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Article

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OPERATIONS, INFORMATION & TECHNOLOGY | RESEARCH ARTICLE

Appraisal and benchmarking of third-party logistic service provider by exploration of risk-based approach

Nitin Kumar Sahu^{1*}, Atul Kumar Sahu¹ and Anoop Kumar Sahu²

Abstract: In the present era, Reverse Logistics Support has monitored as a momentous realm, where stuffs are transferred from point of consumption to origin. The companies who provide the logistic equipments, i.e. Truck, Joseph Cyril Bomford, and Shipment, etc. to its partner's firms called Third-Party Logistics (3PL) service provider. Today, the feasible 3PL service provider evaluation-opt problem is yet an amorous dilemma. The appraisal and benchmarking of logistics service providers in extent of index; allied risk-based indices and their interrelated metrics; outlooked as a great tool for each international firm, in order that firm could obtain their core goals. The novelty of manuscript is that here, a hairy-based approach has been integrated and then implemented upon a novel developed multi hierarchical third-party logistics (3PL) service providers appraisal index in purpose to umpire the 3PL provider for their strong and ill's core indices. Moreover, the overall score (S_j) system has also been carried out for benchmarking the 3PL provider companies, where s_1 has been found as the best 3PL service provider. The developed approach enabled the manager of firms to make the verdict towards the best inclusive evaluation process of 3PL performance appraisal and

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PUBLIC INTEREST STATEMENT

In the present era, the market demand is turbulence, where Supply Chain Management has been found growing towards the collusion due to the compound networking. Consequently, the verdict at apiece instance of up and downstream SC networking searched so momentous. In present exposure, Third Party Logistic (3PL) provider appraisal-evaluation dilemma has been solved. Moreover, manager/readers have been assisted via the Verdict Support System for solving 3PL provider appraisal and evaluation dilemma in extent of firm's SC up and downstream indices. The reader could also avail this manuscript in objective to answer their real life dilemmas e.g. logistic equipment (Truck, Joseph Cyril Bomford and Shipment, etc.) provider evaluation-opt perspective. Furthermore, it would shine facilities the forthcoming novelist in order to diagnostic their practical problems and even develop robust verdict making system. Eventually, this manuscript encompasses the well relevancy to entertain the public/reader/manager/novelists.



Anoop Kumar Sahu

benchmarking. A numerical illustration has also been provided to validate the verdict support system.

Subjects: Science; Social Sciences; Technology

Keywords: third-party logistics service provider; fuzzy analytic hierarchy process (FAHP)

1. Introduction

In present era, apiece industry's logistic activities are carried out in purpose to transform inputs into goods. Logistics has been currently considered as uppermost aspects, where organizations can diminish costs and provide advance in customer service. Reverse logistic processes assist enterprises in enhancing their competitiveness and build their commercial reputation by providing systems and processes to help customers return products and components either for repair, reuse, or disposal. The significance and value attached towards reverse logistics system chiefly from strict environmental regulations and diminishing raw material resources. Reverse logistics (reverse supply chains) concentrate on those streams where there is some value to be recovered and deal with the management of products in a reverse way. It is the process of managing the flow of returned products and information from the point of consumption to the origin and plays a noteworthy role in integrating the supply chain of industries. Reverse logistics is becoming an area of competitive advantage as its focus is on waste management, material recovery through recycling, and part or product recovery through remanufacturing, refurbishment, and reuse. The main benefits of logistics alliances are to allow the outsourcing company to concentrate on the core competence, increase the efficiency, improve the service, reduce the transportation cost, restructure the supply chains, and establish the marketplace legitimacy. The products and components collected for reverse logistics are often widely dispersed, which complicates efforts to efficiently collect, reuse, and reassemble used components for reprocessing and remanufacturing.

Currently, logistics outsourcing or third-party logistics (3PL) is an emerging trend in the global market. Third-party logistics service providers are the companies to execute logistics functions, which have been traditionally operational within an organization. The demand of third-party logistics (3PL) provider becomes a progressively more significant concern for corporations seeking improved customer service and cost reduction. Basically, a 3PL provider involves using external companies to perform logistics functions which have been conventionally operational within an organization. Specifically, a 3PL provider can offer an enterprise with its needed services, such as professional logistics transportation, warehousing, logistics information system, product returns service, inventory management, and product packaging. Hence, 3PL plays a key role in the logistic activities between the outsourcing company, the marketplace, and the customers. The main benefits of logistics alliances are to allow the outsourcing company to concentrate on the core competence, increase the efficiency, improve the service, reduce the transportation cost, restructure the supply chains, and establish the marketplace legitimacy.

Presently, companies are looking for the path to evaluate and opt the best 3PL service provider's firms amongst preferred sources for bringing the continues cum rapid production in firm. Consequently, the authors perceived self-motivation in order to organize the research towards eliminating the evaluation and opt problem of 3PL service provider's firms in the boundary of uncertain or certain data. Later, the motivation transformed into research objective/agenda.

Therefore, the uppermost objectives of present research to evaluation and then opting of appropriate logistics provider's firm amongst preferred alternatives under uncertain data has been carried out. A numerical example has been to test the proposed approach. Moreover, a way to identify all indices of 3PL provider has also been proposed. Subsequently, the proper selection of 3PL provider is extremely crucial for the development and proficiency of an enterprise.

2. State of art and problem formulation

In recent years, there has been a surge of academic interest and publications in the area of third-party logistics (3PL). This can be partly explained by the growing trend of outsourcing logistics activities in a wide variety of industrial sectors (Transport Intelligence, 2004). The continuing wave of consolidation within the 3PL industry has also resulted in the emergence of large companies that have the capabilities to offer sophisticated logistics solutions on a continental or even global scale. Such logistics service providers (LSPs) strive to assume a more strategic role within the supply chain of clients, expanding their scale and scope of operations (Selviaridis & Spring, 2007).

Yan, Chaudhry, and Chaudhry (2003) postulated a case-based reasoning model framework for 3PL evaluation and selection system. Zhang, Li, Liu, Li, and Zhang (2004) formulated an Analytic Hierarchy Process-based (AHP) model to a case study for examining the function in 3PL vendor selection. Koh and Tan (2005) investigated on selection of foreign and domestic Third-Party Logistics (3PL) enterprises in China that use e-commerce to gain competitive advantages. So, Kim, Cheong, and Cho (2006) applied the AHP to evaluate the service quality of third-party logistics (3PL) service providers. The authors first conceptualized five dimensions of 3PL service quality (i.e. tangibles, reliability, responsiveness, assurance, and empathy); then AHP method was adapted to determine the relative weights of the five service quality dimensions and eventually select the best third party logistics service provider. Wang, Zantow, Lai, and Wang (2006) investigated the impact of IT (Information Technology) on the financial performance of 3PL in China and found that greater IT uptake could offer 3PL companies better financial performance. Karagul and Albayrakoglu (2007) presented a multi-criterion decision-making (MCDM) model for outsourcing logistics services in the Turkish automotive industry. An AHP model was created to select the best 3PL provider among multiple candidates. Bayazit (2012) also applied AHP in selection of a 3PL provider.

