorities in accordance with domestic legislation.

The overall organization of the transport of dangerous goods is a technologically demanding task. Transport organization comprises meeting various technical, technological, commercial, economic, and other requirements that are all mutually interconnected, as such creating a functional system that represents the obligation of each carrier. Precise knowledge of transport requirements, in both spatial and temporal terms, is a condition for planning and organizing rational and economical transport.

Companies that produce or use hazardous materials are frequently unable to provide full transport services, as they have specific and varied capacities that must be used in providing complete transport services, which is why they often turn to 3PL services. Also, in organizing transport, numerous extra security requirements that are specific to dangerous materials must be met. When systematically viewed within an economic context, some companies find it more economically viable to outsource transport to third-party logistics providers (3PL), than to own and use their own fleets. Assessing the logistics sector, a number of companies will abolish or reduce their own fleet and hire 3PL service providers to handle transport, with the goal of reducing total costs and increasing profits [3]. In practice, this solution has in certain cases shown to be correct [4,5], and is especially interesting as relevant to the area of dangerous goods transport, where cost is not the only criterion. The evaluation of 3PL providers is a critical step for any manufacturer looking to select a suitable 3PL provider as a business partner [6]. Today, evaluation of 3PL providers is most often done using multi-criteria decision-making methods.

The process of multi-criteria decision-making is characterized by inaccuracy and uncertainty of real indicators, as well as the appearance of confusion in human thinking. In such situations, in order to provide a more realistic representation of the value of the decision attribute, different approaches are used. These are most often based on interval numbers, such as: fuzzy sets [7], rough numbers [8,9], gray theory [10], *Z* numbers [11], and other approaches. The basic idea of applying algorithms to decision-making based on an interval approach (interval numbers, gray theory, and so on) involves the application of interval numbers to present the value of decision attributes. However, the interval limits of interval numbers are very difficult to determine and are based on the experience and intuitive perception of the decision maker [12]. Many authors display the uncertainty in defining the value of the decision attribute by using fuzzy sets in their basic premise [7] or through various extensions of fuzzy theory [13,14]. In addition to the fuzzy theory, a very convenient tool for dealing with imprecision, without the influence of subjectivism, is the theory of rude sets [15]. In extant literature, rough set theory is successfully applied to a large number of different areas of human activity. It can be said that rough sets' application is not only adequate, but often irreplaceable when it comes to the analysis of inaccuracy, indeterminacy, and uncertainty [16].

There are a number of papers that deal with the application of rough numbers for group decision-making, such as the rough AHP methods [9], the hybrid rough AHP-TOPSIS [17], rough AHP-VIKOR [18,19], rough AHP-MABAC [20], and rough DEMATEL-ANP-MAIRCA models [21,22]. In all extant published papers that deal with the application of rough numbers in group decision-making, the aggregation of decisions is based on arithmetic or geometric averaging. This paper presents the mathematical formulation of a new rough Dombi weighted geometric averaging (RDWGA) operator for the aggregation of rough expert preference. The RDWGA operator was developed to aggregate the values of rough numbers and determine the initial rough matrix of multi-criteria decision-making, which represents one of the key contributors to this paper. Another contribution of this paper is the introduction of rough SWARA and WASPAS models into the evaluation methodology and selection of 3PL providers for the transport of dangerous goods. The proposed models enable the evaluation of alternatives despite lack of quantitative information and imprecisions in the decision-making process.

This paper has several objectives. The first objective refers to the development of a model that will enable chemical industry companies to evaluate and select 3PL providers for the transport of dangerous goods. The Rough Dombi aggregator was developed to allow for a more accurate consensus in group decision-making. The second goal of the paper is to improve the methodology for imprecision processing in the field of group multi-criteria decision-making. The third objective of this paper is to present Dombi operations on rough numbers. Finally, the fourth goal of this paper is to bridge the gap that exists in the methodology for evaluating 3PL providers for the transport of dangerous goods, through a new approach to dealing with imprecision based on rough numbers.

In addition to the introductory considerations, the paper is structured into an additional five sections. The second section presents a review of the state of the sector, with an emphasis on the last few years. The third section consists of algorithms of the applied methods. The algorithm of the new RDWGA operator is presented, as well as the steps of the Rough SWARA and the Rough WASPAS methods. The fourth section describes a case study and details calculation of the applied methods and aggregators. The fifth section presents a sensitivity analysis in three parts, while in the sixth section, conclusions are drawn with an emphasis on the contributions made and future research.

2. Literature Review

Transportation is one of the dominant logistics processes in a supply chain [23,24], and the increasing demand for transport services is a growing trend [25]. The main reasons for this are: an increase in the volume and division of labor, the transfer of part of the production process to suppliers, seasonal fluctuations, different quantity orders, more frequent deliveries, and others. In most logistics systems, the share of transport costs in total costs is significant [26]. In today's environment, efficient transport is a competitive advantage, with many companies now focusing on optimizing logistics functions [27]. Low costs, short transport times, and an acceptable level of risk are all challenges for logistics managers.

For many companies, the cost of transport is the highest logistics cost [28]. In order to rationalize costs, the logistics sector will adopt a strategy to develop the company's transport sector [29,30] and make a business decision: to possess its own vehicle fleet, hire a 3PL provider, or use both options depending on the relevant needs [31]. Possessing its own vehicle fleet is a cost-efficient option if the available capacity of the vehicles is continuously used, which further causes a high cost of bound capital [32].

The use of logistics providers is a function in which a company hands over one or more different elements of its supply chain to a 3PL provider [33]. A third-party logistics (3PL) provider is an external provider that manages, controls, and delivers logistics activities on behalf of a shipper [34]. This implies that the provider is capable of carrying out transport, customs clearance, storage, distribution of goods, and other logistics activities for clients [35]. According to Langley [3], the most popular activities to outsource are domestic transportation (80%), warehousing (66%), international transportation (60%), freight forwarding (48%), and customs brokerage (45%).

Research in the area of 3PL began to significantly appear in 1994 [36] and has since then slowly grown. The external supply of logistics services is part of a trend toward outsourcing logistics activities [37]. The scope of 3PL may range from a relatively limited combination of activities (e.g., transport and warehousing) to a comprehensive set of logistics services. Bhatnagar et al. [38] lists the decision-making factors for choosing "3PL" providers and the main reasons for "3PL" activities: cost savings (86.8%), customer satisfaction (76.3%), and flexibility (75%). A key reason for such outsourcing is that with intensified global competition, companies are concentrating their energies on core activities that are critical for survival, and leaving the rest to specialist firms [39]. Batarlienė and Jarašūnienė [40] undertook research on 3PL that seeks to present the influence of 3PL on companies, as well as how to choose the key factors for optimizing business. They cite two main reasons for companies choosing to hire a logistics provider, which are: the company's business being in trouble or the company's rapid development, which subsequently necessitates seeking additional opportunities to improve business performance. In the evaluation and selection of 3PL providers, methods classified in different groups have thus been applied: decision-making techniques, statistical approaches, artificial intelligence, and mathematical programming [41–49].

The paper examined the evaluation and selection of 3PL providers for the transport of hazardous substances in the chemical industry. Although there are many studies about the selection of 3PL providers, studies related to 3PL provider selection for the transport of dangerous goods are scarce. The selection of 3PL providers for the transport of dangerous goods is especially specific because of the inevitable risks that arise [50] and the additional requirements that must be met by transport companies [51].

The results of studies carried out by Leroux et al. [52] with 106 companies handling dangerous materials show that transport activities are generally outsourced. Hanqing and Ru [53] formed a 3PL mathematical model for the treatment of electrical waste and electronic equipment, as a class of dangerous goods.

Eroğlu et al. [54] demonstrated an approach for determining the criterion importance degree in the 3PL provider selection process for the transport of dangerous materials, with the example of fuel as a multi-criterion decision-making (MCDM) problem. Bali and Eroğlu [55] conducted studies on 3PL provider selection for dangerous materials. They developed a MCDM assessment model to select the most suitable 3PL provider using fuzzy DEMATEL and fuzzy TOPSIS. Fuzzy DEMATEL was used to determine weight of the criteria and fuzzy TOPSIS was used to evaluate alternative 3PL providers. Finally, Eliacostas [56] wrote about the perspective of using 3PL providers for the safe routing of dangerous goods transport.

Evaluation and selection of Third-party logistics provider is one of very important areas for all participants in the supply chain. A large number of MCDM approaches is proposed for solving this problem in recent years. In [57] integrated approach consists of fuzzy SWARA and fuzzy COPRAS for sustainable third-party reverse logistics provider selection is proposed. Fuzzy SWARA in combination with fuzzy MOORA is proposed in [58] for third-party reverse logistics provider (3PRLP) evaluation. The authors of [59] developed a novel integrated model consisting of fuzzy DEMATEL and fuzzy TOPSIS methods that helps companies to evaluate and select an appropriate logistics provider. Improving the quality of service, increasing the efficiency, and decreasing the cost, according to Ecer [60], can be achieved through the proper selection of a logistics provider. In this research, he demonstrated a novel approach that integrated Fuzzy AHP and EDAS method. In [61], a real-life case study in a confectionary company is presented to demonstrate the potential use of an integrated model that consists of fuzzy AHP and fuzzy TOPSIS methods. In that study, a model is proposed to provide a systematic decision support tool for 3PL provider evaluation, especially for a 3PL transportation provider. The authors of [62] combined the cumulative prospect theory, the PROMETHEE II method, and a knowledge of thermodynamics to solve hesitant fuzzy linguistic MCDM problems. They solved the problem of green logistics provider selection. The same problem was also solved in [63,64]. To select the preferred service provider, the authors of [63] used a hybrid method combining a variant of ELECTRE I accounting for the effect of reinforced preference, the revised Simos procedure, and Stochastic Multi-criteria Acceptability Analysis. In [64], the authors extended the ELECTRE method and proposed a new methodology for handling fuzzy multi-criteria decision-making problems based upon interval type-2 fuzzy sets. Awasthi and Baležentis [65] developed a hybrid model for logistics service provider selection, which consists of three phases. In the first phase, the authors identified the selection criteria using four categories: benefits, costs, opportunities, and risks (BOCR). The second phase involves generating linguistic ratings for potential partners on identified criteria by a committee of decision-making experts. In the third phase, the final partner selection is done using fuzzy MULTIMOORA. The importance of this area is also demonstrated in [66], wherein the authors developed a novel integrated approach based on the CRiteria Importance Through Inter-criteria Correlation (CRITIC) and Weighted Aggregated Sum Product ASsessment (WASPAS) methods for the evaluation of 3PL providers with IT2FSs.

Evaluating 3PL providers for the transport of dangerous goods is rare, so this is one motivation for the execution of this research.

3. Methodology

Figure 1 shows the methodology for the evaluation of 3PL providers in the transportation of dangerous goods; it consists of three phases. Each of these phases and steps are explained in detail.

