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WEIGHTING THE FACTORS AFFECTING LOGISTICS OUTSOURCING

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Abstract: *Today, growing and changing competitive conditions, products, and services, free movement of labor, and businesses with the information they develop strategies that create value to obtain a competitive advantage. Now, final buyers have the convenience of purchasing the products they demand with the features and conditions they want and at the price they accept. In such an environment, businesses use their supply chain and logistics activities more effectively and efficiently than their competitors. Today, achieving a strategic superiority in a global market where the content and quality of the products are the same is only possible by delivering the desired products to the customer at the desired price, at the desired time, in the desired amount, through the right channel, as quickly as possible and without any damage. In such a situation, the desire to focus on the main activities of the enterprises, the need for effective logistics operations, etc. logistics outsourcing has increased rapidly for reasons. Businesses can carry out logistics activities requiring expertise thanks to third party logistics (3PL) service providers in the field such as transportation, storage, customs clearance, without investing in logistics. For logistics outsourcing to be beneficial, a correct logistics service provider must be selected under the needs of the business. Selecting the right logistics service provider is important in increasing the benefit of outsourcing. In this study neutrosophic AHP was used to prioritize the factors.*

Key words: *Logistics, Outsourcing, Neutrosophic AHP.*

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1. Introduction

Nowadays, with the effects of the competitive environment and the effect of globalization, businesses transfer their work areas other than their main products to the enterprises that carry out their main activity products under the name of outsourcing to reduce costs and focus on their core competencies. In this way, businesses develop that product by focusing on their main products and at the same time, they can carry outside activities more systematically with the help of specialized enterprises.

One of the issues where businesses transfer business to a structure outside the business with the help of outsourcing other than their main products is logistics services. Businesses that feel the intensity of competition are extremely strong and think that it is difficult to allocate resources and time for logistics elements, get help from logistics companies specialized in their field to carry out one or more of their activities (such as warehousing, transportation, and inventory management) and thus, this situation provides them to become professional. Logistics services have been transferred to businesses that provide 3PL services to provide better quality and less cost. At this point, it is important for businesses that will receive 3PL services to be able to select and eliminate the companies that provide this service and to make a decision to agree with the right one.

The selection process of the 3PL business has played an important role in determining the performance of logistics activities. If a 3PL business that is not suitable for the business is selected, the quality of the logistics service is low, the efficiency of the logistics activities decreases, the customer and the business are damaged so there is a disconnection between the 3PL business and the customer and the business, etc. serious problems may be encountered. Due to these problems, the customer can reduce the reputation of the business in the sector and lead to the loss of trust in the business. In the face of increasing competition with globalization and rising customer expectations, businesses that produce products and services focus on their main abilities and skills by leaving their logistics activities to 3PL. During this process, the relations between the logistics service provider and the enterprises receiving the service have come to the fore regarding service standards. The relationships that businesses establish with logistics service providers contribute to the increasing efficiency of the buyer businesses in operational and financial matters.

The purpose of this study is to determine and weigh the factors of outsourcing in logistics companies operating in Giresun. For the solution of these extremely complicated and complex elements, Neutrosophic AHP as a Multi-Criteria Decision Making method was used. In the following part of the study, the literature has been reviewed, and the methods applied in the third part has been explained. In the fourth part, the method of the study has been applied to the problem, and in the last part, the study has been ended by making suggestions regarding the results and future studies.

2. Literature Review

If an enterprise chooses the external source from which it will receive services for the realization of its logistics activities and transfer its activities to it, it will be important that it starts by choosing 3PL enterprises that are specialized in their fields. In recent years, there are many logistics service providers and they provide advantages to their customers by effectively performing logistics activities in today's competitive environment. While choosing the 3PL businesses, the business manager, who will receive logistics services, handles all other units of the business and chooses the 3PL business that will provide the best integration to this process, suitable for the technological infrastructure, offer the most advantages, and will add positive values to the reputation and financial power of the enterprise.

