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Full Length Research Paper

A decision model for evaluating third-party logistics providers using fuzzy analytic hierarchy process

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As a consequence of an increasing trend toward the outsourcing of logistics activities, shippers have been faced with the inevitability of selecting an appropriate third-party logistics (3PL) provider. The selection process for the identification of a 3PL provider that best fits user requirements involves multiple criteria and alternatives and may be one of the most complex decisions facing logistics users. In this regard, this study proposes an evaluation framework and methodology for selecting a suitable 3PL provider and illustrates the process of evaluation and selection through a case study. It is expected that the results of this study will provide a practical reference for logistics managers who want to engage the best 3PL provider. Future research using different datasets is warranted to verify the generalizability of the findings.

Key words: third-party logistics, fuzzy analytic hierarchy process, multi-criteria decision making, sensitivity analysis.

INTRODUCTION

The third-party logistics (3PL) industry worldwide has continued its growth in recent years, and is increasing in importance as a means of coping with rapid changes in the global competitive environment. As a consequence of an increasing trend toward the outsourcing of logistics activities, shippers have been faced with an inevitable need to select the best suitable 3PL provider. The use of 3PL providers can yield important benefits such as reduced logistics costs and fixed logistics assets, improved order fill rates, and shortened average order-cycle lengths and cash-to-cash cycles. 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 decision making problem for selecting the best 3PL provider has been receiving much attention recently among scholars as well as business practitioners. However, most studies have simply listed selection criteria for 3PL providers through survey methods; thus, they have not provided an integrated view. In this regard, this study proposes an integrated framework to assist decision makers in selecting the most appropriate 3PL provider.

Evaluating and selecting 3PL providers can be regarded as a multi-criteria decision making (MCDM) process in which a decision maker chooses, under several selection criteria, the best option among alternatives. One of the extensively used methods for MCDM is the analytic hierarchy process (AHP) introduced by Saaty (1980). Many researchers have applied AHP to solve MCDM problems in a number of different areas such as economic planning, energy policy, project selection, and budget allocation. However, the standard AHP has often been criticized for its inability to precisely handle the inherent uncertainty or vagueness associated with the mapping of a decision maker's judgment to a number (Chan and Kumar, 2007). In many practical cases, decision makers can be imprecise about their own level of preference because of incomplete information or knowledge, the vagueness of the human thought process, and the inherent complexity and uncertainty of the decision environment. Thus, it is difficult for a decision maker to express pair wise comparison judgments as exact numerical values on a ratio scale. To go beyond this limitation, it is more natural to express the com-parison ratios as interval numbers or fuzzy sets because they are suitable in representing uncertain human judgments. For this reason, this study applies a fuzzy modification of AHP (that is, fuzzy AHP) to determine the relative importance of selection criteria and

Table 1. Outsourced logistics services.

Logistics activities	North America			Europe			Asia Pacific		
	2006 (%)	2007 (%)	2008 (%)	2006 (%)	2007 (%)	2008 (%)	2006 (%)	2007 (%)	2008 (%)
Domestic transportation	83	77	78	95	91	92	95	85	91
International transportation	83	68	69	95	87	89	95	89	89
Warehousing	74	71	70	76	68	73	77	73	75
Customs clearance and brokerage	71	65	66	59	58	57	83	78	81
Forwarding	55	51	48	54	51	44	66	60	70
Shipment consolidation	44	44	46	50	44	43	53	45	55
Reverse logistics (defective, repair, return)	28	32	31	44	33	42	36	29	41
Cross-docking	36	36	37	40	35	43	30	26	35
Transportation management	27	33	39	36	41	38	48	27	36
Product labeling, packaging, assembly, kitting	26	31	29	45	33	42	33	34	37
Freight bill auditing and payment	55	51	54	22	18	20	18	14	21
Supply chain consultancy by 3PL provider	21	18	21	16	11	15	16	11	14
Order entry, processing and fulfillment	14	13	12	10	7	14	14	15	21
Fleet management	13	11	9	20	21	15	21	12	14
LLP/4PL services	12	13	11	13	11	13	6	10	14
Customer service	8	10	11	9	10	10	13	17	12

Note: The data in this table were collected from the annual third-party logistics study by C. John Langley, Jr. and research sponsors (www.3plstudy.com).

to eventually choose the best 3PL provider.

The overall objective of this study is to establish a decision criteria framework for evaluating 3PL providers and to propose an analytical method for selecting the best-suited 3PL provider. To achieve this objective, the paper is organized as follows. Firstly, in Section 2, some basic concepts of 3PL are described and a review of the literature on 3PL selection criteria is provided. The fuzzy AHP methodology is also introduced in Section 3. In Section 4, an empirical case study is presented to demonstrate the applicability of the proposed framework and approach. Finally, Section 5 concludes with a discussion of the findings and their implications.

