An Application of Fuzzy Delphi and Fuzzy AHP for Multi-criteria Evaluation Model of Fourth Party Logistics

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Abstract: -
In the global tide, modern businesses face a high uncertainty and heavy variation of degree in the dynamic environment. Organizations have to maintain their competitive advantage by applying IT continuously; therefore, the condition forces business models to differ greatly from before. When businesses want to achieve supply chain integration, they may outsource their parts of businesses to fourth party logistics (4PLs) company. 4PLs company plays the role of integrator, which provides both information technology and supply chain integration capabilities. It not only creates different values of each segment in the supply chain, but also elevates the effects in supply chain management for business. Therefore, how to select an appropriate 4PLs company is an important decision for business. Through this study, we can understand these evaluation criteria and their weights, so as to aid the selection of 4PLs for businesses.

Key-Words: - Fourth Party Logistics, Supply Chain Integration Capabilities, Information Technology Capabilities, Fuzzy Delphi Method, Fuzzy Analytic Hierarchy Process

1 Introduction

We have learned something via observing the dynamic and intensive environment: the firms have to maintain their competitive advantages by linking with other firms to enhance its competitive strength. The success of the firm is largely determined by the strength of its supply chain. With few exceptions, companies outsourced most parts of supply chain operations to various service providers, each of which manages only certain discrete activities in a whole supply chain.

Traditional third party logistics(3PLs) such as forwarders or carriers are currently common practices while fourth party logistics (4PLs) are emerging to address needs of the client organizations managing only certain discrete activities in a whole supply chain are main players for logistic services in the past. As global operations become a de facto standard of market competition, companies are desperately calling for an integrated service provider to coordinate all related activities for seamless supply chain operations. 4PLs is thus emerging to provide a total solution for supply chain [9].

While 4PLs is seemingly a sound business concept to fill the gap in order fulfillment between manufacturers and customers, the exact business scope it should cover remains yet to be specified. And the consistent plays the role of integrator, which provides both information technology and supply chain integration capabilities. It not only creates different values of each segment in the supply chain, but also elevates the effects in supply chain management for business. In our research, the analysis and integration of theories and studies relate to the 4PLs criteria selection include 4PLs, supply chain integration capabilities, and information technology capabilities. In addition, the collection of variables is separated into two groups, which are supply chain integration capabilities and information technology capabilities, as initiatory evaluation dimensions.

Then the first-stage questionnaire investigation is conducted by Fuzzy Delphi Method (FDM). To select the professionals with the experience of logistics from the industry and academic experts, such as, the senior managers of UPS and FedEx, the MIS director of China Airline, the manager of technology enterprise, and the academic circles form the experts group as the questionnaire subjects. At the first stage, the questionnaire is designed in a fuzzy linguistic scale, and every expert rates the importance of individual criterion in the form of a triangular fuzzy number, and then they reach a consensus in determining the importance to serve as the primary evaluation criteria of 4PLs. At the second stage, the statistic results are provided to these experts and

pair-comparison of all criteria is made, thus the weight of individual criteria is calculated by Fuzzy Analytic Hierarchy Process (FAHP). Hence, the fuzzy multi-criteria model of 4PLs is established through the process of the experts' rating of the criteria.

The remainder of this paper is organized as follows. Section 2 reviews the 4PLs, supply chain integration capabilities, information technology capabilities, Fuzzy Delphi Method, and Fuzzy Analytic Hierarchy Process, in Section 3, we present the methodology and the analysis result, and Section 4 is the conclusion.

2 Literature Review

2.1 Fourth Party Logistics

Fourth party logistics (4PLs) company works as an integrator, which provides both information technology and supply chain integration capabilities. Not only does it create different values of each segment in the supply chain, but elevates the effects in supply chain management of business.

With the constraint of its capability, 3PLs can not provide whole logistics services and comprehensive management for all supply chain processes, which resemble in development and management of logistics information technology, the institution of customer services prior to or behind the product delivery and order processing [9].

The notion of 4PLs was originally introduced and registered as a trademark by Accenture in 1996, which is a famous management consulting company. Accenture indicates that the logistics development turns from supplier's storage and transportation concerned to supplier providing a suite of more integrated solutions for supply chain. According to the definition of Accenture, "the 4PLs provider is an integrator of supply chain, which can integrate various resources, capacities and techniques both of company internal and complementary service vendors"[1]. 4PLs is a supply chain integrator who assembles and manages the resources, capabilities and technology of its own organization with those of complementary service provider to distribute a comprehensive supply chain solution and to provide extreme whole benefits [9].

4PLs is in the best-of-breed position to integrate the various logistics services among the whole supply chain. It also has the expertise to dominate resources, technology, and processes [7]. A successful 4PLs must employ the strategic supply chain expertise and invest in new technology. 4PLs also maintain the relationships with shipper and logistics service provider [26]. As stated by these studies, we defined the 4PLs which is the integrator of supply chain, utilizing the responsiveness of information technology and the expertise, incorporate the internal physical facilities, technology capabilities, and resources through planning, analyzing, coordinating, and controlling, providing the best supply chain solution for customers.

2.2 Supply Chain Integration Capabilities

Supply Chain contains four tiers: supply, manufacturing, distribution, and customer. There are plentiful facilities in each tier. [3] Therefore, how to incorporate effective and efficient integration of supplier into value chain and supply chain is a crucial factor for manufacturers in achieving improvements necessary for maintaining competitive advantages [23].

Supply chain integration capabilities (SCIC) means that the business processes from end user to the manufacturer which contain the products, services, information, and value added for customers [17]. SCIC merges the relationships, activities, functions, processes, and locations in supply chain which connects a firm with its customer, suppliers, and other channel members. It integrates their relationships, activities, functions, processes, and locations. It also improves the effectiveness and efficiency of supply chain for customers [21].

