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Selection of Logistics Service Provider for the E-Commerce Companies in Pakistan Based on Integrated GRA-TOPSIS Approach

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Abstract: Recently, the demand for third-party logistics providers has become extremely relevant and the key subject for businesses to enhance their service quality and minimize logistics costs. The key success factor for an e-commerce business is product delivery, and the third-party logistics service provider is responsible for that. Each 3PLP has its own business characteristics, meaning it is important to select the most suitable logistics provider for the e-commerce business. This study uses a combination of grey relational analysis (GRA) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, assisting decision makers in choosing the best logistics service provider for their e-business. A case study of an e-commerce company based in Faisalabad, Pakistan, was selected to demonstrate the steps of the proposed methods. In this process, seven criteria of logistics suppliers were considered, and then the best alternatives among four logistics provider companies were selected using the proposed method.

Keywords: logistics provider; outsource; decision making; e-commerce; TOPSIS; GRA

MSC: 90B06; 90B50; 90C29; 90C08

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1. Introduction

In today's world, traditional businesses are moving towards online businesses. COVID-19 introduced a major change in the buying behavior of consumers. Consumers prefer to buy products online in the comfort of their own home, rather than physically going to make a purchase. E-commerce means buying or selling products and services through the internet (e.g., websites, online stores, social media). It opens a new way of conducting business, particularly for small and medium enterprises (SMEs), because it does not require a physical store or office, and most of the business activities are performed online [1]. Logistics are considered to be the backbone of any business. Logistics in e-commerce involve picking up the order, storing it in the warehouse, sorting, and delivering the order to a specific customer at a certain time and place. In online businesses, all logistics activities are performed by third-party logistics providers (3PLPs). The goal of online businesses is to satisfy their customers. This cannot only be achieved by offering good-quality products; customers must also be provided with a high-quality service, which involves delivering goods on time and to the correct location. There are different third-party logistics providers that are available in the market, each with their own business objectives and services. The evaluation and selection of logistics providers is a complex problem because it includes different alternatives and selection criteria [2–4].

For developing countries such as Pakistan, with a population of 220 million and 183 million active internet users, the penetration of e-commerce business is very fast. Pakistan's Ministry of Commerce revealed that the growth rate of e-commerce business is up to 35%, with the value of Rs being 96 billion in the first four months of 2021. The majority (98%) of e-commerce businesses in Pakistan are small and medium enterprises (SME), meaning they are considered to be very important for Pakistan's economy. In total, 22 third-party logistics companies are working with e-commerce businesses in Pakistan. This makes the selection of the appropriate logistics providers a key issue for e-commerce business because it allows businesses to gain a competitive advantage and achieve operational efficiency and customer satisfaction. Most of the SMEs lack in resources, meaning the evaluation and selection of a logistics service provider (LSP) are key factors, and the area addressed in this study [5]. The aim of this study was to prioritize and select the best third-party logistics provider that meets the criteria and requirements set by e-commerce companies operating in Pakistan. In previous studies, we identified different criteria for the evaluation and selection of 3PLPs, such as low delivery costs, flexibility, customization, operational efficiency, lead time, service quality, reverse logistics, warehousing, order pickup, order delivery, firm reputation, reliability, green technology, and customer satisfaction [6,7]. Due to the fact that the selection and evaluation process consists of decision makers, alternatives, and criteria, it is considered as a multi-criteria decision-making problem (MCDM) that needs to be solved. Different methods have been used before for the selection of 3PL providers, such as the fuzzy TOPSIS, AHP, SWARA, and MOORA methods [1,2,4,8–11].

In previous years, studies have been carried out on the selection of 3PLPs in different industries and countries. For example, Adal et al. [2] checked the application of the proposed approach on a textile company in Turkey. Aggrawal [8] checked the application of the proposed method on a manufacturing company in India. Raut et al. [10] checked the practical application of their approach on a mining firm. Peng [4] used an example of a food company in regard to choosing the right logistics service provider. Ravi et al. [12] checked the application of the proposed approach on a computer company. Bai et al. [13] proposed the use of a model for selecting a 3PLP for an e-commerce company in China. However, to the best of our knowledge, no previous study has focused on the selection of 3PLPs for e-commerce businesses specifically in Pakistan. To fulfill this research gap, this study proposes the use of the integrated TOPSIS and GRA methods for the evaluation and selection of third-party logistics providers for e-commerce businesses in Pakistan. Due to the decision-making process involved, and the subjectivity of qualitative criteria, group MCDM results in uncertainty and vagueness. Grey relational analysis is a part of grey system theory. The GRA method has been successfully used in cases where there is uncertainty or only partial information is available. The TOPSIS method obtains a compromised solution, with the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution [14]. Moreover, the case of an e-commerce company named Denim Leftover, based in Pakistan, was considered, in order to check the application of the proposed approach. The novelty of this study can be found in its selection criteria, as these criteria are defined by the experience of experts (decision makers) in this field, as well as past studies, particularly regarding Pakistan's e-commerce business perspective. Furthermore, the main contributions of this article are as follows:

(1) This study helps e-commerce businesses, as well as new e-businesses, in Pakistan to choose and select the best third-party logistics service provider company; the one that is compatible with the business's objectives will lead the company to achieving a competitive advantage and suitable customer satisfaction, and minimizing their logistics costs.