Işıklar, Alptekin, and Büyüközkan (2007) proposed an intelligent decision support framework for effective 3PL evaluation and selection. The proposed framework integrated case-based reasoning, rule-based reasoning, and compromise programming techniques in fuzzy environment. This real-time decision-making approach dealt with uncertain and imprecise decision situations. Zhou, Min, Xu, and Cao (2008) identified factors that significantly affected the operational efficiency of Chinese 3PLs and proposed ways to improve the competitiveness of 3PLs. Green, Turner, Roberts, Nagendra, and Winingar (2008) reported on choosing a 3PL partner and examine the perspective of one major company heavily involved as a broker and provider of logistics services. Hamdan and (Jamie) Rogers (2008) introduced data envelopment analysis (DEA) as a tool to evaluate the efficiency of a group of third-party logistics (3PL) warehouse logistics operations. Cheng, Chen, and Chuang (2008) studied to figure out the evaluation factors and their weights to aid the selection of 4PL (Fourth-Party Logistic) for businesses. The primary criteria to evaluate 4PL were established with Fuzzy Delphi Method (FDM), and then Fuzzy Analytic Hierarchy Process (FAHP) was employed to calculate the weights of these criteria, so as to build the Fuzzy Multi-criteria model of 4PL. Çakir, Tozan, and Vayvay (2009) also proposed LSP selection decision support system based on the FAHP method. Qureshi, Kumar, and Kumar (2009a) proposed a methodology based on combined approach of AHP and Graph theory and derived a LSP (layered service provider) selection index which evaluates and ranks the 3PL service provider, to help shippers and also proposed coefficients of similarity, coefficients of dissimilarity, and the identification sets for further comparison of 3PL service providers. In another paper, Qureshi, Kumar, and Kumar (2009b) used the FAHP approach to support a generic logistics benchmarking process and benchmarked performance levels of the LOGINET, a 3PL services provider.

Perçin (2009) recommended the use of a two-phase analytical hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) approach in the evaluation of 3PL providers. Liu and Fang (2009) examined the relationship between customer satisfaction and logistic costs, and used the gray correlation analysis method to study the relationship between customer satisfaction and various activity centers. The research result could offer decision-making references to save costs and enhance customer satisfaction for 3PL enterprises. Kannan (2009) proposed a structured model for evaluating and selecting the best third-party reverse logistics provider (3PRLP)

under fuzzy environment for the battery industry. In this paper, the multi-criteria decision-making tools such as AHP and FAHP were adopted to solve the problem of selection of 3PRLP. Vinay, Kannan, and Sasikumar (2009) explained the concept of supply chain, logistics, the need for the novel trends for logistics outsourcing, the newer terms like Fifth-Party Logistics Providers (5PLP) and Seventh-Party Logistics (7PL), benefits, and also highlighted the barriers of 3PLP implementation.

Rajesh, Pugazhendhi, and Ganesh (2010) proposed a classification framework and suggested some new research settings in selection of the third-party logistics (3PL) service providers as 3PL plays a key role in the logistic activities between the outsourcing company, the marketplace, and the customers. Singh Bhatti, Kumar, and Kumar (2010) examined to model the choice parameters for selection of third-party logistics service providers in global lead logistics provider (LLP) environments. AHP modeling was carried out after questionnaire-based survey, results of which were moderated with inputs from experts from industry and academics. The findings of this study revealed the underlying sub-parameters which come into play while rating/choosing or evaluating service providers in the global LLP situations of today. Saen (2010) introduced a model to rank third-party reverse logistic (3PL) providers with regard to various criteria, including dual-role factors, which was based on DEA.

Soh (2010) proposed an evaluation framework and methodology based on FAHP for selecting a suitable 3PL provider and illustrated the process of evaluation and selection through a case study. Gupta, Sachdeva, and Bhardwaj (2010) proposed a framework to select the 3PL service provider using FDM to shortlist the most important criteria and most probable service providers and fuzzy TOPSIS to choose the best service provider by finding the closeness to the Positive Ideal Solution. Ding and Chou (2011) aimed to develop a fuzzy MCDM model to select middle managers for 3PLs. Lin et al. (2012) proposed an indicator system for data integration towards 3PL provider selection through analyzing the features and role of third-party logistics. The authors also established a comprehensive evaluation model for 3PL suppliers based on fuzzy sets.

Third-party logistics (3PL), which is growing around the world, is drawing the due attention at government, industrial, academicians, and practitioner's levels. The worldwide trend in globalization has led many companies to outsource so as to focus on their core competencies (Gupta, Sachdeva, & Bhardwaj, 2011). Evaluation and selection of 3PL service providers can be viewed as a complex multi-criteria decision-making (MCDM) problem mostly supported by decision information against subjective qualitative criteria. Such a decision-modeling requires human judgment to assign importance weight (priority) against each of the selection criterion as well as performance extent in terms of linguistic variables. Linguistic variables are difficult to analyze through mathematical operations unless these are represented by numbers because these linguistic judgment may sometimes represent imprecise, incomplete information, and are highly influenced by the decision-making attitude of the experts. Fuzzy logic and the theory of gray numbers can fruitfully tackle such kinds of uncertainty, inconsistency arising from subjective judgment of the decision-makers.

In the field of non-deterministic, verdict-making theory as well as analytical technique, fuzzy decision-making theory as well as technique and triangular and trapezoidal fuzzy numbers received more attentions along with research results in recent years (Govindan & Murugesan, 2011; Kahraman, Cebeci, & Ulukan, 2003; Soh, 2010). As stated by Govindan and Murugesan (2011), in practice, while fuzzy AHP requires weighty computations, it is a more systematic method than the others, and it is more capable of capturing a human's appraisal of ambiguity when complex multi-attribute decision-making problems are considered, so it has theoretical significance and practical value to introduce triangular fuzzy numbers combined with AHP in fuzzy system theory. Numerical illustration has also been provided through an empirical case study.

Next, by conducting the sufficient magnitude of literature reviews pertaining to 3LP service provider evaluation and selection, what the authors looked for that fewer problems for evaluating the 3PL service provider have been formulated and diagnosed in confine of subjective data. Consequently,

authors considered evaluation-opt problem of 3PL service provider as a momentous problem to be diagnosed in this manuscript.

3. Theory of FAHP and integrated hairy methodology (Chang, 1996)

The AHP first introduced by Saaty (1980) is a powerful, flexible, and systematic method widely used for decision problems with many criteria and alternatives because of its great capacity to handle qualitative and quantitative criteria used in such problems. It is a tool used for solving complex decision problems to solve many dilemma in different areas of human requirements, such as political, financial, and various others different interests. The AHP provides a comprehensive and rational framework to help managers set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. In conventional AHP, the pair-wise comparison is established using a scale which converts the human preferences between available alternatives. Even though the discrete scale of AHP has the advantages of simplicity and ease of use, it is not sufficient to take into account the uncertainty associated with the mapping of one's perception to a number. However, due to vagueness and uncertainty in the decision-maker's judgment, a crisp, pair-wise comparison with a conventional AHP may be unable to accurately capture the decision-maker's judgment. Therefore, fuzzy logic is introduced into the pair-wise comparison to deal with the deficiency in the traditional AHP. This is referred to as fuzzy AHP. The linguistic assessment of human feelings and judgments are vague and it is not reasonable to represent it in terms of precise numbers. To give interval judgments than fixed value judgments is more confident for decision-makers. So, triangular fuzzy numbers are used to decide the priority of one decision variable over another in fuzzy AHP.

The fuzzy AHP makes the verdict in accordance with the priority weights. It is used to set up the comparison matrixes on the basis of assigned priority weight value in objective or subjective term by a particular group (constructed group merely assigns priority weight value against a criterion and rest of priority weight is transferred by itself to that criteria opponent). Whereas reaming methods process the verdict with taking into the concert of perception of each member allied in group against each criterion, which make calculation so complex and solicits big data availability. Therefore, fuzzy AHP is the best approach from both perspectives, i.e. solicit fewer calculation as well as minimum data.

