Strategic logistics outsourcing: An integrated QFD and fuzzy AHP approach

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ABSTRACT

This paper develops an integrated approach, combining quality function deployment (QFD), fuzzy set theory, and analytic hierarchy process (AHP) approach, to evaluate and select the optimal third-party logistics service providers (3PLs). In the approach, multiple evaluating criteria are derived from the requirements of company stakeholders using a series of house of quality (HOQ). The importance of evaluating criteria is prioritized with respect to the degree of achieving the stakeholder requirements using fuzzy AHP. Based on the ranked criteria, alternative 3PLs are evaluated and compared with each other using fuzzy AHP again to make an optimal selection. The effectiveness of proposed approach is demonstrated by applying it to a Hong Kong based enterprise that supplies hard disk components. The proposed integrated approach outperforms the existing approaches because the outsourcing strategy and 3PLs selection are derived from the corporate/business strategy.

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1. Introduction

Logistics outsourcing or third-party logistics is regarded as using external companies to perform some or all logistics functions, including transportation, distribution, warehousing, inventory management, order processing, and material handling, that have traditionally been performed within an outsourcing firm (Işıklar, Alptekin, & Büyüközkan, 2007; Razzaque & Sheng, 1998; Sink & Langley, 1997). Those logistics functions can be treated as non value-added activities because they are critical to the smooth running of the business, but not a unique ingredient of the overall product (Sink & Langley, 1997). Because of this reason, firms tend to outsource those activities to the external companies or 3PLs, and focus on value-added activities to develop sustainable competitive advantage.

Evaluation and selection of 3PL is a critical step in the logistics outsourcing process because an appropriate 3PL will help the outsourcing firms to reduce capital investment in facilities, equipment, information technology and manpower, increase the flexibility of outsourcing firms in adapting to changes in the market, reduce inventory and improve inventory turnover rate, improve on-time delivery, reduce the transportation cost, and so on (Liu & Wang, 2009; Razzaque & Sheng, 1998).

Choosing the right 3PLs involves much more than scanning a series of price list, and choices will depend on a wide range of factors which involve both quantitative and qualitative. Various individual and integrated multi-criteria decision making approaches have been proposed for the 3PL selection, such as AHP, analytic network process (ANP), artificial neural networks (ANN), case-based reasoning (CBR), data envelopment analysis (DEA), rule-based reasoning (RBR), technique for order preference by similarity to ideal solution (TOPSIS), and so on. Although these approaches can deal with multiple and conflicting criteria, they have not taken into consideration the impact of business objectives and requirements of company stakeholders on the evaluating criteria. In reality, the weightings of 3PL evaluating criteria depend a lot on business priorities and strategies. In cases where the weightings are assigned arbitrarily and subjectively without considering the "voice" of company stakeholders, the selected 3PL cannot provide what the company exactly wants.

To enable the "voice" of company stakeholders is considered, this paper develops an integrated approach, combining QFD, fuzzy set theory, and AHP, for selecting 3PL strategically. HOQ, a technique of QFD, is responsible for translating the requirements of company stakeholders into evaluating criteria. Since multiple evaluating criteria are proposed, and some of them are qualitative and uncertain, the fuzzy set theory is therefore incorporated into the traditional AHP to enable company stakeholders to express their linguistic preferences, and to transform those preferences into the quantitative form for comparison. Fuzzy AHP is responsible for the assignment of importance ratings and relationship weightings in the HOQs so that inconsistencies due to subjective judgments can be avoided. Based on the ranked criteria, alternative

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3PLs are evaluated and compared with each other using fuzzy AHP again to make an optimal selection.

2. Literature review

Various multi-criteria decision making approaches have been proposed to tackle the logistics outsourcing problem. Menon, McGinnis, and Ackerman (1998) proposed nine criteria for the 3PL evaluation and selection, including price, on-time delivery, error rate, financial stability, creative management, meet or exceed promises, availability of top management, responsive to unforeseen problems, and meet performance and quality requirements.

Meade and Sarkis (2002) applied ANP to select the best third-party reverse logistics service provider. The decision factors and clusters considered in the ANP model include location of product in its lifecycle, the organizational performance criteria, the reverse logistics process functions required by the organization, and the organizational role of reverse logistics.

Bottani and Rizzi (2006) developed a fuzzy TOPSIS approach to rank and select the most suitable 3 PL with respect to nine criteria, including compatibility, financial stability, flexibility of service, performance, price, physical equipment and information systems, quality, strategic attitude, and trust and fairness.