(2) This study highlights the 3PLPs that are lacking in regard to each criterion, allowing 3PLPs to improve their business functions, and to attract more e-businesses as their customers.

The structure of this paper is as follows: Section 2 provides a literature review on the selection and evaluation of 3PLPs, as well as the method selection. Section 3 defines the methodology and the framework of the TOPSIS and GRA methods. The results analysis of the case study in Pakistan is presented in Section 4. Finally, Section 5 includes the discussion and conclusion of this study.

2. Literature Review

2.1. Development Status of Third-Party Logistics Suppliers in Pakistan

The third-party logistics provider sector has become a thriving industry over the last decade. Outsourcing logistics activities enables companies to save time and pay more attention to other core business activities. Furthermore, third-party logistics service providers have expertise in their field, enabling companies to minimize their logistics costs, resolve bottleneck problems, promise the delivery of goods, and provide a high-quality service to customers. With the 23rd largest road network in the world and one of the fastest-growing economies in Asia, Pakistan is the key player in global third-party logistics. Modern and advanced transport and logistics infrastructure are the key success factors of a country. During the last two decades, Pakistan has invested a huge amount of money in the development of the country's logistics infrastructure and has been involved in mega development projects under the China–Pakistan Economic Corridor (CPEC) [15]. According to the report issued by the Ministry of Commerce, Pakistan is a country that has more than 98% of businesses that are small and medium enterprises (SMEs). Undoubtedly, they have contracted with 3PLPs. E-commerce development has a direct impact on the economic development of any country. As e-businesses are an interest in Pakistan, these numbers are gradually increasing, and it is estimated that by 2040, 95% of retail sales and purchases will be made online [16]. In e-commerce, almost all companies use the services of 3PLPs which are responsible for collecting, warehousing, sorting, and shipping the parcels to customers. One of the key stakeholders of an e-commerce company is its customers, and customer satisfaction is the top priority of any company as it can only be attained by achieving their expectations such as high-quality products and on-time deliveries. It is important to note that every third-party logistics service provider company has its business model and characteristics, and the choice of the best suitable 3PLP is very important for an e-commerce company. There are different evaluation criteria set by e-commerce companies, and different methods have been used by researchers to evaluate and select the best alternative logistics supplier. The methods and criteria are discussed under the next heading.

2.2. Method Selection

Various noteworthy studies have applied different multi-criteria decision-making (MCDM) techniques according to various decision selection criteria for the evaluation and selection of the appropriate 3PLP. For example, Raut et al. [10] proposed an integrated data envelopment analysis (DEA) and AHP-based decision framework to evaluate and select a 3PLP. They concluded that the DEA coefficient score is very important which should be taken seriously by the management while making decisions on an efficient and effective 3PLP. Ravi et al. [12] used a combination of AHP and TOPSIS methods to solve the problem of selecting a 3PRLP in the computer industry. They considered 10 attributes in their study. Ilgin and Ali [17] proposed an integrated MCDM methodology to solve a problem related to the return of used products which is considered reverse logistics. They designed a 3PRLP network for efficient dealing of used products. In the study of Bali et al. [18], they introduced an integrated DEA-TOPSIS method to evaluate and select a 3PLP for an electrical radiator company. This method can be used for the evaluation of alternatives in different periods. Adal et al. [2] developed a systematic and integrated decision analysis approach for 3PLP evaluation and selection. They used an integrated DEMATEL, ANP, and DEA approach for their study. Datta et al. [19] proposed the six indexes for 3PL providers, which were finance performance, service level, client relationship, management, infrastructure, and enterprise culture, using the fuzzy TOPSIS method. Perçin et al. [20] introduced integrated fuzzy multiple-objective approaches and proposed a model which can be useful for 3PLP selection decisions faced by the Turkish autoparts industry. Raut et al. [21] presented a sustainable relationship framework for 3PLP selection from an environmental sustainability perspective based on data envelopment analysis (DEA) and the analytical network process (ANP). Choudhury et al. [22] suggested the following evaluation indexes that should be considered when selecting a sustainable 3PL provider: response time, transportation cost, operating cost, vehicle rejection, vehicle capacity, corporate social responsibility, and health and safety expenses, based on the DEA methodology. Aggarwal [8] highlighted the 14 major selection criteria for 3PL providers based on the literature and used the DEA-AHP technique to select the most appropriate 3PL provider. Wang et al. [11] adopted the fuzzy analytical hierarchy process (fuzzy AHP) and fuzzy TOPSIS methods to select a 3PRLP for an online business in Vietnam. They found lead time, customer voice, cost, delivery, and service and quality to be the most important factors when selecting a 3PRLP. Xu et al. [23] argued that five factors should be considered by e-commerce companies when selecting a third-party logistics service provider: logistics service quality, logistics service cost, logistics enterprise capability, level of information, and enterprise development prospects, based on the AHP method. Bai et al. [13] proposed an AHP model for the selection and evaluation of third-party logistics providers for e-commerce businesses by considering cost, stability, service level, and sustainability as an evaluation index. Nuengphasuk and Samanchuen [1] found that location, cost, and delivery are the dominant evaluation indexes in the selection process of 3PL providers based on the AHP and TOPSIS methods. Peng et al. [4] established an AHP judgment matrix for third-party logistics provider evaluation with cost, operating efficiency, service quality, and technology level.