In fuzzy AHP, the triangular fuzzy numbers are used in the pair-wise comparison process to express subjective judgments. The triangular fuzzy numbers are defined by three real numbers, expressed as $\tilde{M} = (l, m, u)$. The parameters l , m , and u indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event, respectively. Their membership functions are described as Equation (1). The relations between the linguistic scales and their corresponding triangular fuzzy numbers, used by experts in this study, are given in Table 2.

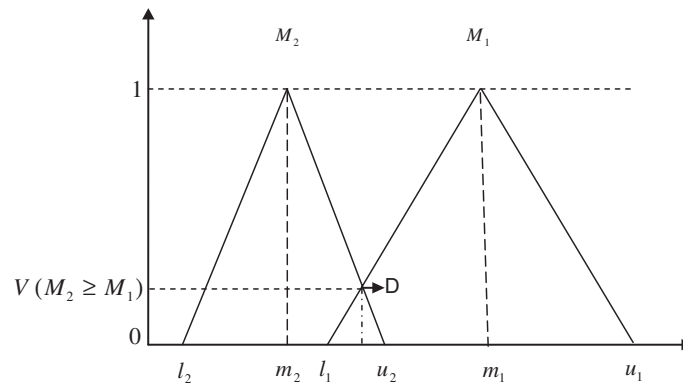
Definition 1 A fuzzy number \tilde{M} in R is a Triangular Fuzzy Number if its membership function $\mu_{\tilde{M}}(x):R \rightarrow [0, 1]$ satisfies Equation (1):

$$\mu_{\tilde{M}}(x) = \begin{cases} (x - l)/(m - l) & l \leq x \leq m \\ (u - x)/(u - m), & m \leq x \leq u \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

From Equation (1), l and u mean the lower and upper bounds of the fuzzy number \tilde{M} , and m is the modal value for \tilde{M} (Figure 1).

Definition 2 The algebraic operational laws of Triangular Fuzzy Number $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are performed as follows Equations (2-7).

Figure 1. The intersection between M_1 and M_2 .



• **Addition of the fuzzy number \oplus**

$$M_1 \oplus M_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2)$$

$$= (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{2}$$

• **Multiplication of the fuzzy number \otimes**

$$M_1 \otimes M_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \tag{3}$$

• **Subtraction of the fuzzy number $-$**

$$M_1 - M_2 = (l_1, m_1, u_1) - (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \tag{4}$$

• **Division of a fuzzy number $/$**

$$M_1 / M_2 = (l_1, m_1, u_1) / (l_2, m_2, u_2)$$

$$= (l_1 / u_2, m_1 / m_2, u_1 / l_2) \text{ for } l_1, l_2 < 0, m_1, m_2 < 0, u_1, u_2 < 0 \tag{5}$$

• **Reciprocal of the fuzzy number**

$$M_1^{-1} \approx (l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1) \tag{6}$$

• **Multiplication of constant**

$$(\lambda, \lambda, \lambda) \otimes (l_1, m_1, u_1) = (\lambda l_1, \lambda m_1, \lambda u_1), \quad \lambda > 0, \lambda \in R \tag{7}$$

• **Value of fuzzy synthetic extent**

Let $X = \{x_1, x_2, x_3, \dots, x_n\}$ be an object set, and $U = \{u_1, u_2, u_3, \dots, u_m\}$ be a goal set. According to the method of extent analysis, we now take each object and perform extent analysis for each goal respectively. Therefore, we can get m extent analysis values for each object, with the following signs:

$$M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m \quad i = 1, 2, \dots, n, \text{ where all the } M_{g_i}^j \quad (j = 1, 2, \dots, m) \text{ are triangular fuzzy numbers.}$$

The steps of Chang's extent analysis can be given as follows:

Step 1: The value of fuzzy synthetic extent with respect to the i th object is defined as:

$$S_i = \sum_{j=1}^m M_{g_i}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j \right]^{-1} \tag{8}$$

Step 2: Since $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility $M_1 \geq M_2$ defined as:

$$V(\tilde{M}_1 \geq \tilde{M}_2) = \sup_{x \geq y} [\min(\mu_{M_1}(x), \mu_{M_2}(y))]$$

$$V(\tilde{M}_2 \geq \tilde{M}_1) = \text{hgt}(\tilde{M}_1 \cap \tilde{M}_2) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases} \quad (9)$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} (Figure 1). To compare M_1 and M_2 both value of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are required.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1, 2, \dots, k)$ can be defined by;

$$V(M \geq M_1, M_2, \dots, M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \dots \text{ and } (M \geq M_k)] \\ = \min V(M \geq M_i), i = 1, 2, \dots, k. \quad (10)$$

Step 4: Assume that $d(X_i) = \min V(S_i \geq S_k)$ for $k = 1, 2, \dots, n; k \neq i$. Then, the weight vector is given by

$$W' = (d'(X_1), d'(X_2), \dots, d'(X_n))^T \quad (11)$$

where $X_i = (1, 2, \dots, n)$ are n elements.

Step 5: via normalization, the normalized weight vectors are:

$$W = (d(X_1), d(X_2), \dots, d(X_n))^T \quad (12)$$

where W is a non-fuzzy number that gives the priority weights of one criterion over another.

The normalized weight vectors are calculated as:

$$NW_i = \frac{W_i}{\sum W_i} \quad (13)$$

Definition 3 Consistency of pair-wise comparison matrix (Alonso & Lamata, 2006; Ramík & Korviny, 2010; Saaty, 1980):

In classical AHP, we consider an $n \times n$ pair-wise comparison matrix A with positive elements such that

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \quad (14)$$

This matrix is reciprocal, if $a_{ij} = \frac{1}{a_{ji}}$ for each $1 \leq i, j \leq n$. We say that A is consistent if

$$a_{ij} * a_{jk} = a_{ik} \tag{15}$$

for each $1 \leq i, j, k \leq n$.

If for some i, j, k , Equation (15) does not hold, than A is said to be *inconsistent*. In AHP, it is assumed that $\frac{1}{9} \leq a_{ij} \leq 9$, for all $1 \leq i, j \leq n$, Saaty, 1991. The inconsistency of A is measured by the *consistency index* CI_n as

$$CI_n = \frac{\lambda_{max} - n}{n - 1} \tag{16}$$

where λ_{max} is the *principle eigenvalue* of A . It holds $CI_n \geq 0$.

If A is an $n \times n$ positive reciprocal (PR) matrix, then A is consistent if $CI_n = 0$. To provide a measure independent of the order of the matrix, n , Saaty proposed the *consistency ratio* (CR). This is obtained by taking the ratio between CI_n to its expected value over a large number of positive reciprocal matrices of order n , whose entries are randomly chosen in the set of values $S = \left\{ \frac{1}{9}, \dots, 9 \right\}$. For this consistency measure, he proposed a 10% threshold for the (CR) to accept the estimation. In practical decision situations, inconsistency is “acceptable” if $CR < 0.1$.