As stated by Ballou et al., SCIC is consist of "(1) intra-functional coordination (administration of the activities and processes within the logistics function of a firm); (2) coordination of inter-functional activities, such as between logistics and finance, logistics and production, and logistics and marketing, as they take place among the functional areas of the firm; and (3) coordination of inter-organizational supply chain activities that take place between legally separate firms within the product-flow channel, such as between a firm and its suppliers" [2]. SCIC also can divide into two types; the first type of integration involves coordinating and integrating the forward physical flow of distributions between suppliers, manufacturers, and customers. The other type of integration involves the backward coordination of information technologies and the flow of data from customers to suppliers [8].

From the internal supply chain integration (e.g., transportation, logistics, sales, procurement, and manufacturing) and external supply chain integration (e.g., operational planning, channel power, loyalty, and interactive relationships), Morash and Clinton [20] aimed the role of transportation capabilities in international supply chain management. Moreover, Morash and Clinton [21] discussed customer value from inter-organizational integration and

intra-organizational integration in 1998. Frohlich and Westbrook [8] focus on arcs of integration in international supply chain strategies, and Narasimhan and Kim [22] aimed the effect of diversification and performance to supply chain integration. According to these studies, we regard as SCIC can separate into three dimensions, which are external supply chain integration (ESCI), internal supply chain integration (ISCI) and supply chain performance (SCP). ESCI means that the integration of supplier, customer and the members in the supply chain. ISCI indicates the intra organizational integration, specialization, and regular interdepartmental meetings et cetera, and SCP means the customer satisfaction, operational efficiency, and service quality et cetera.

2.3 Information Technology Capabilities

Information Technology (IT), as defined by the Information Technology Association of America (ITAA), is composed of these parts: the study, design, development, implementation, support or management of computer-based information systems which is inclusive of software applications and computer hardware."

In Fortune 200 firms, they will spend 20-40% of budget on information technology (IT) to maintain their competitive advantage [19]. Using IT to manage the supply chain processes substantially increase in the firms. IT can enhance supply chain dexterity, reduce cycle time, achieve higher efficiency, and timely deliver products [28]. IT has become a critical component of a firm's competitive advantage. Firms must endeavor to differentiate themselves by employing and adapting of new IT [24]. The implementation of IT in the supply chain can enable a firm to develop and accumulate knowledge warehouse with customers, suppliers, and market demands, which influences firm performance [27].

A successful Information system (IS) is the most critical factor of measuring the information technology capabilities (ITC). DeLone and McLean [6] proposed a refined IS successful model which includes information quality, system quality, and service quality, intention to use, user satisfaction, and net benefits. From IS structure and IS success, Heo and Han [10] evaluated the impact of IS on business performance. Jiang et al. [15] discussed the IS service performance from self-perceptions and user perceptions. Ragu-Nathan et al., [24] focused on the effect of top management support for IS performance. As stated by these studies, we regard ITC can be separated into five dimensions, which are information system structure (ISS), information system success factor (ISSF), user perception (UP), information system utility (ISU), work performance (WP). ISS means the centralization of IS, and standardization of IS et cetera. ISSF indicates the operation speed of IS, powerful integration IS, and information characteristics of IS and so on. UP means the user participation, educational Training, and IS experts' attitude and participation. ISU indicate that utilizing IS to raise the efficiency, achieving goals by utilizing IS, and diversification capabilities of IS et cetera. WP means that loyalty of MIS professionals, skills of MIS professionals, and work quality of MIS professionals.

2.4 Fuzzy Delphi Method and Fuzzy Analytic Hierarchy Process

The role of decision-making is become more complicated today. Accordingly, the importance of experts' suggestion can not be more emphasized in various fields. Delphi Method is a technique for structuring an effective group communication process by providing feedback of individual contributions of information and assessment of the group judgment, and enabling individuals to re-evaluate their judgments. Since its development in the 1960s at Rand Corporation, the Delphi method has been widely used as a forecasting technique. On the other hand, Delphi Method use crisp number and mean to become the evaluation criteria, these shortcomings might distort the experts' opinion.

In order to solve the problem of traditional Delphi method, Ishikawa et al. [14] used the fuzzy theory into the Delphi Method to improve time-consuming problems from Hwang and Lin [13] such as the convergence of experts' options. Furthermore, because people are often uncertain in assigning the evaluation in crisp number, to overcome the problem, this study adopts the fuzzy linguistic scale.

The analytic hierarchy process (AHP) methodology was developed by Satty [25]. It is a powerful method in solving complex decision problems. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. By reducing complex decisions to a series of simple pair wise comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts to arrive at the best decision, but also provides a clear rationale for the choices made.

Hence, AHP approach has been widely applied in various relative fields to solve the decision-making problems with multiple hierarchies under the situation of uncertainty. Besides, due to the defect of traditional AHP application by Buckley [4] such as the characteristics of subjectiveness, fuzziness, and imprecision, many researches incorporated the Fuzzy

theory into the AHP method to improve its application. [5]

In this study, due to the fuzziness existed in the part of evaluation criteria, we decide to adopt the Fuzzy Delphi Method (FDM) to form the primary evaluation criteria of 4PLs selection, and employ the Fuzzy Analytic Hierarchy Process (FAHP) to calculate the weight of individual criteria so as to establish the Fuzzy Multi-criteria Model of 4PLs selection criteria. The evaluation factors directly related to our study's purpose are included through the survey of relative literatures about supply chain integration capabilities and information technology capabilities.

3 The Methodology and the Analysis of Results

3.1 Choosing the Experts

This study focuses on the analysis of evaluation criteria of 4PLs selection. Thus the experts chosen are the professionals in the fields related to our research with the experience of industrial and academic experts. Besides, they should be have at least 3 years of working experience with the logistics or transportation experiences, and their positions are at least the rank of managers or assistant professors. In general, the numbers of expert are from three to fifteen [18]. This study is sent out to ten experts in Taiwan and ten effective responses were received from five members of industrial experts, such as, UPS, FedEx, China Airlines, and five members of academic experts from university faculties.