In almost every scenario, a reliable decision requires the analysis of different criteria and alternatives, and in more complex cases, it almost becomes difficult to make the optimal decision. To solve these issues, different multi-criteria decision-making (MCDM) methods were proposed in previous studies [14,24]. However, this study uses the combination of TOPSIS and GRA methods for the selection and evaluation of the best alternative logistics provider. The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is a widely used method to solve multi-criteria decision-making problems as it can avoid some flaws of existing multi-attribute methods [25]. It was first proposed in 1981 by Hwang and Yoon [26]. The TOPSIS method is measured by the distance between schemes, where the shortest distance of the object from the ideal solution and the furthest distance from the non-ideal solution are considered to represent the best scheme [27]. When the closeness of the positive and negative ideal schemes at any point in the TOPSIS method is equal, the pros and cons of the schemes cannot be distinguished. TOPSIS is widely used to solve multi-criteria decision-making problems [3,24,28–30]. The grey relational analysis (GRA) method was developed by Deng in 1982, which focuses on the decision-making process, with partial information known and other information yet to be discovered [31]. In this method, the correlation between the reference sequence and comparability sequences is obtained, and thereafter, the ranking is established according to this correlation [9]. Moreover, the GRA method analyzes the changing trend between alternatives and can serialize and present the interrelationships of physical prototypes. However, this method can only analyze the relevance of the same factors and calculate the degree of relevance of the factors in each plan to the same ideal plan factor. Only using grey relational analysis (GRA) as a decision-making problem tool has insufficient comprehensiveness. Therefore, this article integrates the TOPSIS method and GRA method to solve the problem of the selection of a third-party logistics provider.

2.3. Selection of Logistics Service Provider Criteria

The criteria for selecting the third-party logistics service provider were obtained from previous studies; many criteria were provided and studied in previous studies according to the nature of the business. In this study, the seven most important criteria are defined as area of delivery (C1), delivery cost (C2), lead time (C3), payment settlement time (C4), service quality (C5), flexibility (C6), and IT capabilities (C7). These criteria can be used in the evaluation and selection process of third-party logistics service providers for e-commerce businesses. The crucial factors identified through the extensive literature review and experts are presented in Table 1. The definition of each criterion is explained as follows.

Table 1. List of criteria used in third-party logistics provider selection.

Sr. No.	Criteria	Description	References
1	Area of Delivery (C1)	This is an important factor to consider in the 3PLP selection process. It refers to the delivery coverage area in which logistics companies can deliver.	[1,2,6,7,18,22]
2	Delivery Cost (C2)	Cost delivery generally includes the cost for delivery of the product to the customer.	[1,2,6–8,11,13,18,19,23]
3	Lead Time (C3)	This includes the time that is required for the delivery of customer orders. It is also called the transit time.	[2,6,8,10,11,13,18,21–23]
4	Payment Settlement Time (C4)	This is considered an important evaluation criterion for selecting a 3PLP because the Pakistan payment system uses cash on delivery (COD) which means the customer pays after receiving the order. Moreover, payment is first transferred to the 3PLP company's account, and after that, it will be given to an e-commerce company. Therefore, this is the time taken by 3PLPs to give the order payment to the e-commerce company.	[6,13,15,22]
5	Service Quality (C5)	Service quality is related to customer satisfaction. It is the responsibility of the company to deal with customers during the delivery process and provide after-sales services.	[1,4,6,11,18,21,22]
6	Flexibility (C6)	It is the responsibility of an organization to adapt to meet the customers' demands and changing situations of the future. This also includes the ability to respond to the uncertainty of customers.	[1,6–8,10,11,18,19,23]
7	IT Capabilities (C7)	This refers to an information system and tracking system for customers to keep track of their packages and check the delivery status via a mobile application or website.	[1,2,7,8,18,29]

3. Model Building

3.1. Index Assignment

The seven indicators determined in Section 2 are all qualitative indicators, and the expert survey method was used to determine the specific value of each evaluation index. Five experts were used for subjective assignment, and the relative weight of these five experts was determined according to their relative importance:

$$\omega = (\omega_1, \omega_2, \ldots, \omega_5), \text{ and } \sum_{i=1}^{5} \omega_i = 1 \tag{1}$$

Assuming that the five-person expert group's survey concludes on each evaluation index, and each is divided into 7 levels, the corresponding relationship between the 7-level linguistic evaluation value and the degree of membership is established. The specific corresponding relationship is shown in Table 2.

Table 2. Correspondence between linguistic variable values and evaluation values.

Linguistic Variables	Judgment Value
Best (F1)/Highest (W1)	0.95
Very good (F2)/Very high (W2)	0.85
Good (F3)/High (W3)	0.70
Medium (F4)/Medium (W4)	0.50
Poor (F5)/Low (W5)	0.30
Very poor (F6)/Very low (W6)	0.15
Very poor (F7)/Very low (W7)	0.05

If the expert investigation conclusions are x_i, the comprehensive evaluation index y of each evaluation index can be expressed as $y = \sum_{i=1}^{5} \omega_i x_i$.

3.2. Construction of Decision Matrix

After the preliminary screening of experts, there are still m logistics suppliers to choose from, and there are n evaluation indicators to build a decision matrix A.