To calculate the Consistency Ratio for the set of judgments using the CI for the corresponding value from large samples of matrices of purely random judgments using the table below, derived from Saaty’s book, in which the upper row is the order of the random matrix, and the lower is the corresponding index of consistency for random judgments, Saaty defined the consistency ratio(CR) as:

$$CR = \frac{CI}{RI} \tag{17}$$

where RI is the average value of CI for random matrices using the (Saaty, 1980) given scale.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

4. Numerical example

The proposed approach has been modeled aiming to choose the best 3PL LSP applicable to case organizations/enterprises. The primary task in 3PL provider selection decision modeling is to form a verdict-making team of analysts (decision makers) having sufficient knowledge and expertise in logistics activities and allied aspects. The team should be constructed including experts from the host organization, such as sales, marketing, manufacturing, finance, and logistics as well. Next, the evaluation team should recommend all possible evaluation criteria prior to decision-making. Here, 11 important criteria followed by 51 significant metrics have been considered (Çakir et al., 2009; Chen & Wu, 2011; Ding & Chou, 2011; Göl & Çatay, 2007; Govindan & Murugesan, 2011; Hsiao, Kemp, van der Vorst, & (Onno) Omta, 2010; Kannan, 2009; Olugu & Wong, 2011; Shan, 2012; Soh, 2010; Wong, 2012), as a case modeling. Four LSPs have been considered for the decision alternatives, and these are alternatives S_1 , S_2 , S_3 , and S_4 . Table 1 illustrates a representation of 3PL providers’ section criterions.

Now each decision-maker (DM) is instructed to select appropriate linguistic terms to assign the importance weight against each of the evaluation criterion. The reason behind exploring linguistic terms instead of numerical numbers is that human judgments are often subjective in nature; may be vague, incomplete, and imprecise, therefore, the importance of the criteria, i.e. priory weight are all evaluated in terms of linguistic terms. For each of the selection criterion/core indices, a linguistic term set such as Just equal (JE), Equally important (EI), Weakly important (WI), Strongly more

Table 1. Third-party service provider risk multi-indices-based hierarchical appraisal index

	Risk-based indices	Risk-based metrics
Appraisal and benchmarking of 3 PL service providers	Price of agile service	Shipment cost
		Money transaction ability
		Additional charges
		Data transaction potential
		Dimension and Excellency in equipment
		Time consumption on delivery of goods
		Level of employees happiness
		Litheness in processes
	Market Image of third-party logistic	Bazaar prestige
		Agile delivery to warehouses
		International market data
		Practice for manufacturing comparable goods
	Continuing alliances	Data transaction ability
		Eagerness for exploring employees to handle downstream activities
		Reliance level
		Profit booking and threat sharing
		Effectiveness of cross-functional management
		Friendship
	Funding condition	Shipment prices
		Overall financial condition
	Packing intensity	Delivery on lead time
		Effectiveness in service
		Litheness and effectiveness
	Transportation and building structure	International service capability
		Availability of manpower to tackle the logistic systems
	Third-party logistics overhauls	Stuff refill
		Warehouse terminal availability on schedule tenure
		Shipment coordination and collaboration
Evaluation of shipper		
Shortest shipment services		
Downstream transportation functionality	Recovery of scraps	
	Casing of stuff	
	Cargo storing	
	Shortest routing	
	Halfway processing	
	Deliverance of stuff	

(Continued)

Table 1. (Continued)

	Risk-based indices	Risk-based metrics
	Managerial responsibility	Grievance
		Reprocess
		Reproduction
		Re utilization
		Dumping
	Fulfillment of customer's order	Coordination level
		Swiftness in service
		Price saving
		Overall working relations
	Data machinery availability	Storehouse administrative curriculum
		Order supervision
		Evaluation of supply chain strategy activities
		Order chasing system
		Transportation price

important (SMI), Very strongly more important (VSMI), and Absolutely more important (AMI) has been selected to assign criteria weights (Table 2).

First, the pair-wise comparison matrix is constructed with the help of expert team and the same is shown in Table 3. By applying Equation (8), the value of fuzzy synthetic extent with respect to the goal was calculated:

$$S_1 \text{ (Price of Agile Service)} = (0.028, 0.047, 0.092)$$

$$S_2 \text{ (Market Image of Third Party Logistic)} = (0.078, 0.136, 0.223)$$

$$S_3 \text{ (Continuing Alliances)} = (0.053, 0.095, 0.159)$$

$$S_4 \text{ (Funding Condition)} = (0.062, 0.105, 0.189)$$

$$S_5 \text{ (Packing Intensity)} = (0.049, 0.083, 0.148)$$

$$S_6 \text{ (Transportation and Building Structure)} = (0.071, 0.119, 0.204)$$

$$S_7 \text{ (third party logistics Overhauls)} = (0.032, 0.061, 0.125)$$

$$S_8 \text{ (Downstream Transportation Functionality)} = (0.034, 0.065, 0.114)$$

Table 2. Fuzzy Importance scale with triangular fuzzy number for core indices and metrics

Verbal judgment	Triangular fuzzy number	Triangular fuzzy number (fraction form)	Reverse triangular fuzzy number	Reverse triangular fuzzy number (fraction form)
Just equal (JE)	(1, 1, 1)	(1.00, 1.00, 1.00)	(1, 1, 1)	(1.00, 1.00, 1.00)
Equally important (EI)	(1/2, 1, 3/2)	(0.50, 1.00, 1.50)	(2/3, 1, 2)	(0.67, 1.00, 2.00)
Weakly important (WI)	(1, 3/2, 2)	(1.00, 1.50, 2.00)	(1/2, 2/3, 1)	(0.50, 0.67, 1.00)
Strongly more important (SMI)	(3/2, 2, 5/2)	(1.50, 2.00, 2.50)	(2/5, 1/2, 2/3)	(0.40, 0.50, 0.67)
Very strongly more important (VSMI)	(2, 5/2, 3)	(2.00, 2.50, 3.00)	(1/3, 2/5, 1/2)	(0.33, 0.40, 0.50)
Absolutely more important (AMI)	(5/2, 3, 7/2)	(2.50, 3.00, 3.50)	(2/7, 1/3, 2/5)	(0.29, 0.33, 0.40)

Table 3. Fuzzy pair-wise comparison matrix at core indices level

Criteria	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀	C ₁₁
C ₁	(1, 1, 1)	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)
C ₂	(2, 5/2, 3)	(1, 1, 1)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(5/2, 3, 7/2)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(2, 5/2, 3)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(2, 5/2, 3)
C ₃	(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(1/3, 2/5, 1/2)	(1, 3/2, 2)	(3/2, 2, 5/2)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(3/2, 2, 5/2)
C ₄	(1, 3/2, 2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(2, 5/2, 3)	(2/3, 1, 2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)	(2/3, 1, 2)
C ₅	(3/2, 2, 5/2)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(2/7, 1/3, 2/5)	(1, 1, 1)	(1/2, 2/3, 1)	(2/3, 1, 2)	(1/2, 2/3, 1)	(2, 5/2, 3)	(2/3, 1, 2)	(2, 5/2, 3)
C ₆	(2, 5/2, 3)	(2/5, 1/2, 2/3)	(2, 5/2, 3)	(1, 3/2, 2)	(1, 3/2, 2)	(1, 1, 1)	(2/3, 1, 2)	(5/2, 3, 7/2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(5/2, 3, 7/2)
C ₇	(1, 3/2, 2)	(2/3, 1, 2)	(1/2, 2/3, 1)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1, 1, 1)	(2/3, 1, 2)	(2/7, 1/3, 2/5)	(2/3, 1, 2)	(2/7, 1/3, 2/5)
C ₈	(3/2, 2, 5/2)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(1, 3/2, 2)	(2/7, 1/3, 2/5)	(1/2, 1, 3/2)	(1, 1, 1)	(1/3, 2/5, 1/2)	(1/2, 2/3, 1)	(1/2, 1, 3/2)
C ₉	(2, 5/2, 3)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(5/2, 3, 7/2)	(2, 5/2, 3)	(1, 1, 1)	(2, 5/2, 3)	(2/5, 1/2, 2/3)
C ₁₀	(1/2, 1, 3/2)	(2/3, 1, 2)	(2, 5/2, 3)	(2/7, 1/3, 2/5)	(1/2, 1, 3/2)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(1, 1, 1)	(1/3, 2/5, 1/2)
C ₁₁	(3/2, 2, 5/2)	(1/3, 2/5, 1/2)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(1/3, 2/5, 1/2)	(2/7, 1/3, 2/5)	(5/2, 3, 7/2)	(2/3, 1, 2)	(3/2, 2, 5/2)	(2, 5/2, 3)	(1, 1, 1)