When the literature has been examined; Dapiran et al. (1996) and Bhatnagar et al. (1999) have revealed that service delivery and price are the most important factors for outsourcing criteria. Boyson et al. (1999) stated three headings as service costs, customer service, and financial stability as the most important criteria. Petroni and Braglia (2000) introduced different criteria such as reputation, geographical location, financial stability, experience, technological competence, flexibility, production capacity, and management competence. Menon et al. (1998) suggested nine criteria for 3PL evaluation and selection, such as price, timely delivery, error rate, financial stability, creative management, fulfillment or exceeding promises, the presence of senior management, responding to unforeseen problems, meeting performance and quality requirements. Prater and Ghosh (2005) determined that SMEs operate abroad with the need to follow their customers in their research. Besides, the international communication problem between overseas facilities poses a major obstacle for SMEs. Another finding obtained from the research is that SMEs engaged in operational commercial activities in European countries, especially in Germany, started to be interested in environmental issues such as reverse logistics. Bottani and Rizzi (2006) developed the Fuzzy TOPSIS approach in their studies and determined nine criteria such as compatibility, financial stability, service flexibility, performance, price, physical equipment, and information systems, quality, strategic attitude, trust, and justice to select the most suitable 3PL business. It has been worked on research by Arbore and Ordanini (2006), in which the outsourcing strategies of SMEs were examined in terms of the size of the enterprise and the geographical region to which these enterprises are affiliated. In this research, it has been determined that the size of the enterprise is a relative dimension in the choice of outsourcing strategy for SMEs in terms of internal resources. Işıklar et al. (2007) used an integrated approach combining CBR, RBR, and consensus programming to address the 3PL selection problem. The evaluation criteria include cost, quality, technical ability, financial stability, successful track record, service category, personnel qualification, information technology, comparable culture, region, etc. Jharkharia and Shankar (2007) used the ANP approach in their study to select the most suitable 3PL according to four main determinative criteria such as compatibility, cost, quality, and reputation. Fu and Liu (2007) determined the weights of the criteria with the AHP technique by considering five factors for outsourcing, including cost, quality, project, certification, and delivery performance in their study. Qureshi et al., (2008) developed an interpretative structural modeling-based approach to define and classify key criteria and to examine their roles in 3PL evaluation. In the study, quality of service, size, and quality of fixed assets, management quality, computing capability, delivery performance, information sharing, and trust, operational performance, compliance, financial stability, geographic spread and range, long-term relationship, reputation, the optimal cost in operation and delivery, volatility and flexibility as 15 criteria were determined. Liu and Wang (2009) presented a three-step approach for the evaluation and selection of 3PL enterprises. In the first stage, the fuzzy Delphi method was used to define important evaluation criteria. Next, a fuzzy inference method has been applied to estimate non-eligible 3PL businesses. At the last stage, a fuzzy linear assignment approach has been developed for final selection. Mickaitis et al. (2009) obtained from their study, on the outsourcing of SMEs in Lithuania; it has been observed that outsourcing is widely used in SMEs in Lithuania, and the main factors for these enterprises to prefer outsourcing are to reduce costs, increase efficiency and productivity, and increase quality. The short-term benefits of outsourcing have been identified as reducing the need for personnel, allowing better concentration on basic activities, and reducing costs. Ji-Fan Ren et al. (2010) obtained from their study examining the determinants of the partnership quality of SMEs in China on outsourcing; it has been determined that perceived benefits of outsourcing, outsourcing competency management, the correct definition of outsourcing, and senior management's attitude towards outsourcing are significantly related to the quality of outsourcing. In light of the findings obtained from a study by O'Regan and Kling (2011) examining whether outsourcing is a competitive factor for SMEs operating in the production sector; It has been observed that small enterprises with low R&D investments tend to outsource. Özbek and Eren (2013) adopted the analytical network process approach for the selection of 3PL companies in their studies and considered quality, long-term relationships, company image, and operational performance as the basic criteria. Govindan et al. (2016) used the DEMATEL method in their examinations and determined that the most important criteria in the selection of 3PL companies are delivery performance, technology level, financial stability, human resources management, service quality, and customer satisfaction, respectively. Sremac et al. (2018) applied with a total of 10 logistics providers for the transport of dangerous goods for chemical industry companies in their study. The importance of the eight criteria underlying the study in which the assessment was made, it was determined using the Rough-SWARA method. Korucuk (2018) evaluated the criteria to be used in the selection of Third-Party Logistics (3PL) in cold chain transportation companies in Istanbul and made the selection of the best 3PL. As a result of the study, it has been determined that “Business Performance” is the most important main criterion in the selection of 3PL companies, and the “C” option is the best 3PL provider company. Erdoğan and Tokgöz (2020) investigated the role of formal and relational governance in the success of outsourcing in information technology (IT) in the aviation industry. According to the results of the research contracts and relationship norms in the success of IT outsourcing business aviation operating in Turkey, it is effective individually. Also, they stated that formal and relational governance mechanisms are complementary rather than substitutes for each other.

