Third-Party Logistics Provider Selection for Sustainable Last-Mile Delivery: A Case Study of E-Shop in Belgrade

Libor Švadlenka[1] , Sara Bošković[1] , Stefan Jovčić[1] , Vladimir Simic[2*] , Shashank Kumar[3] ,
Marina Zanne[4]

[1] Department of Transport Management, Marketing, and Logistics, Faculty of Transport Engineering,
University of Pardubice, 53210 Pardubice, Czech Republic
[2] Faculty of Transport and Traffic Engineering, University of Belgrade, 11010 Belgrade, Serbia
[3] Operations and Supply Chain Management, Symbiosis Institute of Operations Management, Nashik, India
[4] Faculty of Maritime Studies and Transport, University of Ljubljana, 6320 Portorose, Slovenia

* Correspondence: Vladimir Simic (vsima@sf.bg.ac.rs)

Abstract: Last-mile delivery (LMD) is one of the crucial phases of the shipping process. Since e-commerce rapidly evolves, there are many issues that should be addressed in city logistics. This paper specifically tackles the issue of Third-Party Logistics (3PL) provider selection for sustainable last-mile delivery. The 3PL selection problem has been solved for the e-shop company from Belgrade, which has online sales. The management of the e-shop company has identified five possible 3PL providers. Those five 3PL providers have been evaluated according to six criteria such as distribution cost, on-time delivery, flexibility of distribution, IT capability, good cultural fit, and customer satisfaction index. To evaluate and rank the 3PL providers, two multi-criteria decision-making methods were coupled. The first one is a Best-Worst Method (BWM) used to find the criteria weights, while the second one is a Combined Compromised Solution (CoCoSo) method utilized to rank the 3PL providers from best to worst one. To check the stability as well as the robustness of the applied methods, sensitivity and comparative analyses are performed. The results show high confidence in the applied methods.

Keywords: Third-party logistics; Multi-criteria decision making; Last-mile delivery; Combined compromised solution; Best-worst method

1. Introduction

Last-Mile Delivery (LMD) describes the final and one of the most important and sensitive phases of the shipping process [1]. This is the phase where the final customers receive the ordered shipments at their addresses. Due to globalization as well as the rapid development of e-commerce, there is a notable increasing number of online orders. The other reason for the increasing number of online orders is the epidemiological situation all over the world. People would rather explore online shops on a website and simply order the desired products to their addresses than physically go there. Bearing that fact in mind, shippers have found themselves in difficulties and doubts, especially in the cities, when it comes to the overall organization of the shipping process. The development of e-commerce markets had opened many questions regarding last-mile delivery [2]. On the other hand, in the last few years, there had been many challenges when performing deliveries due to many of the market risks such as COVID-19, the increase in urban population, and traffic congestion [3]. According to the European Commission document from Brussels [4], at least 30 million zero-emission vehicles would be in operation on European roads and 100 European cities would be climate neutral. Therefore, it is of huge importance to make all transport modes more adaptable and sustainable. From a sustainability perspective, the shippers in terms of last-mile delivery should follow many factors. E-commerce companies that sell their products online must carefully monitor the standards and procedures to make their business more effective and viable. Some e-commerce companies perform the last-mile delivery by themselves, while others contract a third party. One of the issues in the last-mile delivery

process is the collaboration with the external business partners i.e., 3PL service providers, and their selection. Since the 3PL providers (DHL, FedEx, TNT, Posts, etc.) is the main connection between sellers and buyers, choosing the right one is significant for sustainable last-mile delivery.

This paper aims to address the 3PL provider selection problem for sustainable last-mile delivery. Namely, an e-shop company from Belgrade should decide on the best 3PL service provider that will perform the LMD of its products to the final customers in the territory of Belgrade. The 3PL selection problem is not so easy task for decision-makers since multiple conflicting criteria interfere in a decision-making process. Nowadays, there are many multi-criteria decision-making methods used to solve this or similar kinds of problems. In this paper, to solve the problem mentioned, the two multi-criteria decision-making methods are coupled. The first one is the Best-Worst Method (BWM) used to find the criteria weights, while the second one is the Combined Compromise Solution (CoCoSo) method used to rank the alternatives from best to worst. In addition, the sensitivity analysis is performed to test the stability of the applied CoCoSo method. Besides, a comparative analysis is done to compare the results with some multi-criteria decision-making (MCDM) methods.

There are some contributions of this paper:
1) For the first time, the BWM-CoCoSo methods are coupled to find the best 3PL alternative for the e-shop company in Belgrade.
2) The BWM-CoCoSo method is applied to a real-life case study in Belgrade which should be seen as a practical contribution.
3) The applied methodology is tested and verified in the case study involving 5 3PL providers. The sensitivity analysis of the applied methods is performed, and the high stability of the results is demonstrated; In addition, the comparative analysis is provided, and the presented results are highly confident.

In addition to contributions, there are certain limitations of this study such as:
i) There are not so many criteria considered in a decision-making process. The identified criteria from the literature were of special interest to the e-shop company's management who decides on the best 3PL. The six identified criteria were enough according to the e-shop company's management opinion because the economic, social, and technical pillars need to be tackled.
ii) Since the 3PL selection problem deals with uncertainty, the applied methods are not combined with fuzzy logic. This limitation should be considered as a future research direction of the paper.

The rest of the paper is structured in the following manner: Section 2 reveals the review of the literature in terms of criteria and methods used to solve the 3PL selection problem. Section 3 elaborates on the methodology that is applied to the problem mentioned. Section 4 is the application of the methodology to the real-life case study of the e-shop company from Belgrade. Section 5 gives some general managerial implications on the considered problem. Section 6 concludes and gives future directions for the paper.

2. Literature Review

The literature review is organized into three sub-sections. The first one identifies the evaluation criteria for 3PL provider selection. The second one reveals the available methods used to solve the 3PL provider selection problem, while the third one focuses on the existing state-of-the-art applications of the Best-Worst Method (BWM) and CoCoSo method.

2.1 Evaluation Criteria for 3PL Service Provider Selection

Table 1. Evaluation criteria for the 3PL selection process

Criterion	Definition	References
Distribution Cost	The Cost that 3PL should require for the distribution process.	[5-7]
On-Time Delivery	Whether the 3PL respects the promised distribution timeframes	[8-11]
Flexibility of Distribution	The ability to react faster to market turbulences	[7, 9-11]
IT Capability	The level of IT capability in terms of customer order management, track and trace technologies, web portal, etc.	[7, 9, 12, 13]
Good Cultural Fit	How well will the 3PL and the e-shop company be able to collaborate based on their respective internal business cultures	[14]
Customer Satisfaction Index	The index of customer satisfaction in terms of collaboration with the 3PL provider	[10, 11]

This subsection investigates the criteria that are used in 3PL service provider selection by various authors. Many conflicting criteria affect the 3PL selection process. However, some of the criteria that should be used in this paper are sorted out from the literature review. The identified criteria are briefly defined and summarized in Table 1.