S₉ (Managerial Responsibility) = (0.063, 0.106, 0.173)

S₁₀ (Fulfillment of Customer’s Order) = (0.043, 0.080, 0.143)

S₁₁ (Data Machinery Availability) = (0.061, 0.104, 0.174)

These synthetic values were compared by using Equation (9). With the help of Equations (10–12), the minimum degree of possibility of superiority of each criterion over another is obtained. This further decides the weight vectors of the criteria. Therefore, the weight vector is given as:

W' = (0.136, 1.000, 0.663, 0.783, 0.571, 0.884, 0.387, 0.339, 0.765, 0.542, 0.749)

The normalized value of this vector decides the priority weights of each criterion over another. The normalized weight vectors are calculated using Equation (13) and the same is given in Table 15.

This indicates that *Market Image of Third Party Logistic* is the most important core indices (0.1466) for selecting a 3PL provider compared to Transportation and Building Structure (0.1296), Funding Condition (0.1148), Managerial Responsibility (0.1122), Data Machinery Availability (0.1098), Continuing Alliances (0.0973), 3PL Overhauls (0.0837), Fulfillment of Customer’s Order (0.0795), Packing Intensity (0.0568), Downstream Transportation Functionality (0.0498), and Price of Agile Service (0.0199).

By following the same procedure, the pair-wise comparison matrix for metrics are constructed with the help of expert team and the same is shown in Tables 4–14, and the priority weights of metrics were calculated as given in Table 16.

The global composite priority weights given in Table 17 were calculated by multiplying the priority weights of metrics with those of their corresponding main criteria/core indices in the next higher level of the hierarchy, indicating the ranking order of metrics. This indicates that *Availability of manpower to tackle the Logistic systems* (0.129618) is the most important metrics in selecting a 3PL provider, followed by various other metrics.

Table 4. Fuzzy pair-wise comparison matrix at metrics level for (C₁)

Metrics	C ₁₁	C ₁₂	C ₁₃	C ₁₄	C ₁₅	C ₁₆	C ₁₇	C ₁₈
C ₁₁	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
C ₁₂	(1, 3/2, 2)	(1, 1, 1)	(5/2, 3, 7/2)	(2, 5/2, 3)	(1, 3/2, 2)	(5/2, 3, 7/2)	(2, 5/2, 3)	(1, 3/2, 2)
C ₁₃	(3/2, 2, 5/2)	(2/7, 1/3, 2/5)	(1, 1, 1)	(2/3, 1, 2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(2/3, 1, 2)	(3/2, 2, 5/2)
C ₁₄	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1, 1, 1)	(2/7, 1/3, 2/5)	(1/2, 2/3, 1)	(2/7, 1/3, 2/5)	(1/2, 2/3, 1)
C ₁₅	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(5/2, 3, 7/2)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 2/3, 1)	(1/2, 1, 3/2)
C ₁₆	(3/2, 2, 5/2)	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(1, 3/2, 2)	(2/3, 1, 2)	(1, 1, 1)	(1, 3/2, 2)	(5/2, 3, 7/2)
C ₁₇	(2, 5/2, 3)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(5/2, 3, 7/2)	(1, 3/2, 2)	(1/2, 2/3, 1)	(1, 1, 1)	(2, 5/2, 3)
C ₁₈	(3/2, 2, 5/2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(2/3, 1, 2)	(2/7, 1/3, 2/5)	(1/3, 2/5, 1/2)	(1, 1, 1)

Table 5. Fuzzy pair-wise comparison matrix at metrics level for (C₂)

Metrics	C ₂₁	C ₂₂	C ₂₃	C ₂₄
C ₂₁	(1, 1, 1)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
C ₂₂	(3/2, 2, 5/2)	(1, 1, 1)	(1, 3/2, 2)	(1/2, 1, 3/2)
C ₂₃	(2, 5/2, 3)	(1/2, 2/3, 1)	(1, 1, 1)	(1, 3/2, 2)
C ₂₄	(3/2, 2, 5/2)	(2/3, 1, 2)	(1/2, 2/3, 1)	(1, 1, 1)

Table 6. Fuzzy pair-wise comparison matrix at metrics level for (C₃)

Metrics	C ₃₁	C ₃₂	C ₃₃	C ₃₄	C ₃₅	C ₃₆	C ₃₇
C ₃₁	(1, 1, 1)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(2/3, 1, 2)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(5/2, 3, 7/2)
C ₃₂	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)	(3/2, 2, 5/2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 1, 3/2)
C ₃₃	(2/7, 1/3, 2/5)	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)
C ₃₄	(1/2, 1, 3/2)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(1/2, 1, 3/2)	(2, 5/2, 3)
C ₃₅	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(2, 5/2, 3)	(1/2, 1, 3/2)	(1, 1, 1)	(2/3, 1, 2)	(2/7, 1/3, 2/5)
C ₃₆	(2/3, 1, 2)	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1, 3/2, 2)
C ₃₇	(2/7, 1/3, 2/5)	(2/3, 1, 2)	(2, 5/2, 3)	(1/3, 2/5, 1/2)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(1, 1, 1)

Table 7. Fuzzy pair-wise comparison matrix at metrics level for (C₄)

Metrics	C ₄₁	C ₄₂
C ₄₁	(1, 1, 1)	(1/3, 2/5, 1/2)
C ₄₂	(2, 5/2, 3)	(1, 1, 1)

The pair-wise comparison judgment matrix of the nine-point rating scale was adopted in this study. The relative weight vector was obtained by normalizing the geometric means for each row of the matrix, and the idealized weight vector was obtained by dividing each value of the relative weight vector by its largest value. Thus, the idealized weights of Outstanding, Excellent, Very Good, Above Average, Average, Below Average, Fair, Poor, Very Poor were determined as 1.0000, 0.5616, 0.5095, 0.3519, 0.2411, 0.1652, 0.1141, 0.0802, 0.0581, respectively,

The Consistency Index for a matrix is calculated from Equation (16), as $(\lambda_{\max} - n)/(n - 1)$ and, since $n = 9$ for this matrix, the CI is 0.03499. The final step is to calculate the Consistency Ratio for this set of judgments using the CI for the corresponding value from large samples of matrices of purely random judgments using the table above in Definition 3, derived from Saaty's book, in which the upper row is the order of the random matrix, and the lower is the corresponding index of

Table 8. Fuzzy pair-wise comparison matrix at metrics level for (C₅)

Metrics	C ₅₁	C ₅₂	C ₅₃
C ₅₁	(1, 1, 1)	(2, 5/2, 3)	(2, 5/2, 3)
C ₅₂	(1/3, 2/5, 1/2)	(1, 1, 1)	(2/3, 1, 2)
C ₅₃	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1, 1, 1)