When businesses want to work with a company that provides logistics services, it is not an easy process to decide which company to be in the market. There is more than one third party logistics company with different competencies and skills in the market. Outsourcing for logistics operations should be determined by experts. The increasing demand for outsourcing also increases the service alternatives offered. Logistics service provider companies, which increase the level of competition, enable access with high quality and the most affordable cost level. The factors affecting the choice of outsourcing of enterprises have been listed as follows:

Table 1. 3PL Main Selection Criteria

Criteria	Authors
Customer Service Quality	Menon et al. (1998), Boyson et al. (1999), Bottani and Rizzi (2006), Işıklar et al. (2007), Jharkharia and Shankar (2007), Fu and Liu (2007), Qureshi et al. (2008), Bhatti et al. (2010), Chen and Wu (2011), Erkayman et al. (2012), Li et al. (2012), Govindan et al. (2012), Bansal and Kumar (2013), Cirpin and Kabadayi (2015), Hwang et al. (2016), Sremac et al. (2018)
Computing Capability	Bottani and Rizzi (2006), Işıklar et al. (2007), Bhatti et al. (2010), Rajesh et al. (2011), Erkayman et al. (2012), Bansal and Kumar (2013), Hwang et al. (2016), Sremac et al. (2018)
Operational Performance	Chen and Wu (2011), Wong (2012), Korucuk (2018)
Cost	Menon et al. (1998), Boyson et al. (1999), Bottani and Rizzi (2006), Işıklar et al. (2007), Fu and Liu (2007), Jharkharia and Shankar (2007), Qureshi et al. (2008), Vijayvargiya and Dey (2010), Rajesh et al. (2011), Chen and Wu (2011), Govindan et al. (2012), Erkayman et al. (2012), Bansal and Kumar (2013), Cirpin and Kabadayi (2015), Hwang et al. (2016), Sremac et al. (2018), Korucuk(2018)
Supply Chain Capability	Bhatti et al. (2010), Sremac et al. (2018)
Sustainability	Bansal and Kumar (2013), Cirpin and Kabadayi (2015)
Risk Management Capability	Perçin (2009), Rajesh et al. (2011), Sremac et al. (2018), Korucuk (2018)
Confidence	Petroni and Braglia (2000), Bottani and Rizzi (2006), Jharkharia and Shankar (2007), Qureshi etal. (2008), Bansal and Kumar (2013), Sremac et al. (2018)
Geographical Location Suitability	Petroni and Braglia (2000), Qureshi et al. (2008), Govindan et al. (2012), Bansal and Kumar (2013)
History of Performance	Petroni and Braglia (2000), Fu and Liu (2007), Qureshi et al. (2008), Govindan et al. (2012)
Value Added Service	Vijayvargiya and Dey (2010), Bansal and Kumar (2013)
On Time Delivery	Rajesh et al. (2011), Erkayman et al. (2012), Govindan et al. (2012)
Flexibility	Petroni and Braglia (2000), Bottani and Rizzi (2006), Erkayman et al. (2012), Govindan et al. (2012), Korucuk (2018)