According to the review of the literature, six criteria have been sorted out as the crucial ones for the e-shop company. Those six criteria are distribution costs, on-time delivery, the flexibility of distribution, IT capability, good cultural fit as well as customer satisfaction index. In addition, as can be noticed from Table 1, many authors in this field used some of those criteria to solve the 3PL provider selection problem.

2.2 Evaluation Methods for 3PL Service Provider Selection

This subsection surveys the existing methods for the 3PL provider selection process. Many methods were applied to solve the 3PL provider selection problem. Most of the methods belong to the multi-criteria decision-making methods. The available methods from the literature are briefly summarized in Table 2.

Table 2. Existing MCDM methods in 3PL provider selection

Reference	Method(s)
Govindan et al. [15]	Fuzzy-ELECTRE
Kilincci & Onal [16]	Fuzzy-AHP and Fuzzy-Objective LP
Arikan [17]	Fuzzy-AHP
Laptate [18]	Fuzzy-Modified-TOPSIS
Jayant and Singh [19]	AHP-VIKOR
Gürcan et al. [20]	AHP
Rezaeisaray et al. [21]	DEMATEL, Fuzzy-ANP, DEA
Kumar et al. [22]	TODIM, PROMETHEE
Garside and Saputro [23]	Fuzzy-AHP, Grey-TOPSIS
Singh et al. [24]	Fuzzy-AHP, Fuzzy-TOPSIS
Raut et al. [25]	DEA, ANP
Sremac et al. [26]	Rough SWARA, Rough WASPAS, Rough SAW, Rough EDAS, Rough MABAC, Rough TOPSIS
Zarbakhshnia et al. [27]	SWARA, COPRAS
Bianchini [28]	AHP, TOPSIS
Roy et al. [29]	
Paché and Aguezzoul [30]	FARE-MABAC based on IVFRN
Özcan and Ahıskalı [31]	AHP, ELECTRE I
Ulutas and Topal [32]	AHP, TOPSIS, Goal Programming
Ulutas [33]	SWARA, RPSI, IOCRA
Our Study	Grey-SWARA, Grey-CODAS BWM-CoCoSo

As can be noticed, there are various MCDM methods used to solve the 3PL Service Provider selection problem. Most of the methods are coupled with fuzzy logic and the expert's opinions and participation are mostly included. In this paper, the CoCoSo method is integrated with the BWM method to obtain the best 3PL provider solution for last-mile delivery. The combination of those methods has not been previously applied to the E-shop company to solve a real-life case study, which should be considered as one of the practical contributions. The next subsection reveals the current state of applications of the BWM and the CoCoSo methods in various fields.

2.3 An Overview of the Application of the Best-Worst Method (BWM) and CoCoSo Method

This subsection reveals the application of the Best-Worst Method (BWM) and the CoCoSo method to various MCDM problems. The summary of the available applications of the BWM and CoCoSo is presented in Table 3 and Table 4, respectively.

Table 3. Summary of the available applications of the BWM

Reference	Problem considered
Ortega et al. [34]	Sustainable Park and Ride Facility Location
Pamučar et al. [35]	Renewable Energy
Zhou et al. [36]	Evaluation of Urban Photovoltaic Charging Station
Moslem et al. [37]	Mobility choice after COVID-19 in Italy
Kant and Gupta [38]	Sustainable Urban Freight Strategies in Jaipur city
Ali and Rashid [39]	Robot Selection Process
Mahmoudi [40]	Multiple Experts MCDM problem under uncertainty
Ozmen and Aydogan [41]	Logistics Center Location
Rodríguez-Gutiérez et al. [42]	SMEs under sustainability perspective
Duleba et al. [43]	Commuting Modal Spit
Guler and Yomralioglu [44]	Bicycle Station and Lane Location Selection

Based on the articles reviewed, there are various fields addressed by the BWM and CoCoSo methods. When it comes to the BWM method, there were considered the problems such as sustainable park-and-ride facility location, renewable energy, evaluation of urban photovoltaic charging stations, mobility choice after COVID-19 in Italy, logistics center location, robot selection process, etc. On the other side, regarding the CoCoSo method, the addressed problems were in Manufacturing Technology Selection, Electric Vehicle Selection, Sustainable Supplier Selection, Temporary Hospital Location, Logistics Center Location, Personnel Selection, etc. Nevertheless, it can be noticed that the applications of the BWM and CoCoSo have not previously been tackling the last-mile delivery issue in the e-commerce industry. Bearing in mind the potential of combining the BWM and the CoCoSo methods, this paper deals with the 3PL provider selection for sustainable last-mile delivery in the e-shop company. Since e-shop companies sell their products online, it is of huge importance to have a great business partner for the last-mile delivery of shipments to the final customers. For that reason, the integration of the mentioned methods should be considered an excellent approach in the 3PL selection process to make the LMD process more effective and sustainable.

Table 4. Summary of the available applications of the CoCoSo method

Reference	Problem considered
Yazdani and Chatterjee [45]	Manufacturing Technology Selection
Biswas et al. [46]	Electric Vehicle Selection
Wen et al. [47]	HFL-CoCoSo
Ecer and Pamučar [48]	Sustainable Supplier Selection
Zolfani et al. [49]	Temporary Hospital Location
Ulutaş et al. [50]	Logistics Center Location
Peng and Florentin [51]	China's rare earth industry security
Popović [52]	Personnel Selection
Our Study	3PL Provider Selection for Sustainable Last-Mile Delivery

3. Methodology

This section describes the methodology that is to be used to solve the 3PL service provider selection problem for sustainable last-mile delivery. A flowchart of the proposed BWM-CoCoSo methodology is given in Figure 1.