3.2 Determining the Evaluation Criteria

The Fuzzy Delphi Method is employed to explore the important criteria of 4PLs selection, and there are the following steps:

Step 1. Building the Evaluation Criteria

At the first stage, through the literature survey of supply chain integration capability and information technology capability, we obtain important variables such as "external supply chain integration", "internal supply chain integration", "supply chain performance", "information system structure", "information system capability", "user perception", "information system utility", and "work performance". And these variables are organized as dimensions.

At this stage, twenty-four supply chain integration characteristics, and twenty-six information technology characteristics are totally chosen, and the SCIC are further classified into three categories according to the classification of domestic prospectus as ESCI, ISCI and SCP. The ITC are further classified into five categories according to the classification of domestic prospectus as ISS, ISSF, UP, ISU, and WP.

Step 2. Collecting the Experts' Opinions

The selected experts are asked to answer the questionnaire in a 9-point fuzzy semantic differential scale of "absolutely important", "very important", "pretty important", "quite important", "no comment", "fairly unimportant", "quite unimportant", "very unimportant", and "absolutely unimportant". And the experts assign a relative importance to individual criteria with respect to two dimensions of supply chain integration and information technology in order to form the important criteria of 4PLs selection. As shown in Figure 1.

Step 3. Applying the Fuzzy Delphi Method to Select the Evaluation Criteria

(i) Establishing the Triangular Fuzzy Function

The experts' estimations gathered by prior step are used to establish the triangular fuzzy function of individual criteria through the process of Fuzzy Delphi Method by Ishikawa et al. [14]. The process of application is as follows:

1. The elements of evaluation set are determined by the experts' questionnaires of high-yield bonds selection. Given a score of 100 and 0 to the traditional binary logics of "absolutely important" and "absolutely unimportant" respectively, the other elements of evaluation set are quantified objectively through the treatment of Fuzzy Delphi Method.

2. The questionnaires are designed for the elements of set other than "absolutely important" and "absolutely unimportant", and the experts are invited to fill the quantitative score interval of individual elements in the evaluation set. The maximum of interval value is the experts' most optimistic cognition of the quantitative score for the element, and the minimum of interval value is the experts' most conservative cognition of the quantitative score for the element.

3. Solving the minimum L, geometric mean M, and the maximum U of all experts' most optimistic cognition score for individual elements, along with the minimum l, geometric mean m, and the maximum u of all experts' most conservative cognition score for individual elements, respectively.

Triangular fuzzy number $A = (L, M, U)_{L\text{-}R}$ of all experts' most optimistic cognition for individual elements and triangular fuzzy number $a = (l, m, u)_{L\text{-}R}$ of all experts' most conservative cognition for individual elements are established, respectively. It is shown as Figure 1.

Table 1. The Triangular Fuzzy Function with Respect to each Evaluation Criteria by industrial experts

	Dimensions	Evaluation Criteria	The Most Conservative Cognition [min, median, max]	Gray Interval	The Most Optimistic Cognition [min, median, max]	The Median in Gray Interval
Supply Chain Integration	External Supply Chain Integration	Extent of Partner Relationships	[60,76.5103,90]	[70,90]	[70,85.2425,100]	80
		Communication with Customers	[70,82.2248,94]	[80,94]	[80,90.5609,100]	87
		Members' Participation	[60,74.3965,95]	[70,95]	[70,83.2580,100]	82.5
		Members' Loyalty	[60,72.5572,84]	[70,84]	[70,82.4105,94]	77
		Resource Sharing	[60,68.9892,84]	[70,84]	[70,78.6287,94]	77
		Importance of Green Logistics	[66,69.7368,75]	[76,75]	[76,80.5509,84]	75.5
		Importance of Reverse Logistics	[60,72.7047,90]	[70,90]	[70,84.2549,100]	80
		Supply Chain Reengineering	[60,67.7990,76]	[70,76]	[70,78.9604,87]	73
		Members' Sharing of Performance Result	[44,60.0997,75]	[68,75]	[68,74.6814,84]	71.5
		Benefits Derived from Partner Relationships	[38,64.7659,85]	[44,85]	[44,73.0806,94]	64.5
		Frequent Members' Assessment Measurements	[54,69.9477,85]	[66,85]	[66,79.8968,90]	75.5
	Internal Supply Chain Integration	Specialization	[66,71.6243,80]	[76,80]	[76,82.4709,90]	78
		Intra Organizational Integration	[66,77.1243,85]	[84,85]	[84,88.1668,90]	84.5
		Regular Interdepartmental Meetings	[66,71.3055,76]	[80,76]	[80,82.7583,87]	78
		Competitive Strategy	[28,56.0999,75]	[38,75]	[38,66.8216,83]	56.5
		Providing 3PLs Services	[28,62.9415,84]	[38,84]	[38,73.4285,94]	61
	Supply Chain Performance	Customer Satisfaction	[68,78.9892,95]	[76,95]	[76,86.7916,100]	85.5
		Reducing Delays	[60,70.5508,85]	[70,85]	[70,79.3736,94]	77.5
		Operational Efficiency	[66,71.9085,90]	[75,90]	[75,82.5370,100]	82.5
		Flexibility	[44,64.3782,80]	[68,80]	[68,79.0381,90]	74
		Problem Solving Capability	[68,76.9552,90]	[76,90]	[76,86.1434,100]	83
		Frequency of New Services	[28,53.8397,68]	[38,68]	[38,65.1424,84]	53
		Service Quality	[60,79.6109,94]	[70,94]	[70,88.6055,100]	82
		Cost Leadership	[44,70.4713,95]	[68,95]	[68,85.5019,100]	81.5
Information Technology	Information System Structure	Responsiveness of HW and SW	[68,80.6809,95]	[76,95]	[76,89.4142,100]	85.5
		Centralization of IS	[60,68.7410,95]	[70,95]	[70,79.2607,100]	82.5
		Standardization of IS	[60,70.8933,85]	[70,85]	[70,81.8928,90]	77.5
		Sharing of IS Resources and Data	[44,65.2727,85]	[68,85]	[68,79.8131,90]	76.5
		Capability and Attitude of IS Department	[60,79.9912,95]	[70,95]	[70,89.4436,100]	82.5
	Information System Success Factor	Operation Speed of IS	[60,74.7291,85]	[70,85]	[70,83.4651,94]	77.5
		Information Characteristics of IS	[60,83.5532,95]	[70,95]	[70,91.1734,100]	82.5
		Electronic Data Interchange	[68,73.1828,84]	[76,84]	[76,82.3834,94]	80
		Data Integration	[60,69.5840,84]	[70,84]	[70,78.6028,94]	77
		Powerful Integration IS	[60,71.2103,85]	[70,85]	[70,81.6085,90]	77.5
		Top Management Support	[60,74.3965,95]	[70,95]	[70,83.2580,100]	82.5
	User Perception	IS Experts' Attitude and Participation	[70,74.8290,84]	[80,84]	[80,84.6410,94]	82
		User Participation	[60,74.3965,85]	[70,85]	[70,83.7559,94]	77.5
		Educational Training	[44,61.9814,75]	[68,75]	[68,76.7027,84]	71.5
	Information System Utility	Diversification Capabilities of IS	[60,69.1407,76]	[70,76]	[70,80.5773,87]	73
		Utilizing IS to Raise the Efficiency	[70, 80.5751,95]	[80,95]	[80,89.9489,100]	87.5
		Achieving Goals by Utilizing IS	[60,76.4101,95]	[70,95]	[70,85.2425,100]	82.5
		Enhancing financial performance by utilizing IS	[44,72.2318,95]	[68,95]	[68,85.6237,100]	81.5
		User Satisfaction with IS	[44,64.5,85]	[68,85]	[68,77.6274,94]	76.5
		Facilitation of IS	[44,64.5,85]	[68,85]	[68,79.7285,94]	76.5
		Extensibility of IS	[60,77.5,95]	[70,95]	[70,83.2580,100]	82.5
	Work Performance	Attitude of MIS Professionals	[44,64.5,85]	[68,85]	[68,77.9550,90]	76.5
		Trust between MIS Professionals and Users	[70,77.5,85]	[80,85]	[80,86.0229,94]	82.5
		Loyalty of MIS Professionals	[40,67.5,95]	[60,95]	[60,78.6028,100]	77.5
		Skills of MIS Professionals	[60,77.5,95]	[70,95]	[70,83.2580,100]	82.5
		Work Quality of MIS Professionals	[60,77.5,95]	[70,95]	[70,87.0578,100]	82.5