LITERATURE REVIEW

The outsourcing of logistics activities to 3PL providers has now become a widely accepted practice across many industries. In fact, over 60% of Fortune 500 firms have at least one contract with a 3PL provider (Eyefortransport's USA Outsourcing Logistics Report 2007). The terms of 'third party logistics', 'logistics outsourcing', and 'contract logistics' have generally been used interchangeably both in literature and practice. 3PL refers to the utilization of external organizations to perform all or part of the logistics activities that have traditionally been performed within an organization (Lieb and Randall, 1996). A third party is neither the shipper (first party) nor the customer (second party) in the supply chain (Maltz and Lieb, 1995).

Table 1 summarizes the specific logistics services outsourced by 3PL users. As indicated in Table 1, the most frequently outsourced services in 2008 were domestic and international transportation, followed by warehousing, customs clearance and brokerage, and forwarding. Most companies have cited greater flexibility, operational efficiency, improved customer service levels, enhanced supply chain performance, and better focus on their core businesses as the advantages of engaging 3PL providers (Sahay and Mohan, 2006).

Evaluation criteria for selecting 3PL providers

To evaluate all possible supplier candidates and select the most suitable supplier, a set of criteria must be defined. By establishing a set of selection criteria, a company will be better able to select a 3PL provider that will best fit its needs and existing operations (Bhatnagar et al., 1999).

Sink and Langley (1997) presented a conceptual model of the 3PL buying process, which is composed of five distinct steps: (1) identify the need to outsource logistics, (2) develop feasible alternatives, (3) evaluate and select a supplier, (4) implement service, and (5) assess ongoing service performance. They characterized the selection phase as an essential task in the logistics outsourcing management. Indeed, studies have started to provide empirical evidence supporting the important impact supplier selection criteria have on the operational performance and the overall business performance of both the outsourcing company and the outsourcing service provider (Kannan and Tan, 2002).

Evaluation criteria for selecting a 3PL provider have been widely discussed in prior literature. The two most frequently cited reasons for outsourcing logistics activities are cost savings and service improvement expectations through outsourcing.

Many studies have emphasized financial soundness as an essential requisite for logistics partners (Bottani and Rizzi, 2006). However, cost is not the single most important decision variable; logistics service issues are also considered (Selviaridis and Spring, 2007). Thus, 3PL users need to balance cost with service (Setthakaset and Basnet, 2005). Roberts (1994) proposed the level of service provided, the quality of people, and cost as the three most used evaluation criteria in the choice of a qualified logistics provider. This is also reflected in the work of Bhatnagar et al. (1999), Dapiran et al. (1996) and Lieb et al. (1993); they found that cost and service represent the most important criteria in logistics outsourcing decisions. Boyson et al. (1999) found that financial stability, customer service capability, and service price were rated as the most important characteristic for selecting 3PL providers.

In addition to cost and service, a variety of other selection criteria have been cited in prior literature. According to a survey of 154 firms offering warehousing services in the United States by Spencer et al. (1994), the most important evaluative criteria for selecting external or third-party service providers are, in descending order of importance, the following: on-time performance, service quality, communication, reliability, service speed, and flexibility. Menon et al. (1998) reported that logistics managers consider perceived performance and perceived capability as important factors in selecting 3PL providers and that these variables tend to increase in importance when the external environment is competitive. Perceived performance is comprised of perceived on-time shipments and deliveries, the ability to meet promises, the availability of top management, and superior error rates. Perceived capability is comprised of perceived creative management and the financial stability of the provider. Aghazadeh (2003) provided five steps to selec-ting an effective 3PL provider and presented four relevant criteria: similar value/objectives, up-to-date information technology systems, trustworthy key management, and a relationship of mutual respect and shared willingness.

In 2003, the International Warehouse Logistics Associa-tion, which comprises more than 550 logistics companies of North America, identified the following ranking of 3PL selection criteria (in a descending order): price, reliability, service quality, on-time performance, cost reduction, flexibility and innovation, good communication, management quality, location, customize service, speed of service, order cycle time, easy to work with, customer support, vendor reputation, technical competence, special exper-tise, systems capabilities, variety of available services, decreased labor problems, personal relationships, decreased asset commitment, and early notification of disruptions. Huang and Kadar (2002), based on their survey of the 3PL market in China, ranked the following criteria for the selection of 3PL providers (from the most to least important in a descending order): industry/operation experience, reputation, lower price, network coverage, own strategic asset, integrated logistics pro-viding capability, and good IT system. Moberg and Speh (2004) investigated the criteria that are considered most important to U.S. warehousing customers when selecting third party providers. According to their empirical survey, the top four selection criteria are responsiveness to service requirements, quality of management, track record of ethical importance, and ability to provide value-added services. The less important selection criteria are (in a descending order): low cost, specific channel expertise, knowledge of market, personal relationship with key contacts, willingness to assume risk, investment in state-of-art technologies, size of firm, and national market coverage.

The abovementioned studies clearly show that the 3PL selection is an MCDM problem, including both quantitative and qualitative factors that are often in conflict with one another. Accordingly, this study proposes a balanced and integrated multi-criteria hierarchical framework for selecting 3PL providers through a careful examination of relevant criteria.

RESEARCH METHODOLOGY

The selection of a 3PL provider, which is characterized by multiple conflicting criteria, should be considered and evaluated in terms of many different criteria.