Namely, the two multi-criteria decision-making methods are coupled to obtain the final rank of the alternatives. The first one is the Best-Worst Method (BWM), which is used to find the criteria's importance since not all criteria are equally important. The second one is the Combined Compromise Solution (CoCoSo) method which is used to obtain the final rank of the 3PL alternatives. The methodology is applied to a real-life case study in an e-shop company in Belgrade.
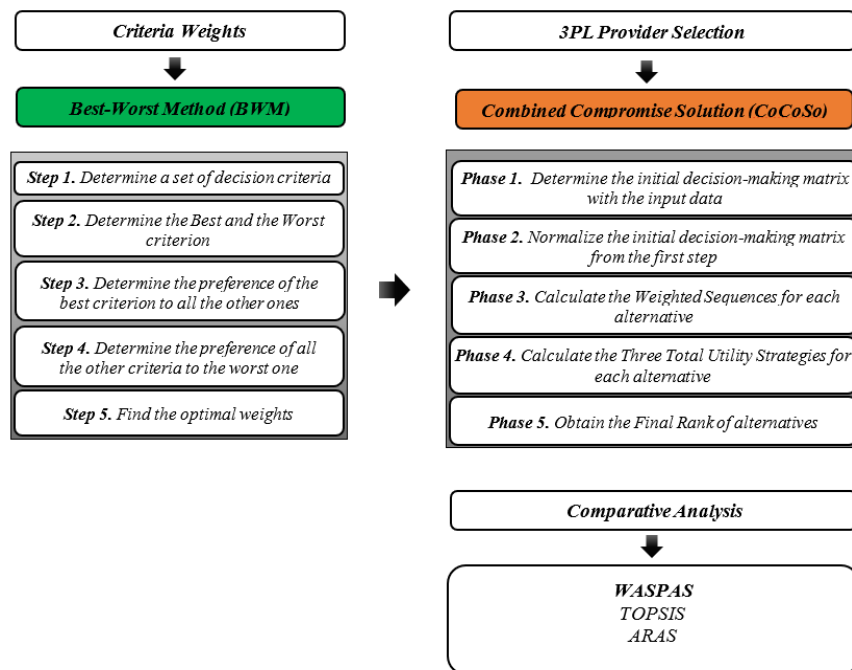

Figure 1. A flowchart of the BWM-CoCoSo methods

3.1 Best-Worst Method

The Best-Worst method was originally developed by Rezaei [53]. This method aims at obtaining the criteria weights since not all criteria are equally important. This method is based on the idea that when making a pairwise comparison a_{ij}, the decision-maker considers both the direction and the strength of the preference i over j. The Best-Worst Method is elaborated through the following steps [53]:

Step 1. Determine a set of decision criteria.

The criteria $\{c_1, c_2, ... c_n\}$ are determined to be used to make a desirable decision.

Step 2. Determine the Best (e.g., most desirable, most important) and the Worst (e.g., less desirable, less important) criterion.

In the case that more than one criterion is the best or the worst one, one of them can be chosen arbitrarily. At this step, the decision-maker identifies the best and the worst criterion in general, and no comparison is performed.

Step 3. Determine the preference of the best criterion to all the other ones, using a scale between 1 and 9.

The resulting vector Best-to-Others should be defined:

$$A_B = (a_{B1}, a_{B2,...} a_{Bn}) \tag{1}$$

where, a_{Bj} shows the preference of the best criterion B over criterion j. So, it is clear that $a_{BB} = 1$.

Step 4. Determine the preference of all the other criteria to the worst one, using a scale between 1 and 9.

The resulting Others-to-Worst vector should be defined:

$$A_w = (a_{1w}, a_{2w,...} a_{nw})^T \tag{2}$$

where, a_{jw} indicates the preference of the criterion j to the worst one W. It is clear that $a_{ww} = 1$.

Step 5. Find the optimal weights $(w_1^*, w_2^*, ..., w_n^*)$.

The optimal weight for the criteria is the one where for each pair of W_B/W_j and W_j/W_w, we have $W_B/W_j = a_{Bj}$ and $W_j/W_w = a_{jw}$. To fulfill these conditions for all j, we should find a solution where the maximum absolute differences $\left|\frac{W_B}{W_j} - a_{Bj}\right|$ and $\left|\frac{W_j}{W_w} - a_{jw}\right|$ for all j is minimized. Considering the non-negativity and sum condition for the weights would lead to the following problem:

$$min \max_j \left\{ \left|\frac{W_B}{W_j} - a_{Bj}\right|, \left|\frac{W_j}{W_w} - a_{jw}\right| \right\} \tag{3}$$

s.t. $\sum_j W_j = 1$; $W_j \geq 0$ for all j.

After Eq. (3), the problem can be reformulated to the following linear programming problem: Min ξ
s.t.

$$\begin{aligned} \left|\frac{W_B}{W_j} - a_{Bj}\right| &\leq \xi, \text{ for all j.} \\ \left|\frac{W_j}{W_w} - a_{jw}\right| &\leq \xi, \text{ for all j.} \end{aligned} \tag{4}$$

$\sum_j W_j = 1$; $W_j \geq 0$ for all j.

By solving Eq. (4), the optimal weights $(w_1^*, w_2^*, ..., w_n^*)$ and ξ^* are obtained. The consistency ratio of the model is calculated using the following equation:

$$Consistency\ Ratio = \frac{\xi}{CI} \tag{5}$$

where, ξ is the optimal objective value of model (5), and CI is the consistency index which can be taken from Table 5.

Table 5. Consistency index [53]

a_{Bw}	1	2	3	4	5	6	7	8	9
CI max (ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

3.2 Combined Compromise Solution (CoCoSo) Method

A Combined Compromise Solution (CoCoSo) method [54] belongs to multi-criteria decision-making methods. This method was originally developed by Yazdani et al. [54], where the authors applied the aggregation strategies. In addition, they considered a distance measure, which originates from the grey relational coefficient and targets to enhance the flexibility of the results. The CoCoSo method is based on an integrated Simple Additive Weighting (SAW) method and an Exponentially Weighted Product (EWP) model. The CoCoSo method can be explained through the following phases [54]:

Phase 1: Determine the initial decision-making matrix with the input data

$$X = \begin{bmatrix} x_{11} & \cdots & x_{12} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{21} & \cdots & x_{22} & \cdots & x_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}, \ i = 1,2,\dots,m, j = 1,2,\dots,n; \tag{6}$$

Phase 2: Normalize the initial decision-making matrix from the first phase

There are two equations to be used in the normalization process, depending on the criteria type. If the criterion is a beneficial (B), there is the following equation for normalization:

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \ i = 1,2,\dots,m, j = 1,2,\dots,n; \tag{7}$$

If the criterion is non-beneficial i.e., cost (C), there is the following equation for normalization:

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \ i = 1,2,\dots,m, j = 1,2,\dots,n; \tag{8}$$

Phase 3: Calculate the weighted sequences S_i and P_i for each alternative

$$S_i = \sum_{j=1}^{n}(w_j \cdot r_{ij}), \ i = 1,2,\dots,m; \tag{9}$$

$$P_i = \sum_{j=1}^{n}(r_{ij})^{w_j}, \ i = 1,2,\dots,m; \tag{10}$$

Phase 4: Calculate the three total utility strategies for each alternative

The first strategy of total utility (K_{ia}) expresses the arithmetic mean of the sum of S_i and P_i values:

$$K_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)}, i = 1,2,\dots,m; \tag{11}$$