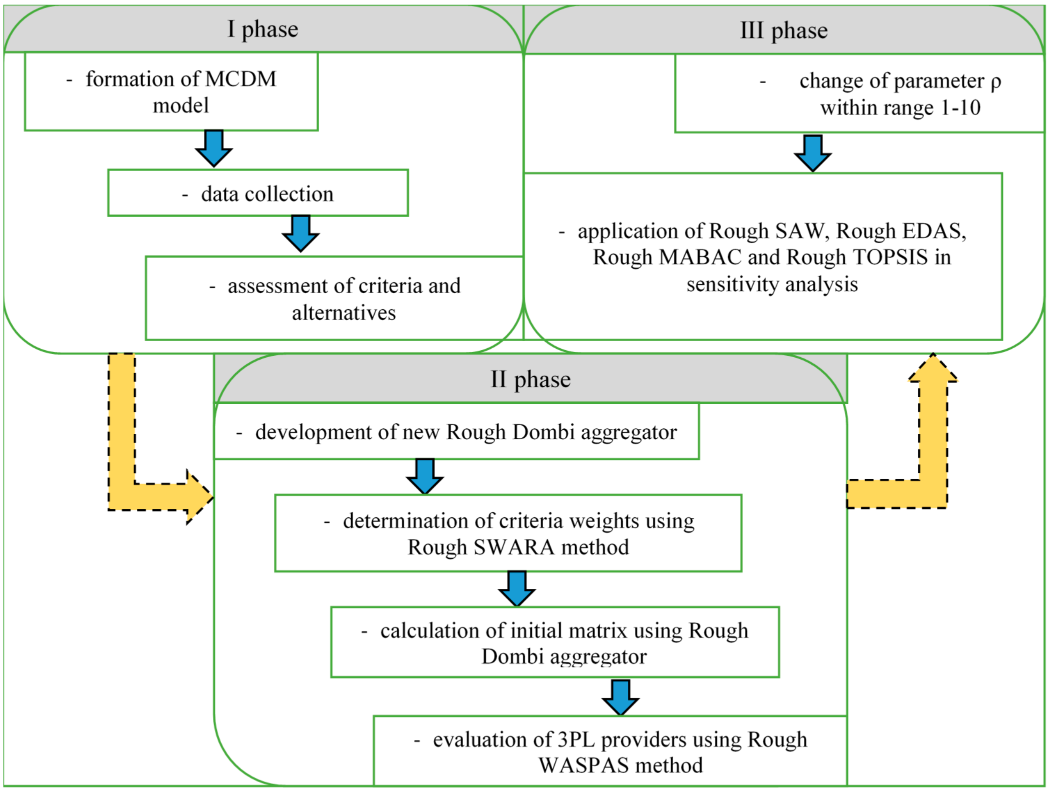

Figure 1. Methodology for evaluation 3PL provider.

3.1. New Rough Dombi Aggregator

Definition 1. *Let p and q be any two real numbers. Then, the Dombi T-norm and T-conorm between p and q are defined as follows [67]:*

$$O_D(p,q) = \frac{1}{1+\left\{\left(\frac{1-p}{p}\right)^{\rho}+\left(\frac{1-q}{q}\right)^{\rho}\right\}^{1/\rho}} \tag{1}$$

$$O_D^c(p,q) = 1-\frac{1}{1+\left\{\left(\frac{p}{1-p}\right)^{\rho}+\left(\frac{q}{1-q}\right)^{\rho}\right\}^{1/\rho}}, \tag{2}$$

where $\rho > 0$ *and* $(p,q) \in [0,1]$.

In accordance with the Dombi T-norm and the T-conorm, Dombi operations are defined by rough numbers.

Definition 2. *Assuming that* $RN(\varphi_1) = [\underline{Lim}(\varphi_1), \overline{Lim}(\varphi_1)]$ *i* $RN(\varphi_2) = [\underline{Lim}(\varphi_2), \overline{Lim}(\varphi_2)]$ *are two rough numbers,* $\rho, \gamma > 0$ *and let it be* $f(RN(\varphi_i)) = \left[f(\underline{Lim}(\varphi_i)), f(\overline{Lim}(\varphi_i))\right] = \left[\frac{\underline{Lim}(\varphi_i)}{\sum_{i=1}^{n}\underline{Lim}(\varphi_i)}, \frac{\overline{Lim}(\varphi_i)}{\sum_{i=1}^{n}\overline{Lim}(\varphi_i)}\right]$ *rough function, then some operational lows of rough numbers based on the Dombi T-norm and T-conorm can be defined as follows:*

(1) Addition "+"

$$RN(\varphi_1) + RN(\varphi_2) = \left[\frac{\sum_{j=1}^{2}\underline{Lim}(\varphi_j)}{1+\left\{\left(\frac{1-f(\underline{Lim}(\varphi_1))}{f(\underline{Lim}(\varphi_1))}\right)^{\rho}+\left(\frac{1-f(\underline{Lim}(\varphi_2))}{f(\underline{Lim}(\varphi_2))}\right)^{\rho}\right\}^{1/\rho}}, \frac{\sum_{j=1}^{2}\overline{Lim}(\varphi_j)}{1+\left\{\left(\frac{1-f(\overline{Lim}(\varphi_1))}{f(\overline{Lim}(\varphi_1))}\right)^{\rho}+\left(\frac{1-f(\overline{Lim}(\varphi_2))}{f(\overline{Lim}(\varphi_2))}\right)^{\rho}\right\}^{1/\rho}}\right] \quad (3)$$

(2) Multiplication "×"

$$RN(\varphi_1) \times RN(\varphi_2) = \left[\frac{\sum_{j=1}^{2}\underline{Lim}(\varphi_j)}{1+\left\{\left(\frac{1-f(\underline{Lim}(\varphi_1))}{f(\underline{Lim}(\varphi_1))}\right)^{\rho}+\left(\frac{1-f(\underline{Lim}(\varphi_2))}{f(\underline{Lim}(\varphi_2))}\right)^{\rho}\right\}^{1/\rho}}, \frac{\sum_{j=1}^{2}\overline{Lim}(\varphi_j)}{1+\left\{\left(\frac{1-f(\overline{Lim}(\varphi_1))}{f(\overline{Lim}(\varphi_1))}\right)^{\rho}+\left(\frac{1-f(\overline{Lim}(\varphi_2))}{f(\overline{Lim}(\varphi_2))}\right)^{\rho}\right\}^{1/\rho}}\right] \quad (4)$$

(3) Scalar multiplication, where $\gamma > 0$

$$\gamma RN(\varphi_1) = \left[\underline{Lim}(\varphi_1) - \frac{\underline{Lim}(\varphi_1)}{1+\left\{\gamma\left(\frac{\underline{Lim}(\varphi_1)}{1-\underline{Lim}(\varphi_1)}\right)^{\rho}\right\}^{1/\rho}}, \underline{Lim}(\varphi_1) - \frac{\overline{Lim}(\varphi_1)}{1+\left\{\gamma\left(\frac{\overline{Lim}(\varphi_1)}{1-\overline{Lim}(\varphi_1)}\right)^{\rho}\right\}^{1/\rho}}\right] \quad (5)$$

(4) Power, where $\gamma > 0$

$$\{RN(\varphi_1)\}^{\gamma} = \left[\frac{\underline{Lim}(\varphi_1)}{1+\left\{\gamma\left(\frac{1-\underline{Lim}(\varphi_1)}{\underline{Lim}(\varphi_1)}\right)^{\rho}\right\}^{1/\rho}}, \frac{\overline{Lim}(\varphi_1)}{1+\left\{\gamma\left(\frac{1-\overline{Lim}(\varphi_1)}{\overline{Lim}(\varphi_1)}\right)^{\rho}\right\}^{1/\rho}}\right]. \quad (6)$$

On the basis of rough operators (3)–(6), the rough Dombi weighted geometric averaging (RNDWGA) operator was derived.

Definition 3. *If* $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$; $(j = 1, 2, ..., n)$, *the set of rough numbers (RNs) in R, and* $w_j \in [0, 1]$ *represents the weight coefficient of* $RN(\varphi_j)$, $(j = 1, 2, ..., n)$, *which fulfills the requirement that* $\sum_{j=1}^{n} w_j = 1$. *We can then define the RNDWGA operator as follows:*

$$RNDWGA\{RN(\varphi_1), RN(\varphi_2), ..., RN(\varphi_n)\} = \prod_{j=1}^{n}(RN(\varphi_j))^{w_j}. \quad (7)$$

Theorem 1. *If* $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$; $(j = 1, 2, ..., n)$, *the set of rough numbers (RNs) in R, then we can define the aggregated values of rough numbers from set R with Equation (7). The aggregated values of RN are obtained with Equation (8):*

$$RNDWGA\{RN(\varphi_1), RN(\varphi_2), ..., RN(\varphi_n)\} = \left[\frac{\sum_{j=1}^{n}\underline{Lim}(\varphi_j)}{1+\left\{\sum_{j=1}^{n} w_j\left(\frac{1-f(\underline{Lim}(\varphi_j))}{f(\underline{Lim}(\varphi_j))}\right)^{\rho}\right\}^{1/\rho}}, \frac{\sum_{j=1}^{n}\overline{Lim}(\varphi_j)}{1+\left\{\sum_{j=1}^{n} w_j\left(\frac{1-f(\overline{Lim}(\varphi_j))}{f(\overline{Lim}(\varphi_j))}\right)^{\rho}\right\}^{1/\rho}}\right], \quad (8)$$

where $w_j \in [0,1]$ *the weighted coefficients of rough numbers* $RN(\varphi_j)$, $j = 1,2,\ldots,n$, *which fulfill the condition that* $\sum_{j=1}^{n} w_j = 1$ *and* $f(RN(\varphi_i)) = \begin{cases} f(\underline{Lim}(\varphi_i)) = \frac{\underline{Lim}(\varphi_i)}{\sum_{i=1}^{n} \underline{Lim}(\varphi_i)}; \\ f(\overline{Lim}(\varphi_i)) = \frac{\overline{Lim}(\varphi_i)}{\sum_{i=1}^{n} \overline{Lim}(\varphi_i)}. \end{cases}$ *represents a rough function.*

Proof. If $n = 2$, on the basis of Dombi operations with rough numbers, Equations (4) and (6), we get the following expression:

$$
\begin{aligned}
&RNDWGA\{RN(\varphi_1), RN(\varphi_2)\} \\
&= \left[\frac{\sum_{j=1}^{2} \underline{Lim}(\varphi_j)}{1+\left\{ w_1\left(\frac{1-f(\underline{Lim}(\varphi_1))}{f(\underline{Lim}(\varphi_1))}\right)^{\rho} + w_2\left(\frac{1-f(\underline{Lim}(\varphi_2))}{f(\underline{Lim}(\varphi_2))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\sum_{j=1}^{2} \overline{Lim}(\varphi_j)}{1+\left\{ w_1\left(\frac{1-f(\overline{Lim}(\varphi_1))}{f(\overline{Lim}(\varphi_1))}\right)^{\rho} + w_2\left(\frac{1-f(\overline{Lim}(\varphi_2))}{f(\overline{Lim}(\varphi_2))}\right)^{\rho} \right\}^{1/\rho}} \right] \\
&= \left[\frac{\sum_{j=1}^{2} \underline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{2} w_j\left(\frac{1-f(\underline{Lim}(\varphi_j))}{f(\underline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\sum_{j=1}^{2} \overline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{2} w_j\left(\frac{1-f(\overline{Lim}(\varphi_j))}{f(\overline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}} \right]
\end{aligned}.
$$

If $n = r$, we obtain the following expression on the basis of Equation (8):

$$
RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_r)\} = \left[\frac{\sum_{j=1}^{r} \underline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{r} w_j\left(\frac{1-f(\underline{Lim}(\varphi_j))}{f(\underline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\sum_{j=1}^{r} \overline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{r} w_j\left(\frac{1-f(\overline{Lim}(\varphi_j))}{f(\overline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}} \right].
$$

If $n = r + 1$, we get the following expression:

$$
\begin{aligned}
&RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_r)\} \\
&= \left[\frac{\sum_{j=1}^{r} \underline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{r} w_j\left(\frac{1-f(\underline{Lim}(\varphi_j))}{f(\underline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\sum_{j=1}^{r} \overline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{r} w_j\left(\frac{1-f(\overline{Lim}(\varphi_j))}{f(\overline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}} \right] + w_{r+1} RN(\varphi_{r+1}) \\
&= \left[\frac{\sum_{j=1}^{r+1} \underline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{r+1} w_j\left(\frac{1-f(\underline{Lim}(\varphi_j))}{f(\underline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\sum_{j=1}^{r+1} \overline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{r+1} w_j\left(\frac{1-f(\overline{Lim}(\varphi_j))}{f(\overline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}} \right]
\end{aligned}.
$$