AHP is one of the most widely used methods for addressing such MCDM problems. Although AHP is widely known as an MCDM method, it has often been criticized in the literature (Goodwin and Wright, 2004). The most criticized aspect is the use of a ratio scale in pair-wise comparisons, rather than an interval scale commonly used in multi-attribute utility theory.

In the conventional AHP, a pair-wise comparison is made by using a nine-point ratio scale (Saaty, 1980) to represent a decision maker's judgment or preference. Even though a crisp scale of 1 to 9 may be easy to apply and use, it does not explicitly take into account the aspects of uncertainty, vagueness, or fuzziness commonly inherent in human decision making processes. For instance, when evaluating different suppliers, due to incomplete and uncertain information regarding potential suppliers and their performance, decision makers often find it is difficult to express their preferences precisely. In these situations, fuzzy set theory introduced by Zadeh (1965) has been used to model the imprecision of human judgments. Hence, this study presents an approach that integrates the concept of fuzzy set theory with AHP to select a 3PL provider that best satisfies the determined criteria.

Many applications of the fuzzy extended AHP methodology can be found in recent literature. Liu and Wang (2009) presented an integrated fuzzy approach (fuzzy delphi, fuzzy inference, and fuzzy linear assignment) for the evaluation and selection of 3PL providers. Celik et al. (2009) utilized the fuzzy AHP methodology to model the shipping registry selection. Cheng et al. (2008) applied the fuzzy AHP method to calculate the relative importance among individual dimensions and sub-criteria on the evaluation of fourth party logistics (4PLs) selection criteria. Sevkli et al. (2008) integrated the AHP methodology with the fuzzy multi-objective linear programming model to solve supplier selection problems of an appliance manufacturer based in Turkey. Zhang and Feng (2007) used fuzzy AHP to discuss a selection approach of reverse logistics provider

Table 2. Triangular fuzzy conversion scale.

Linguistic scale	Triangular fuzzy number	Triangular fuzzy reciprocal number
Equally important	(1, 1, 1)	(1, 1, 1)
Weakly more important	(2/3, 1, 3/2)	(2/3, 1, 3/2)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Absolutely more important	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

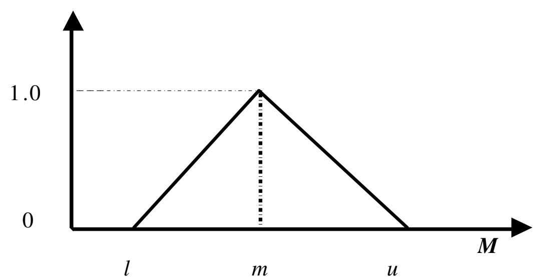

Figure 1. Triangular fuzzy number $\tilde{M}$.

through a case study. Chen et al. (2006) presented a hierarchical multi-criteria decision making model based on fuzzy set theory to address the supplier selection problem in supply chain management. So (2006) proposed an approach based on fuzzy AHP and balanced scorecard (BSC) for the logistics outsourcing decision. This paper takes an approach different from those proposed in prior literature; this study utilizes both the relative and absolute measurements for weighting a hierarchical structure and ranking the alternatives.

Fuzzy analytic hierarchy process

In fuzzy AHP, the triangular fuzzy numbers are used in the pair-wise comparison process to express subjective judgments. As shown in Figure 1, the triangular fuzzy numbers are defined by three real numbers, expressed as (*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.

$$\mu(x/\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u. \end{cases} \tag{1}$$

The methodology of fuzzy AHP, based on Chang's extent analysis (1992, 1996), follows. Let $X = \{x_1, x_2, ..., x_n\}$ be an object set, and $G = \{g_1, g_2, ..., g_n\}$ be a goal set. According to the principles of Chang's extent analysis, each object is taken and extent analysis for each goal is executed, respectively. This means that it is possible to obtain the values of *m* extent analysis that can be demonstrated as $M_{gi}^1, M_{gi}^2, ..., M_{gi}^m, \; i = 1, 2, ..., n$, where all the $M_{gi}^j \; (j = 1,2,....,m)$ 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:

$$S_i = \sum_{j=1}^{m} M_{ij} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij} \right]^{-1} \tag{2}$$

Where;

$\sum_{j=1}^{m} M_{ij} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right), \sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right)$, and

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right).$$

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 of $M_1 = (l_1, m_1, u_1) \ge M_2 = (l_2, m_2, u_2)$ is defined as:

$$V\left(\tilde{M}_1 \ge \tilde{M}_2\right) = height(\tilde{M}_1 \cap \tilde{M}_2) = \mu_{M_1}(d)$$
$$= \begin{cases} 1, & if \quad m_1 \ge m_2 \\ 0, & if \quad l_2 \ge u_1 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & if \quad m_2 \ge m_1 \end{cases} \tag{3}$$

Where; *d* is the ordinate of the highest intersection point *D* between μ_{M_1} and μ_{M_2} (Figure 2). To compare M_1 and M_2, both values of $V(M_1 \ge M_2)$ and $V(M_2 \ge M_1)$ are required.