The second strategy of total utility (K_{ib}) expresses the sum of the relative relations S_i and P_i with their worst values:

$$K_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i}, i = 1,2,\dots,m; \tag{12}$$

The third strategy of total utility (K_{ic}) expresses a balanced compromise of S_i and P_i values:

$$K_{ic} = \frac{\lambda S_i + (1-\lambda)P_i}{(\lambda \max_i S_i + (1-\lambda)\max_i P_i)}, 0 \leq \lambda \leq 1; \tag{13}$$

Phase 5: Obtain the final rank of alternatives.
The final ranking of the alternatives is determined based on K_i:

$$K_i = (K_{ia} \cdot K_{ib} \cdot K_{ic})^{\frac{1}{3}} + \frac{1}{3}(K_{ia} + K_{ib} + K_{ic}); \tag{14}$$

4. Case Study of 3PL Provider Selection for LMD in Belgrade

The previously described methodology is applied to the e-shop company from Belgrade, the capital of the Republic of Serbia. According to a discussion with the company's top management, its name is not mentioned due

to internal policy reasons. However, it is one of the leaders in Serbia in online selling goods and mostly operates on a national level. When it comes to storage goods, it has its warehouse where the ordered products come from to the final customers. Currently, the e-shop company has a contract with the two 3PL service providers for the last-mile delivery, which names are also not unfolded due to their policy of privacy. The final customers who buy their products online have the option to select the 3PL provider who should deliver the product to their final address. However, the e-shop company's contract with the one 3PL service provider may end soon, according to a discussion with the top management. It will mean that the e-shop company will have only one 3PL service provider and will need to find another 3PL business partner for the last-mile delivery to collaborate with. As its manager stated, the e-shop company is looking for a 3PL service provider who would fulfill its expectations and perform the last-mile delivery process, in the territory of Belgrade, as efficiently and productively as possible. In addition, according to the literature review, the authors of this paper sorted out some of the crucial criteria (Distribution Cost (C_1), On-time Delivery (C_2), Flexibility of Distribution (C_3), IT Capability (C_4), Good Cultural Fit (C_5) and Customer Satisfaction Index (C_6)) for the 3PL selection process. The e-shop company's management completely agreed with the criteria selected. In addition, five 3PL service providers operate in the territory of the Republic of Serbia as possible alternatives. Those five 3PLs are identified by the experts from the E-shop company and compared according to the above-mentioned criteria. The authors of this paper in collaboration with the top management of the e-shop company, by applying the BWM method, determined the criteria weights for the 3PL selection process since not all criteria have the same weight when deciding on the best 3PL. The illustrative description of the problem is given in Figure 2.
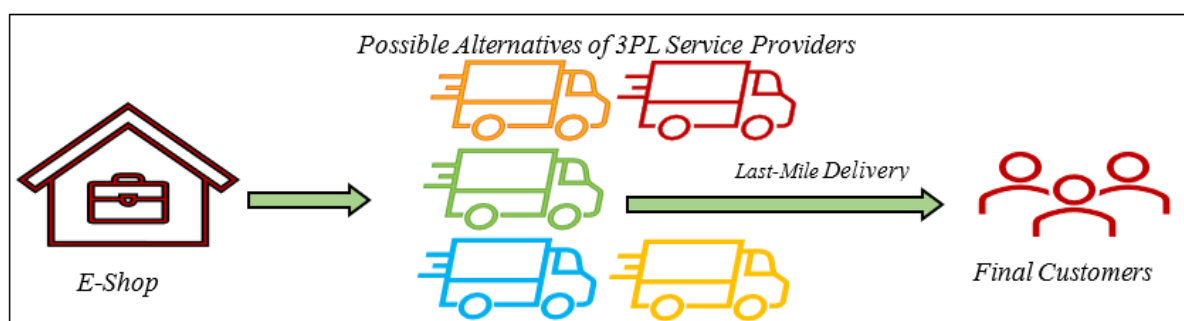

Figure 2. Illustration of the problem

According to the BWM method, the criteria weights are determined and presented in Table 6.

Table 6. The criteria weights identified by the BWM method

	Distribution Cost (€/km)	On-Time Delivery (%)	Flexibility of Distribution (1-5)	IT Capability (1-5)	Good Cultural Fit (1-5)	Customer Satisfaction Index (1-3)
Weights	0.3421	0.1466	0.1099	0.1466	0.2199	0.0349

The obtained criteria weights from the BWM method are utilized within the CoCoSo method to rank the alternatives from best to worst. The initial decision-making matrix and all the following steps of the CoCoSo method are presented in Tables 7-10.

Table 7. The initial (CoCoSo) decision-making matrix

	Distribution Cost (€/km)	On-Time Delivery (%)	The flexibility of Distribution (1-5)	IT Capability (1-5)	Good Cultural Fit (1-5)	Customer Satisfaction Index (1-3)
3PL-1	0.95	99.98	3	4	4	3
3PL-2	0.93	99.88	3	5	5	2
3PL-3	0.97	98.85	4	5	3	3
3PL-4	0.99	99.99	5	5	5	2
3PL-5	0.95	99.90	5	4	4	3
	0.93	99.99	5	5	5	3
	0.99	98.85	3	4	3	2
Weights	0.3421	0.1466	0.1099	0.1466	0.2199	0.0349
	min	max	max	max	max	max

Table 8. Normalization of the input data

	Distribution Cost (€/km)	On-Time Delivery (%)	Flexibility of Distribution (1-5)	IT Capability (1-5)	Good Cultural Fit (1-5)	Customer Satisfaction Index (1-3)
3PL-1	0.6667	0.9912	0.0000	0.0000	0.5000	1.0000
3PL-2	1.0000	0.9035	0.0000	1.0000	1.0000	0.0000
3PL-3	0.3333	0.0000	0.5000	1.0000	0.0000	1.0000
3PL-4	0.0000	1.0000	1.0000	1.0000	1.0000	0.0000
3PL-5	0.6667	0.9211	1.0000	0.0000	0.5000	1.0000
Weights	0.3421	0.1466	0.1099	0.1466	0.2199	0.0349