We can thus assume that Theorem 1 is correct for $n = r + 1$, and Equation (8) applies to all n. □

Theorem 2 (Idempotency). *Assuming* $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$; $(j = 1,2,\ldots,n)$, *the set of rough numbers (RNs) in R, if* $RN(\varphi_j) = RN(\varphi)$, *then:*

$$
RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = RNDWGA\{RN(\varphi), RN(\varphi), \ldots, RN(\varphi)\}.
$$

Proof. Since $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)] = RN(\varphi)$; $(j = 1,2,\ldots,n)$, by applying Equation (8) we obtain the following calculations:

$$
\begin{aligned}
&RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \\
&= \left[\frac{\sum_{j=1}^{n} \underline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{n} w_j\left(\frac{1-f(\underline{Lim}(\varphi_j))}{f(\underline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\sum_{j=1}^{n} \overline{Lim}(\varphi_j)}{1+\left\{ \sum_{j=1}^{n} w_j\left(\frac{1-f(\overline{Lim}(\varphi_j))}{f(\overline{Lim}(\varphi_j))}\right)^{\rho} \right\}^{1/\rho}} \right] \\
&= \left[\frac{\underline{Lim}(\varphi)}{1+\left\{ \left(\frac{1-f(\underline{Lim}(\varphi))}{f(\underline{Lim}(\varphi))}\right)^{\rho} \right\}^{1/\rho}}, \frac{\overline{Lim}(\varphi)}{1+\left\{ \left(\frac{1-f(\overline{Lim}(\varphi))}{f(\overline{Lim}(\varphi))}\right)^{\rho} \right\}^{1/\rho}} \right] = RN(\varphi)
\end{aligned}.
$$

As such, we conclude that $RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = RN(\varphi)$. □

Theorem 3 (Reducibility)**.** *When $w = (1/n, 1/n, \ldots, 1/n)$, it is obvious that the expression is applicable.*

$$RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \left[\frac{\sum_{j=1}^{n} \underline{Lim}(\varphi_j)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\underline{Lim}(\varphi_j)\right)}{f\left(\underline{Lim}(\varphi_j)\right)}\right)^{\rho}\right\}^{1/\rho}}, \frac{\sum_{j=1}^{n} \overline{Lim}(\varphi_j)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\overline{Lim}(\varphi_j)\right)}{f\left(\overline{Lim}(\varphi_j)\right)}\right)^{\rho}\right\}^{1/\rho}} \right]$$

Proof. On the basis of Equation (8), the property is obvious. □

Theorem 4 (Boundedness)**.** *Assuming $RN(\varphi_j) = [\underline{Lim}(\varphi_j), \overline{Lim}(\varphi_j)]$; $(j = 1, 2, \ldots, n)$, set of rough numbers (RNs) in R, if $RN(\varphi_j^-) = \left[\min\{\underline{Lim}(\varphi_j)\}, \min\{\overline{Lim}(\varphi_j)\}\right]$ and $RN(\varphi_j^+) = \left[\max\{\underline{Lim}(\varphi_j)\}, \max\{\overline{Lim}(\varphi_j)\}\right]$, it is then applicable that $RN(\varphi_j^-) \leq RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \leq RN(\varphi_j^+)$.*

Proof. Let us assume that $RN(\varphi_j^-) = \min\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \left[\underline{Lim}(\varphi_j^-), \overline{Lim}(\varphi_j^-)\right]$ and $RN(\varphi_j^+) = \max\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = \left[\underline{Lim}(\varphi_j^+), \overline{Lim}(\varphi_j^+)\right]$. We then have $\underline{Lim}(\varphi_j^-) = \min\limits_j\{\underline{Lim}(\varphi_j)\}$, $\overline{Lim}(\varphi_j^-) = \min\limits_j\{\overline{Lim}(\varphi_j)\}$, $\underline{Lim}(\varphi_j^+) = \max\limits_j\{\underline{Lim}(\varphi_j)\}$, and $\overline{Lim}(\varphi_j^+) = \max\limits_j\{\overline{Lim}(\varphi_j)\}$. On the basis of that, we obtain that the following condition is viable:

$$\frac{\sum_{j=1}^{n} \underline{Lim}(\varphi_j^-)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\underline{Lim}(\varphi_j^-)\right)}{f\left(\underline{Lim}(\varphi_j^-)\right)}\right)^{\rho}\right\}^{1/\rho}} \leq \frac{\sum_{j=1}^{n} \underline{Lim}(\varphi_j)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\underline{Lim}(\varphi_j)\right)}{f\left(\underline{Lim}(\varphi_j)\right)}\right)^{\rho}\right\}^{1/\rho}} \leq \frac{\sum_{j=1}^{n} \underline{Lim}(\varphi_j^+)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\underline{Lim}(\varphi_j^+)\right)}{f\left(\underline{Lim}(\varphi_j^+)\right)}\right)^{\rho}\right\}^{1/\rho}}$$

$$\frac{\sum_{j=1}^{n} \overline{Lim}(\varphi_j^-)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\overline{Lim}(\varphi_j^-)\right)}{f\left(\overline{Lim}(\varphi_j^-)\right)}\right)^{\rho}\right\}^{1/\rho}} \leq \frac{\sum_{j=1}^{n} \overline{Lim}(\varphi_j)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\overline{Lim}(\varphi_j)\right)}{f\left(\overline{Lim}(\varphi_j)\right)}\right)^{\rho}\right\}^{1/\rho}} \leq \frac{\sum_{j=1}^{n} \overline{Lim}(\varphi_j^+)}{1+\left\{\sum\limits_{j=1}^{n} \frac{1}{n}\left(\frac{1-f\left(\overline{Lim}(\varphi_j^+)\right)}{f\left(\overline{Lim}(\varphi_j^+)\right)}\right)^{\rho}\right\}^{1/\rho}}$$

On the basis of the presented inequalities, we can conclude that the previously set condition $RN(\varphi_j^-) \leq RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} \leq RN(\varphi_j^+)$ is applicable. □

Theorem 5 (Commutativity)**.** *Let the set of rough numbers $(RN(\varphi_1'), RN(\varphi_2'), \ldots, RN(\varphi_n'))$ represent any permutation of $(RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n))$. It is then applicable that*

$$RNDWGA\{RN(\varphi_1), RN(\varphi_2), \ldots, RN(\varphi_n)\} = RNDWGA\{RN(\varphi_1'), RN(\varphi_2'), \ldots, RN(\varphi_n')\}.$$

Proof. The property is obvious. □

3.2. Rough SWARA Method

The SWARA (Step-wise Weight Assessment Ratio Analysis) method is one method for determining weight values that play an important role in a decision-making process. The method was developed by Kersuliene et al. [68] and, according to them, its basic characteristic is the possibility of assessing experts' opinions on the significance of criteria in the process of determining their weights.

Zavadskas et al. [69] developed a Rough SWARA method that consists of the following steps:

Step 1: Define a set of criteria that participate in a decision-making process.

Step 2: Form a team of k experts who will assess the significance of the criteria. First, it is necessary to rank the criteria according to their importance, from the most significant to the least significant. Subsequently, S_j—is determined in such a way, beginning with the second criterion, that we can determine how important criterion c_1 is compared to criterion c_{1-n}.

Step 3: Converting the individual responses of experts into a group rough matrix c_j. Each individual response of experts k_1, k_2, ..., k_n should be converted into a rough group matrix using Equations (1)–(6) [69]:

$$RN(C_j) = \left[c_j^L, c_j^U\right]_{1\times m}. \tag{9}$$

Step 4: Normalization of matrix $RN(C_j)$ in order to obtain matrix $RN(S_j)$ (10):

$$RN(S_j) = \left[s_j^L, s_j^U\right]_{1\times m}. \tag{10}$$

The elements of matrix $RN(S_j)$ are obtained by applying Equation (11):

$$RN(S_j) = \frac{\left[c_j^L, c_j^U\right]}{\max\left[c_j^L, c_j^U\right]}. \tag{11}$$

The first element of matrix $RN(S_j)$, i.e., $\left[s_j^L, s_j^U\right] = [1.00, 1.00]$, because $j = 1$. For other elements $j > 1$, Equation (18) can be calculated using Equation (12):

$$RN\underset{j=2}{\overset{m}{(S_j)}} = \left[\frac{c_j^L}{\max c_j^U}, \frac{c_j^U}{\max c_j^L}\right]_{1\times m}. \tag{12}$$

Step 5: Calculate matrix $RN(K_j)$ (13):

$$RN(K_j) = \left[k_j^L, k_j^U\right]_{1\times m} \tag{13}$$

by applying Equation (14):

$$RN\underset{j=2}{\overset{m}{(K_j)}} = \left[s_j^L + 1, s_j^U + 1\right]_{1\times m}. \tag{14}$$

Step 6: Determine the matrix of recalculated weights $RN(Q_j)$ (15):

$$RN(Q_j) = \left[q_j^L, q_j^U\right]_{1\times m}. \tag{15}$$

The elements of matrix $RN(Q_j)$ are obtained by applying Equation (16):

$$RN(Q_j)\left[q_j^L = \begin{cases} 1.00 \; j = 1 \\ \frac{q_{j-1}^L}{k_j^U} \; j > 1 \end{cases}, q_j^U = \begin{cases} 1.00 \; j = 1 \\ \frac{q_{j-1}^U}{k_j^L} \; j > 1 \end{cases}\right]. \tag{16}$$

Step 7: The calculation of the matrix of relative weight values $RN(W_j)$ (17):

$$RN(W_j) = \left[w_j^L, w_j^U\right]_{1\times m}. \tag{17}$$

Individual weight values of criteria are obtained by applying Equation (18):

$$\left[w_j^L, w_j^U\right] = \left[\frac{\left[q_j^L, q_j^U\right]}{\sum_{j=1}^{m}\left[q_j^L, q_j^U\right]}\right]. \tag{18}$$

3.3. Rough WASPAS Method

The Weighted Aggregated Sum Product Assessment (WASPAS) method [70] represents a relatively new MCDM method, one already proven to be a robust method in a number of publications.

The proposed Rough WASPAS method consists of the following steps [71]:

Step 1: Formulation of a model that consists of m alternatives and n criteria.

Step 2: Formation of a team of k experts for the evaluation of alternatives according to all criteria.

Step 3: Formation of initial individual matrices based on evaluations made by experts. It is necessary to form as many individual matrices as there are experts. If the model includes e.g., 5 experts, it is necessary to form 5 individual matrices.

Step 4: Converting the individual matrix into a group rough matrix. Each individual matrix of experts $k_1, k_2, ..., k_n$ needs to be converted into a rough group matrix (RGM):

$$RGM = \begin{bmatrix} \left[x_{11}{}^L, x_{11}{}^U\right] & \left[x_{12}{}^L, x_{12}{}^U\right] & \cdots & \left[x_{1n}{}^L, x_{1n}{}^U\right] \\ \left[x_{21}{}^L, x_{21}{}^U\right] & \left[x_{22}{}^L, x_{22}{}^U\right] & \cdots & \left[x_{2n}{}^L, x_{2n}{}^U\right] \\ \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ \left[x_{m1}{}^L, x_{m1}{}^U\right] & \left[x_{m2}{}^L, x_{m2}{}^U\right] & \cdots & \left[x_{mn}{}^L, x_{mn}{}^U\right] \end{bmatrix}. \tag{19}$$

Step 5: In this step, it is necessary to normalize the previous matrix using Equations (20) and (21):

$$n_{ij} = \frac{\left[x^L{}_{ij}; x^U{}_{ij}\right]}{\max\left[x^{+L}{}_{ij}; x^{+U}{}_{ij}\right]} \quad for \quad c_1, c_2, c_3 \ldots c_n \in B \tag{20}$$

$$n_{ij} = \frac{\min\left[x^{-L}{}_{ij}; x^{-U}{}_{ij}\right]}{\left[x^L{}_{ij}; x^U{}_{ij}\right]} \quad for \quad c_1, c_2, c_3 \ldots, c_n \in C, \tag{21}$$

where $\left[x_{ij}{}^L; x_{ij}{}^U\right]$ denotes the values from the initial rough group matrix, $\max\left[x_{ij}{}^{+L}; x_{ij}{}^{+U}\right]$ represents the maximum value of criterion if the same belongs a set of benefit criteria and $\min\left[x_{ij}{}^{-L}; x_{ij}{}^{-U}\right]$ represent the minimal value of criterion if the same belongs a set of cost criteria.