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

$$V(M \ge M_1, M_2, ..., M_k) = V\left[(M \ge M_1) \; and \; (M \ge M_2) \; and ... and \; (M \ge M_k)\right]$$
$$= \min \; V(M \ge M_i), \quad i = 1,2,...,k. \tag{4}$$

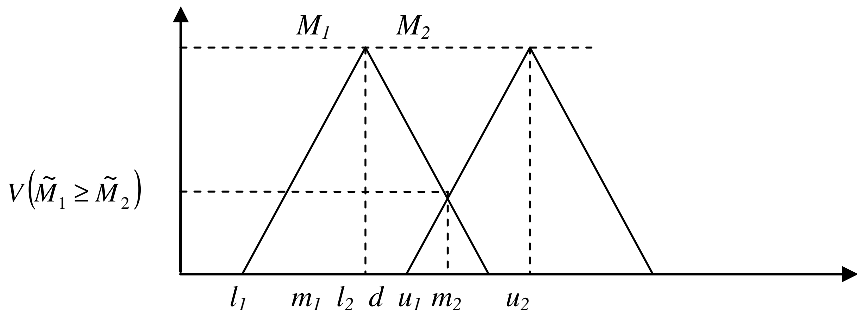

Figure 2. The intersection between M_1 and M_2.

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

$$W' = (d'(X_1), d'(X_2), ..., d'(X_n))^T \quad (5)$$

Where; $X_i = (i = 1,2,...,n)$ are *n* elements.

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

$$W = (d(X_1), d(X_2), ..., d(X_n))^T \quad (6)$$

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

EMPIRICAL RESULTS

In order to demonstrate a practical application of the approach presented in this paper, an empirical case study was performed with a local manufacturing firm that had wanted to engage the services of an appropriate 3PL provider. First, a decision hierarchy for selecting a 3PL provider was designed with five levels as illustrated in Figure 3. The top level of the hierarchy stands for the ultimate goal: to evaluate and select a 3PL provider that best meets the shipper's requirements. The selection criteria and the sub-criteria, which were generated through a process of literature review and brainstorming, are shown in the second and third levels, respectively. To construct the criteria framework, a preliminary list of 21 criteria was prepared from relevant literature and subsequently presented to three academic experts for their review to determine the final set of candidate criteria. After an intense discussion and a round of voting, a final list of 13 criteria was determined. During this phase, the 13 criteria were categorized into five groups: finance, service level, relationship, management, and infrastructure. At the fourth level, the absolute measurement mode of AHP was applied to represent the performance of each alternative under each sub-criterion in the immediately preceding level. The use of absolute measurements rather than pairwise comparisons is recommended when a large number of entities are to be compared. Evaluators generally do not have enough information and experience to adequately consider all alternatives; as such, it is very difficult to distinguish among and compare alternatives. Saaty (1990) also pointed out that, "with the absolute measurement of AHP, there can never be a reversal in the rank of the alternatives by adding or deleting other alternatives." For this study, a five-point rating scale of outstanding, good, average, fair, and poor (Liberatore, 1987) was used. The lowest level contained the alternatives to be evaluated: four different 3PL providers.

After constructing the decision hierarchy, pair-wise comparisons were performed by a group of seven participants from the case company. The participants were requested to compare all of the main criteria and the sub-criteria of a given main criterion in terms of their relative importance, using the scale given in Table 2. All pair-wise comparison judgments were represented as triangular fuzzy numbers in this study. As an example, one of the fuzzy judgment matrices of main criteria with respect to the goal is shown in Table 3. Then, as shown in Table 4, an aggregated pairwise comparison matrix was constructed by integrating the fuzzy judgment values of different partici-pants through the fuzzy geometric mean method (Buckley, 1985). Buckley (1985) defined the fuzzy geometric mean $\tilde{r}_j$ and fuzzy weights $\tilde{w}_j$ of the *j-th* criterion from *m* evaluators as follows: $\tilde{w}_j = \tilde{r}_j \otimes (\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_m)^{-1}$; $\tilde{r}_j = (\tilde{a}_{j1} \otimes \cdots \otimes \tilde{a}_{jm})^{1/m}$, where $\oplus$ and $\otimes$ represent the addition and multiplication operations of fuzzy numbers, respectively.

After obtaining the fuzzified pairwise comparison matrices, the relative importance (weights) of all criteria and sub-criteria were calculated by the fuzzy AHP method described in Section 2.3. To identify the computation stages clearly, the pairwise judgments from Table 4 were evaluated as follows.