In the literature review, it has been determined that there are limited studies on logistics outsourcing and choosing the most ideal company. The study differs from other studies in terms of the method used and the province applied. It is thought that it will contribute to the literature with this aspect.

Table 2. 3PL Selection Criteria

Main Criteria	Sub-criteria
Cost	Transportation / Storage and Documentation Cost, Payment Terms, Discount Offers
Customer Service Quality	Scope of Services, Flexibility and Reliability, Timeliness and Ease of Transaction / Communication, Customer Satisfaction and Cooperation, Value Added Service
Computing Capability	EDI Presence and Compatibility, Computing Network Availability, Data Integrity and Reliability, System Stability
Operational Performance	Delivery Performance and Reliability, Relationship Management, Geolocation Compliance, Performance History, Document Accuracy
Supply Chain Capability	Trained Logistics Staff, Infrastructure / Equipment and Logistics Technology, Efficiency Capacity, Risk Management Capability, Reverse Logistics Function
Sustainability	Economic responsibility, Social responsibility, Environmental responsibility

3. Methodology

In this section firstly neutrosophic set (NS) is introduced then a single-valued neutrosophic set (SVNS) as a special case of NS is explained too. Besides the steps of the neutrosophic AHP as newly developed multi-criteria, decision-making method are stated.

3.1. Neutrosophic Set

Smarandache (1998) introduced the concept of Neutrosophic Sets (NS) having with a degree of truth, indeterminacy, and falsity membership functions in which all of them are independent. Let U be a universe of discourse and $x \in U$. The neutrosophic set (NS) N can be expressed by a truth membership function $T_N(x)$, an indeterminacy membership function $I_N(x)$ and a falsity membership function $F_N(x)$, and is represented as $N = \{< x: T_N(x), I_N(x), F_N(x) >, x \in U\}$. Also the functions of $T_N(x)$, $I_N(x)$ and $F_N(x)$ are real standard or real nonstandard subsets of $]0^-, 1^+[$ and can be presented as $T, I, F: U \to]0^-, 1^+[$. There is not any restriction on the sum of the functions of $T_N(x), I_N(x)$ and $F_N(x)$ so $0^- \leq supT_N(x) + supI_N(x) + supF_N(x) \leq 3^+$.

The complement of an NS N is represented by N^C and described as below:

$$T_N^C(x) = 1^+ \ominus T_N(x) \tag{1}$$

$$I_N^C(x) = 1^+ \ominus I_N(x) \tag{2}$$

$$F_N^C(x) = 1^+ \ominus F_N(x) \text{ for all} x \in U \tag{3}$$

A NS, N is contained in other NS P in other words , $N \subseteq P$ if and only if $infT_N(x) \leq infT_P(x)$, $supT_N(x) \leq supT_P(x)$, $infI_N(x) \geq infI_P(x)$, $supI_N(x) \geq supI_P(x)$,), $infF_N(x) \geq infF_P(x)$, $supF_N(x) \geq supF_P(x)$, for all $x \in U$ (Biswas et al., 2016).