With "+" and "−", values are marked in terms of easier recognition of the same criteria that belong to a different type of criteria.

Equations (20) and (21) can be written more simply as:

$$n_{ij} = \left[\frac{x^L{}_{ij}}{x^{+U}{}_{ij}}; \frac{x^U{}_{ij}}{x^{+L}{}_{ij}}\right] \quad for \quad c_1, c_2, c_3 \ldots, c_n \in B \tag{22}$$

$$n_{ij} = \left[\frac{x^{-L}{}_{ij}}{x^U{}_{ij}}; \frac{x^{-U}{}_{ij}}{x^L{}_{ij}}\right] \quad for \quad c_1, c_2, c_3 \ldots, c_n \in C \tag{23}$$

and we get a normalized matrix that looks like Equation (24):

$$NM = \begin{bmatrix} [n_{11}^L, n_{11}^U] & [n_{12}^L, n_{12}^U] & \cdots & [n_{1n}^L, n_{1n}^U] \\ [n_{21}^L, n_{21}^U] & [n_{22}^L, n_{22}^U] & \cdots & [n_{2n}^L, n_{2n}^U] \\ \vdots & \vdots & \ddots & \vdots \\ [n_{m1}^L, n_{m1}^U] & [n_{m2}^L, n_{m2}^U] & \cdots & [n_{mn}^L, n_{mn}^U] \end{bmatrix}. \quad (24)$$

Step 6: Weighting of the normalized matrix by multiplying the previously obtained matrix with the weighted values of criteria (Equation (25)):

$$V_n = \left[v_{ij}{}^L ; v_{ij}^U \right]_{mxn} \quad (25)$$

$$v^L{}_{ij} = w_j^L \times n_{ij,}^L \quad i = 1, 2, \ldots, m$$

$$v_{ij}^U = w_j^U \times n_{ij,}^U \quad i = 1, 2, \ldots, m,$$

where $w_j{}^L$ is the lower limit, and $w_j{}^U$ is the upper limit of the weight value of the criterion obtained by applying one of the MCDM methods to determine the significance of the criteria.

Step 7: Summing up all the values of the obtained alternatives (Equation (26)):

$$Q_i = \left[q_{ij}^L ; q_{ij}^U \right]_{1 \times m} \quad (26)$$

$$q_{ij}^L = \sum_{j=1}^{n} v_{ij}^L ; q_{ij}^U = \sum_{j=1}^{n} v_{ij}^U .$$

Step 8: Determination of the weighted product model using Equation (27):

$$P_i = \left[p_{ij}^L ; p_{ij}^U \right]_{1 \times m} \quad (27)$$

$$p_{ij}^L = \prod_{j=1}^{n} \left(n_{ij}^L \right)^{w_j^L}$$

$$p_{ij}^U = \prod_{j=1}^{n} \left(n_{ij}^U \right)^{w_j^U} .$$

Step 9: Determination of the relative values of alternative A_i (Equation (28)):

$$A_i = \left[a_{ij}^L ; a_{ij}^U \right]_{1 \times m} \quad (28)$$

$$A_i = \lambda \times Q_i + (1 - \lambda) \times P_i .$$

Coefficient λ can be crisp values in the range of 0, 0.1, 0.2, . . . , 1.0, but it is recommended to apply Equation (29) for its calculation:

$$A_i = 0.5 + \frac{\sum P_i}{\sum Q_i + \sum P_i} = \frac{\sum \left[p_{ij}^L ; p_{ij}^U \right]}{\sum \left[q_{ij}^L ; q_{ij}^U \right] + \sum \left[p_{ij}^L ; p_{ij}^U \right]} . \quad (29)$$

Step 10: Ranking the alternatives. The highest value of the alternative is the best ranked, while the lowest value reflects the worst alternative.

4. Case Study

The model was developed based on the evaluation of five logistics experts and their experience in selecting 3PL providers for the largest chemical enterprises in the Republic of Serbia. These are the largest producers of dangerous materials, and also important companies within the chemical industry of Southeastern Europe. Experts with a minimum of 10 years of experience in logistics and the transport of hazardous goods were chosen. As experts from this field of research, professionals from the Department for the Transport of Hazardous Goods at the Ministry of Construction and Traffic Infrastructure, traffic inspectors and safety advisors were surveyed. After interviews with experts, the collected data were processed, and the aggregation of the expert opinion was obtained. The collecting of data through interviews with experts was carried out in April 2018 and May 2018.

4.1. Formation of a Multi-Criteria Model

The multi-criteria model consists of a total of 10 logistics providers that represent alternatives that were evaluated on the basis of the eight criteria detailed in Table 1. The authors, based on interviews with authorized and managerial persons in leading companies of the chemical industry, who are safety advisors in the transport of dangerous goods, selected the eight most important criteria for selecting the 3PL provider. The research involved five experts who evaluated the significance of the criteria, i.e., evaluated the alternatives according to the given criteria.

Table 1. Criteria on the basis of which the logistics provider was evaluated.

No	Criteria	Description of Criteria
1.	Vehicle fleet condition	The basic feature of this criterion is the average age of the vehicle fleet. Transport is carried out by technically adequate and modern vehicles equipped with the appropriate equipment and in accordance with applicable regulations.
2.	Financial stability	The logistics provider delivers a financial report on positive business practices and a certificate of the settlement of tax liabilities, i.e., a certificate from the tax authorities that confirms no extant debts in connection with the payment of taxes, fees, etc.
3.	Professionalization of drivers	The logistics provider employs drivers that have a certificate of approval for the transport of dangerous goods. The ongoing education of drivers is organized through seminars, additional and specialist training programs, safe and eco-friendly driving programs, etc.
4.	Cost of transport	Covers all costs incurred by the carrier during the performance of services.
5.	Application of risk mitigation measures	The logistics provider has one or more designated security advisors for the transport of dangerous goods. At points of loading/unloading, the property of the contracting authority or third parties is treated with special care. The carrier acquaints his workers with the rules of conduct, movement, safety, fire protection, and all other measures and procedures.
6.	Application of IT in transport organization	Controls, monitors, and manages the vehicle fleet through GPS. Possesses software appropriate for the selection of optimal routes, specifically for the transport of dangerous goods.
7.	Compensation for damages caused during transportation	The logistics provider is responsible for any damage, degradation, or loss of goods in whole or in part, as well as delay in delivery. The carrier shall reimburse in full all costs and damages to the goods, the property of the purchaser, as well as third parties or property of third parties, and damage caused by environmental pollution, including the costs of remedying the damage that arises.
8.	Reliability	The logistics provider carries out the transport service in accordance with agreed deadlines and the needs of the contracting authority, observing the provisions of the contract.

It is important to note that, in the complete calculation of the multi-criteria model, all criteria are labeled as criteria belonging to a beneficial group. If the criteria in Table 2 are observed, it can be noticed that the first criterion of the vehicle fleet's condition and the fourth criterion of transport cost are essentially cost criteria that need to be minimized. However, the experts evaluated the criteria according to the following scale: 1 = very bad, 3 = bad, 5 = medium, 7 = good, and 9 = very good; for this reason all the criteria are in the beneficial group.

Explanation: In Table 2 the first and fourth criteria, which represent quantitative criteria, are presented, and their values and estimates are given by the first expert involved in this research.

If the average age of the company's fleet is lower, that alternative is considered better. Additionally, if the cost of transport, expressed in euros per kilometer, is lower, that is also the better alternative. In Table 2, we see that the alternatives with the lowest values according to the cost criterion have been given the best marks. Taking this into account, all criteria mentioned below are beneficial. For example, for the first criterion of the fleet's age, the first alternative is the average age of the fleet, which is four years old, and the given alternative is assigned the highest value, while the alternative whose average age is nine years has the lowest value, or the worst mark. The same applies to the fourth criterion, which is the price of transport, where the alternative with the lowest price was given the highest rating.

Table 2. Explanation of the criteria based on the evaluation of the first expert.

Cost Criteria	Condition of the Vehicle Fleet		Cost of Transport	
	Average Age of the Fleet (in Years)	**Mark**	**Cost (Eur/km)**	**Mark**
A_1	4	7	0.85	9
A_2	6	5	1.10	1
A_3	6	5	0.80	9
A_4	6	5	1.00	5
A_5	8	3	0.95	5
A_6	6	5	1.15	1
A_7	5	7	1.00	5
A_8	6	5	1.00	5
A_9	9	1	0.90	7
A_{10}	5	7	0.95	5

4.2. Calculation of the Weight Values of the Criteria Using the Rough SWARA Method

In the first step of this method, it is necessary to define the criteria that will be included in the multi-criteria model. All criteria have been presented and discussed in the previous chapter. Subsequently, in the second step, a team of five experts was gathered. They evaluated the criteria in the following way: each of the experts determined which criterion was the most important, and then evaluated how much more significant the best criterion is in comparison to the others shown in Table 3.

Table 3. Evaluation of criteria by five experts.

	E_1	E_2	E_3	E_4	E_5
C_1	5	2	3	4	4
C_2	7	7	5	5	8
C_3	3	4	7	3	2
C_4	1	1	1	2	1
C_5	4	6	4	1	3
C_6	6	5	8	7	6
C_7	8	8	6	6	7
C_8	2	3	2	2	5

In Table 3, we can see that, on the basis of expert evaluation, four experts determined that the fourth criterion, cost of shipping, was the most important. The sixth and seventh criteria were each twice marked as the worst, while the second criterion was determined as such only once. After completing the third step of the Rough SWARA method, it is necessary to transform the individual responses of the experts into a group matrix as follows:

$$\widetilde{c}_3 = \{3, 4, 7, 3, 2\}$$

$$\underline{Lim}(3) = \frac{1}{3}(2+3+3) = 2.67,\ \overline{Lim}(3) = \frac{1}{4}(3+4+7+3) = 4.25$$

$$\underline{Lim}(4) = \frac{1}{4}(3+4+3+2) = 3.00,\ \overline{Lim}(4) = \frac{1}{2}(4+7) = 5.50$$

$$\underline{Lim}(7) = \frac{1}{5}(3+4+7+3+2) = 3.80,\ \overline{Lim}(7) = 7.00$$

$$\underline{Lim}(3) = \frac{1}{3}(2+3+3) = 2.67,\ \overline{Lim}(3) = \frac{1}{4}(3+4+7+3) = 4.25$$

$$\underline{Lim}(2) = 2,\ \overline{Lim}(2) = \frac{1}{5}(3+4+7+3+2) = 3.80$$

$$RN(c_3^1) = RN(c_3^4) = [2.67, 4.25];\ RN(c_3^2) = [3.00, 5.50];\ RN(c_3^3) = [3.80, 7.00];\ RN(c_3^5) = [2.00, 3.80]$$

$$c_3^L = \frac{c_3^1 + c_3^2 + c_3^3 + c_3^4 + c_3^5}{n} = \frac{2.67 + 3.00 + 3.80 + 2.67 + 2.00}{5} = 2.83$$

$$c_3^U = \frac{c_3^1 + c_3^2 + c_3^3 + c_3^4 + c_3^5}{n} = \frac{4.25 + 5.50 + 7.00 + 4.25 + 3.80}{5} = 4.96.$$

Based on the presented calculation example, complete matrix c_j was determined.