Note: Gray zones are the sum of weight that exceeds 80 percent.

Table 2. The Triangular Fuzzy Function with Respect to each Evaluation Criteria by academic experts

	Dimensions	Evaluation Criteria	The Most Conservative Cognition [min, median, max]	Gray Interval	The Most Optimistic Cognition [min, median, max]	The Median in Gray Interval
Supply Chain Integration	External Supply Chain Integration	Extent of Partner Relationships	[70,79.9906,86]	[83,86]	[83,92.3661,100]	84.5
		Communication with Customers	[32,63.3529,85]	[42,85]	[42,77.9959,100]	63.5
		Members' Participation	[55,72.5116,85]	[75,85]	[75,89.0157,100]	80
		Members' Loyalty	[25,53.5074,86]	[40,86]	[40,69.4869,100]	63
		Resource Sharing	[67,70.9465,75]	[80,75]	[80,86.4075,95]	77.5
		Importance of Green Logistics	[35,48.9860,73]	[45,73]	[45,64.6509,83]	59
		Importance of Reverse Logistics	[35,50.9516,73]	[45,73]	[45,66.3546,83]	59
		Supply Chain Reengineering	[46,57.2248,70]	[71,70]	[71,75.5034,80]	70.5
		Members' Sharing of Performance Result	[55,68.8553,80]	[75,80]	[75,85.1304,92]	77.5
		Benefits Derived from Partner Relationships	[35,58.0477,73]	[55,73]	[55,75.0785,92]	64
		Frequent Members' Assessment Measurements	[55,65.9918,86]	[70,86]	[70,80.9964,100]	78
	Internal Supply Chain Integration	Specialization	[55,72.6020,92]	[75,92]	[75,88.7949,100]	83.5
		Intra Organizational Integration	[55,62.4622,70]	[75,70]	[75,79.9515,83]	72.5
		Regular Interdepartmental Meetings	[35,49.9173,70]	[55,70]	[55,66.9945,80]	62.5
		Competitive Strategy	[55,68.4841,80]	[75,80]	[75,84.3819,92]	77.5
		Providing 3PLs Services	[40,51.7066,60]	[60,60]	[60,68.8740,82]	60
	Supply Chain Performance	Customer Satisfaction	[32,69.2333,86]	[42,86]	[42,82.3187,100]	64
		Reducing Delays	[20,49.9136,85]	[30,85]	[30,64.9878,100]	57.5
		Operational Efficiency	[55,64.6550,73]	[70,73]	[70,80.2455,92]	71.5
		Flexibility	[55,69.7498,80]	[75,80]	[75,85.7595,92]	77.5
		Problem Solving Capability	[55,73.3209,86]	[75,86]	[75,87.2017,100]	80.5
		Frequency of New Services	[35,51.0212,70]	[45,70]	[45,67.6506,82]	57.5
		Service Quality	[35,59.9692,75]	[55,75]	[55,78.1474,92]	65
		Cost Leadership	[32,56.5423,86]	[42,86]	[42,72.3836,100]	64
Information Technology	Information System Structure	Responsiveness of HW and SW	[70,74.5789,86]	[80,86]	[80,87.8606,100]	83
		Centralization of IS	[35,53.5181,80]	[55,80]	[55,72.0995,90]	67.5
		Standardization of IS	[55,72.8686,86]	[75,86]	[75,86.9853,100]	80.5
		Sharing of IS Resources and Data	[55,65.2634,85]	[70,85]	[70,81.7799,100]	77.5
		Capability and Attitude of IS Department	[60,70.0640,80]	[70,80]	[70,85.5039,95]	75
	Information System Success Factor	Operation Speed of IS	[55,68.0272,86]	[71,86]	[71,82.5525,100]	78.5
		Information Characteristics of IS	[70,81.2032,92]	[80,92]	[80,94.6592,100]	86
		Electronic Data Interchange	[10,52.5364,86]	[20,86]	[20,69.1140,100]	53
		Data Integration	[70,77.5318,86]	[80,86]	[80,91.1965,100]	83
		Powerful Integration IS	[60,73.3194,86]	[70,86]	[70,86.9418,100]	78
		Top Management Support	[55,76.4469,92]	[75,92]	[75,90.5126,100]	83.5
	User Perception	IS Experts' Attitude and Participation	[70,76.5974,86]	[83,86]	[83,89.9548,100]	84.5
		User Participation	[67,74.3060,92]	[80,92]	[80,89.6883,100]	86
		Educational Training	[40,62.8557,80]	[60,80]	[60,81.0218,95]	70
	Information System Utility	Diversification Capabilities of IS	[63,71.6141,85]	[80,85]	[80,89.0304,100]	82.5
		Utilizing IS to Raise the Efficiency	[67,72.7449,85]	[80,85]	[80,87.2985,100]	82.5
		Achieving Goals by Utilizing IS	[55,71.9622,86]	[70,86]	[70,86.0757,100]	78
		Enhancing financial performance by utilizing IS	[40,64.7164,86]	[60,86]	[60,81.7100,100]	73
		User Satisfaction with IS	[60,72.3147,86]	[70,86]	[70,85.5452,100]	78
		Facilitation of IS	[55,72.8686,86]	[71,86]	[71,86.0370,100]	78.5
		Extensibility of IS	[60,76.5674,86]	[70,86]	[70,89.2723,100]	78
	Work Performance	Attitude of MIS Professionals	[35,67.9990,92]	[55,92]	[55,83.0881,100]	73.5
		Trust between MIS Professionals and Users	[67,74.2135,80]	[83,80]	[83,89.9114,95]	81.5
		Loyalty of MIS Professionals	[35,57.8376,92]	[55,92]	[55,77.1452,100]	73.5
		Skills of MIS Professionals	[55,72.6020,92]	[75,92]	[75,88.7949,100]	83.5
		Work Quality of MIS Professionals	[70,81.2032,92]	[80,92]	[80,94.6592,100]	86