3.2. Single valued neutrosophic sets (SVNS)

Single Valued Neutrosophic Set (SVNS) as a special case of NS for considering indeterminate, inconsistent, and incomplete information was developed by Wang, Smarandache, Zhang, and Sunderraman (2010). They acquire the interval [0,1]instead of/for solving the real-world problems. Let U be a universe of discourse and $x \in U$. A single-valued neutrosophic set B in U is described by a truth membership function$T_B(x)$, an indeterminacy membership function $I_B(x)$and a falsity membership function $F_B(x)$. When U is continuous an SVNS, B is depicted as$B = \int_x \frac{<T_B(x), I_B(x), F_B(x)>}{x} : x \in U$. When U is discrete a SVNS B can be represented$B = \sum_{i=1}^{n} \frac{<T_B(x_i), I_B(x_i), F_B(x_i)>}{x_i} : x_i \in U$ as (Mondal, Pramanik, & Smarandache, 2016) The functions of $T_B(x), I_B(x)$ and $F_B(x)$ are real standard subsets of [0,1] that is $T_B(x): U \to [0,1]$, $I_B(x): U \to [0,1]$and $F_B(x): U \to [0,1]$. Also the sum of $T_B(x), I_B(x)$ and $F_B(x)$ are in [0,3] that$0 \leq T_B(x) + I_B(x) + F_B(x) \leq 3$ (Biswas et al., 2016).

Let a single-valued neutrosophic triangular number $\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle$ is a special neutrosophic set on R. Additionally $\alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \in [0,1]$ and $b_1, b_2, b_3 \in R$ where $b_1 \leq b_2 \leq b_3$. Truth, indeterminacy, and falsity membership functions of this number can be computed as below (Abdel-Basset et al., 2017).

$$T_{\tilde{b}}(x) = \begin{cases} \alpha_{\tilde{b}} \left(\frac{x-b_1}{b_2-b_1}\right) & (b_1 \leq x \leq b_2) \\ \alpha_{\tilde{b}} & (x = b_2) \\ \alpha_{\tilde{b}} \left(\frac{b_3-x}{b_3-b_2}\right) & (b_2 < x \leq b_3) \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

$$I_{\tilde{b}}(x) = \begin{cases} \left(\frac{b_2-x+\theta_{\tilde{b}}(x-b_1)}{b_2-b_1}\right) & (b_1 \leq x \leq b_2) \\ \theta_{\tilde{b}} & (x = b_2) \\ \left(\frac{x-b_2+\theta_{\tilde{b}}(b_3-x)}{b_3-b_2}\right) & (b_2 < x \leq b_3) \\ 1 & \text{otherwise} \end{cases} \tag{5}$$

$$F_{\tilde{b}}(x) = \begin{cases} \left(\frac{b_2-x+\beta_{\tilde{b}}(x-b_1)}{b_2-b_1}\right) & (b_1 \leq x \leq b_2) \\ \beta_{\tilde{b}} & (x = b_2) \\ \left(\frac{x-b_2+\beta_{\tilde{b}}(b_3-x)}{b_3-b_2}\right) & (b_2 < x \leq b_3) \\ 1 & \text{otherwise} \end{cases} \tag{6}$$

According to the Eqs. (4)-(6) $\alpha_{\tilde{b}}, \theta_{\tilde{b}},$ *and* $\beta_{\tilde{b}}$ denote maximum truth membership, minimum indeterminacy membership, and minimum falsity membership degrees respectively.

Suppose $\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle$ and $\tilde{c} = \langle (c_1, c_2, c_3); \alpha_{\tilde{c}}, \theta_{\tilde{c}}, \beta_{\tilde{c}} \rangle$ as two single-valued triangular neutrosophic numbers and $\lambda \neq 0$ as a real number. Considering the addition of the abovementioned condition of two single-valued triangular neutrosophic numbers are denoted as follows (Abdel-Basset et al., 2017).

$$\tilde{b} + \tilde{c} = \langle (b_1 + c_1, b_2 + c_2, b_3 + c_3); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \tag{7}$$

Subtraction of two single-valued triangular neutrosophic numbers are defined as Eq.(8):

$$\tilde{b} - \tilde{c} = \langle (b_1 - c_3, b_2 - c_2, b_3 - c_1); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \quad (8)$$