From Table 4, the values of fuzzy synthetic extent with respect to the goal were calculated by using equation 2:

$S_1(Finance) = (3.75, 4.44, 5.36) \otimes (1/30.28, 1/25.55, 1/21.73) = (0.17, 0.24, 0.34)$

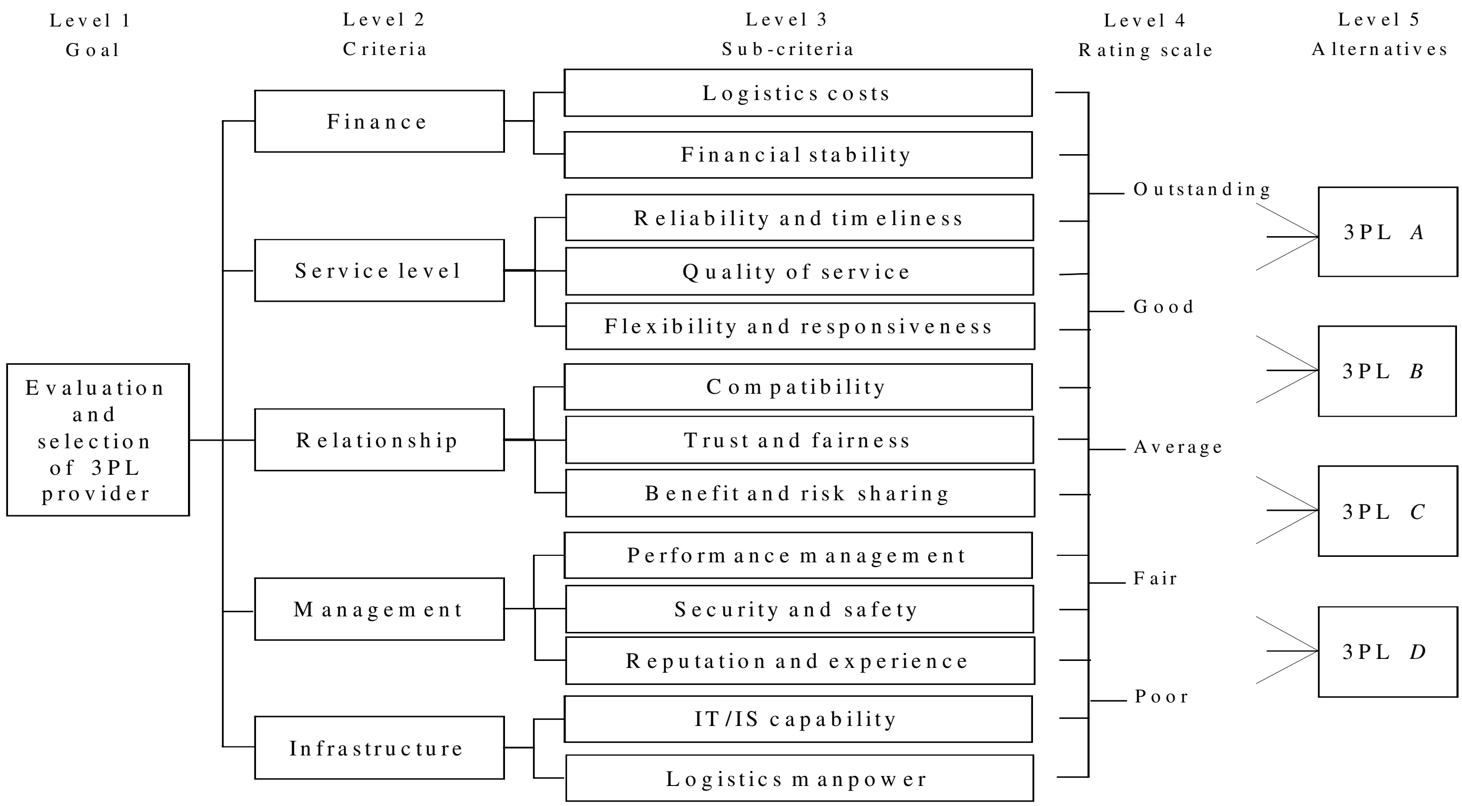

Figure 3. Decision hierarchy for selecting a 3PL provider.

Table 3. Triangular fuzzy judgment matrix for main criteria.

Criteria	Finance	Service level	Relationship	Management	Infrastructure
Finance	(1, 1, 1)	(2/3, 1, 3/2)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)	(5/2, 3, 7/2)
Service level	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)	(5/2, 3, 7/2)
Relationship	(2/7, 1/3, 2/5)	(2/3, 1, 3/2)	(1, 1, 1)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)
Management	(5/2, 3, 7/2)	(1, 1, 1)	(5/2, 3, 7/2)	(1, 1, 1)	(3/2, 2, 5/2)
Infrastructure	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)	(1, 1, 1)

$$S_3(Relationship) = (4.57, 5.42, 6.45) \otimes (1/30.28, 1/25.55, 1/21.73) = (0.15, 0.21, 0.30)$$

$$S_4(Management) = (3.71, 4.36, 5.21) \otimes (1/30.28, 1/25.55, 1/21.73) = (0.12, 0.17, 0.24)$$

$$S_5(Infrastructure) = (4.53, 5.17, 5.89) \otimes (1/30.28, 1/25.55, 1/21.73) = (0.15, 0.20, 0.27)$$

These synthetic values were compared by using equation 3, and $V(S_1 \geq S_2) = 0.53$, $V(S_1 \geq S_3) = 0.72$, $V(S_1 \geq S_4) = 1$, $V(S_1 \geq S_5) = 0.77$, $V(S_2 \geq S_1) = 1$, $V(S_2 \geq S_3) = 1$, $V(S_2 \geq S_4) = 1$, $V(S_2 \geq S_5) = 1$, $V(S_3 \geq S_1) = 1$, $V(S_3 \geq S_2) = 0.81$, $V(S_3 \geq S_4) = 1$, $V(S_3 \geq S_5) = 1$, $V(S_4 \geq S_1) = 0.97$, $V(S_4 \geq S_2) = 0.50$, $V(S_4 \geq S_3) = 0.68$, $V(S_4 \geq S_5) = 0.74$, $V(S_5 \geq S_1) = 1$, $V(S_5 \geq S_2) = 0.72$, $V(S_5 \geq S_3) = 0.93$, $V(S_5 \geq S_4) = 1$ were obtained.