Note: Gray zones are the sum of weight that exceeds 80 percent.

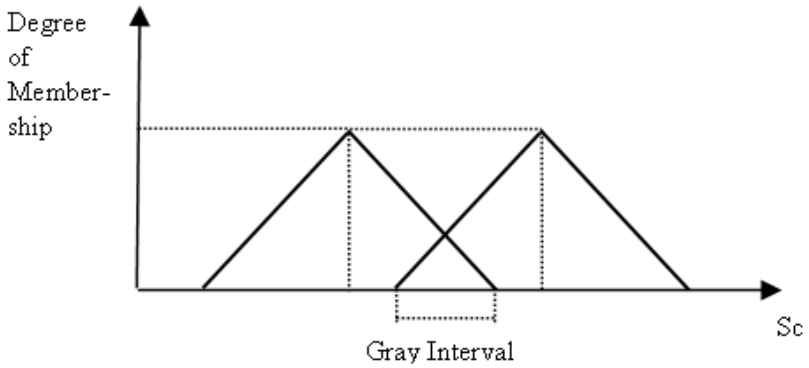

Fig. 1. Triangular fuzzy number of the most optimistic cognition and the most conservative cognition

(ii) Analyzing the Value of Triangular Fuzzy Function

To organize and analyze the experts questionnaire collected at first stage, triangular fuzzy function with respect to individual evaluation criteria is established as shown in Table 1 and Table 2.

(iii) Selecting the Evaluation Criteria

When selecting the evaluation criteria, it is generally considered important if the importance is greater than 80%. Hence, we assign the score of more than 80 to the median of gray interval as threshold, and the important criteria consistently agreed by those experts are accordingly selected.

Obtained from the collected experts' questionnaires, there are 29 important criteria commonly agreed by 10 experts. They are listed as follows.

In supply chain integration:

1. External supply chain integration: (1) extent of partner relationships, (2) communication with customers, (3) members' participation, and (4) importance of reverse logistics.

2. Internal supply chain integration: (1) specialization, and (2) intra organizational integration.

3. Supply chain performance: (1) customer satisfaction, (2) operational efficiency, (3) problem solving capability, (4) services quality, and (5) cost leadership.

In information technology,

1. Information system structure: (1) responsiveness of HW and SW, (2) centralization of IS, (3) standardization of IS and (4) capability and attitude of IS department.

2. Information system success factor: (1) information characteristics of IS, (2) electronic data interchange, (3) data integration, and (4) top management support.

3. User perception: (1) IS experts' attitude and participation and (2) user participation.

4. Information system utility: (1) diversification capabilities of IS, (2) utilizing IS to raise the efficiency, (3) achieving goals by utilizing IS, (4) enhancing financial performance by utilizing IS, (5) extensibility of IS, and (6) trust between MIS professionals and users.

5. Work performance: (1) skills of MIS professionals and (2) work quality of MIS professionals.

3.3 Applying the Fuzzy Analytic Hierarchy Process

In this section, we apply the fuzzy analytic hierarchy process (FAHP) to calculate the weights of individual dimension and individual criteria of 4PLs selection. The process is listed as follows.

Step 1. Building the Hierarchical Structure

First is to build the hierarchical structure. The goal is placed at the top of hierarchy, and the general criteria (dimensions) are placed at second level. The secondary subcriteria with respect to each dimension are placed at third level, and the tertiary subcriteria with respect to each secondary subcriteria are placed at the fourth level.

In our case, the goal at the top level is "evaluation of 4PLs criteria selection", and there are two evaluation dimensions of "supply chain integration" and "information technology" at second level. With respect to each dimension at the second level, there are some secondary sub criteria listed at third level. For example, there are three secondary sub criteria: "external supply chain integration", "internal supply chain integration", and "supply chain performance" with respect to the dimension "supply chain integration".