In the next step, it is necessary to normalize matrix c_j by applying Equations (10)–(12).

$$RN(s_1) = \left[\frac{c_1^L}{c_7^U}, \frac{c_1^U}{c_7^L}\right] = \left[\frac{2.92}{7.53}, \frac{4.25}{6.47}\right] = [0.388, 0.658]$$

$$RN(s_2) = \left[\frac{c_2^L}{c_7^U}, \frac{c_2^U}{c_7^L}\right] = \left[\frac{5.68}{7.53}, \frac{7.09}{6.47}\right] = [0.754, 1.097]$$

In the same way, other elements of matrix $RN(S_j)$ whose elements are arranged according to significance, i.e., from the most relevant to the least significant, are calculated.

$$\begin{aligned}
RN(c_4) &= [1.000,\ 1.000],\\
RN(c_8) &= [0.293,\ 0.538],\\
RN(c_5) &= [0.334,\ 0.717],\\
RN(c_1) &= [0.388,\ 0.658],\\
RN(c_3) &= [0.375,\ 0.767],\\
RN(c_2) &= [0.754,\ 1.097],\\
RN(c_6) &= [0.763,\ 1.095],\\
RN(c_7) &= [0.858,\ 1.165],\\
RN(c_3) &= [0.882,\ 1.133].
\end{aligned}$$

In the fifth step it is necessary to increase all the elements of the previous matrix, except the first element, by one at both the lower and upper limits of the rough number, which is achieved using Equation (14):

$$
\begin{aligned}
RN(c_4) &= [1.000,\ 1.000],\\
RN(c_8) &= [1.293,\ 1.538],\\
RN(c_5) &= [1.334,\ 1.717],\\
RN(c_1) &= [1.388,\ 1.658],\\
RN(c_3) &= [1.375,\ 1.767],\\
RN(c_2) &= [1.754,\ 2.097],\\
RN(c_6) &= [1.763,\ 2.095],\\
RN(c_7) &= [1.858,\ 2.165],\\
RN(c_3) &= [0.882,\ 1.133].
\end{aligned}
$$

Calculation of the recalculated weights is obtained using Equation (16):

$$q_8^L = \frac{q_{j-1}^L}{k_j^U} = \frac{q_4^L}{k_8^U} = \frac{1.000}{1.538} = 0.650, \quad q_8^U = \frac{q_{j-1}^U}{k_j^L} = \frac{q_4^U}{k_8^L} = \frac{1.000}{1.293} = 0.773$$

$$q_5^L = \frac{q_{j-1}^L}{k_j^U} = \frac{q_8^L}{k_5^U} = \frac{0.650}{1.717} = 0.379, \quad q_5^U = \frac{q_{j-1}^U}{k_j^L} = \frac{q_8^U}{k_5^L} = \frac{0.773}{1.334} = 0.579$$

$$
\begin{aligned}
RN(c_4) &= [1.000,\ 1.000],\\
RN(c_8) &= [0.650,\ 0.773],\\
RN(c_5) &= [0.379,\ 0.579],\\
RN(c_1) &= [0.228,\ 0.418],\\
RN(c_3) &= [0.129,\ 0.304],\\
RN(c_2) &= [0.062,\ 0.173],\\
RN(c_6) &= [0.029,\ 0.098],\\
RN(c_7) &= [0.014,\ 0.053],\\
RN(c_3) &= [0.882,\ 1.133].
\end{aligned}
$$

Finally, by applying Equation (18), the final values of the significance of the criteria shown in Table 4 are obtained.

Table 4. The final weight values of the criteria obtained using the Rough SWARA method.

	Weights	
C_1	0.067	0.168
C_2	0.018	0.069
C_3	0.038	0.122
C_4	0.294	0.401
C_5	0.111	0.233
C_6	0.009	0.039
C_7	0.004	0.021
C_8	0.191	0.310

The most important criterion for evaluating logistics providers is the price of transport, while the second most important criterion is reliability. The most important criteria for evaluating logistics providers are compensation for damage caused during transport and the professionalization of drivers.

4.3. Aggregation of the Initial Matrix Based on the Developed RNDWGA Operator

In order to perform aggregation of the initial rough matrix using the developed Rough Dombi aggregator, it is first necessary to transform the expert evaluations shown in Table 5 into rough matrices, in the same way as explained in the transformation of individual criteria estimates into a coarse matrix.

After the transformation is carried out, five rough matrices are obtained, for which the performed Rough Dombi Aggregator operations are applied. Using Equation (8), individual expert rough matrices are transformed into an aggregated rough initial matrix of decision-making. So, for example, at positions A$_1$–C$_2$, we obtain the following values in the expert correspondence matrices: $RN(x_{12}^{E1}) = [7.8, 9]$, $RN(x_{12}^{E2}) = [7, 7.8]$, $RN(x_{12}^{E3}) = [7, 7.8]$, $RN(x_{12}^{E4}) = [7, 7.8]$, and $RN(x_{12}^{E5}) = [7.8, 9]$. As has been stated, the study included participation from five experts who were assigned the following weighted values: $w_E = (0.202, 0.197, 0.206, 0.200, 0.195)^T$. Based on the displayed values, Equation (8), and assuming $\rho = 1$, an aggregation of values was made at positions A$_1$–C$_2$:

$$RNDWGA(x_{12}) = \begin{cases} \underline{Lim}(x_{12}) = \frac{\sum_{j=1}^{5} \underline{Lim}(\varphi_j)}{1+\left\{\sum\limits_{j=1}^{5} w_j \left(\frac{1-f\left(\underline{Lim}(\varphi_j)\right)}{f\left(\underline{Lim}(\varphi_j)\right)}\right)^{\rho}\right\}^{1/\rho}} = \frac{36.6}{1+\left(0.202\times\left(\frac{1-0.213}{0.213}\right)+0.197\times\left(\frac{1-0.191}{0.191}\right)+\ldots+0.195\times\left(\frac{1-0.213}{0.213}\right)\right)} = 7.30 \\ \overline{Lim}(x_{12}) = \frac{\sum_{j=1}^{5} \overline{Lim}(\varphi_j)}{1+\left\{\sum\limits_{j=1}^{5} w_j \left(\frac{1-f\left(\overline{Lim}(\varphi_j)\right)}{f\left(\overline{Lim}(\varphi_j)\right)}\right)^{\rho}\right\}^{1/\rho}} = \frac{41.4}{1+\left(0.202\times\left(\frac{1-0.217}{0.217}\right)+0.197\times\left(\frac{1-0.188}{0.188}\right)+\ldots+0.195\times\left(\frac{1-0.2172}{0.217}\right)\right)} = 8.24 \end{cases}$$

where values $f(RN(\varphi_i))$ represent rough functions. The rough function at positions A$_1$–C$_2$ for the correspondent matrix of the first expert is obtained by applying the following expression:

$$f(RN(\varphi_1)) = \begin{cases} f\left(\underline{Lim}(\varphi_1)\right) = \frac{\underline{Lim}(\varphi_1)}{\sum_{i=1}^{5} \underline{Lim}(\varphi_i)} = \frac{7.8}{36.6} = 0.213; \\ f\left(\overline{Lim}(\varphi_1)\right) = \frac{\overline{Lim}(\varphi_i)}{\sum_{i=1}^{5} \overline{Lim}(\varphi_1)} = \frac{9}{41.4} = 0.217. \end{cases}$$

In a similar way, we obtain the rough functions of the expert correspondence matrices' remaining elements.

Table 5. Assessment of alternatives by an expert team.

	Expert 1								Expert 2							
	C$_1$	**C$_2$**	**C$_3$**	**C$_4$**	**C$_5$**	**C$_6$**	**C$_7$**	**C$_8$**	**C$_1$**	**C$_2$**	**C$_3$**	**C$_4$**	**C$_5$**	**C$_6$**	**C$_7$**	**C$_8$**
A$_1$	7	9	7	9	7	9	7	9	9	7	5	9	9	9	7	9
A$_2$	5	7	7	1	5	9	9	5	5	7	7	3	9	7	5	7
A$_3$	5	9	9	9	9	6	9	9	5	5	5	9	5	9	7	9
A$_4$	5	5	7	5	5	9	5	3	5	7	3	5	7	7	9	7
A$_5$	3	7	5	5	3	9	5	7	3	7	9	7	7	9	5	7
A$_6$	5	9	5	1	9	7	7	9	5	9	7	1	3	7	7	9
A$_7$	7	5	7	5	7	7	9	7	7	9	7	5	1	7	9	7
A$_8$	5	7	9	5	9	7	7	7	5	7	9	5	5	7	7	7
A$_9$	1	9	5	7	5	3	5	9	1	5	5	7	7	7	9	7
A$_{10}$	7	7	3	5	7	7	9	5	7	7	5	7	9	7	7	7
	Expert 4								**Expert 5**							
	C$_1$	**C$_2$**	**C$_3$**	**C$_4$**	**C$_5$**	**C$_6$**	**C$_7$**	**C$_8$**	**C$_1$**	**C$_2$**	**C$_3$**	**C$_4$**	**C$_5$**	**C$_6$**	**C$_7$**	**C$_8$**
A$_1$	9	7	7	9	9	9	9	9	9	9	5	9	7	9	9	7
A$_2$	5	5	5	1	9	9	5	7	5	7	9	3	9	5	9	7
A$_3$	5	9	9	9	5	7	9	7	5	9	5	9	9	7	7	9
A$_4$	5	7	9	3	7	9	7	9	5	7	5	5	5	5	9	7
A$_5$	3	5	5	5	7	7	9	5	3	7	7	7	5	7	7	7
A$_6$	5	9	9	1	7	5	7	9	5	7	7	3	9	7	9	9
A$_7$	7	3	7	3	5	5	5	3	9	7	5	5	7	5	7	5
A$_8$	7	7	5	3	9	7	5	9	5	7	9	5	7	7	9	3
A$_9$	1	3	3	7	5	7	5	1	1	5	3	7	3	5	7	3
A$_{10}$	7	7	9	5	7	7	9	5	9	7	7	7	7	7	7	5

Finally, using a RNDWGA operator, we obtain rough aggregated value $RN(x_{12}) = [7.30, 8.24]$ in the A_1–C_2 position, Table 6. The aggregation of the remaining values from Table 6 is carried out in a similar way (using Equation (8)).

Table 6. Dombi rough averaged matrix.