Table 9. Fuzzy pair-wise comparison matrix at metrics level for (C₆)

Metrics	C ₆₁	C ₆₂
C ₆₁	(1, 1, 1)	(2/5, 1/2, 2/3)
C ₆₂	(3/2, 2, 5/2)	(1, 1, 1)

Table 10. Fuzzy pair-wise comparison matrix at metrics level for (C₇)

Metrics	C ₇₁	C ₇₂	C ₇₃	C ₇₄	C ₇₅
C ₇₁	(1, 1, 1)	(1/2, 1, 3/2)	(2, 5/2, 3)	(1/2, 1, 3/2)	(2, 5/2, 3)
C ₇₂	(2/3, 1, 2)	(1, 1, 1)	(1/3, 2/5, 1/2)	(1/2, 1, 3/2)	(1/3, 2/5, 1/2)
C ₇₃	(1/3, 2/5, 1/2)	(2, 5/2, 3)	(1, 1, 1)	(3/2, 2, 5/2)	(1, 1, 1)
C ₇₄	(2/3, 1, 2)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1/3, 2/5, 1/2)
C ₇₅	(1/3, 2/5, 1/2)	(2, 5/2, 3)	(1, 1, 1)	(2, 5/2, 3)	(1, 1, 1)

Table 11. Fuzzy pair-wise comparison matrix at metrics level for (C₈)

Metrics	C ₈₁	C ₈₂	C ₈₃	C ₈₄	C ₈₅	C ₈₆
C ₈₁	(1, 1, 1)	(1, 3/2, 2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)	(1, 1, 1)	(1/2, 2/3, 1)
C ₈₂	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 1, 3/2)	(2, 5/2, 3)	(1/2, 1, 3/2)	(1, 1, 1)
C ₈₃	(1, 3/2, 2)	(2/3, 1, 2)	(1, 1, 1)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)
C ₈₄	(2/7, 1/3, 2/5)	(1/3, 2/5, 1/2)	(2/7, 1/3, 2/5)	(1, 1, 1)	(2, 5/2, 3)	(3/2, 2, 5/2)
C ₈₅	(1, 1, 1)	(2/3, 1, 2)	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(1, 1, 1)	(1, 1, 1)
C ₈₆	(1, 3/2, 2)	(1, 1, 1)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)

Table 12. Fuzzy pair-wise comparison matrix at metrics level for (C₉)

Metrics	C ₉₁	C ₉₂	C ₉₃	C ₉₄	C ₉₅
C ₉₁	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 2)	(3/2, 2, 5/2)	(2/3, 1, 2)
C ₉₂	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/3, 1, 2)	(1/2, 2/3, 1)	(5/2, 3, 7/2)
C ₉₃	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1, 1, 1)	(2/3, 1, 2)	(2/5, 1/2, 2/3)
C ₉₄	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)
C ₉₅	(1/2, 1, 3/2)	(2/7, 1/3, 2/5)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)	(1, 1, 1)

Table 13. Fuzzy pair-wise comparison matrix at metrics level for (C₁₀)

Metrics	C ₁₀₁	C ₁₀₂	C ₁₀₃	C ₁₀₄
C ₁₀₁	(1, 1, 1)	(5/2, 3, 7/2)	(1/2, 2/3, 1)	(1/2, 2/3, 1)
C ₁₀₂	(2/7, 1/3, 2/5)	(1, 1, 1)	(2/3, 1, 2)	(2, 5/2, 3)
C ₁₀₃	(1, 3/2, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 1, 3/2)
C ₁₀₄	(1, 3/2, 2)	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(1, 1, 1)

Table 14. Fuzzy pair-wise comparison matrix at metrics level for (C₁₁)

Metrics	C ₁₁₁	C ₁₁₂	C ₁₁₃	C ₁₁₄	C ₁₁₅
C ₁₁₁	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)	(2/5, 1/2, 2/3)	(5/2, 3, 7/2)
C ₁₁₂	(1, 1, 1)	(1, 1, 1)	(2/7, 1/3, 2/5)	(1, 1, 1)	(3/2, 2, 5/2)
C ₁₁₃	(1/2, 2/3, 1)	(5/2, 3, 7/2)	(1, 1, 1)	(1/2, 1, 3/2)	(3/2, 2, 5/2)
C ₁₁₄	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	(2/3, 1, 2)
C ₁₁₅	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(1, 1, 1)

Table 15. The normalized priority weight vectors of core indices

Main criterions	Priority weight
Cost of service	0.0199
Reputation of the 3PL	0.1466
Long-term relationships	0.0973
Finance	0.1148
Service level	0.0837
Infrastructure	0.1296
Third-party logistics services (3PLS)	0.0568
Reverse logistics function (RLFs)	0.0498
Organizational role (OR)	0.1122
User satisfaction (US)	0.0795
IT applications (IT)	0.1098

Table 16. The normalized priority weight vectors of metrics

Metrics	Priority weight
Shipment cost	0.00000
Money transaction ability	0.26376
Additional charges	0.19055
Data transaction potential	0.00000
Dimension and Excellency in equipment	0.14885
Time consumption on delivery of goods	0.14846
Level of employees happiness	0.18761
Litheness in processes	0.06078
Bazaar prestige	0.01013
Agile delivery to warehouses	0.34335
International market data	0.35392
Practice for manufacturing comparable goods	0.29260
Data transaction ability	0.26796
Eagerness for exploring employees to handle downstream activities	0.11385
Reliance level	0.00257
Profit booking and threat sharing	0.14177
Effectiveness of cross-functional management	0.13627
Friendship	0.16918
Price of alliance	0.16840

(Continued)

Table 16. (Continued)

Metrics	Priority weight
Shipment prices	0.00000
Overall financial condition	1.00000
Delivery on lead time	0.50000
Effectiveness in service	0.00000
Litheness and effectiveness	0.50000
International service capability	0.00000
Availability of manpower to tackle the Logistic systems	1.00000
Stuff refill	0.28637
Warehouse terminal availability on schedule tenure	0.09665
Shipment coordination and collaboration	0.23681
Evaluation of shipper	0.12032
Shortest shipment services	0.25985
Recovery of scraps	0.21104
Casing of stuff	0.18356
Cargo storing	0.31072
Shortest routing	0.13778
Halfway processing	0.11487
Deliverance of stuff	0.04202
Grievance	0.24589
Reprocess	0.21925
Reproduction	0.16253
Re utilization	0.21172
Dumping	0.16062
Coordination level	0.28899
Swiftiness in service	0.26171
Price saving	0.24193
Overall working relations	0.20737
Storehouse administrative curriculum	0.27488
Order supervision	0.15537
Evaluation of supply chain strategy activities	0.31088
Order chasing system	0.23854
Transportation price	0.02032

consistency for random judgments. Using Equation (17), Consistency Ratio, $0.03499/1.45 = 0.02413$. According to Saaty, in practical decision situations, inconsistency is “acceptable” if $CR > 0.1$

Subsequently, participants were requested to assign a rating scale to a 3PL provider with respect to each of the metrics, and the resulting consensus rating scores were placed in the column titled “rating scores” in Table 18. Finally, the overall score for each of the four alternative 3PL providers were computed in purpose to evaluate the score and opt the most appropriate 3PL provider. The overall score S_i for the i th 3PL providers were obtained using the following formula (Soh, 2010).

$$S_i = \sum_{j=1}^n v_j r_{ij} \text{ textfor } i = 1, 2, \dots, n.$$

Table 17. Overall ranking of core indices for evaluation and selection of 3PL provider