Moreover, there are several tertiary subcriteria with respect to each secondary subcriteria, such as "extent of partner relationships", "communication with customers", "members' participation", and "importance of reverse logistics" with respect to

"external supply chain integration". The detail of hierarchical structure is shown in Table 1.

Step 2. Building the Pairwise Comparison Matrix
By the second questionnaires collected from experts, we obtain the relative importance of paired factors at level n+1 under the evaluation of criteria at level n by individual experts' opinions, and the pairwise comparison matrix is accordingly formed.

Step 3. Building Triangular Fuzzy Numbers
Concerning the relative importance of individual evaluation criteria in pairwise comparison matrix, triangular fuzzy number is adopted to integrate all experts' opinions. This could adequately present the fuzziness of all experts' opinions with respect to the relative importance of paired factors.

$$\tilde{\alpha}_{ij} = (\alpha_{ij}, \beta_{ij}, \delta_{ij})_{L-R} \quad (1)$$

Where

$\tilde{\alpha}_{ij}$: Triangular fuzzy number

α_{ij}: The minimum of the j-th subcriteria subordinated to the i-th general criteria

β_{ij} : The geometric mean of the j-th subcriteria subordinated to the i-th general criteria

δ_{ij}: The maximum of the j-th subcriteria subordinated to the i-th general criteria

L-R: Fuzzy interval of triangular fuzzy numbers

Step 4. Building the Fuzzy Positive Reciprocal Matrix
After the triangular fuzzy numbers are solved to represent the fuzziness of experts' opinions, the fuzzy positive reciprocal matrix A can be further built.

$$A = [\tilde{\alpha}_{ij}]$$
$$\tilde{\alpha}_{ij} = [\alpha_{ij}, \beta_{ij}, \delta_{ij}] \quad (2)$$

Step 5. Calculating the Fuzzy Weights of Fuzzy Positive Reciprocal Matrix
In our study, we employ the method which is developed by Buckley [4] and improved by Hsu [12] to calculate the fuzzy weights. This method is based on the experts' precise value and synthesizes the experts' opinions with the geometric mean instead of the fuzzy numbers input directly by experts. Thus, not only the consistency but also the concept of normalization is easily achieved. Through the following formulas, the positive reciprocal geometric mean Zi and the fuzzy weight $\overline{W_i}$ can be obtained.

$$Z_i = [\tilde{\alpha}_{i1} \otimes \ldots \otimes \tilde{\alpha}_{in}]^{1/n}, \forall_i$$
$$\overline{W_i} = Z_i \otimes (Z_1 \oplus \ldots \oplus Z_n)^{-1} \quad (3)$$

Where Zi is the geometric mean of triangular fuzzy numbers

$$\tilde{\alpha}_1 \otimes \tilde{\alpha}_2 \cong (\alpha_1 \times \alpha_2, \beta_1 \times \beta_2, \delta_1 \times \delta_2)$$
$$\tilde{\alpha}_1 \oplus \tilde{\alpha}_2 \cong (\alpha_1 + \alpha_2, \beta_1 + \beta_2, \delta_1 + \delta_2)$$
$$Z_1^{-1} = (\delta_1^{-1}, \beta_1^{-1}, \alpha_1^{-1})_{L-R}$$
$$\tilde{\alpha}_1^{\frac{1}{n}} = \left(\alpha_1^{\frac{1}{n}}, \beta_1^{\frac{1}{n}}, \delta_1^{\frac{1}{n}}\right)$$

Step 6. Defuzzification
Since the weights of individual dimensions and criteria are fuzzy values, it is necessary to solve a nonfuzzy value by the process of defuzzification. In our study, the Centroid method is employed to defuzzy, and the reasons are: (1) the Centroid method is widely used in relative literatures as Klir's and Yuan's [16], and (2) the solution can be figured out quite quickly. Through the following formulas, the defuzzified weight Wi can be obtained.

$$W_i = \frac{W_{\alpha i} + W\beta_i + W\delta_i}{3} \quad (4)$$

$W_{\alpha i}$: The right-end value of the fuzzy weight

$W_{\beta i}$: The fuzzy weight's value with the degree of membership as 1

$W_{\delta i}$: The left-end value of the fuzzy weight

Step 7. Normalization
In order to effectively compare the importance among various dimensions and criteria, we normalize the obtained weights as follows.

$$NW_i = \frac{W_i}{\sum_{i=1}^{i=n} W_i} \quad (5)$$

Step 8. Syntheses of Hierarchy
The weights of individual dimensions (criteria) and subcriteria can be obtained by step 1 through step 7. If the weights of criteria or subcriteria at upper hierarchy need to be calculated, then the weights of their subordinated subcriteria should be synthesized. By the following formula, the syntheses of weights at various level of hierarchy can be obtained.

$$NW_k = NW_i \times NW_{ip} \quad (6)$$

3.4 The Empirical Results

In this research, we apply the Fuzzy Analytic Hierarchy Process (FAHP) method to calculate the relative importance among individual dimensions and subcriteria on the evaluation of 4PLs selection criteria, and the empirical results such as the weights and the ranks of individual criteria or subcriteria are also presented in Figure 2 and Figure 3. Where the obtained weights are the decimals below individual criteria or subcriteria, and the ranks of individual

lowest subcriteria are the numbers in parentheses below the weights.

Generally, the more weighted value of criterion means that experts consider that is more important. According to the Pareto Principle rule, the 80 percent can represent the importance of whole. Consequently, the study sums the weighted value in descending order, the front sixteen criteria (weighted value is 0.8024) of industrial viewpoint. Whereas, the front fifteen criteria (weighted value is 0.8032) of academic viewpoint. In brief, there are sixteen criteria selection of 4PLs, as shown in Table 3.