Thereafter, the minimum degree of possibility was determined from equation 4:

$$d'(Finance) = \min(0.53,\ 0.72,\ 1,\ 0.77) = 0.532$$

$$d'(Service\ level) = \min(1,\ 1,\ 1,\ 1) = 1$$

$$d'(Relationship) = \min(1,\ 0.81,\ 1,\ 1) = 0.812$$

Table 4. Fuzzy aggregate pairwise comparison matrix for main criteria.

Criteria	Finance	Service level	Relationship	Management	Infrastructure
Finance	(1.00, 1.00, 1.00)	(0.527, 0.635,0.777)	(0.692, 0.906,1.196)	(0.703, 0.944,1.261)	(0.828, 0.960, 1.129)
Service level	(1.287, 1.575,1.898)	(1.00, 1.00, 1.00)	(0.703, 0.906,1.178)	(1.157, 1.511,1.940)	(1.015, 1.170, 1.343)
Relationship	(0.836, 1.104,1.445)	(0.849, 1.104,1.423)	(1.00, 1.00, 1.00)	(0.953, 1.104,1.267)	(0.934, 1.104, 1.314)
Management	(0.793, 1.060,1.423)	(0.516, 0.662,0.864)	(0.789, 0.906,1.049)	(1.00, 1.00, 1.00)	(0.613, 0.731, 0.877)
Infrastructure	(0.886, 1.042,1.208)	(0.745, 0.855,0.985)	(0.761, 0.906,1.070)	(1.140, 1.369,1.630)	(1.00, 1.00, 1.00)

$$d'(Management) = \min(0.97,\ \ 0.50,\ \ 0.68,\ \ 0.74) = 0.496$$

$$d'(Infrastructure) = \min(1,\ \ 0.72,\ \ 0.93,\ \ 1) = 0.722$$

Using equation (5), the weight vector from Table 4 was determined as $W' = (0.532,\ 1,\ 0.812,\ 0.496,\ 0.722)^T$. After the normalization through equation (6), the priority weights of main criteria were obtained as $(0.149,\ 0.281,\ 0.228,\ 0.139,\ 0.203)^T$. This indicates that service level is the most important criteria (0.281) in selecting a 3PL provider, followed by relationship (0.228), infrastructure (0.203), finance (0.149), and management (0.139). By following the same procedure, the sub-criteria were compared with respect to their correspond-ding main criteria, and the priority weights of sub-criteria were calculated as given in the second column of Table 5. The global composite priority weights given in the third column of Table 5 were calculated by multiplying the priority weights of sub-criteria with those of their corresponding main criteria in the next higher level of the hierarchy.

The weighting for each alternative under each sub-criterion was performed through a rating scale technique used by Liberatore (Liberatore, 1987; Liberatore et al., 1992) as well as proposed in many books of Saaty (1994, p.17). Table 6 shows the pair-wise comparison judgment matrix of the five-point rating scale 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, good, average, fair, and poor were determined as 1.000, 0.517, 0.254, 0.125 and 0.065, respectively. Subse-quently, participants were requested to assign a rating scale to a 3PL provider with respect to each of the sub-criterion, and the resulting consensus rating scores were placed in the column titled "rating scores" in Table 5. With the use of idealized weights, the main advantage is that it prevents the undesirable rank reversal phenol-menon, which potentially occurs when a new alternative is added or an existing alternative is removed from a set of alternatives (Rao, 2007).

Finally, the overall score for each of the four alternative 3PL providers was computed for the purpose of selecting the most appropriate 3PL provider. The overall score S_i for the i-th 3PL provider was obtained using the following formula:

$$S_i = \sum_{j=1}^{n} v_j\, r_{ij} \quad \text{for } i = 1,2,\ldots,n,$$

Where; v_j is the global weight of j-th sub-criterion and r_{ij} is the rating score of i-th 3PL provider with respect to j-th sub-criterion.

After renormalizing the overall scores in Table 6, 3PL *D* was determined to be the most suitable alternative with respect to the shipper's requirements because it had the highest overall score (0.305) among the four alternatives.