Goal	Attributes (Level 1)	Priority weight (Level 1)	Metrics (Level 2)	Priority weight (Level 2)	Overall priority weight	Ranking
Appraisal and benchmarking of 3 PL Service providers	(C ₁)	0.0199	C ₁₁	0.00000	0.000000	46
			C ₁₂	0.26376	0.005251	36
			C ₁₃	0.19055	0.003794	37
			C ₁₄	0.00000	0.000000	46
			C ₁₅	0.14885	0.002963	39
			C ₁₆	0.14846	0.002956	40
			C ₁₇	0.18761	0.003735	38
			C ₁₈	0.06078	0.001210	44
	(C ₂)	0.1466	C ₂₁	0.01013	0.001485	43
			C ₂₂	0.34335	0.050349	4
			C ₂₃	0.35392	0.051901	3
			C ₂₄	0.29260	0.042908	5
	(C ₃)	0.0973	C ₃₁	0.26796	0.026070	11
			C ₃₂	0.11385	0.011076	29
			C ₃₃	0.00257	0.000251	45
			C ₃₄	0.14177	0.013793	26
			C ₃₅	0.13627	0.013258	28
			C ₃₆	0.16918	0.016459	21
			C ₃₇	0.16840	0.016384	22
	(C ₄)	0.1148	C ₄₁	0.00000	0.000000	46
			C ₄₂	1.00000	0.114818	2
	(C ₅)	0.0837	C ₅₁	0.50000	0.041854	6
			C ₅₂	0.00000	0.000000	46
			C ₅₃	0.50000	0.041854	6
	(C ₆)	0.1296	C ₆₁	0.00000	0.000000	46
			C ₆₂	1.00000	0.129618	1
	(C ₇)	0.0568	C ₇₁	0.28637	0.016269	23
			C ₇₂	0.09665	0.005491	35
			C ₇₃	0.23681	0.013453	27
			C ₇₄	0.12032	0.006835	33
			C ₇₅	0.25985	0.014762	25
	(C ₈)	0.0498	C ₈₁	0.21104	0.010506	30
			C ₈₂	0.18356	0.009138	31
			C ₈₃	0.31072	0.015468	24
			C ₈₄	0.13778	0.006859	32
			C ₈₅	0.11487	0.005719	34
			C ₈₆	0.04202	0.002092	42
(C ₉)	0.1122	C ₉₁	0.24589	0.027579	9	
		C ₉₂	0.21925	0.024591	12	
		C ₉₃	0.16253	0.018229	17	
		C ₉₄	0.21172	0.023747	13	
		C ₉₅	0.16062	0.018015	18	

(Continued)

Table 17. (Continued)

Goal	Attributes (Level 1)	Priority weight (Level 1)	Metrics (Level 2)	Priority weight (Level 2)	Overall priority weight	Ranking
	(C ₁₀)	0.0795	C ₁₀₁	0.28899	0.022961	14
			C ₁₀₂	0.26171	0.020794	15
			C ₁₀₃	0.24193	0.019222	16
			C ₁₀₄	0.20737	0.016476	20
	(C ₁₁)	0.1098	C ₁₁₁	0.27488	0.030184	8
			C ₁₁₂	0.15537	0.017061	19
			C ₁₁₃	0.31088	0.034137	7
			C ₁₁₄	0.23854	0.026193	10
			C ₁₁₅	0.02032	0.002232	41

where v_j is the global weight of j th metrics and r_{ij} is the rating score of i th 3PL provider with respect to j th metrics.

After renormalizing the overall scores in Table 18, S_1 was found to be the most suitable alternative amongst entire four third-party logistics Service Provider because it had the highest overall score (**0.26783**) among the four alternatives. Hence, alternative sorting is as following

$$S_1 > S_4 > S_2 > S_3$$

6. Managerial implication

Businesses are going global to take advantage of more cost-effective sources of goods and services, to enter new markets, and to implement higher margin, high-performance business models. The third-party logistics (3PL) industry worldwide has continued its expansion in the last few years as

Table 18. Overall scores of 3PL providers

Metrics	Local weight (LW)	Global weight (GW)	3PL (A)		3PL (B)		3PL (C)		3PL (D)	
			Rating scores	X GW	Rating scores	X GW	Rating scores	X GW	Rating scores	X GW
<i>Price of agile service (C₇)</i>	0.01991									
Shipment Cost	0.00000	0.000000	0.5095	0.00000	0.3519	0.00000	0.1652	0.00000	0.3519	0.00000
Money Transaction ability	0.26376	0.005251	0.5616	0.00295	1.0000	0.00525	0.5095	0.00268	0.5095	0.00268
Additional charges	0.19055	0.003794	0.1141	0.00043	0.5095	0.00193	0.5616	0.00213	0.1652	0.00063
Data Transaction potential	0.00000	0.000000	1.0000	0.00000	0.1141	0.00000	0.3519	0.00000	0.1141	0.00000
Dimension and Excellency in Equipment	0.14885	0.002963	0.1141	0.00034	0.5095	0.00151	0.2411	0.00071	0.5095	0.00151
Time consumption on Delivery of goods	0.14846	0.002956	0.3519	0.00104	0.1141	0.00034	0.1652	0.00049	0.5616	0.00166
Level of employees happiness	0.18761	0.003735	0.2411	0.00090	0.3519	0.00131	0.5095	0.00190	0.1141	0.00043
Litheness in processes	0.06078	0.001210	0.5095	0.00062	0.1652	0.00020	0.1652	0.00020	0.5095	0.00062
<i>Market image of third party logistic (C₂)</i>	0.14664									

(Continued)

Table 18. (Continued)

