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

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**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]<br>Roy et al. [29] | AHP, TOPSIS |
| 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.

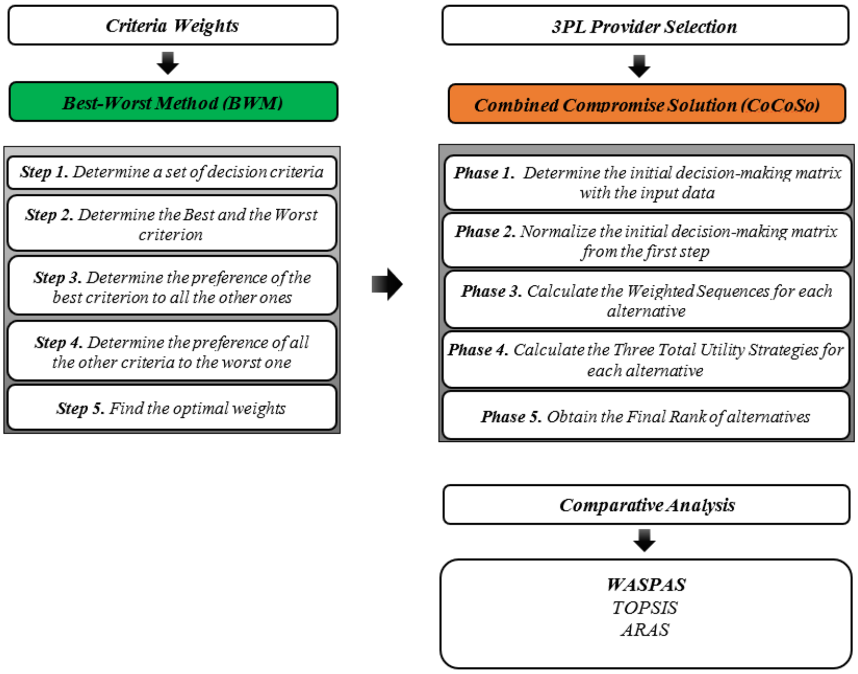


**Figure 1.** A flowchart of the BWM-CoCoSo methods

### 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 $\{c_1, c_2, \ldots c_n\}$ 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:

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

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:

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

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 $(\mathrm{w}_1^*, \mathrm{w}_2^*, \ldots, \mathrm{w}_n^*)$.

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 $\xi$ 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 $(w_1^*, w_2^*, \ldots, w_n^*)$ and $\xi^*$ are obtained. The consistency ratio of the model is calculated using the following equation:

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

where, $\xi$ 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

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

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:

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \ i = 1,2,\ldots,m, j = 1,2,\ldots,\mathrm{n}; \quad (7)$$

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

$$r_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \ i = 1,2,\ldots,m, j = 1,2,\ldots,\mathrm{n}; \quad (8)$$

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

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

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

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:

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

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

$$K_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i}, i = 1,2,\ldots,m; \quad (12)$$

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

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

Phase 5: Obtain the final rank of alternatives.

The final ranking of the alternatives is determined based on $K_i$:

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

## 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.

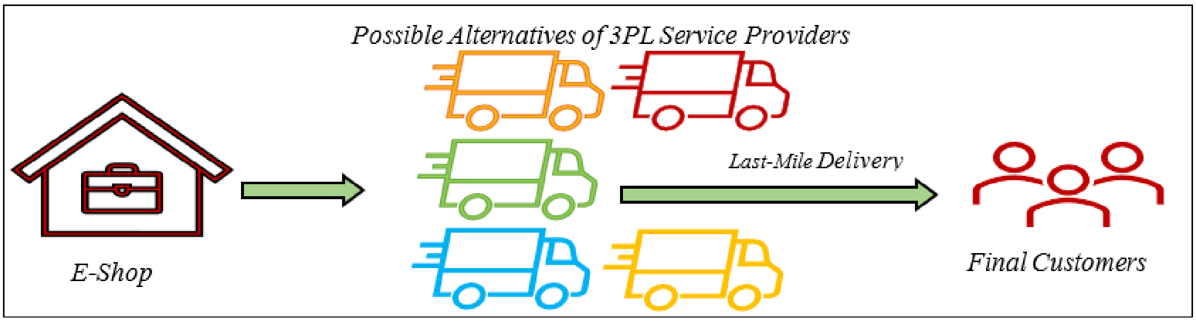


**Figure 2.** Illustration of the problem

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

| | Si*Pi | Kia | Kib | Kic | 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.

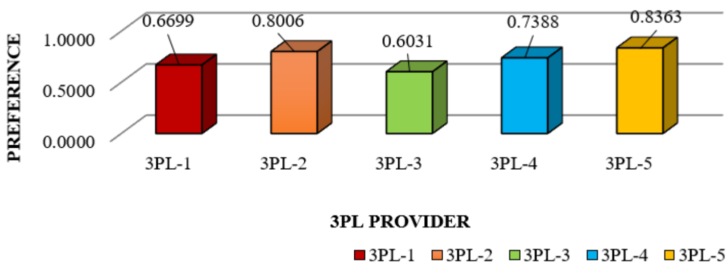


**Figure 3.** The final rank of the alternatives (3PL providers)

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 $\Delta s$, then the weight of other criteria changes by $\Delta t$ [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

| Δ1 | $W_i$, i=1,..,6 | The Best-Ranked 3PL |
|---|---|---|
| **0.40** | 0.5421<br>0.1021<br>0.0765<br>0.1021<br>0.1530<br>0.0243 | 3PL-5 |
| **-0.10** | 0.0421<br>0.2135<br>0.1600<br>0.2135<br>0.3201<br>0.0508 | 3PL-5 |
| **0.10** | 0.2421<br>0.1689<br>0.1266<br>0.1689<br>0.2533<br>0.0402 | 3PL-5 |
| **0.20** | 0.3421<br>0.1466<br>0.1099<br>0.1466<br>0.2199<br>0.0349 | 3PL-5 |
| **0.30** | 0.4421<br>0.1243<br>0.0932<br>0.1243<br>0.1864<br>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

| Δ2 | The Best-Ranked 3PL | Δ3 | The Best-Ranked 3PL | Δ4 | The Best-Ranked 3PL | Δ5 | The Best-Ranked 3PL | Δ6 | 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.

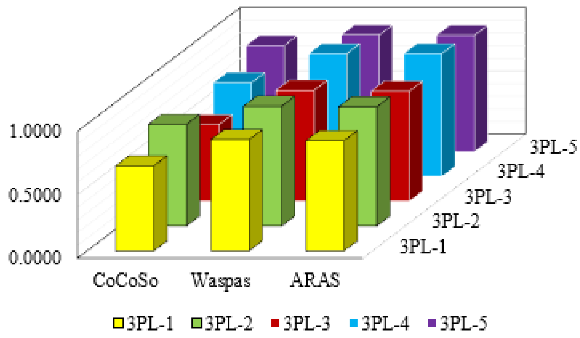


**Figure 4.** Comparative analysis with the WASPAS, TOPSIS, and ARAS

## 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.


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## Conflicts of Interest

The authors declare no conflict of interest.

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