Table 9. Obtained weighted sequences S_i and P_i for each alternative

	Distribution Cost (€/km)	On-Time Delivery (%)	Flexibility of Distribution (1-5)	IT Capability (1-5)	Good Cultural Fit (1-5)	Customer Satisfaction Index (1-3)	S_i	P_i
3PL-1	0.2281	0.1453	0.0000	0.0000	0.1100	0.0349	0.5182	3.7278
3PL-2	0.3421	0.1325	0.0000	0.1466	0.2199	0.0000	0.8411	3.9852
3PL-3	0.1140	0.0000	0.0550	0.1466	0.0000	0.0349	0.3505	3.6134
3PL-4	0.0000	0.1466	0.1099	0.1466	0.2199	0.0000	0.6230	4.0000
3PL-5	0.2281	0.1350	0.1099	0.0000	0.1100	0.0349	0.6178	4.7171
						min	0.3505	3.6134
						max	0.8411	4.7171

Table 10. Total utility strategies for each alternative and final rank

	S_i*P_i	K_{ia}	K_{ib}	K_{ic}	Rank
3PL-1	4.2460	0.1847	0.1797	0.7639	0.6699
3PL-2	4.8263	0.2099	0.2508	0.8683	0.8006
3PL-3	3.9639	0.1724	0.1432	0.7132	0.6031
3PL-4	4.6230	0.2011	0.2065	0.8317	0.7388
3PL-5	5.3350	0.2320	0.2197	0.9598	0.8363
	22.9942				

The final rank of the 3PL alternatives is presented in Figure 3.
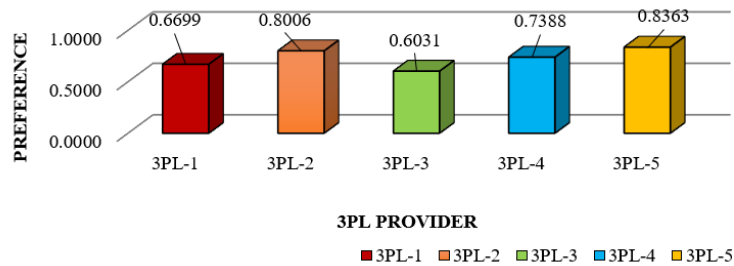

Figure 3. The final rank of the alternatives (3PL providers)

When it comes to the ranking alternatives, it can be concluded that the best 3PL solution for performing the last-mile delivery was the 3PL-5 with a preference of 0.8363, followed by 3PL-2 (0.8006), 3PL-4 (0.7388), 3PL-1 (0.6699), and 3PL-3 (0.6031) respectively. To test the robustness of the methodology, a sensitivity analysis was proposed. The results of the sensitivity analysis are presented in the next subsection.

4.1 Sensitivity Analysis of the CoCoSo Method

The sensitivity analysis of the BWM-CoCoSo method is performed. The main objective of the sensitivity analysis was to examine the stability of the applied BWM-CoCoSo method. In other words, the method is stable if the change in weight of one criterion does not affect the final ranking of alternatives. If the weight of the *n-th* criterion changes by *Δs*, then the weight of other criteria changes by *Δt* [55].

$$\Delta t = \frac{\Delta s \cdot W_j}{W_s - 1} \tag{15}$$

Based on the Eq. (10), the results of the sensitivity analysis are presented in Table 11.

Table 11. Various weight variations of the "Distribution Cost" criterion

$\Delta 1$	W_i, i=1,..,6	The Best-Ranked 3PL
0.40	0.5421 0.1021 0.0765 0.1021 0.1530 0.0243	3PL-5
-0.10	0.0421 0.2135 0.1600 0.2135 0.3201 0.0508	3PL-5
0.10	0.2421 0.1689 0.1266 0.1689 0.2533 0.0402	3PL-5
0.20	0.3421 0.1466 0.1099 0.1466 0.2199 0.0349	3PL-5
0.30	0.4421 0.1243 0.0932 0.1243 0.1864 0.0296	3PL-5

The same procedure is applied to all the other criteria weights, and the obtained results of all other criteria are presented in Table 12.

Table 12. Variations of all the other criteria weights

$\Delta 2$	The Best-Ranked 3PL	$\Delta 3$	The Best-Ranked 3PL	$\Delta 4$	The Best-Ranked 3PL	$\Delta 5$	The Best-Ranked 3PL	$\Delta 6$	The Best-Ranked 3PL
-0.1	3PL-5	-0.1	3PL-5	-0.035	3PL-4	-0.02	3PL-5	-0.02	3PL-5
0.1	3PL-5	0.01	3PL-5	-0.030	3PL-4	-0.01	3PL-5	-0.01	3PL-5
0.2	3PL-5	0.05	3PL-5	0.2	3PL-5	0.1	3PL-5	0.10	3PL-5
0.3	3PL-5	0.1	3PL-5	0.4	3PL-5	0.2	3PL-5	0.60	3PL-5
0.4	3PL-5	0.2	3PL-5	0.5	3PL-5	0.3	3PL-5	0.90	3PL-2

It can be concluded that the applied BWM-CoCoSo method is very strong and stable. The most stable criteria are the distribution cost, on-time delivery, and the flexibility of distribution, while the IT capability, the good cultural fit, and the customer satisfaction index leads to a change in ranking alternatives.

4.2 Comparative Analysis

After the CoCoSo method had been applied to rank the 3PL alternatives, a comparative analysis was performed. The results obtained by the BWM-CoCoSo method were compared to the other MCDM methods to check the reliability (Figure 4).

The 3PL selection problem was solved by the two well-known MCDM methods such as WASPAS [56], and ARAS [57]. In the case of the BWM-CoCoSo method, the highest preference was assigned to 3PL-5, followed by 3PL-2. In addition, the ARAS method ranked 3PL-2 as the best possible solution, followed by 3PL-4 and 3PL-5. According to the WASPAS method, 3PL-4 was ranked the highest, 3PL-2 was ranked as the second best one, and

3PL-5 was ranked third, which is also a good position. In the end, after performing the comparative analysis, it can be stated that the BWM-CoCoSo method is effective and gives confidential results in a decision-making process.
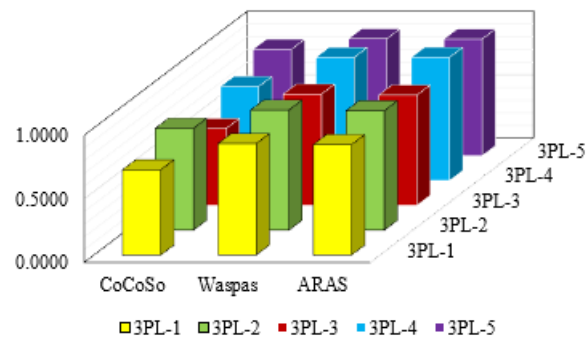

Figure 4. Comparative analysis with the WASPAS, TOPSIS, and ARAS

5. Managerial Implications

In city logistics, the 3PL providers for last-mile delivery should be one of the most essential factors. The quality of the last-mile delivery in cities will be depending on the 3PL companies, their strategies, organization, behavior, etc. In this regard, e-commerce companies should carefully monitor and assess the 3PL providers to make the last-mile delivery business more effective, sustainable, as well as up to date. Since there are many new 3PL players in the market, it is necessary to select the best one. Without using some of the multi-criteria decision-making techniques, the problem of 3PL selection for last-mile delivery can be harder, or wrong in many cases. It may badly affect not only the e-shop companies but also the final customers who are the most essential part of the last-mile delivery problem. In addition, the 3PL companies should follow future standards, trends, and procedures and offer a set of the best last-mile delivery solutions to their collaboration partners. This paper demonstrated a possible approach for ranking the 3PL providers that should be useful to managers in the e-commerce business in assessing the best 3PL collaboration partner.