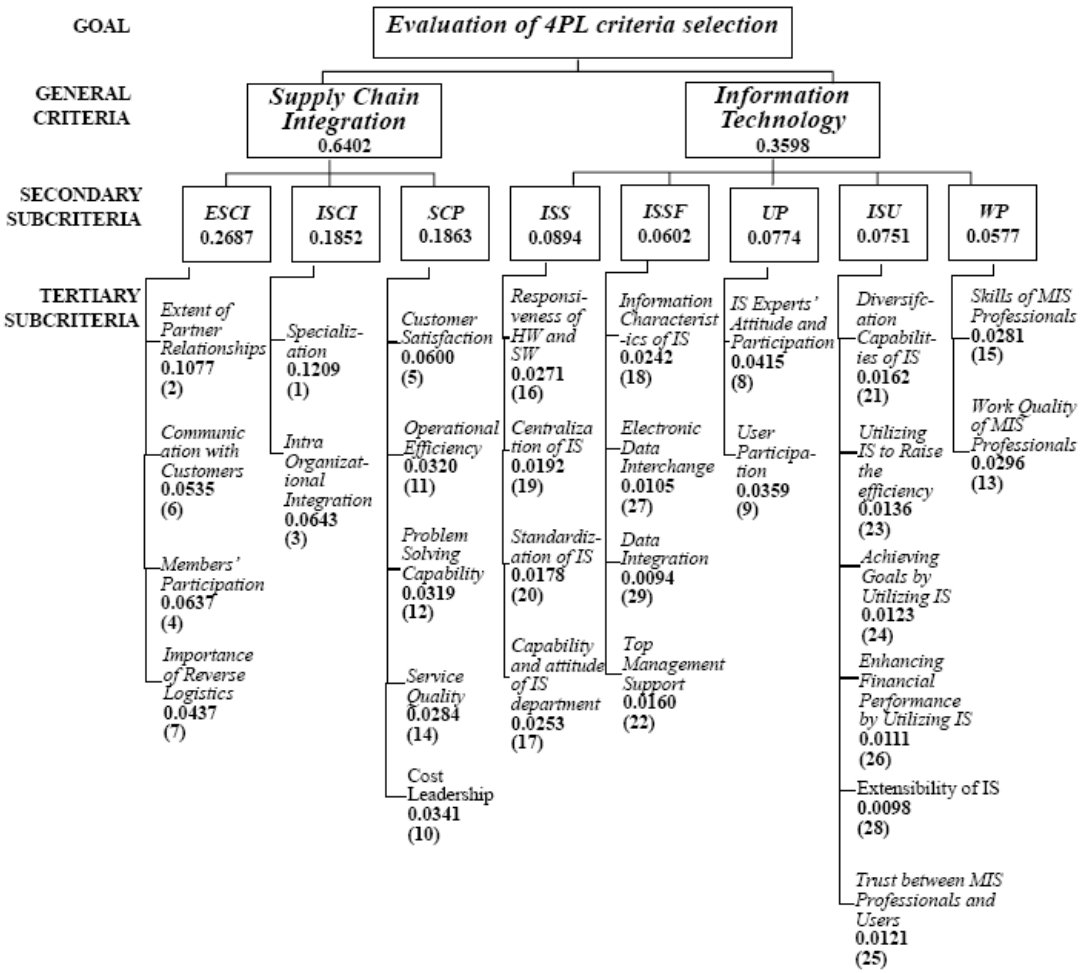

Fig. 2. Hierarchy Structure for Evaluation Criteria of 4PLs Selection by Industrial Experts