Among them,

$$A = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ a_{m1} & a_{m2} & \ldots & a_{mn} \end{bmatrix} \tag{2}$$

In order to eliminate the impact of different evaluation index dimensions on the evaluation results, firstly, the index matrix is normalized.

For the benefit index, the normalization operator is

$$b_{ij} = \frac{a_{ij}}{\min\limits_{1 \le i \le m} a_{ij}},\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n. \tag{3}$$

For the cost index, the normalization operator is

$$b_{ij} = 1 - \frac{\min\limits_{1 \le i \le m} a_{ij} - a_{ij}}{\max\limits_{1 \le i \le m} a_{ij}},\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n. \tag{4}$$

After the data are normalized, the normalized decision matrix C can be obtained

$$C = \begin{bmatrix} c_{11}c_{12}\ldots c_{1n} \\ c_{21}c_{22}\ldots C_{2n} \\ \ldots\ldots\ldots \\ c_{m1}c_{m2}\ldots c_{mn} \end{bmatrix} \tag{5}$$

Among them, $c_{ij} = \frac{b_{ij}}{\sum\limits_{i=1}^{m} b_{ij}}$.

3.3. Determination of Evaluation Index Weight

The methods to determine the weight of each index include the subjective method, objective method, and combined subjective and objective method. The subjective evaluation method includes the AHP method and expert evaluation method, which is limited by decision makers' preferences, cognitive level, and experience. The common methods of the objective assignment method include the information entropy method, deviation method, and normal distribution method, which can better retain the objectivity of decision making information, but it is easy to ignore the subjective bias of decision makers. Taking into account the advantages and disadvantages of subjective and objective assignment and improving the reliability of the weight, the combination of the subjective and objective methods is usually used for assignment.

The subjective weight can be evaluated by the decision maker, and therefore the weight of the j index is $\vec{\lambda}_j$.

The entropy weight method is used to determine the objective weight of the wordlist, the information entropy of the j index is

$$H_j = -\frac{1}{In\ m} \sum_{i=1}^{m} c_{ij} In\ c_{ij} \tag{6}$$

and the entropy weight is

$$\overleftarrow{\lambda}_j = \frac{1 - H_j}{\sum\limits_{j=1}^{n} \left(1 - H_j\right)} \tag{7}$$

The comprehensive weight is

$$\lambda_j = \frac{\overrightarrow{\lambda}_j \overleftarrow{\lambda}_j}{\sum\limits_{j=1}^{n} \overrightarrow{\lambda}_j \overleftarrow{\lambda}_j},\ j = 1, 2, \ldots, n \tag{8}$$

The index matrix is weighted to obtain the weighted decision matrix D.

$$D = \begin{bmatrix} d_{11} & d_{12} & \ldots & d_{1n} \\ d_{21} & d_{22} & \ldots & d_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ d_{m1} & d_{m2} & \ldots & d_{mn} \end{bmatrix} \tag{9}$$

Among them, $d_{ij} = \omega_j c_{ij},\ i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n.$

3.4. TOPSIS Method

The TOPSIS method realizes comparative analysis through the distance between the alternative scheme and the ideal target. The best and worst hypothetical schemes are drawn up through each scheme, and then the ideal distances between each scheme and the best and worst schemes are compared for selection. The calculation distance is the key point of this method. If a scheme is the furthest away from the unsatisfactory scheme and closest to the optimal scheme, the optimal selection scheme can be deduced. TOPSIS is a commonly used evaluation method of multi-objective decision making. In terms of data processing, it can retain the most original information in each alternative for analysis. The calculation process of this method is simple, and the idea is to achieve a clear, good integrity, adaptability, and reliability. The calculation steps are as follows:

Step 1: Build a decision matrix $A = \left(a_{ij}\right)_{m \times n}$;

Step 2: Calculate the weight value of the indicator λ;

Step 3: Construct a weighted decision matrix $D = \left(d_{ij}\right)_{m \times n}$;

Step 4: Determine the ideal plan, and the positive and negative ideal plans; the algorithm formula of the positive and negative ideal plans is as follows:

$$d^+ = \left(d_1^+, d_2^+, \ldots, d_m^+,\right)$$
$$d^- = \left(d_1^-, d_2^-, \ldots, d_m^-,\right)$$

where $\begin{cases} d_j^+ = \max\limits_{1 \le i \le x} & d_{ij} \\ d_j^- = \min\limits_{1 \le i \le x} & d_{ij} \end{cases}$;

Step 5: Calculate the Euclidean distance between each plan and the positive and negative ideal plan:

$$D_i^+ = \sqrt{\sum_{i=1}^{n} \left(d_{ij} - d_j^+\right)^2}$$

$$D_i^- = \sqrt{\sum_{i=1}^{n} \left(d_{ij} - d_j^-\right)^2}$$

Step 6: Calculate the relative closeness:

$$C_j = \frac{D_i^+}{D_i^+ + D_i^-}$$

Step 7: Sort the schemes through the calculated proximity and select the optimal scheme.