	C_1		C_2		C_3		C_4		C_5		C_6		C_7		C_8	
A_1	8.22	8.92	7.30	8.24	5.66	7.42	9.00	9.00	7.30	8.24	9.00	9.00	7.30	8.23	8.23	8.92
A_2	5.08	5.67	5.65	6.65	6.21	7.64	1.48	2.62	7.26	8.83	6.37	8.24	5.53	7.38	6.20	6.92
A_3	5.08	5.67	6.65	8.63	6.23	8.30	9.00	9.00	6.22	8.29	6.66	7.69	7.30	8.24	8.22	8.92
A_4	5.08	5.67	5.65	6.65	4.53	7.40	4.16	4.91	5.66	6.66	6.37	8.24	6.35	8.22	5.07	7.54
A_5	3.00	3.00	5.65	6.65	5.65	7.40	5.65	6.65	4.28	6.21	6.35	8.23	5.30	6.94	5.65	6.65
A_6	5.08	5.67	7.67	8.66	6.21	7.64	1.06	1.56	4.09	7.51	6.20	6.92	7.07	7.67	9.00	9.00
A_7	7.30	8.24	4.28	6.97	6.21	6.92	4.16	4.91	2.58	6.11	5.66	6.66	5.79	7.95	4.55	6.63
A_8	5.30	6.23	7.00	7.00	7.27	8.83	4.16	4.91	4.59	7.96	7.08	7.68	6.21	7.64	5.17	8.14
A_9	1.00	1.00	4.22	6.28	3.62	5.39	7.00	7.00	4.30	6.22	4.54	6.62	5.30	6.93	2.19	6.71
A_{10}	7.30	8.24	7.08	7.68	4.61	7.97	5.65	6.65	7.30	8.24	7.08	7.68	7.30	8.24	5.29	6.23

4.4. Evaluation of Transport Companies Using the Rough WASPAS Method

After all previous calculations and obtaining an average Rough Dombi initial matrix, we need to apply Equation (20):

$$n_{ij} = \frac{[x^L{}_{ij}; x^U{}_{ij}]}{\max[x^{+L}{}_{ij}; x^{+U}{}_{ij}]} \quad for \quad c_1, c_2, c_3 \ldots c_n \in B,$$

or Equation (22) for the normalization of the initial matrix. Only Equation (22) is applied for normalization because, as explained, all the criteria in this multi-criteria model belong to the group of beneficial criteria. An example of normalization is:

$$n_{21} = \left[\frac{x^L_{ij}}{x^{+U}_{ij}}; \frac{x^U_{ij}}{x^{+L}_{ij}}\right] = \left[\frac{x^L_{12}}{x^{+U}_{11}}; \frac{x^U_{12}}{x^{+L}_{11}}\right] = \left[\frac{5.08}{8.92}; \frac{5.67}{8.22}\right] = [0.92, 1.08]$$

In the same way, it is necessary to calculate all elements of the normalized matrix in Table 7.

Table 7. Normalized matrix.

	C_1		C_2		C_3		C_4		C_5		C_6		C_7		C_8	
A_1	0.92	1.08	0.84	1.07	0.64	1.02	1.00	1.00	0.83	1.13	1.00	1.00	0.89	1.13	0.91	0.99
A_2	0.57	0.69	0.65	0.87	0.70	1.05	0.16	0.29	0.82	1.21	0.71	0.92	0.67	1.01	0.69	0.77
A_3	0.57	0.69	0.77	1.13	0.71	1.14	1.00	1.00	0.70	1.14	0.74	0.85	0.89	1.13	0.91	0.99
A_4	0.57	0.69	0.65	0.87	0.51	1.02	0.46	0.55	0.64	0.91	0.71	0.92	0.77	1.13	0.56	0.84
A_5	0.34	0.36	0.65	0.87	0.64	1.02	0.63	0.74	0.49	0.85	0.71	0.91	0.64	0.95	0.63	0.74
A_6	0.57	0.69	0.89	1.13	0.70	1.05	0.12	0.17	0.46	1.03	0.69	0.77	0.86	1.05	1.00	1.00
A_7	0.82	1.00	0.49	0.91	0.70	0.95	0.46	0.55	0.29	0.84	0.63	0.74	0.70	1.09	0.51	0.74
A_8	0.59	0.76	0.81	0.91	0.82	1.21	0.46	0.55	0.52	1.09	0.79	0.85	0.75	1.05	0.57	0.90
A_9	0.11	0.12	0.49	0.82	0.41	0.74	0.78	0.78	0.49	0.85	0.50	0.74	0.64	0.95	0.24	0.75
A_{10}	0.82	1.00	0.82	1.00	0.52	1.10	0.63	0.74	0.83	1.13	0.79	0.85	0.89	1.13	0.59	0.69

The next step is weighting the normalized matrices with the weights of the criteria obtained using the Rough SWARA method. In order to obtain the weighted normalized matrix shown in Table 8, Equation (25) was applied.

Table 8. Weighted normalized matrix.

	C_1		C_2		C_3		C_4		C_5		C_6		C_7		C_8	
A_1	0.06	0.18	0.02	0.07	0.02	0.12	0.29	0.40	0.09	0.26	0.01	0.04	0.00	0.02	0.18	0.31
A_2	0.04	0.12	0.01	0.06	0.03	0.13	0.05	0.12	0.09	0.28	0.01	0.04	0.00	0.02	0.13	0.24
A_3	0.04	0.12	0.01	0.08	0.03	0.14	0.29	0.40	0.08	0.26	0.01	0.03	0.00	0.02	0.17	0.31
A_4	0.04	0.12	0.01	0.06	0.02	0.12	0.14	0.22	0.07	0.21	0.01	0.04	0.00	0.02	0.11	0.26
A_5	0.02	0.06	0.01	0.06	0.02	0.12	0.18	0.30	0.05	0.20	0.01	0.04	0.00	0.02	0.12	0.23
A_6	0.04	0.12	0.02	0.08	0.03	0.13	0.03	0.07	0.05	0.24	0.01	0.03	0.00	0.02	0.19	0.31
A_7	0.06	0.17	0.01	0.06	0.03	0.12	0.14	0.22	0.03	0.19	0.01	0.03	0.00	0.02	0.10	0.23
A_8	0.04	0.13	0.01	0.06	0.03	0.15	0.14	0.22	0.06	0.25	0.01	0.03	0.00	0.02	0.11	0.28
A_9	0.01	0.02	0.01	0.06	0.02	0.09	0.23	0.31	0.05	0.20	0.00	0.03	0.00	0.02	0.05	0.23
A_{10}	0.06	0.17	0.01	0.07	0.02	0.13	0.18	0.30	0.09	0.26	0.01	0.03	0.00	0.02	0.11	0.21

The seventh step summarizes the values into rows using Equation (26) and obtains matrix Q_i. Applying Equation (27) from step eight, the following matrix is obtained:

$$Q_i \begin{bmatrix} [0.675, 1.416] \\ [0.358, 0.998] \\ [0.637, 1.363] \\ [0.394, 1.051] \\ [0.427, 1.026] \\ [0.368, 0.994] \\ [0.364, 1.042] \\ [0.400, 1.148] \\ [0.369, 0.959] \\ [0.490, 1.203] \end{bmatrix} \quad P_i \begin{bmatrix} [0.938, 1.050] \\ [0.503, 0.547] \\ [0.891, 0.985] \\ [0.630, 0.677] \\ [0.664, 0.648] \\ [0.462, 0.471] \\ [0.583, 0.669] \\ [0.634, 0.750] \\ [0.535, 0.524] \\ [0.738, 0.820] \end{bmatrix}$$

In the ninth step, relative values of the alternatives (Table 9) are calculated using Equation (28), while λ *is* obtained using Equation (29) and equals:

$$\lambda = [0.859, 1.146]$$

Table 9. Determining the relative values of alternatives and ranking.

	$\lambda \times Q_i$	$(1-\lambda) \times P_i$	A_i	Rank
A_1	[0.580, 1.622]	[−0.137, 0.148]	[0.443, 1.770]	1
A_2	[0.307, 1.143]	[−0.073, 0.077]	[0.234, 1.221]	8
A_3	[0.547, 1.562]	[−0.130, 0.139]	[0.417, 1.701]	2
A_4	[0.338, 1.205]	[−0.092, 0.096]	[0.246, 1.300]	5
A_5	[0.366, 1.175]	[−0.097, 0.092]	[0.269, 1.267]	6
A_6	[0.316, 1.139]	[−0.067, 0.067]	[0.249, 1.205]	9
A_7	[0.313, 1.139]	[−0.085, 0.095]	[0.228, 1.288]	7
A_8	[0.343, 1.193]	[−0.092, 0.106]	[0.251, 1.421]	4
A_9	[0.317, 1.098]	[−0.078, 0.074]	[0.239, 1.172]	10
A_{10}	[0.420, 1.379]	[−0.108, 0.116]	[0.313, 1.494]	3

Based on the presented budget, it can be observed that the transport company listed under one is one of the best, while company number three is in second position. The worst transport companies are alternatives six and nine.

5. Sensitivity Analysis

The sensitivity analysis was carried out in three parts. The first part relates to the change of parameter ρ, which changes within a range of 1–10, which means that a total of 10 scenarios were formed, whereby in each scenario parameter ρ increases by one. Table 10 shows the ranks of alternatives when changing parameter ρ.

Table 10. Ranking order with different parameter ρ.

Parameter ρ	**LNNDWGA**	
	Q_i	**Ranking Order**
$\rho = 1$	$Q_1 = 1.107$; $Q_2 = 0.727$; $Q_3 = 1.059$; $Q_4 = 0.773$; $Q_5 = 0.768$; $Q_6 = 0.727$; $Q_7 = 0.758$; $Q_8 = 0.836$; $Q_9 = 0.706$; $Q_{10} = 0.904$	A1 > A3 > A10 > A8 > A4 > A5 > A7 > A2 > A6 > A9
$\rho = 2$	$Q_1 = 1.107$; $Q_2 = 0.727$; $Q_3 = 1.059$; $Q_4 = 0.773$; $Q_5 = 0.768$; $Q_6 = 0.727$; $Q_7 = 0.758$; $Q_8 = 0.836$; $Q_9 = 0.706$; $Q_{10} = 0.904$	A1 > A3 > A10 > A8 > A4 > A5 > A7 > A2 > A6 > A9
$\rho = 3$	$Q_1 = 1.118$; $Q_2 = 0.731$; $Q_3 = 1.067$; $Q_4 = 0.773$; $Q_5 = 0.772$; $Q_6 = 0.728$; $Q_7 = 0.757$; $Q_8 = 0.835$; $Q_9 = 0.699$; $Q_{10} = 0.91$	A1 > A3 > A10 > A8 > A4 > A5 > A7 > A2 > A6 > A9
$\rho = 4$	$Q_1 = 1.124$; $Q_2 = 0.734$; $Q_3 = 1.071$; $Q_4 = 0.774$; $Q_5 = 0.774$; $Q_6 = 0.731$; $Q_7 = 0.759$; $Q_8 = 0.836$; $Q_9 = 0.698$; $Q_{10} = 0.914$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9
$\rho = 5$	$Q_1 = 1.129$; $Q_2 = 0.736$; $Q_3 = 1.075$; $Q_4 = 0.775$; $Q_5 = 0.776$; $Q_6 = 0.733$; $Q_7 = 0.76$; $Q_8 = 0.837$; $Q_9 = 0.697$; $Q_{10} = 0.917$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9
$\rho = 6$	$Q_1 = 1.133$; $Q_2 = 0.739$; $Q_3 = 1.079$; $Q_4 = 0.776$; $Q_5 = 0.778$; $Q_6 = 0.735$; $Q_7 = 0.761$; $Q_8 = 0.838$; $Q_9 = 0.696$; $Q_{10} = 0.92$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9
$\rho = 7$	$Q_1 = 1.137$; $Q_2 = 0.741$; $Q_3 = 1.082$; $Q_4 = 0.777$; $Q_5 = 0.779$; $Q_6 = 0.737$; $Q_7 = 0.762$; $Q_8 = 0.839$; $Q_9 = 0.695$; $Q_{10} = 0.922$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9
$\rho = 8$	$Q_1 = 1.141$; $Q_2 = 0.742$; $Q_3 = 1.084$; $Q_4 = 0.778$; $Q_5 = 0.78$; $Q_6 = 0.739$; $Q_7 = 0.763$; $Q_8 = 0.84$; $Q_9 = 0.695$; $Q_{10} = 0.924$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9
$\rho = 9$	$Q_1 = 1.144$; $Q_2 = 0.744$; $Q_3 = 1.086$; $Q_4 = 0.779$; $Q_5 = 0.781$; $Q_6 = 0.741$; $Q_7 = 0.764$; $Q_8 = 0.84$; $Q_9 = 0.694$; $Q_{10} = 0.925$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9
$\rho = 10$	$Q_1 = 1.146$; $Q_2 = 0.745$; $Q_3 = 1.087$; $Q_4 = 0.779$; $Q_5 = 0.781$; $Q_6 = 0.743$; $Q_7 = 0.764$; $Q_8 = 0.841$; $Q_9 = 0.694$; $Q_{10} = 0.926$	A1 > A3 > A10 > A8 > A5 > A4 > A7 > A2 > A6 > A9

Table 10 shows that a change in parameter ρ does not significantly affect the rank of alternatives. The only change occurs with alternatives four and five, which shift places. Alternative four is in in the fifth position the first three scenarios, while in the other scenarios, with the rise in parameter ρ, it occupies the sixth position. It is important to note that a change in this parameter, or rather its increase, effects an increase in coefficient λ, whose value surpasses one.