In addition, a sensitivity analysis was performed to test the reliability of the final result. Since the priorities and rankings of the alternatives were heavily dependent on the weights given to the decision criteria, it was necessary to examine how sensitive the recommended decision was to the changes in the importance of the major criteria (Saaty, 1995). A series of sensitivity analy-ses were conducted using the Expert Choice Software. Figure 4 shows the performance sensitivity analysis graph, where the five criteria are repre-sented as vertical bars, the left y-axis gives the criteria importance, and the right y-axis gives the alternative priorities with respect to each criterion. The figure shows that 3PL *D* outperformed all other alternatives on most criteria, even though 3PL *C* performed better on the relationship criterion and 3PL. A performed better on the management criterion. The gradient sensitivity analysis in Figure 5 represents the variation of 3PL providers' ranking to the changes in the relative importance of service level as the most influential selection criterion. 3PL *D* still completely dominated all other alternatives, despite a certain degree of variation in the decision weights. Overall,

Table 5. Overall scores of 3PL providers.

Criteria/Sub-criteria	Local Weights (LW)	Global Weights (GW)	3PL *A*		3PL *B*		3PL *C*		3PL *D*	
			Rating scores	× GW	Rating scores	× GW	Rating scores	× GW	Rating scores	× GW
Finance	0.149									
Logistics costs	0.395	0.059	0.254	0.015	0.125	0.007	0.517	0.030	0.254	0.015
Financial stability	0.605	0.090	0.517	0.047	0.254	0.023	0.125	0.011	0.517	0.047
Service level	0.281									
Reliability and timeliness	0.378	0.106	0.254	0.027	0.517	0.055	0.517	0.055	0.254	0.027
Quality of service	0.405	0.114	0.125	0.014	0.254	0.029	0.125	0.014	0.517	0.059
Flexibility and responsiveness	0.217	0.061	0.254	0.015	0.125	0.008	0.254	0.015	0.125	0.008
Relationship	0.228									
Compatibility	0.454	0.104	0.125	0.013	0.125	0.013	0.517	0.054	0.254	0.026
Trust and fairness	0.160	0.036	0.517	0.019	0.254	0.009	0.254	0.009	0.254	0.009
Benefit and risk sharing	0.386	0.088	0.254	0.022	0.254	0.022	0.517	0.046	0.517	0.046
Management	0.139									
Performance management	0.312	0.043	0.517	0.022	0.125	0.005	0.254	0.011	0.254	0.011
Security and safety	0.295	0.041	0.254	0.010	0.254	0.010	0.517	0.021	0.125	0.005
Reputation and experience	0.392	0.055	0.254	0.014	0.125	0.007	0.254	0.014	0.254	0.014
Infrastructure	0.203									
IT/IS capability	0.784	0.159	0.125	0.020	0.254	0.040	0.125	0.020	0.517	0.082
Logistics manpower	0.216	0.044	0.517	0.023	0.125	0.005	0.517	0.023	0.254	0.011
Overall scores				0.262		0.235		0.323		0.359
Renormalized scores				0.222		0.199		0.274		0.305

Table 6. Pairwise comparison judgment matrix for five-point rating scale.

Ratings	Outstanding	Good	Average	Fair	Poor	Relative vector	Idealized vector
Outstanding	1	3	5	7	9	0.510	1.000
Good	1/3	1	3	5	7	0.264	0.517
Average	1/5	1/3	1	3	5	0.130	0.254
Fair	1/7	1/5	1/5	1	3	0.064	0.125
Poor	1/9	1/7	1/7	1/3	1	0.033	0.065

Inconsistency index = 0.053.

the sensitivity analysis confirmed the robustness of the study findings.

DISCUSSION AND CONCLUSION

Outsourcing has become a common practice in many industries, particularly in the logistics and supply chain management. With more companies outsourcing their logistics operations, selecting appropriate and desirable 3PL providers has become a critical strategic decision. Nevertheless, relatively little empirical research has been undertaken on this issue, mainly because of complexities and uncertainties inherent in the decision making process. In this light, the present study provides a practical approach and methodology for companies to select a 3PL provider that best meets their requirements.

In essence, the 3PL provider selection process is an MCDM problem which involves subjective value judge ments. Although AHP is the most common method for an MCDM problem, AHP seems insufficient and imprecise in terms of accurately capturing a decision maker's subject-

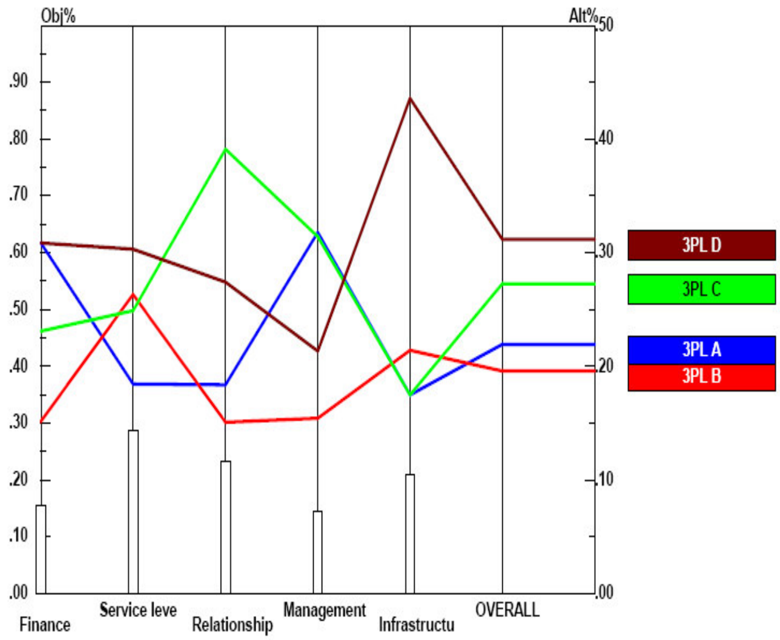

Figure 4. Performance sensitivity of alternatives.