Metrics	Local weight (LW)	Global weight (GW)	3PL (A)		3PL (B)		3PL (C)		3PL (D)	
			Rating scores	X GW	Rating scores	X GW	Rating scores	X GW	Rating scores	X GW
Bazaar Prestige	0.01013	0.001485	0.1652	0.00025	0.5095	0.00076	0.5616	0.00083	0.1652	0.00025
Agile Delivery to warehouses	0.34335	0.050349	0.1652	0.00832	0.5616	0.02828	0.1652	0.00832	0.3519	0.01772
International Market data	0.35392	0.051901	0.5616	0.02915	0.1141	0.00592	0.5095	0.02644	0.1141	0.00592
Practice For manufacturing comparable goods	0.29260	0.042908	0.1141	0.00490	0.2411	0.01035	0.1652	0.00709	0.5095	0.02186
<i>Continuing alliances (C₃)</i>	0.09729									
Data Transaction ability	0.26796	0.026070	0.1652	0.00431	0.5095	0.01328	0.3519	0.00917	0.1141	0.00297
Eagerness for Exploring Employees to Handle Down-stream Activities	0.11385	0.011076	0.5095	0.00564	0.1141	0.00126	0.2411	0.00267	0.2411	0.00267
Reliance level	0.00257	0.000251	0.1652	0.00004	0.1652	0.00004	0.5095	0.00013	0.5095	0.00013
Profit booking and threat sharing	0.14177	0.013793	0.3519	0.00485	0.5616	0.00775	0.5616	0.00775	0.5616	0.00775
Effectiveness of Cross-functional management	0.13627	0.013258	0.5616	0.00745	0.1652	0.00219	0.1652	0.00219	0.1652	0.00219
Friendship	0.16918	0.016459	0.2411	0.00397	0.3519	0.00579	0.1141	0.00188	0.1141	0.00188
Price of alliance	0.16840	0.016384	0.5095	0.00835	0.2411	0.00395	0.5095	0.00835	0.5095	0.00835
<i>Funding condition (C₄)</i>	0.11482									
Shipment prices	0.00000	0.000000	0.1141	0.00000	0.5095	0.00000	0.1141	0.00000	0.3519	0.00000
Overall Financial condition	1.00000	0.114818	0.3519	0.04040	0.5616	0.06448	0.2411	0.02769	0.2411	0.02769
<i>Packing intensity (C₅)</i>	0.08371									
Delivery on lead time	0.50000	0.041854	0.5095	0.02133	0.3519	0.01473	0.3519	0.01473	0.5616	0.02350
Effectiveness in service	0.00000	0.000000	1.0000	0.00000	0.1141	0.00000	0.5616	0.00000	0.1141	0.00000
Litheness and Effectiveness	0.50000	0.041854	0.5616	0.02350	0.5095	0.02133	0.1141	0.00478	0.5095	0.02133
<i>Transportation and building structure (C₆)</i>	0.12962									
International service capability	0.00000	0.000000	0.1652	0.00000	0.1141	0.00000	0.5095	0.00000	0.1141	0.00000
Availability of manpower to tackle the Logistic systems	1.00000	0.129618	0.5095	0.06604	0.5616	0.07279	0.1652	0.02142	0.1652	0.02142
<i>Third-party logistics over-hauls (C₇)</i>	0.05681									
Stuff refill	0.28637	0.016269	0.1141	0.00186	1.0000	0.01627	0.1141	0.00186	0.5616	0.00914
Warehouse terminal availability on schedule tenure	0.09665	0.005491	0.5616	0.00308	0.1652	0.00091	0.5095	0.00280	0.2411	0.00132
Shipment coordination and collaboration	0.23681	0.013453	0.1141	0.00154	0.1141	0.00154	0.1652	0.00222	0.5095	0.00685
Evaluation of shipper	0.12032	0.006835	0.5616	0.00384	0.3519	0.00241	1.0000	0.00684	0.1141	0.00078
Shortest shipment services	0.25985	0.014762	0.3519	0.00519	0.5095	0.00752	0.5095	0.00752	1.0000	0.01476
<i>Downstream transportation functionality (C₈)</i>	0.04978									
Recovery of scraps	0.21104	0.010506	0.2411	0.00253	0.1141	0.00120	0.2411	0.00253	0.1652	0.00174
Casing of stuff	0.18356	0.009138	0.1652	0.00151	0.5616	0.00513	0.1141	0.00104	0.5095	0.00466
Cargo Storing	0.31072	0.015468	0.5095	0.00788	0.1141	0.00177	0.5616	0.00869	0.5616	0.00869
Shortest Routing	0.13778	0.006859	1.0000	0.00686	0.1652	0.00113	0.1652	0.00113	0.1141	0.00078
Halfway processing	0.11487	0.005719	0.1652	0.00094	0.5095	0.00291	0.1652	0.00094	0.3519	0.00201

(Continued)

Table 18. (Continued)

Metrics	Local weight (LW)	Global weight (GW)	3PL (A)		3PL (B)		3PL (C)		3PL (D)	
			Rating scores	X GW	Rating scores	X GW	Rating scores	X GW	Rating scores	X GW
Deliverance of stuff	0.04202	0.002092	0.1141	0.00024	0.1652	0.00035	0.5095	0.00107	0.1141	0.00024
<i>Managerial responsibility (C₉)</i>	0.11216									
Grievance	0.24589	0.027579	0.5095	0.01405	1.0000	0.02758	0.1141	0.00315	0.2411	0.00665
Reprocess	0.21925	0.024591	0.5616	0.01381	0.1652	0.00406	0.2411	0.00593	0.5616	0.01381
Reproduction	0.16253	0.018229	0.1141	0.00208	0.1652	0.00301	0.5616	0.01024	0.5095	0.00929
Re-utilization	0.21172	0.023747	0.3519	0.00836	0.3519	0.00836	0.1141	0.00271	0.1652	0.00392
Dumping	0.16062	0.018015	0.2411	0.00434	0.5095	0.00918	1.0000	0.01801	1.0000	0.01801
<i>Fulfillment of customer's order (C₁₀)</i>	0.07945									
Coordination level	0.28899	0.022961	0.3519	0.00808	0.1652	0.00379	0.5095	0.01170	0.1141	0.00262
Swiftiness in Service	0.26171	0.020794	0.5616	0.01168	0.5616	0.01168	0.1652	0.00344	0.5095	0.01060
Price saving	0.24193	0.019222	0.5095	0.00979	0.2411	0.00463	0.5616	0.01079	0.3519	0.00676
Overall working relations	0.20737	0.016476	1.0000	0.01648	0.1652	0.00272	0.2411	0.00397	0.2411	0.00397
<i>Data machinery availability (C₁₁)</i>	0.10981									
Storehouse Administrative curriculum	0.27488	0.030184	0.1652	0.00499	0.5095	0.01538	0.3519	0.01062	0.5616	0.01695
Order supervision	0.15537	0.017061	0.5616	0.00958	0.2411	0.00411	0.5095	0.00869	0.1652	0.00282
Evaluation of supply chain strategy activities	0.31088	0.034137	0.5095	0.01739	0.5616	0.01917	0.1652	0.00564	1.0000	0.03414
Order Chasing System	0.23854	0.026193	0.2411	0.00632	0.3519	0.00922	0.5616	0.01471	0.5095	0.01335
Transportation price	0.02032	0.002232	0.5616	0.00125	0.5095	0.00114	0.3519	0.00079	0.2411	0.00054
<i>Overall scores</i>			20.2628		18.6429		18.0853		18.6634	
<i>Renormalized scores</i>			0.26783		0.24642		0.23905		0.24669	

Logistics plays a significant role in integrating the supply chain of industries, where industries can cut expenses and improve their customer service quality. Specifically, a provider can offer an enterprise with its desirable services such as professional logistics transportation, warehousing, logistics information system, product returns service, inventory management, and product packaging. Hence, 3PL plays a key role in the logistic activities between the outsourcing company, the marketplace, and the customers.

If an appropriate 3PL provider is not selected, serious problems can occur, such as low-quality logistics services and contract non-fulfillment. This may then lead to the damaged reputation, image, and trust of the shipper. Hence, the selection of a suitable 3PL provider is an important factor that determines the logistics performance.

The proposed risk handling hairy AHP appraisalment platform provides important information that can be explored by enterprise top management on managing 3PL relationships; selection and contract management of 3PL service providers for building collaborative supply chain partnerships; and identifying significant success factors for 3PL implementation and establishing performance measures for long-term 3PL relationships. The reporting of this paper can be efficiently applied from both a manufacturer's and 3PL provider's perspective.

7. Conclusion

Presently, many companies consider logistics outsourcing as very important to increase their competitive advantages. A successful 3PL provider selection plays a critical role in building the long-term alliances amongst the outsourcing company and providers. In present exposure, the proposed risk handling (integrated Hairy) has been explored, where 3PL service providers have been examined for their strong and ill's core indices via multi hierarchical appraisal index, rather than that, the overall score (S_i) system has also been carried out for benchmarking the 3PL provider companies, where s_1 has been found as the best 3PL service provider. An applicability of the proposed approach has been shown in an automotive company for the selection of the third-party logistic provider. The technique can also be applied effectively to help any managerial decision-making. The findings provide valuable insights for logistics practitioners, academicians, and educators, as well as policy-makers, and also integrate selection criteria and metrics under the global supply chain environment.

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