The inverse of a single-valued triangular neutrosophic number $(\tilde{b} \neq 0)$can be denoted as below:

$$\tilde{b}^{-1} = \langle \left(\frac{1}{b_3}, \frac{1}{b_2}, \frac{1}{b_1}\right); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle \quad (9)$$

Multiplication of a single-valued triangular neutrosophic number by a constant value is represented as follows:

$$\lambda\tilde{b} = \begin{cases} \langle (\lambda b_1, \lambda b_2, \lambda b_3); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle \; if \; (\lambda > 0) \\ \langle (\lambda b_3, \lambda b_2, \lambda b_1); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle \; if \; (\lambda < 0) \end{cases} \quad (10)$$

Division of a single-valued triangular neutrosophic number by a constant value is denoted as Eq.(11):

$$\frac{\tilde{b}}{\lambda} = \begin{cases} \langle \left(\frac{b_1}{\lambda}, \frac{b_2}{\lambda}, \frac{b_3}{\lambda}\right); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle \; if \; (\lambda > 0) \\ \langle \left(\frac{b_3}{\lambda}, \frac{b_2}{\lambda}, \frac{b_1}{\lambda}\right); \alpha_{\tilde{b}}, \theta_{\tilde{b}}, \beta_{\tilde{b}} \rangle \; if \; (\lambda < 0) \end{cases} \quad (11)$$

Multiplication of two single-valued triangular neutrosophic numbers can be seen as follows:

$$\tilde{b}\tilde{c} = \begin{cases} \langle (b_1 c_1, b_2 c_2, b_3 c_3); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \; if \; (b_3 > 0, c_3 > 0) \\ \langle (b_1 c_3, b_2 c_2, b_3 c_1); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \; if \; (b_3 < 0, c_3 > 0) \\ \langle (b_3 c_3, b_2 c_2, b_1 c_1); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \; if \; (b_3 < 0, c_3 < 0) \end{cases} \quad (12)$$

Division of two single-valued triangular neutrosophic numbers can be denoted as Eq.(13):

$$\frac{\tilde{b}}{\tilde{c}} = \begin{cases} \langle \left(\frac{b_1}{c_3}, \frac{b_2}{c_2}, \frac{b_3}{c_1}\right); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \; if \; (b_3 > 0, c_3 > 0) \\ \langle \left(\frac{b_3}{c_3}, \frac{b_2}{c_2}, \frac{b_1}{c_1}\right); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \; if \; (b_3 < 0, c_3 > 0) \\ \langle \left(\frac{b_3}{c_1}, \frac{b_2}{c_2}, \frac{b_1}{c_3}\right); \alpha_{\tilde{b}} \wedge \alpha_{\tilde{c}}, \theta_{\tilde{b}} \vee \theta_{\tilde{c}}, \beta_{\tilde{b}} \vee \beta_{\tilde{c}} \rangle \; if \; (b_3 < 0, c_3 < 0) \end{cases} \quad (13)$$

Score function (s_b) for a single-valued triangular neutrosophic number $b = (b_1, b_2, b_3)$ can be found as below (Stanujkic et al., 2017).

$$s_b = (1 + b_1 - 2 * b_2 - b_3)/2 \quad (14)$$

where $s_b \in [-1,1]$.

3.3. Neutrosophic AHP

Steps of neutrosophic AHP are depicted as below (Abdel-Basset et al., 2017):

Step 1: Decision problem is arranged in terms of hierarchical viewpoint composed of goal, criteria, sub-criteria, and alternatives respectively.

Step 2: Pairwise comparisons are constructed to form a neutrosophic evaluation matrix consisting of triangular neutrosophic numbers showing the experts' views. Neutrosophic pairwise evaluation matrix $(\widetilde{D})$can be written as follows:

$$\widetilde{D} = \begin{bmatrix} \tilde{1} & \tilde{d}_{12} & \cdots & \tilde{d}_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{d}_{n1} & \tilde{d}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (15)$$

According to Eq.(15) $\tilde{d}_{ji} = \tilde{d}_{ij}^{-1}$ is valid.