3.5. GRA Method

By analyzing the numerical relationship between the indicators of alternative schemes, the grey correlation master calculates the correlation degree between all indicators of each scheme and the ideal scheme. By analyzing the situation of each scheme, the correlation degree of its change state with time is studied. If the change degree of the correlation index is higher, the change degree is higher; on the contrary, the degree of correlation is lower. Therefore, the correlation between schemes can be measured by the grey correlation degree and can be analyzed and compared by comparing the correlation degree between the ideal scheme and other schemes. The steps are as follows:

Step 1: Construct a decision matrix $A = \left(a_{ij}\right)_{m \times n}$;

Step 2: Calculate the weight value of the indicator w;

Step 3: Construct a weighted normalized decision matrix. Firstly, according to Eqution (5), normalize the decision matrix to obtain $\mathrm{C} = \left(c_{ij}\right)_{x \times m}$, according to the formula $Y = w * \mathrm{c}$, the weighted decision matrix $D = \left(d_{ij}\right)_{x \times m}$ is obtained.

Step 4: Determine the ideal solution.

Through $D = \left(d_{ij}\right)_{x \times m}$ identifying the ideal solution α^+, α^-.

Step 5: Calculate the programs with the program over α^+, α^-. The degree of association is

$$r_{ij} = \frac{\underset{i}{min}\underset{j}{\min}\left|\alpha_{0j} - \alpha_{ij}\right| + \rho \underset{i}{\max}\underset{j}{\max}\left|\alpha_{0j} - \alpha_{ij}\right|}{\left|\alpha_{0j} - \alpha_{ij}\right| + \rho \underset{i}{\max}\underset{j}{\max}\left|\alpha_{0j} - \alpha_{ij}\right|}$$

where r_{ij} and j are the similarities of the points. Research shows that the resolution coefficient $\rho = 0.5$ is the best; therefore, this paper took $\rho = 0.5$.

Step 6: Calculate the overall relevance of each program:

$$R_i = \frac{1}{n}\sum_{j=1}^{n} r_{ij}$$

Step 7: Calculate the closeness:

$$\xi_i = \frac{R_i^+}{R_i^+ + R_i^-}$$

Step 8: Calculate the closeness degree by the grey correlation, sort the schemes, and select the optimal scheme.

3.6. Integrated Method Based on GRA-TOPSIS

The TOPSIS method is measured by the distance between the schemes, but when the closeness of the positive and negative ideal schemes at any point in the TOPSIS method is equal, the pros and cons of the schemes cannot be distinguished. The grey correlation method analyzes the changing trend between alternatives and can serialize and present the interrelationships of physical prototypes. However, this method can only analyze the relevance of the same factors and calculate the degree of relevance of the factors in each plan to the same ideal plan factor. Only with the grey correlation as a decision-making problem tool is there a lack of comprehensiveness. Based on the advantages and disadvantages of the two methods in decision analysis, this article combines the TOPSIS method with the GRA method to solve the problem of the comprehensiveness of the single method in the evaluation process and proposes a third-party logistics supplier selection model based on GRA-TOPSIS. The model solving steps are as follows:

Step 1: Build a decision matrix;

Step 2: Determine the weight of the evaluation index and construct a weighted decision matrix;

Step 3: Determine the positive ideal solution and the negative ideal solution:

$$d^{+} = \left(d_1^{+}, d_2^{+}, \ldots, d_{m'}^{+}\right) \tag{10}$$

$$d^{-} = \left(d_1^{-}, d_2^{-}, \ldots, d_{m'}^{-}\right) \tag{11}$$

where $\begin{cases} d_j^{+} = \max\limits_{1 \le i \le x} \quad d_{ij} \\ d_j^{-} = \min\limits_{1 \le i \le x} \quad d_{ij} \end{cases}$;

Step 4: Calculate the Euclidean distance:

$$D_i^{+} = \sqrt{\sum_{i=1}^{n}\left(d_{ij} - d_j^{+}\right)^2} \tag{12}$$

$$D_i^{-} = \sqrt{\sum_{i=1}^{n}\left(d_{ij} - d_j^{-}\right)^2} \tag{13}$$

Step 5: Calculate the grey correlation coefficient of each plan and the ideal plan $R = \left(r_{ij}\right)_{x \times m'}$ where $\rho = 0.5$:

$$g_{ij}^{+} = \frac{\underset{i}{min}\underset{j}{\min}\left|d_j^{+} - d_{ij}\right| + \rho \underset{i}{\max}\underset{j}{\max}\left|d_j^{+} - d_{ij}\right|}{\left|d_j^{+} - d_{ij}\right| + \rho \underset{i}{\max}\underset{j}{\max}\left|d_j^{+} - d_{ij}\right|} \tag{14}$$

$$g_{ij}^{-} = \frac{\underset{i}{min}\underset{j}{\min}\left|d_j^{-} - d_{ij}\right| + \rho \underset{i}{\max}\underset{j}{\max}\left|d_j^{-} - d_{ij}\right|}{\left|d_j^{-} - d_{ij}\right| + \rho \underset{i}{\max}\underset{j}{\max}\left|d_j^{-} - d_{ij}\right|} \tag{15}$$

Step 6: Calculate the overall grey correlation degree:

$$g_i^{+} = \frac{1}{n}\sum_{j=1}^{n} r_{ij}^{+} \tag{16}$$

$$g_i^{-} = \frac{1}{n}\sum_{j=1}^{n} r_{ij}^{-} \tag{17}$$

Step 7: Normalize the Euclidean distance and the grey correlation degree:

$$D_i^{+} = \frac{d_i^{+}}{\max d_i^{+}} \quad D_i^{-} = \frac{d_i^{-}}{\max d_i^{-}} \tag{18}$$

$$G_i^{+} = \frac{g_i^{+}}{\max r_i^{+}} \quad G_i^{-} = \frac{g_i^{-}}{\max r_i^{-}} \tag{19}$$

Step 8: Calculate the closeness:

$$C_i^{+} = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \tag{20}$$

$$Q_i^{+} = \frac{G_i^{+}}{G_i^{+} + G_i^{-}} \tag{21}$$

$$T_i^{+} = \eta C_i^{+} + (1 - \eta) Q_i^{+} \tag{22}$$

Decision makers can set the value of η according to their preferences.