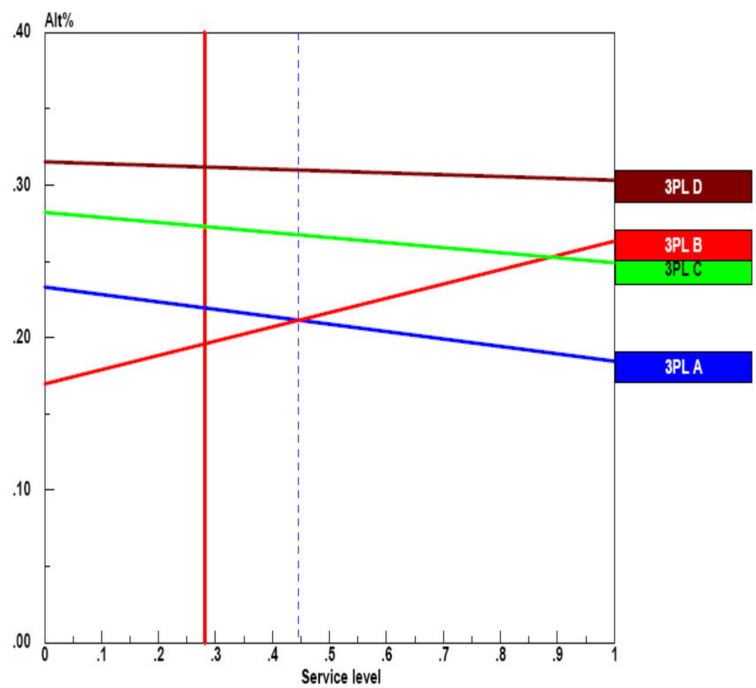

Figure 5. Gradient sensitivity for service level.

tive judgments regarding the interpretation of qualitative evaluation criteria. To compensate for this deficiency in the crisp pairwise comparison of the conventional AHP, a hybrid approach integrating the AHP methodology with fuzzy logic has been proposed and applied to a practical case study for selecting the best-suited 3PL provider. The proposed fuzzy AHP approach has both the advantage of AHP, which decomposes complex decision problems into a systematic hierarchical structure, and the advantage of Fuzzy logic, which reflects the subjectiveness and imprecision inherent in the human decision making process. Thus, this study contributes by extending the fuzzy AHP application to the problem of selecting a 3PL outsourcing partner, which is different from selecting a supplier to provide a specific task or product. In addition, this study uses both the relative and absolute measurements for weighting a hierarchical structure and ranking alternatives, allowing a more realistic and accurate representation of the 3PL provider selection problem.

The main finding of this study is the determination of the relative importance of selection criteria used to evaluate potential 3PL providers. Although many criteria have been proposed in prior literature for the selection of 3PL providers, less focus has been placed to their relative importance. Hence, this study investigates the relative importance using the fuzzy AHP approach. The results suggest information technology capability as the most important criterion for selecting a 3PL provider, which implies that information technology capability of 3PL firms is one of the most critical factors affecting the decision of a logistics user to outsource to a 3PL provider (Lai et al., 2008). This finding reflects the result of a recent survey conducted by Langley (2007), which showed that information technology capability is one of the top three factors in the performance of 3PL providers and one of the three main ongoing problems with 3PL providers reported by logistics users. As such, 3PL providers should maintain a high level of information technology capability to develop and maintain successful logistics outsourcing relationships.

This study also proposes a structured, multi-criteria decision support model for evaluating and selecting the best 3PL provider (Figure 3). With the developed model, four decision choices were assumed for the illustrative purpose, and the process in which an optimal decision choice is made using the fuzzy AHP approach has been explained. It is expected that this study will provide practitioners with a guide that can be used to make better decisions when selecting 3PL providers.

This study used a small sample size, which limits the generalization of the results. However, the AHP-based approach used in this study is a subjective methodology that permits the collection and analysis of data from a small group of experts (Wong and Li, 2008). Nevertheless, future study is warranted to verify the results using different datasets, improving the generalizability of the results.

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ABSTRACT:-The selection of third party logistics (TPL) providers is an important issue for enterprises to outsource their logistics business. In this paper we propose a comprehensive evaluation model for TPL suppliers based on AHP method. Furthermore, we Base on the evaluation index system including logistics cost, the logistics operation efficiency and the basic qualities of service. The efficiency and application of the proposed approach has been illustrated with a case study in Emergency Department of Sfax hospital. The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, shipbuilding and education.