Step 3: Neutrosophic pairwise evaluation matrix is formed by applying a transformed scale for neutrosophic environment seen as Table 3:

Table 3. AHP transformed scale related to neutrosophic triangular numbers (Abdel-Basset et al., 2018)

Value	Explanation	Neutrosophic triangular scale
1	Equally influential	$\tilde{1} = \langle(1,1,1); 0.5,0.5,0.5\rangle$
3	Slightly influential	$\tilde{3} = \langle(2,3,4); 0.3,0.75,0.7\rangle$
5	Strongly influential	$\tilde{5} = \langle(4,5,6); 0.8,0.15,0.2\rangle$
7	Very strongly influential	$\tilde{7} = \langle(6,7,8); 0.9,0.1,0.1\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9,9,9); 1,0,0\rangle$
2	Intermediate values between two close scales	$\tilde{2} = \langle(1,2,3); 0.4,0.65,0.6\rangle$
4		$\tilde{4} = \langle(3,4,5); 0.6,0.35,0.4\rangle$
6		$\tilde{6} = \langle(5,6,7); 0.7,0.25,0.3\rangle$
8		$\tilde{8} = \langle(7,8,9); 0.85,0.1,0.15\rangle$

Step 4: Neutrosophic pairwise evaluation matrix is transformed into a deterministic pairwise evaluation matrix for calculating the weights of criterion as below:

Let $\tilde{d}_{ij} = \langle(d_1, e_1, f_1), \alpha_{\tilde{d}}, \theta_{\tilde{d}}, \beta_{\tilde{d}}\rangle$ be a single-valued neutrosophic number, then the score and accuracy degrees for $\tilde{d}_{ij}$ can be calculated computed as below:

$$S(\tilde{d}_{ij}) = \frac{1}{16}[d_1 + e_1 + f_1]x(2 + \alpha_{\tilde{d}} - \theta_{\tilde{d}} - \beta_{\tilde{d}}) \tag{16}$$

$$A(\tilde{d}_{ij}) = \frac{1}{16}[d_1 + e_1 + f_1]x(2 + \alpha_{\tilde{d}} - \theta_{\tilde{d}} + \beta_{\tilde{d}}) \tag{17}$$

Score and accuracy degrees for $\tilde{d}_{ij}$ are obtained according to the following equations.

$$S(\tilde{d}_{ji}) = 1/S(\tilde{d}_{ij}) \tag{18}$$

$$A(\tilde{d}_{ji}) = 1/A(\tilde{d}_{ij}) \tag{19}$$

The deterministic pairwise evaluation matrix is formed with compensation by the score value of each triangular neutrosophic number related to the neutrosophic pairwise evaluation matrix. The deterministic matrix can be written as below:

$$D = \begin{bmatrix} 1 & d_{12} & \cdots & d_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & \cdots & 1 \end{bmatrix} \tag{20}$$

Ranking of priorities as eigenvector X is obtained according to the following steps:

a)Firstly column entries are normalized by dividing each entry by the sum of column

b)Then row averages are summed.

Step 5: Consistency index (CI) and consistency ratio (CR) values are calculated for measuring the inconsistency for decision-makers' judgments in the entire pairwise evaluation matrix. If CR is greater than 0.1, the process should be repeated because of unreliable judgments.

CI is calculated as below:

a)Each value in the first column of the pairwise evaluation matrix is multiplied by the priority of the first criterion and this process is repeated for all columns. Values are summed across the rows to obtain the weighted sum vector.

b) The elements of the weighted sum vector are divided by corresponding the priority for each criterion. Then the average of values are obtained and showed by λ_{max}.

c) The value of CI is computed as Eq. (21):

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{21}$$

According to Eq.(21), the number of elements being compared is denoted by n.