6. Conclusion

This paper focused on the 3PL provider selection problem for sustainable last-mile delivery. The problem was applied to the real-life case study of the e-shop company from Belgrade, in the Republic of Serbia. Five 3PL providers were taken as possible alternatives for last-mile delivery. Those five 3PL providers were compared according to the six evaluation criteria; i.e., distribution cost, on-time delivery, flexibility of distribution, IT capability, good cultural fit, and customer satisfaction index. Two MCDM methods were used to assess the alternatives according to the mentioned criteria. The first one was the BWM used to obtain the importance of each criterion, while the second one was the CoCoSo method utilized to rank the 3PL providers.

When it comes to criteria weights, the BWM method evaluated the distribution cost (0.3421) as a criterion with the highest importance, followed by good cultural fit (0.2199), on-time delivery (0.1466), IT capability (0.1466), the flexibility of distribution (0.1099) and customer satisfaction index (0.0349), respectively. When the criteria weights were integrated with the CoCoSo method, the final rank of the alternatives was obtained: the highest importance was 3PL-5 (0.8363), followed by 3PL-2 (0.8006), 3PL-4 (0.7388), 3PL-1 (0.6699), and 3PL-3 (0.6031) respectively. The best suggestion for the e-shop company was to select the 3PL-5 to collaborate with while performing the last-mile delivery on the territory of Belgrade. In addition, the sensitivity analysis was performed to check the stability of the applied BWM-CoCoSo method. Namely, the criteria weights were varied to notice how the alternatives would be ranked. The change in criteria weights had shown a high level of stability since there were no dramatic changes in ranking alternatives. Nonetheless, the comparative analysis was performed to compare the results obtained by the BWM-CoCoSo method. The 3PL selection problem was solved by the WASPAS and ARAS methods, where both methods confirmed approximately the same order of the ranking alternatives.

This paper discloses some of its major contributions: *i)* For the first time, the BWM-CoCoSo methods were coupled to obtain the best 3PL provider for the e-shop company; *ii)* The BWM-CoCoSo method was applied to a real-life case study in Belgrade (the Republic of Serbia) which should be seen as a practical contribution. *iii)* The sensitivity analysis of the applied methods was performed, and the high stability of the results is demonstrated; *iv)*

The comparative analysis was provided, and the presented results were highly reliable and confident.

Besides contributions, there were some limitations of this study: a) There have not been so many criteria considered in a decision-making process; However, the e-shop company's management completely agreed on the selected criteria from the literature and there was no need for extending the list. b) Since the 3PL selection problem deals with uncertainty, the applied methods were not combined with the fuzzy sets.

The above-mentioned limitations should be overcome in the future directions of this paper. In the end, it can be concluded that the 3PL selection problem is a crucial and very serious one since they are the main connection between sellers and final customers. With the right selection of a 3PL partner, an e-shop company can have a bunch of benefits such as improved last-mile delivery, satisfied customers, saved costs, and time, while its focus may be on the core activities.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] D. Lazarević and M. Dobrodolac, "Sustainability trends in the postal systems of last-mile delivery," *Perner's Contacts*, vol. 15, no. 1, 2020. https://doi.org/10.46585/pc.2020.1.1547.

[2] K. Ewedairo, P. Chhetri, and F. Jie, "Estimating transportation network impedance to last-mile delivery," *Int. J. Logist. Manag.,* vol. 29, pp. 110-130, 2018. https://doi.org/10.1108/IJLM-10-2016-0247.

[3] H. S. Na, S. J. Kweon, and K. Park, "Characterization and design for last mile logistics: A review of the state of the art and future directions," *Appl. Sci.*, vol. 12, pp. 118-118, 2022. https://doi.org/10.3390/app12010118.

[4] "Sustainable and Smart Mobility Strategy – putting European transport on track for the future, Brussels, Belgium," European Commission, 2020, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0789.

[5] T. U. Daim, A. Udbye, and A. Balasubramanian, "Use of analytic hierarchy process (AHP) for selection of 3PL providers," *J Manuf.,* vol. 24, no. 1, pp. 28-51, 2013. https://doi.org/10.1108/17410381311287472.

[6] Y. M. Chen, M. J. Goan, and P. N. Huang, "Selection process in logistics outsourcing–a view from third party logistics provider," *Prod. Plan. Control*, vol. 22, no. 3, pp. 308-324, 2011. http://dx.doi.org/10.1080/09537287.2010.498611.

[7] O. Bayazit and B. Karpak, "Selection of a third-party logistics service provider for an aerospace company: An analytical decision aiding approach," *Int. J. Logist. Syst. Manag.,* vol. 15, pp. 382-404, 2013. https://doi.org/10.1504/IJLSM.2013.054898.

[8] L. Hwang and K. Yoon, Multiple Attribute Decision Making: Methods and Applications, New York: Springer-Verlag, 1981.

[9] M. N. Qureshi, D. Kumar, and P. Kumar, "An integrated model to identify and classify the key criteria and their role in the assessment of 3PL services providers," *Asia Pac. J. Mark. Logist.,* vol. 20, no. 2, pp. 227-249, 2008. https://doi.org/10.1108/13555850810864579.

[10] P. Kumar and K. S. Rajesh, "A fuzzy AHP and TOPSIS methodology to evaluate 3PL in a supply chain," *J. Model. Manage.*, vol. 7, pp. 287-303, 2012. https://doi.org/10.1108/17465661211283287.

[11] R. Gupta, A. Sachdeva, and A. Bhardwaj, "A framework for selection of logistics outsourcing partner in uncertain environment using TOPSIS," *Int. J. Ind. Syst. Eng.,* vol. 12, no. 2, pp. 223-242, 2012. http://dx.doi.org/10.1504/IJISE.2012.048862.

[12] G. Akman and K. Baynal, "Logistics service provider selection through an integrated fuzzy multicriteria decision making approach," *J. Ind. Eng.,* vol. 2014, Article ID: 794918, 2014. https://doi.org/10.1155/2014/794918.