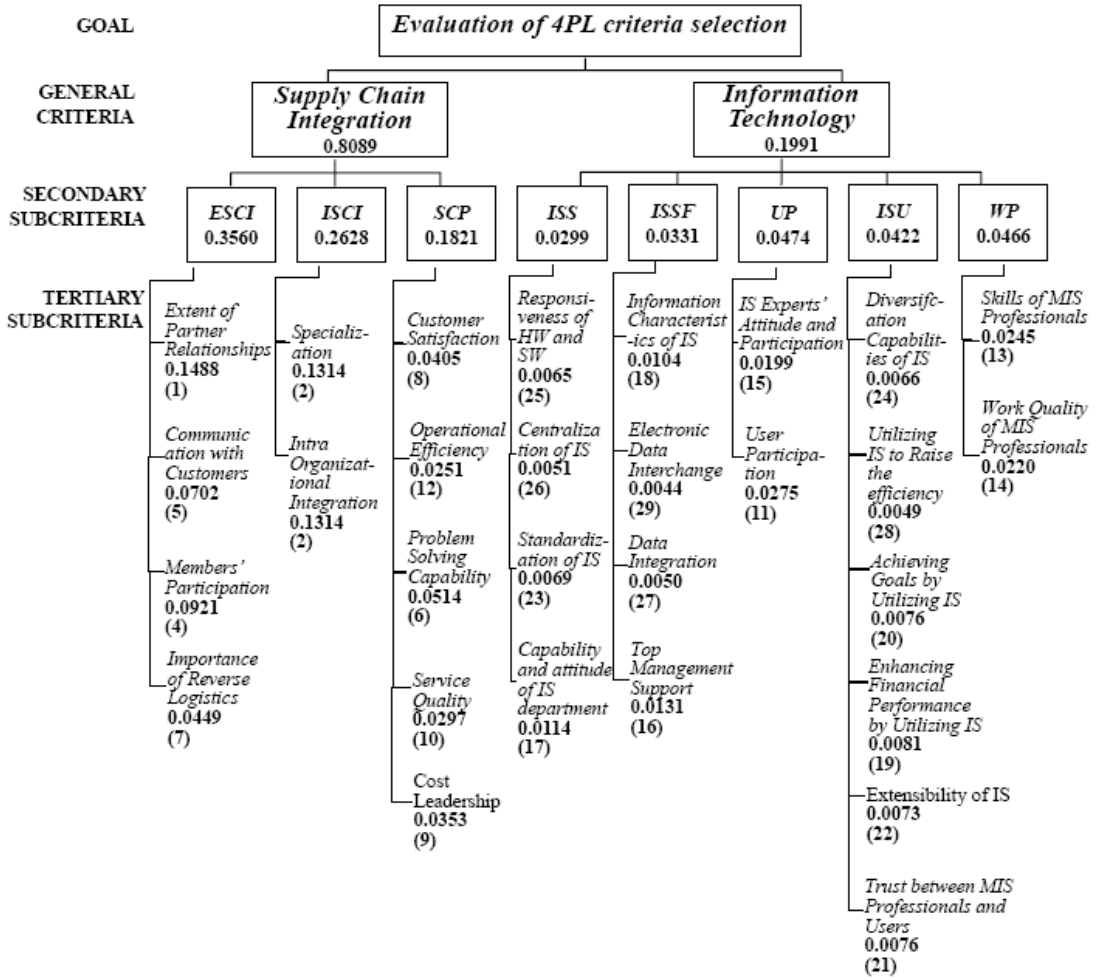

Fig. 3. Hierarchy Structure for Evaluation Criteria of 4PLs Selection by Academic Experts

Table 3. The Most Important Criteria

Goal	General Criteria	Secondary Subcriteria	Tertiary Subcriteria	Weighted Rank of Industrial circles	Weighted Rank of Academic circles	Result
Evaluation of 4PL criteria selection	Supply Chain Integration Capabilities (0.6402, 0.8089)	External Supply Chain Integration (0.2687, 0.3560)	Extent of Partner Relationships	2 (0.1077)	1 (0.1488)	✓
			Communication with Customers	6 (0.0535)	5 (0.0702)	✓
			Members' Participation	4 (0.0637)	4 (0.0921)	✓
			Importance of Reverse Logistics	7 (0.0437)	7 (0.0449)	✓
		Internal Supply Chain Integration (0.1852, 0.2628)	Specialization	1 (0.1209)	2 (0.1314)	✓
			Intra Organizational Integration	3 (0.0643)	2 (0.1314)	✓
		Supply Chain Performance (0.1863, 0.1821)	Customer Satisfaction	5 (0.0600)	8 (0.0405)	✓
			Operational Efficiency	11 (0.0320)	12 (0.0251)	✓
			Problem Solving Capability	12 (0.0319)	6 (0.0514)	✓
			Service Quality	14 (0.0284)	10 (0.0297)	✓
			Cost Leadership	10 (0.0341)	9 (0.0353)	✓
	Information Technology Capabilities (0.3598, 0.1991)	Information System Structure (0.0894, 0.0299)	Responsiveness of HW and SW	16 (0.0271)	25 (0.0065)	✓
			Centralization of IS	19 (0.0192)	26 (0.0051)	
			Standardization of IS	20 (0.0178)	23 (0.0069)	
			Capability and attitude of IS department	17 (0.0253)	17 (0.0114)	
		Information System Critical Success factor (0.0602, 0.0331)	Information Characteristics of IS	18 (0.0242)	18 (0.0104)	
			Electronic Data Interchange	27 (0.0105)	29 (0.0044)	
			Data Integration	29 (0.0094)	27 (0.0050)	
			Top Management	22 (0.0160)	16 (0.0131)	
		User Perception (0.0774, 0.0474)	IS Experts' Attitude and Participation	8 (0.0415)	15 (0.0199)	✓
			User Participation	9 (0.0359)	11 (0.0275)	✓
		Information System Utility (0.0751, 0.0422)	Diversification Capabilities of IS	21 (0.0162)	24 (0.0066)	
			Utilizing IS to Raise the efficiency	23 (0.0136)	28 (0.0049)	
			Achieving Goals by Utilizing IS	24 (0.0123)	20 (0.0076)	
			Enhancing Financial Performance by Utilizing IS	26 (0.0111)	19 (0.0081)	
			Extensibility of IS	28 (0.0098)	22 (0.0073)	
			Trust between MIS Professionals and Users	25 (0.0121)	21 (0.0076)	
		Work Performance (0.0577, 0.0466)	Skills of MIS Professionals	15 (0.0281)	13 (0.0245)	✓
			Work Quality of MIS Professionals	13 (0.0296)	14 (0.0220)	✓

Note: Gray zones are the sum of weight that exceeds 80 percent. "✓"is the most important criteria between industrial and experts' joint agreement, and (industrial experts' weight, academic experts' weight).

4 Conclusion and Further Research

The objective of the study is to offer an evaluation framework of 4PLs built by the key criteria in the uncertainty and complex business environment. In the result, we find that there are eleven subcriteria in the dimension of supply chain integration capabilities, and five subcriteria in the dimension of information technology capabilities. From these views of experts, supply chain integration capabilities are more important than information technology capabilities.

Besides, the results indicate that there are different weights among individual dimensions or criteria and subcriteria rather than equivalent weights. Obtained from comprehensive analysis, five evaluation criteria with most importance are

"Specialization", "Extent of Partner Relationships", "Intra Organizational Integration", "Members' Participation", and "Customer Satisfaction" of industrial viewpoint. Whereas, the five most important criteria of academic viewpoint are "Extent of Partner Relationships", "Specialization", "Intra Organizational Integration", "Members' Participation", and "Communication with Customers." Regardless of the aspect in practices or in theories, the most important five criteria are all focus on the dimension of supply chain integration capabilities.

After referring many academic literatures, we consider that 4PLs possess the capability of supply chain integration and informational technology. Owing to the cost of these two capabilities is quite highly and the progress is also complicated; therefore, this study suggests the company can let 4PLs handle it if they need to carry out supply chain integration and adopt informational technology at the same time.

There still not have real companies be set yet as a result of 4PLs is just an emerging concept. Also, the choosing model built on this study provides standards for company's reference. In sum, we hope the criteria of the evaluation model toward the 4PLs company will be able to work well with industries.

The following researchers can refer and extend the evaluation model we have mentioned and help to develop more in-depth researches. This model can also be applied in different countries and be used to compare the differences of criteria. In addition, other fuzzy multi-attribute methods, like fuzzy TOPSIS, fuzzy DEA, and fuzzy ANP, can be used in it. If we compare this study with results obtained from other methods, there may be something interesting can be discovered.

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