The second part of the sensitivity analysis implies the application of other methods in rough form to check the stability of the model and the results obtained. For these purposes, the following methods were used: Rough SAW [72], Rough EDAS [73], Rough MABAC [20], and Rough TOPSIS [8].

Looking at Figure 2, we can perceive the stability of the obtained results, because even though different methods were applied, the first three positions do not change. The first, third, and tenth alternatives are placed in the first, second, and third places, respectively. The fourth position is filled by alternative eight through all approaches except the Rough TOPSIS, where it fills the fifth position. The fifth alternative is in the fifth position five times through application of the Rough SAW, Rough EDAS, and Rough MABAC, while the Rough WASPAS method places it sixth and the Rough TOPSIS in fourth place. In addition to the aforementioned alternative five, the sixth position contains alternatives four (Rough SAW and Rough MABAC), two (Rough EDAS), and nine (Rough TOPSIS). The biggest changes in rankings are seen in alternative two, which does not retain its position at any one time and as such ranked in the sixth, eighth, ninth, and tenth positions. The worst alternative is nine, which through calculation with four methods finds itself in last (tenth) place, with only the Rough TOPSIS method placing at sixth place.

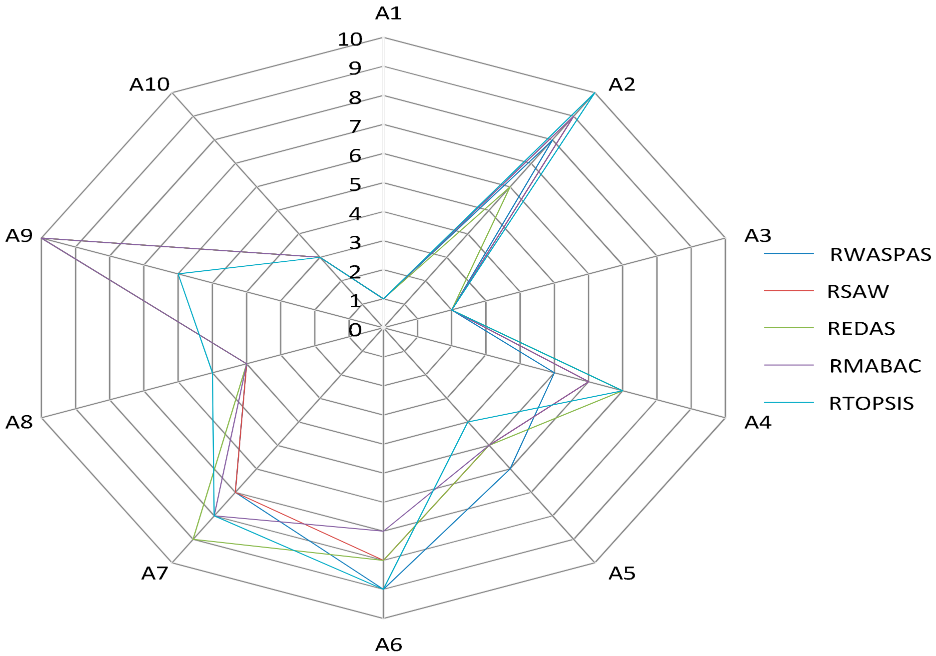

Figure 2. Sensitivity analysis using various rough methods.

The third part of the sensitivity analysis is the application of Spearman's correlation coefficient (Table 11) to determine the correlation of the ranks. Since it is evident that the alternative ranks are almost completely correlated in the first part of the sensitivity analysis, Spearman's correlation coefficient was applied only to the second part of the sensitivity analysis, or in the calculation using different approaches.

Table 11. Statistical comparison of ranks for tested models.

Methods	RWASPAS	RSAW	REDAS	RMABAC	RTOPSIS	Average
RWASPAS	1.000	0.976	0.939	0.958	0.927	0.960
RSAW	-	1.000	0.939	0.994	0.976	0.977
REDAS	-	-	1.000	0.933	0.891	0.941
RMABAC	-	-	-	1.000	0.958	0.979
RTOPSIS	-	-	-	-	1.000	1.000
Overall average						0.971

Based on the total calculated statistical coefficient of correlation (0.971), it can be concluded that the ranks are in high correlation using different methods. When it comes to Rough WASPAS rank correlation with other methods, the lowest correlation is with Rough TOPSIS (0.927), because there is a difference of seven places in ranking, where the highest is in the ranking of the ninth alternative. The next lowest correlation is with Rough EDAS (0.939), because the difference in rank is in alternatives two, four, and seven by two places. There is a higher correlation of ranks with Rough MABAC (0.958) or Rough SAW (0.976), with fewer changes in ranks. The only major change in the ranking is with alternative six, which placed better by two places at Rough MABAC, in relation to the original position obtained by using Rough WASPAS. The Rough SAW has a slightly higher overall correlation coefficient (0.977) with other methods than Rough WASPAS, which means that there are small differences in ranks compared to other methods. The biggest difference is in comparison to Rough EDAS, where alternative two changed rank from ninth to sixth place. Rough EDAS has the lowest correlation coefficient (0.941). Observing the overall ranks and correlation coefficients, it can be concluded that the resulting model is very stable, and the ranks are almost completely correlated since, according to Keshavarz Ghorabaee et al. [74], all values greater than 0.80 represent a very high correlation of ranks.

6. Conclusions

The transport of dangerous goods and its potential consequences arouses public attention because of these materials' detrimental effect on the environment and people, as well as possible accidents. In order to meet the complex demands of today's market, a trend of increased consumption of hazardous substances has appeared, thereby increasing the volume of production and transportation of these goods. Transport is a mandatory logistical activity for supplying users with these materials, regardless of whether they are in raw, semi-processed, or fully processed form.

In the midst of their companies' accelerated development, an increasing number of dangerous substance manufacturers are trying to improve business performance and use the services of a 3PL provider. This study has developed a model that will make it easier for chemical industry companies to evaluate and select 3PL providers for the transport of dangerous goods. The Rough SWARA-WASPAS model, based on new Rough Dombi aggregators, was designed. A sensitivity analysis, carried out in three parts, confirmed the results of the proposed model.

The criteria defined for evaluating logistics providers are specific to the field of dangerous substances, due to the high risks [75] and additional security requirements. One of the benefits of using the services of 3PL carriers is that they have a wider range of operations and are able to satisfy clients who have a high frequency of transport needs on a weekly basis. Specialized carriers better understand the market and customer needs. They also have well-designed strategies and business models to continue improving their offers, regional coverage, and specialization in all industry sectors.

During the course of research, "critical points" in the use of 3PL providers were identified. They are: lack of and unreliable information from the field, flow of documentation, physical flow of reverse logistics (if it exists), company presentation to the customer, slow problem-solving during delivery, and others.

A direction of further study is to support the environmental sustainability of 3PL dangerous material providers, particularly in areas that have been marked as topic areas [76]: influencing factors, green actions, impact on performance, information and communication technology (ICT) tools supporting green actions, energy efficiency in road freight transport, and shipper's perspective and collaboration. Another line of research may be the application of current MCDM methods for the evaluation and selection of 3PL providers for other logistics activities.

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References

1. Tanackov, I.; Janković, Z.; Sremac, S.; Miličić, M.; Vasiljević, M.; Mihaljev-Martinov, J.; Škiljaica, I. Risk distribution of dangerous goods in logistics subsystems. *J. Loss Prev. Process Ind.* **2018**, *54*, 373–383. [CrossRef]

2. Di Fazio, A.; Bettinelli, D.; Louette, E.; Mechin, J.P.; Zazza, M.; Vecchiarelli, P.; Domanico, L. European Pathways to Introduce EGNOS and Galileo for Dangerous Goods Transport. *Transp. Res. Procedia* **2016**, *14*, 1482–1491. [CrossRef]
3. Langley, J. *Third-Party Logistics Study. The State of Logistics Outsourcing*; Capgemini: Paris, France, 2016.
4. Azadi, M.; Saen, R.F. A new chance-constrained data envelopment analysis for selecting third-party reverse logistics providers in the existence of dual-role factors. *Expert Syst. Appl.* **2011**, *38*, 12231–12236. [CrossRef]
5. Lien, N.T.K.; Day, J.-D. Estimating the efficiency of third party Logistics over the world. In Proceedings of the International Conference on System Science and Engineering, Ho Chi Minh City, Vietnam, 21–23 July 2017; pp. 621–624.
6. Jung, H. Evaluation of Third Party Logistics Providers Considering Social Sustainability. *Sustainability* **2017**, *9*, 777. [CrossRef]
7. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
8. 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]
9. Vasiljevic, M.; Fazlollahtabar, H.; Stevic, Z.; Veskovic, S. A rough multicriteria approach for evaluation of the supplier criteria in automotive industry. *Decis. Making Appl. Manag. Eng.* **2018**, *1*, 82–96. [CrossRef]
10. Kuang, H.; Kilgour, D.M.; Hipel, K.W. Grey-based PROMETHEE II with application to evaluation of source water protection strategies. *Inf. Sci.* **2015**, *294*, 376–389. [CrossRef]
11. Kang, B.; Wei, D.; Li, Y.; Deng, Y. A Method of Converting Z-number to Classical Fuzzy Number. *J. Inf. Comput. Sci.* **2012**, *9*, 703–709.
12. Karavidic, Z.; Projovic, D. A multi-criteria decision-making (MCDM) model in the security forces operations based on rough sets. *Decis. Making Appl. Manag. Eng.* **2018**, *1*, 97–120. [CrossRef]
13. Petkovic, D.; Gocić, M.; Shamshirband, S. Adaptive neuro-fuzzy computing technique for precipitation estimation. *Facta Univ. Ser. Mech. Eng.* **2016**, *14*, 209–218. [CrossRef]
14. 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. Making Appl. Manag. Eng.* **2018**, *1*, 143–164. [CrossRef]
15. Pawlak, Z. Rough sets. *Int. J. Comput. Inf. Sci.* **1982**, *11*, 341–356. [CrossRef]
16. Petkovic, D.; Madic, M.; Radovanovic, M.; Gecevska, V. Application of the Performance Selection Index Method for Solving Machining MCDM Problems. *Facta Univ. Ser. Mech. Eng.* **2017**, *15*, 97–106. [CrossRef]
17. Aydogan, E.K. Performance measurement model for Turkish aviation firms using the rough-AHP and TOPSIS methods under fuzzy environment. *Expert Syst. Appl.* **2011**, *38*, 3992–3998. [CrossRef]
18. Ağirgün, B. Supplier Selection Based on Fuzzy Rough-AHP and VIKOR. *Nevşehir Üniversitesi Fen Bilimleri Enstitü Dergisi* **2012**, *2*, 1–11.
19. Zhu, G.N.; Hu, J.; Qi, J.; Gu, C.C.; Peng, J.H. An integrated AHP and VIKOR for design concept evaluation based on rough number. *Adv. Eng. Inf.* **2015**, *29*, 408–418. [CrossRef]
20. Roy, J.; Chatterjee, K.; Bandhopadhyay, A.; Kar, S. Evaluation and selection of Medical Tourism sites: A rough AHP based MABAC approach. *arXiv*, 2016.
21. Pamucar, D.; Mihajlovic, M.; Obradovic, R.; Atanaskovic, 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]
22. Chatterjee, K.; Pamučar, D.; Zavadskas, E.K. Evaluating the performance of suppliers based on using the R'AMATEL-MAIRCA method for green supply chain implementation in electronics industry. *J. Clean. Prod.* **2018**, *184*, 101–129. [CrossRef]
23. Jayaram, J.; Tan, K.-C. Supply chain integration with third-party logistics providers. *Int. J. Prod. Econ.* **2010**, *125*, 262–271. [CrossRef]
24. Candemir, Y.; Çelebi, D. An inquiry into the analysis of the Transport & Logistics Sectors' Role in Economic Development. *Transp. Res. Procedia* **2017**, *25*, 4692–4707. [CrossRef]
25. Varjan, P.; Rovňaníková, D.; Gnap, J. Examining Changes in GDP on the Demand for Road Freight Transport. *Procedia Eng.* **2017**, *192*, 911–916. [CrossRef]
26. Rantasila, K.; Ojala, L. National-level logistics costs: An overview of extant research. *Int. J. Logist. Res. Appl.* **2015**, *18*, 313–324. [CrossRef]