[13] A. Vijayvargiya and A. K. Dey, "An analytical approach for selection of a logistics provider," *Manage. Decis.,* vol. 48, no. 3, pp. 403-418, 2010. https://doi.org/10.1108/00251741011037774.

[14] H. Göl and B. Çatay, "Third-party logistics provider selection: insights from a Turkish automotive company," *Supply Chain Manage. Int. J.*, vol. 12, no. 6, pp. 379-384, 2007. https://doi.org/10.1108/13598540710826290.

[15] K. Govindan, M. C. Grigore, and D. Kannan, "Rranking of third-party logistics provider using Fuzzy-Electre II," In the 40th International Conference on Computers & Industrial Engineering, Awaji, Japan, 2010, IEEE, pp. 1-5. https://doi.org/10.1109/iccie.2010.5668366.

[16] O. Kilincci and S. A. Onal, "Fuzzy AHP approach for supplier selection in a washing machine company," *Expert Syst. Appl.*, vol. 38, no. 8, pp. 9656-9664, 2011. https://doi.org/10.1016/j.eswa.2011.01.159.

[17] F. Arikan, "An interactive solution approach for multiple-objective supplier selection problem with fuzzy parameters," *J. Intell. Manuf.*, vol. 26, pp. 989-998, 2013. https://doi.org/10.1007/s10845-013-0782-6.

[18] V. R. Laptate, "Fuzzy modified TOPSIS for supplier selection problem in supply chain management," *Int. J. Innov. Res. Comput. Sci. Technol.*, vol. 3, no. 4, pp. 22-28, 2015.

[19] A. Jayant and P. Singh, "Application of AHP-VIKOR hybrid MCDM approach for 3pl selection: A case study," *ICAET*, vol. 2015, no. 4, pp. 4-11, 2015.

[20] Ö. F. Gürcan, İ. Yazıcı, Ö. F. Beyca, Ç. Y. Arslan, and F. Eldemir, "Third Party Logistics (3PL) provider selection with AHP application," *Proc. Soc. Behav. Sci.*, vol. 235, pp. 226-234, 2016. https://doi.org/10.1016/j.sbspro.2016.11.018.

[21] M. Rezaeisaray, S. Ebrahimnejad, and K. Khalili-Damghani, "A novel hybrid MCDM approach for outsourcing supplier selection," *J. Model Manag.*, vol. 11, no. 2, pp. 536-559, 2016. https://doi.org/10.1108/jm2-06-2014-0045.

[22] D. K. Sen, S. Datta, and S. S. Mahapatra, "A TODIM-based decision support framework for g-resilient supplier selection in fuzzy environment," *Asia Pac. J. Oper Res.*, vol. 33, no. 5, Article ID: 1650033, 2016. https://doi.org/10.1142/s0217595916500330.

[23] K. Garside and T. E. Saputro, "Evaluation and selection of 3PL provider using fuzzy AHP and grey TOPSIS in group decision making," In AIP Conference Proceedings, Industrial and Manufacturing Engineering Conference (mimec2017), Miri, Malaysia, December 6-8, 2017. https://doi.org/10.1063/1.5010673.

[24] R. K. Singh, A. Gunasekaran, and P. Kumar, "Third party logistics (3PL) selection for cold chain management: a fuzzy AHP and fuzzy TOPSIS approach," *Ann. Oper Res.*, vol. 267, pp. 531-553, 2018. https://doi.org/10.1007/s10479-017-2591-3.

[25] R. Raut, M. Kharat, S. Kamble, and C. S. Kumar, "Sustainable evaluation & selection of potential third-party logistics providers (3PL): An Integrated MCDM Approach," *Benchmarking: Int J.*, vol. 25, no. 1, pp. 76-97, 2018. https://doi.org/10.1108/BIJ-05-2016-0065.

[26] S. Sremac, Ž. Stević, D. Pamučar, M. Arsić, and B. Matić, "Evaluation of a third-party logistics (3PL) Provider using a rough SWARA-WASPAS model based on a new rough dombi aggregator," *Symmetry.*, vol. 10, no. 305, 2018. https://doi.org/10.3390/sym10080305.

[27] N. Zarbakhshnia, Y. Wu, K. Govindan, and H. Soleimani, "A novel hybrid multiple attribute decision-making approach for outsourcing sustainable reverse logistics," *J. Clean Prod.*, vol. 242, Article ID: 118464, 2019. https://doi.org/10.1016/j.jclepro.2019.118461.

[28] A. Bianchini, "3PL provider selection by AHP and TOPSIS methodology," *Benchmarking: Int J.*, vol. 25, no. 1, pp. 235-252, 2018. https://doi.org/10.1108/BIJ-08-2016-0125.

[29] J. Roy, D. Pamučar, and S. Kar, "Evaluation and selection of third-party logistics provider under sustainability perspectives: An interval valued fuzzy-rough approach," *Ann. Oper Res.*, vol. 293, pp. 669-714, 2020. https://doi.org/10.1007/s10479-019-03501-x.

[30] G. Paché and A. Aguezzoul, "An AHP-ELECTRE I approach for 3PL-provider selection," *Int J. Transp Econ.*, vol. 2020, pp. 37-50, 2020.

[31] E. Özcan and M. Ahıskalı, "3PL service provider selection with a goal programming model supported with multicriteria decision making approaches," *Gazi U. J Sci.*, vol. 33, no. 2, pp. 413-427, 2020. https://doi.org/10.35378/gujs.552070.

[32] A. Ulutas and A. Topal, "A new hybrid model based on rough stepwise weight assessment ratio analysis for third-party logistics selection," *Soft Comput.*, vol. 26, pp. 2021-2032, 2021. https://doi.org/10.1007/s00500-021-06374-0.

[33] A. Ulutas, "A grey hybrid model to select the optimal third-party logistics provider," *S Afr. J. Ind Eng.*, vol. 32, no. 1, pp. 171-181, 2021. https://dx.doi.org/10.7166/32-1-2126.

[34] J. Ortega, M. Sarbast, T. János, P. Tamás, J. Palaguachi, and M. Paguay, "Using Best Worst Method for Sustainable Park and Ride Facility Location," *Sus.*, vol. 12, no. 23, Article ID: 10083. 2020. https://doi.org/10.3390/su122310083.

[35] D. Pamučar, F. Ecer, G. Cirovic, and M. A. Arlasheedi, "Application of Improved Best Worst Method (BWM) in Real-World Problems," Mathematics., vol. 8, no. 8, pp. 1342-1342, 2020. https://doi.org/10.3390/math8081342.