Moreover, Figure 1 shows the flow chart of the proposed approach used for solving the multi-criteria decision-making problem.

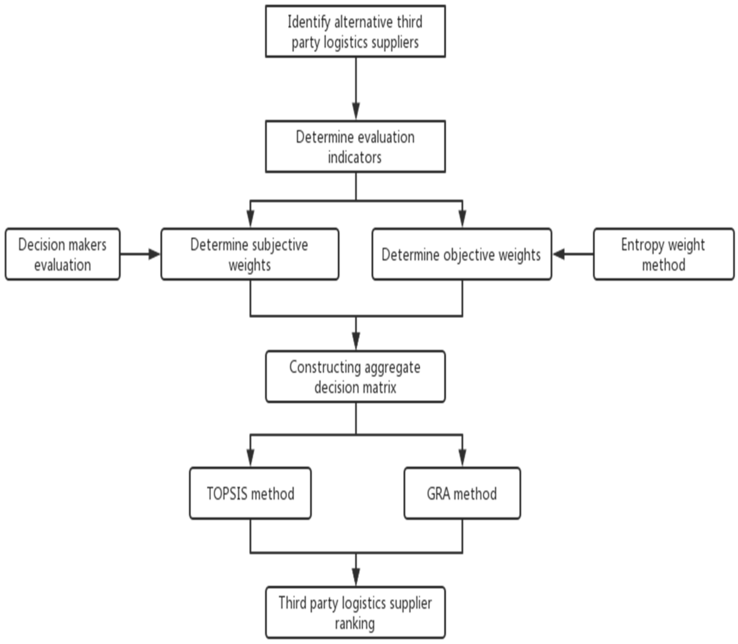

Figure 1. Flow chart of proposed methodology.

4. Case Study

In this section, we present and explain an example by using the methodology explained above. The e-commerce company Denim Leftover, based in Faisalabad, Pakistan, was selected. This is an SME having not more than 50 employees. For SMEs, it is important to select the best 3PLP supplier for their business in order to achieve competitiveness, efficiency, and customer satisfaction. For e-commerce companies, all the logistics activities are performed by third-party logistics providers. This is a complex problem that needs to be solved. This example was chosen to perform the selection of a third-party logistics provider for an e-commerce company (Denim Leftover).

Five experts were selected to determine the evaluation criteria based on their expertise. The evaluation criteria include the area of delivery, delivery costs, service quality, payment schedule, lead time, flexibility, and IT capabilities. According to Section 2.3, the set of evaluation criteria is defined, where C1 represents the area of delivery, C2 represents the delivery cost, C3 represents the lead time, C4 represents the payment settlement time, C5 represents service quality, C6 represents flexibility, and C7 represents IT capabilities. Where C1, C4, C5, C6, and C7 are benefit indicators, the greater the index value, the better; C2 and C3 are cost indicators. The smaller the indicator value, the better. After pre-assessment, a list of potential logistics service providers was developed. A total of four third-party logistics provider alternatives were selected which are Pakistan Post, TCS, M&P, and Leopards. The hierarchical structure for third-party logistics provider selection can be seen in Figure 2.

Step 1: Build a decision matrix and a normalized decision matrix.

The relative weight of the five experts is $\omega = (\omega_1, \omega_2, \ldots, \omega_5)$. The expert survey method was used for assignment, and the relative weight of the five experts is

$$\omega = (0.21,\ 0.16,\ 0.24,\ 0.28,\ 0.11)$$

Five experts obtained the evaluation index assignment table of four candidate logistics suppliers according to Table 2. The results are shown in Table 3. According to Equation (1) and Table 3, the decision matrix is obtained, and the results are shown in Table 4. According to Equations (3) and (4) and Table 3, we can present Table 5.