After the value of CI is calculated, CR can be acquired as below:

$$CR = \frac{CI}{RI} \tag{22}$$

where RI represents the consistency index for randomly generated pairwise evaluation matrix and shown as Table 4.

Table 4. RI table considered for obtaining CR value (Abdel-Basset et al., 2017)

Order of random matrix (n)	0	2	3	4	5	6	7	8	9	10
Related RI value	0	0	0.58	0.9	1.12	1.24	1.32	1.4	1.45	1.49

Step 6: Overall priority values for each alternative are calculated and ranking is executed.

4. Case Study and Analysis

In this study, six criteria (cost, customer service quality, data processing ability, operational performance, supply chain ability, and sustainability) considered for factors affecting outsourcing related to 3PL are weighted via neutrosophic AHP firstly. For this purpose evaluations of five decision-makers in 3PL are considered.

Neutrosophic evaluation matrix in terms of factors affecting outsourcing related to 3PL is constructed through decision-makers' linguistic judgments which are seen as Table 1.

Neutrosophic evaluation matrix is transformed into a crisp one by using Equation (16) and taking the geometric means of 5 decision-makers' views. The crisp evaluation matrix for criteria is shown in Table 5.

Table 5. The crisp evaluation matrix for criteria related to outsourcing

Criteria	Cost	Customer service quality	Data processing ability	Operational performance	Supply chain ability	Sustainability
Cost	1	1.995	0.988	1.337	1.337	0.976
Customer service quality	0.501	1	1.226	0.895	0.654	0.895
Data processing ability	1.012	0.815	1	1.226	0.895	0.895
Operational performance	0.747	1.116	0.815	1	1.226	1.337
Supply chain ability	0.747	1.528	1.116	0.815	1	1.995
Sustainability	1.023	1.116	1.116	0.747	0.501	1

The normalized evaluation matrix for criteria is constructed as Table 6.

Table 6. The normalized evaluation matrix for criteria related to outsourcing

Criteria	Cost	Customer service quality	Data processing ability	Operational performance	Supply chain ability	Sustainability
Cost	0.596	0.203	0.116	0.176	0.169	0.113
Customer service quality	0.079	0.101	0.144	0.118	0.082	0.104
Data processing ability	0.161	0.083	0.117	0.161	0.113	0.104
Operational performance	0.119	0.113	0.096	0.131	0.155	0.155
Supply chain ability	0.119	0.155	0.131	0.107	0.126	0.232
Sustainability	0.163	0.113	0.131	0.098	0.063	0.116

Finally, the priorities for criteria as the eigenvector X are obtained by taking the overall row averages and presented as follows:

Table 7. Priorities for criteria related to outsourcing

Criteria	Priorities
Cost	0.1528
Customer service quality	0.1030
Data processing ability	0.1139
Operational performance	0.1348
Supply chain ability	0.1354
Sustainability	0.1244

According to Table 7, while cost was found as the most important criterion having a value of 0.1529, customer service quality was obtained as the least important one having a value of 0.103.

Then the consistency of decision-makers' judgments is checked by computing CI and CR values. CI value is found as 0.018 and by using Equation (22) CR value is acquired as 0.012. Decision-makers' evaluations are consistent because of having CR value smaller than 0.1.

5. Conclusion

In this study factors affecting outsourcing related 3PL determined by extensive literature review process are ranked by using neutrosophic AHP. Single valued neutrosophic sets are preferred compared to crisp, fuzzy, interval-valued, and intuitionistic sets due to efficiency, flexibility, and easiness for explaining decision-makers' indeterminate judgments. Furthermore ranking of factors affecting outsourcing related to 3PL as a complex real-world decision making problem can be efficiently solved under neutrosophic sets based environment.

For further researches factors affecting outsourcing related to 3PL can be expanded and results can be compared with different multi-criteria decision-making methods. Also, various hybrid techniques can be proposed and applied for real-world complex decision-making problems.

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