[36] J. L. Zhou, Y. N. Wu, C. H. Wu, F. Y. He, B. Y. Zhang, and F. T. Liu, "A geographical information system based multi-criteria decision-making approach for location analysis and evaluation of urban photovoltaic charging station: A case study in Beijing," *Energ Convers. Manage.*, vol. 205, no. 112340, 2020. https://doi.org/10.1016/j.enconman.2019.112340.

[37] S. Moslem, T. Campisi, A. Szmelter-Jarosz, S. Duleba, K. M. Nahiduzzaman, and G. Tesoriere, "Best–Worst Method for Modelling Mobility Choice after COVID-19: Evidence from Italy," *Sus.*, vol. 12, no. 17, pp. 6824, 2020. https://doi.org/10.3390/su12176824.

[38] P. Kant and S. Gupta, "Sustainable urban freight strategies for Jaipur City, India," In Smart and Sustainable Supply Chain and Logistics–Trends, Challenges, Methods and Best Practices, vol. 1, pp. 153-163, 2020. https://doi.org/10.1007/978-3-030-61947-3_10.

[39] A. Ali and T. Rashid, "Best–worst method for robot selection," *Soft Comput.*, vol. 25, pp. 563-583, 2021. https://doi.org/10.1007/s00500-020-05169-z.

[40] A. Mahmoudi, X. M. Mi, H. C. Liao, M. R. Feylizadeh, and Z. Turskis, "Grey Best-Worst Method for Multiple Experts Multiple Criteria Decision Making Under Uncertainty," Informatica, vol. 31, no. 2, pp. 331-357, 2020. https://doi.org/10.15388/20-INFOR409.

[41] M. Özmen and E. K. Aydoğan, "Robust multi-criteria decision-making methodology for real life logistics center location problem," *Artif Intell Rev*, vol. 53, pp. 725-751, 2019. https://doi.org/10.1007/s10462-019-09763-y.

[42] P. Rodríguez-Gutiérrez, M. D. Guerrero-Baena, M. Luque-Vílchez, and F. Castilla-Polo, "An approach to using the best-worst method for supporting sustainability reporting decision-making in SME," *J. Environ. Plann. Man.*, vol. 64, no. 14, pp. 2618-2640, 2021. https://doi.org/10.1080/09640568.2021.1876003.

[43] S. Duleba, S. Moslem, and D. Esztergár-Kiss, "Estimating commuting modal split by using the Best-Worst Method," *Eur. Transp. Res. Rev.*, vol. 13, pp. 1-12, 2021. https://doi.org/10.1186/s12544-021-00489-z.

[44] D. Guler and T. Yomralioglu, "Bicycle station and lane location selection using open-source GIS technology". In Open-Source Geospatial Science for Urban Studies. Lecture Notes in Intelligent Transportation and Infrastructure, Springer, Cham, pp. 9-36, 2021. https://doi.org/10.1007/978-3-030-58232-6_2.

[45] M. Yazdani and P. Chatterjee, "Intelligent decision-making tools in manufacturing technology selection". In Futuristic Composites, Singapore, Springer, pp. 113-126, 2018.

[46] T. K. Biswas, Ž. Stević, P. Chatterjee, and M. Yazdani, "An integrated methodology for evaluation of electric vehicles under sustainable automotive environment," In Advanced Multi-Criteria Decision Making for Addressing Complex Sustainability Issues, CRC press, pp. 41-62, 2019.

[47] Z. Wen, H. C. Liao, E. K. Zavadskas, and A. Al-Barakati, "Selection third-party logistics service providers in supply chain finance by ahesitant fuzzy linguistic combined compromise solution method," *Econ. Res-Ekon. Istraz.*, vol. 32, no. 1, pp. 4033-4058, 2019. https://doi.org/10.1080/1331677X.2019.1678502.

[48] F. Ecer and D. Pamucar, "Sustainable supplier selection: A novel integrated fuzzy best worst method (F-BWM) and fuzzy CoCoSo with Bonferroni (CoCoSo'B) multi-criteria model," *J. Clean. Prod.*, vol. 266, Article ID: 121981, 2020. https://doi.org/10.1016/j.jclepro.2020.121981.

[49] S. H. Zolfani, M. Yazdani, A. Ebadi Torkayesh, and A. Derakhti, "Application of a gray-based decision support framework for location selection of a temporary hospital during COVID-19 pandemic," *Symmetry*, vol. 12, no. 6, pp. 886-886, 2020. https://doi.org/10.3390/sym12060886.

[50] A. Ulutaş, C. B. Karakuş, and A. Topal, "Location selection for logistics center with fuzzy SWARA and CoCoSo methods," *J. Intell. Fuzzy Syst.*, vol. 38, no. 4, pp. 4693-4709, 2020. https://doi.org/10.3233/JIFS-191400.

[51] X. Peng and F. Smarandache, "A decision-making framework for china's rare earth industry security evaluation by neutrosophic soft CoCoSo method," *J. Intell. Fuzzy Syst.*, vol. 39, no. 5, pp. 7571-7585, 2020. https://doi.org/10.3233/JIFS-200847.

[52] M. Popović, "An MCDM approach for personnel selection using the CoCoSo method," *Journal of Process Management New Technologies*, vol. 9, no. 3-4, pp. 78-88, 2021. https://doi.org/10.5937/jouproman2103078P.

[53] J. Rezaei, "Best-worst multi-criteria decision-making method," *Omega*, vol. 53, pp. 49-57, 2015. https://doi.org/10.1016/j.omega.2014.11.009.

[54] M. Yazdani, P. Zarate, E. Kazimieras Zavadskas, and Z. Turskis, "A combined compromise solution (CoCoSo) method for multi-criteria decision-making problems," *Manage. Decis.*, vol. 57, no. 9, pp. 2501-2519, 2019. https://doi.org/10.1108/MD-05-2017-0458.

[55] A. Alinezhad and A. Amini, "Sensitivity analysis of TOPSIS technique: the results of change in the weight of one attribute on the final ranking of alternatives," *J. Optim. Ind. Eng.*, vol. 7, no. 1, pp. 23-28, 2011.

[56] A. Alinezhad and J. Khalili, "WASPAS method," In New Methods and Applications in Multiple Attribute Decision Making (MADM), International Series in Operations Research & Management Science, Springer, Cham., vol. 2019, pp. 93-98, 2019. https://doi.org/10.1007/978-3-030-15009-9_13.

[57] E. K. Zavadskas and Z. Turskis, "A new additive ratio assessment (ARAS) method in multi-criteria decision-making," *Technol. Econ. Dev. Eco.*, vol. 16, no. 2, pp. 159-172, 2010. https://doi.org/10.3846/tede.2010.10.