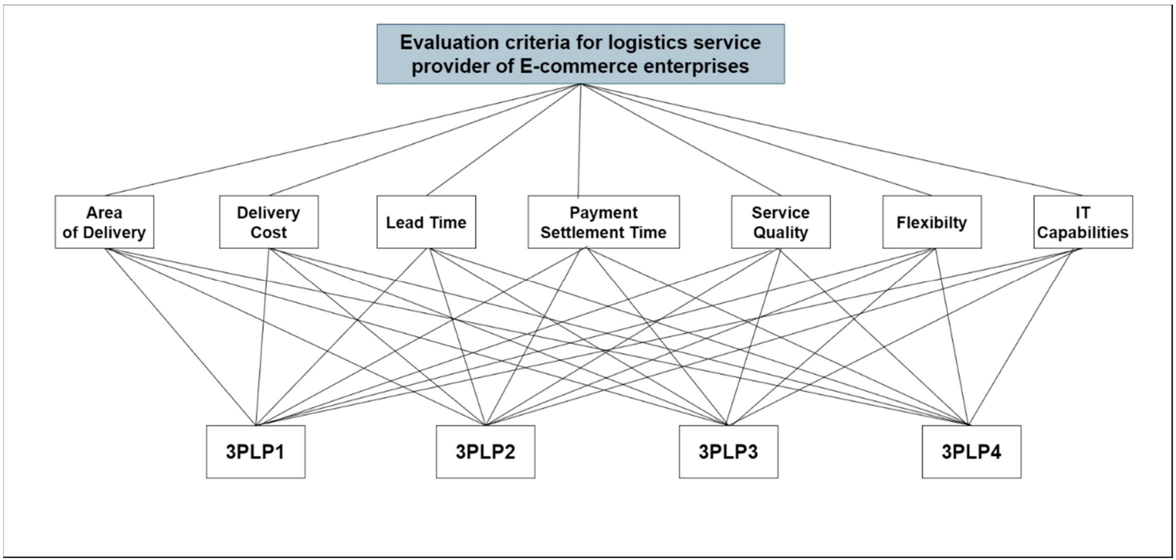

Figure 2. Hierarchical structure for 3PLP selection (source: authors' compilation).

Table 3. Summary table of decision makers' evaluation grades.

	A1					**A2**					**A3**					**A4**				
	E1	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**
C1	F1	F2	F1	F2	F1	F2	F3	F3	F1	F1	F2	F3	F3	F3	F4	F1	F1	W2	F2	F4
C2	W5	W5	W4	W6	W5	W4	W5	W5	W5	W5	W3	F5	W5	W4	W4	W6	W4	W5	W5	W4
C3	W4	W5	W5	W6	W6	W6	W5	W5	W5	W6	W5	W5	W5	W4	W5	W4	W5	W5	W5	W4
C4	F2	F2	F2	F2	F1	F1	F2	F2	F1	F3	F2	F2	F2	F1	F3	F5	F3	F3	F4	F3
C5	F3	F6	F4	F4	F3	F1	F2	F3	F3	F2	F2	F2	F3	F1	F2	F4	F4	F4	F3	F5
C6	F4	F4	F3	F3	F4	F2	F3	F2	F3	F2	F3	F4	F4	F3	F3	F5	F3	F3	F3	F4
C7	F2	F2	F2	F2	F2	F1	F1	F1	F1	F1	F1	F1	F2	F1	F1	F1	F1	F3	F2	F3

Table 4. Decision matrix for selecting third-party logistics providers.

	A1	**A2**	**A3**	**A4**
C1	0.9060	0.8290	0.7095	0.8485
C2	0.3063	0.3420	0.4620	0.3225
C3	0.2835	0.2520	0.3550	0.3640
C4	0.8610	0.8825	0.8615	0.5600
C5	0.5080	0.7930	0.8420	0.5340
C6	0.6040	0.7840	0.6200	0.5940
C7	0.8500	0.9500	0.9260	0.8345

Table 5. The normalized decision matrix for selecting a third-party logistics provider.

	A1	**A2**	**A3**	**A4**
C1	0.2751	0.2517	0.2155	0.2577
C2	0.2136	0.2387	0.3225	0.2251
C3	0.2258	0.2007	0.2836	0.2899
C4	0.2720	0.2788	0.2722	0.1769
C5	0.1898	0.2962	0.3145	0.1995
C6	0.2321	0.3013	0.2383	0.2283
C7	0.2387	0.2668	0.2601	0.2344

Step 2: Determine the weight of the evaluation index and construct a weighted normalized decision matrix.

Five decision makers returned the subjective weights for the seven indicators as $\vec{\omega} = (0.1093, 0.1639, 0.1366, 0.1913, 0.1311, 0.0984, 0.1694)$, and the objective weights calculated by the entropy weight method were $\overleftarrow{\omega} = (0.0492, 0.1781, 0.1483, 0.1967, 0.3210, 0.0874, 0.0193)$ according to Equations (6) and (7). Then, the combined weights $\omega = (0.0367, 0.1994, 0.1383, 0.2571, 0.2874, 0.0587, 0.0223)$ were calculated according to Equation (8). According to the weighted normalized decision matrix, the results are shown in Table 6.

Table 6. The weighted normalized decision matrix for selecting a third-party logistics provider.

	A1	**A2**	**A3**	**A4**
C1	0.0101	0.0092	0.0079	0.0095
C2	0.0426	0.0476	0.0643	0.0449
C3	0.0312	0.0278	0.0392	0.0401
C4	0.0699	0.0717	0.0700	0.0455
C5	0.0545	0.0851	0.0904	0.0573
C6	0.0136	0.0177	0.0140	0.0134
C7	0.0053	0.0060	0.0058	0.0052

Step 3: Determine the positive ideal point and the negative ideal point.

According to Equations (10) and (11), the positive ideal point and the negative ideal point are obtained:

$$d_1^+ = 0.0101,\ d_4^+ = 0.0717,\ d_5^+ = 0.0904, d_6^+ = 0.0177, d_7^+ = 0.0060,$$
$$d_2^- = 0.0426,\ d_3^- = 0.0278$$

Step 4: Calculate the Euclidean distance and the grey correlation degree.