27. Jazairy, A.; Lenhardt, J.; von Haartman, R. Improving logistics performance in cross-border 3PL relationships. *Int. J. Logist. Res. Appl.* **2017**, *20*, 491–513. [CrossRef]
28. Szuster, M. Outsourcing of Transport Service—Perspective of Manufacturers. *Total Logist. Manag.* **2010**, *3*, 87–98.
29. Hertz, S.; Alfredsson, M. Strategic development of third party logistics providers. *Ind. Mark. Manag.* **2003**, *32*, 139–149. [CrossRef]
30. Ho, W.; He, T.; Lee, C.K.M.; Emrouznejad, A. Strategic logistics outsourcing: An integrated QFD and fuzzy AHP approach. *Expert Syst. Appl.* **2012**, *39*, 10841–10850. [CrossRef]
31. Stojanović, Đ. Road freight transport outsourcing trend in Europe—What do we really know about it? *Transp. Res. Procedia* **2017**, *25*, 772–793. [CrossRef]
32. Araz, C.; Mizrak Ozfirat, P.; Ozkarahan, I. An integrated multicriteria decision-making methodology for outsourcing management. *Comput. Oper. Res.* **2007**, *34*, 3738–3756. [CrossRef]
33. Xu, S.; Liu, Y.; Chen, M. Optimisation of partial collaborative transportation scheduling in supply chain management with 3PL using ACO. *Expert Syst. Appl.* **2017**, *71*, 173–191. [CrossRef]
34. Hassini, E.; Surti, C.; Searcy, C. A Literature Review and a Case Study of Sustainable Supply Chains with a Focus on Metrics. *Int. J. Prod. Econ.* **2012**, *140*, 69–82. [CrossRef]
35. Manotas-Duque, D.F.; Osorio-Gómez, J.C.; Rivera, L. Operational risk management in third party logistics (3PL). In *Global Business Expansion: Concepts, Methodologies, Tools, and Applications*; IGI Global: Hershey, PA, USA, 2018; Volume 3, pp. 676–698.
36. Spencer, M.S.; Rogers, D.S.; Daugherty, P.J. JIT systems and external logistics suppliers. *Int. J. Oper. Prod. Manag.* **1994**, *14*, 60–74. [CrossRef]
37. Ogorelc, A.; Logožar, K. Outsourcing of Logistics Activities in Manufacturing Industry. *Promet Traffic Transp.* **2001**, *13*, 387–394. [CrossRef]
38. Bhatnagar, R.; Sohal, A.S.; Millen, R. Third party logistics services: A Singapore perspective. *Int. J. Phys. Distrib. Logist. Manag.* **1999**, *29*, 569–587. [CrossRef]
39. Baykasoğlu, A.; Kaplanoğlu, V.; Durmuşoğlu, Z.D.; Şahin, C. Integrating fuzzy DEMATEL and fuzzy hierarchical TOPSIS methods for truck selection. *Expert Syst. Appl.* **2013**, *40*, 899–907. [CrossRef]
40. Batarlienė, N.; Jarašūnienė, A. "3PL" Service Improvement Opportunities in Transport Companies. *Procedia Eng.* **2017**, *187*, 67–76. [CrossRef]
41. Bottani, E.; Rizzi, A. A fuzzy TOPSIS methodology to support outsourcing of logistics services. *Supply Chain Manag. Int. J.* **2006**, *11*, 294–308. [CrossRef]
42. Jharkharia, S.; Shankar, R. Selection of logistics service provider: An analytic network process (ANP) approach. *Omega* **2007**, *35*, 274–289. [CrossRef]
43. Li, F.; Li, L.; Jin, C.; Wang, R.; Wang, H.; Yang, L. A 3PL supplier selection model based on fuzzy sets. *Comput. Oper. Res.* **2012**, *39*, 1879–1884. [CrossRef]
44. Hu, Z.H.; Sheng, Z.H. A decision support system for public logistics information service management and optimization. *Decis. Support Syst.* **2014**, *59*, 219–229. [CrossRef]
45. Aguezzoul, A. Third-party logistics selection problem: A literature review on criteria and methods. *Omega* **2014**, *49*, 69–78. [CrossRef]
46. Gürcan, Ö.F.; Yazıcı, İ.; Beyca, Ö.F.; Arslan, Ç.Y.; Eldemir, F. Third Party Logistics (3PL) Provider Selection with AHP Application. *Procedia Soc. Behav. Sci.* **2016**, *235*, 226–234. [CrossRef]
47. 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]
48. 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]
49. Yazdani, M.; Zarate, P.; Coulibaly, A.; Zavadskas, E.K. A group decision making support system in logistics and supply chain management. *Expert Syst. Appl.* **2017**, *88*, 376–392. [CrossRef]
50. Cordeiro, F.G.; Stolte Bezerra, B.; Palcheco Peixoto, A.S.; Rodrigues Ramos, R.A. Methodological aspects for modeling the environmental risk of transporting hazardous materials by road. *Transp. Res. Part D Transp. Environ.* **2016**, *44*, 105–121. [CrossRef]
51. Planas, E.; Pastor, E.; Presutto, F.; Tixier, J. Results of the MITRA project: Monitoring and intervention for the transportation of dangerous goods. *J. Hazard. Mater.* **2008**, *152*, 516–526. [CrossRef] [PubMed]

52. Leroux, M.-H.; De Marcellis-Warin, N.; Trepanier, M. Safety management in hazardous materials logistics. *Transp. Lett.* **2010**, *2*, 13–25. [CrossRef]
53. Hanqing, L.; Ru, Y. The models of the reverse 3PL in the treatment of the waste electrical and electronic equipment. In Proceedings of the 2nd International Conference on Modelling and Simulation, Chania Crete, Greece, 1–5 June 2009; Volume 2, pp. 468–473.
54. Eroğlu, Ö.; Balġ, Ö.; Ağdaġ, M. Criteria evaluation model for third party logistics provider selection in fuel transportation. In Proceedings of the International Logistics and Supply Chain Congress, Kayseri, Turkey, 7–9 November 2013; pp. 451–470.
55. Bali, Ö.; Eroğlu, Ö. Assessment of 3PL Providers for Hazardous Materials. *J. Manag. Inf. Sci.* **2014**, *2*, 27–40. [CrossRef]
56. Eliacostas, A. The safe route to HazMat transportation: A 3PL perspective. *Radwaste Solut.* **2017**, *24*, 44–46.
57. Zarbakhshnia, N.; Soleimani, H.; Ghaderi, H. Sustainable third-party reverse logistics provider evaluation and selection using fuzzy SWARA and developed fuzzy COPRAS in the presence of risk criteria. *Appl. Soft Comput.* **2018**, *65*, 307–319. [CrossRef]
58. Mavi, R.K.; Goh, M.; Zarbakhshnia, N. Sustainable third-party reverse logistic provider selection with fuzzy SWARA and fuzzy MOORA in plastic industry. *Int. J. Adv. Manuf. Technol.* **2017**, *91*, 2401–2418. [CrossRef]
59. Alkhatib, S.F.; Darlington, R.; Yang, Z.; Nguyen, T.T. A novel technique for evaluating and selecting logistics service providers based on the logistics resource view. *Expert Syst. Appl.* **2015**, *42*, 6976–6989. [CrossRef]
60. Fatih, E.C.E.R. Third-party logistics (3PLs) provider selection via Fuzzy AHP and EDAS integrated model. *Technol. Econ. Dev. Econ.* **2018**, *24*, 615–634. [CrossRef]
61. Yayla, A.Y.; Oztekin, A.; Gumus, A.T.; Gunasekaran, A. A hybrid data analytic methodology for 3PL transportation provider evaluation using fuzzy multi-criteria decision making. *Int. J. Prod. Res.* **2015**, *53*, 6097–6113. [CrossRef]
62. Liao, H.; Wu, D.; Huang, Y.; Ren, P.; Xu, Z.; Verma, M. Green Logistic Provider Selection with a Hesitant Fuzzy Linguistic Thermodynamic Method Integrating Cumulative Prospect Theory and PROMETHEE. *Sustainability* **2018**, *10*, 1291. [CrossRef]
63. Govindan, K.; Kadziński, M.; Ehling, R.; Miebs, G. Selection of a sustainable third-party reverse logistics provider based on the robustness analysis of an outranking graph kernel conducted with ELECTRE I and SMAA. *Omega* **2018**. [CrossRef]
64. Celik, E.; Gumus, A.T.; Erdogan, M. A new extension of the ELECTRE method based upon interval type-2 fuzzy sets for green logistic service providers evaluation. *J. Test. Eval.* **2015**, *44*, 1813–1827. [CrossRef]
65. Awasthi, A.; Baležentis, T. A hybrid approach based on BOCR and fuzzy MULTIMOORA for logistics service provider selection. *Int. J. Logist. Syst. Manag.* **2017**, *27*, 261–282. [CrossRef]
66. Keshavarz Ghorabaee, M.; Amiri, M.; Kazimieras Zavadskas, E.; Antuchevičienė, J. Assessment of third-party logistics providers using a CRITIC–WASPAS approach with interval type-2 fuzzy sets. *Transport* **2017**, *32*, 66–78. [CrossRef]
67. Dombi, J. A general class of fuzzy operators, the demorgan class of fuzzy operators and fuzziness measures induced by fuzzy operators. *Fuzzy Sets Syst.* **1982**, *8*, 149–163. [CrossRef]
68. Keršuliene, V.; Zavadskas, E.K.; Turskis, Z. Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). *J. Bus. Econ. Manag.* **2010**, *11*, 243–258. [CrossRef]
69. 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]
70. Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J.; Zakarevicius, A. Optimization of weighted aggregated sum product assessment. *Elektron. Elektrotech.* **2012**, *122*, 3–6. [CrossRef]
71. 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]
72. Stević, Ž.; Pamučar, D.; Kazimieras Zavadskas, E.; 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]
73. 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]

74. 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.
75. Torretta, V.; Rada, C.E.; Schiavon, M.; Viotti, P. Decision support systems for assessing risks involved in transporting hazardous materials: A review. *Saf. Sci.* **2017**, *92*, 1–9. [CrossRef]
76. Evangelista, P.; Santoro, L.; Thomas, A. Environmental sustainability in third-party logistics service providers: A systematic literature review from 2000–2016. *Sustainability* **2018**, *10*, 1627. [CrossRef]