The correlation coefficients were calculated according to Equations (12)–(19), and the results are shown in Table 7.

Table 7. Euclidean distance and grey correlation degree for choosing a third-party logistics provider plan.

	TOPSIS				**Grey Relational Analysis Method**			
	$\mathbf{d^+}$	$\mathbf{d^-}$	$\mathbf{D^+}$	$\mathbf{D^-}$	$\mathbf{g^+}$	$\mathbf{g^-}$	$\mathbf{G^+}$	$\mathbf{G^-}$
A1	0.0361	0.0035	0.8514	0.1423	0.5289	0.5647	0.6659	0.8489
A2	0.0053	0.0050	0.1250	0.2033	0.6587	0.6652	0.8293	1.0000
A3	0.0046	0.0246	0.1085	1.0000	0.7943	0.5216	1.0000	0.7841
A4	0.0424	0.0126	1.0000	0.5211	0.6621	0.6525	0.8336	0.9809

Step 5: Comprehensive closeness.

The preference factors η are 0, 0.2, 0.4, 0.5, 0.6, 0.8, and 1.0, respectively, and the ranking of the advantages and disadvantages of each alternative is obtained. The results are shown in Table 8.

It can be seen from the table above that when the value changes from 0 to 1, the result of the scheme optimization ranking is relatively stable, which shows that the reliability and stability of the model are maintained. Alternative A3 always ranks first, indicating that it is the best supplier. Alternative A2 holds the second position, which shows that it is the second best alternative. Alternative A4 is the third priority, and Alternative A1 always ranks last, which means that it is the least important; therefore, Alternative A1 is least likely to be chosen.

Table 8. Sorting results of selecting third-party logistics providers.

Preference Factor η	A1	A2	A3	A4
0	4	3	1	2
0.2	4	2	1	3
0.4	4	2	1	3
0.5	4	2	1	3
0.6	4	2	1	3
0.8	4	2	1	3
1.0	4	2	1	3

5. Discussion

In the digital era, where everything is connected through the internet, people are more likely to buy online, especially with the advantage of it being 24/7 and in the comfort of their own home, which allows customers to take as much time as they need rather than leaving unsatisfied and unwillingly wanting to shop in other stores. The e-commerce industry in Pakistan is growing swiftly. The key success factor of e-commerce business is product delivery, which is carried out by 3PLPs. The elevation in e-commerce opens the door for a new business type called third-party logistics providers. Third-party logistics providers have come up with solutions to problems of e-commerce companies related to warehousing, packing, and delivery of goods or services to their customers. As logistics are considered as the backbone of any business, in the case of e-business, choosing the right logistics company is the key. The selection of 3PLPs has become a critical issue that is the roadmap to the success of e-commerce business as this will lead e-commerce companies to achieving a competitive advantage and help to attain customer satisfaction. For a country such as Pakistan, where almost 98% of e-commerce businesses are small and medium enterprises, working with a suitable 3PLP provides them with benefits that ultimately help them to run their business smoothly. There are several key third-party logistics suppliers available in Pakistan's market, and each 3PLP has its business models and objectives. Therefore, there is a big issue for e-commerce companies to choose a compatible 3PLP that can meet their business objectives. Due to the decision makers, different attributes, and alternatives, the selection of 3PLPs is considered an MCDM problem. Moreover, the results of this study have various implications that are as follows:

(1) The proposed model can aid decision makers in selecting the best 3PLP from various assessable options. Moreover, this model enables decision makers to visualize the impact of various criteria on the alternative at the final solution.
(2) The findings of this paper can assist e-commerce businesses in gaining a better understanding of the third-party logistics supplier selection process and in finding the best 3PLP for their business according to their defined selection criteria.
(3) This model can help logistics managers to comprehend the relative relationship and the degree of significance among the criteria and guide them in finding their influence on the 3PLP selection process.

6. Conclusions

Third-party logistics providers are the main part of the logistics process of a company because they help to reduce costs, improve efficiency, and achieve customer satisfaction. Therefore, the evaluation and selection of 3PLPs are important. The main objective of this study was to select the most appropriate third-party logistics provider (3PLP), and throughout the study, MCDM methods were utilized. This paper proposed an evaluation method based on the TOPSIS and grey relational analysis (GRA) methods on the issue of the selection of third-party logistics providers, adopted a more realistic subjective and objective comprehensive weighting method, and introduced preference factors so that the algorithm can be based on the individual factors of the decision maker, which are adjusted to enhance the flexibility of the algorithm and improve the accuracy of decision making. The proposed approach can assist decision makers in systematically evaluating trade-offs among multiple factors and criteria, therefore helping them in settling on more informed decisions when evaluating and selecting a 3PLP. The results show that Alternative A3 (M&P) is the best suitable third-party logistics company because A3 willingly achieved the selection criteria set by the e-commerce company and decision makers.

There are some limitations related to this current study that can be tended to. In future studies, the number of criteria and alternatives may change according to the needs of the company for a 3PLP. Furthermore, other multi-criteria decision-making methods such as AHP, DEMATEL, and DEA can be used for the evaluation and selection process of 3PLPs. Moreover, in the construction of the algorithm model, considering the uncertainty of third-party logistics supplier selection, the combination of fuzzy set theory and multi-criteria decision-making methods is also a future research direction.

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