Işıklar et al. (2007) presented an integrated approach, combining CBR, RBR, and compromise programming, to deal with the 3PL selection problem. The evaluating criteria include cost, quality, technical capability, financial stability, successful track record, service category, personnel qualification, information technology, comparable culture, region, and so on.

Jharkharia and Shankar (2007) deployed the ANP approach to select the optimal 3PL with respect to four major determinants or criteria, such as compatibility, cost, quality, and reputation.

Göl and Çatay (2007) adopted the AHP approach to select an appropriate 3PL. In the AHP hierarchy, there were five evaluating criteria (general company considerations, capabilities, quality, client relationship, and labor relations), in which multiple sub-factors were proposed.

Efendigil, Önüt, and Kongar (2008) proposed an integrated approach, combining fuzzy AHP and ANN, to select the best third-party reverse logistics provider. Twelve factors were considered, including on-time delivery, fill rate, service quality, unit operation cost, capacity usage, total order cycle time, system flexibility index, integration level, increment in market share, research and development, environmental expenditures, and customer satisfaction.

Zhou, Min, Xu, and Cao (2008) utilized the DEA to measure the efficiencies of Chinese 3PLs. There were four inputs (net fixed asset, salaries and wages, operating expenses, and current liabilities) and one output (operating income) variables in the DEA model.

Qureshi, Kumar, and Kumar (2008) developed an interpretive structural modeling based approach to identify and classify the key criteria, and to study their role in the assessment of 3PLs. There were 15 criteria – service quality, size and quality of fixed assets, quality of management, IT capability, delivery performance, information sharing and trust, operational performance, compatibility, financial stability, geographic spread and range, long-term relationship, reputation, optimum cost, surge capacity, and flexibility in operation and delivery.

Liu and Wang (2009) presented a three-stage approach for the evaluation and selection of 3PLs. At the first stage, a fuzzy Delphi method was used to identify important evaluation criteria. Then, a fuzzy inference method was applied to estimate unsuitable 3PLs. At the final stage, a fuzzy linear assignment approach was developed for the final selection.

There are two drawbacks in the above approaches. First, they fail to consider the impact of business objectives and the require-

ments of company stakeholders into the identification of evaluating criteria. The selected 3PL cannot provide what the outsourcing firms exactly need (Ho, Dey, & Lockström, 2011). To overcome this problem, the proposed approach provides a platform for stakeholders in various functional departments to express their objectives and requirements explicitly, and then translate the requirements into various criteria for performance measurement. Thus, the evaluating factors are related to the strategic intent of company through the involvement of concerned stakeholders. This ensures successful strategic outsourcing because the selected 3PL can achieve the business objectives. Second, natural disasters, accidents, and volatility of the financial market have made the supply chain vulnerable nowadays (Zegordi & Davarzani, 2012). Thus, identifying, analyzing, and responding to risk events proactively are critical in minimizing disruption and losses in supply chains. However, risk-based factors were not considered in the above approaches.

3. Integrated QFD and fuzzy AHP approach

The integrated QFD and fuzzy AHP approach comprises of three HOQs, including HOQ1 – linking company stakeholders with their requirements (steps 1–5), HOQ2 – relating stakeholder requirements to evaluating criteria (steps 6–9), and HOQ3 – benchmarking alternative 3PLs with respect to various criteria (steps 10–13).

Note that the triangular fuzzy membership function and its operational rules are introduced in the AHP to fuzzify and calculate the pairwise comparison results, and thus the traditional AHP becomes the fuzzy AHP.

Each pairwise comparison result is a fuzzy number $(\tilde{F} \,|\, \mu_F(t))$ which possesses the characteristics of triangular fuzzy membership function. The triangular fuzzy number can be expressed as $\tilde{F} = (t_1, t_2, t_3)$ and Eq. (3-1) shows its membership function:

$$\mu_F(x) = \begin{cases} 0 & x < t_1 \\ (x - t_1)(t_2 - t_1) & t_1 \leqslant x \leqslant t_2 \\ (x - t_3)(t_2 - t_3) & t_2 \leqslant x \leqslant t_3 \\ 0 & x > t_3 \end{cases} \tag{3-1}$$

where t_1 denotes the probable minimum value of all the pairwise comparison result, t_2 is the most probable value, and t_3 is probable maximum value.

For the two triangular fuzzy numbers $\tilde{F}_1 = (t_1, t_2, t_3)$ and $\tilde{F}_2 = (r_1, r_2, r_3)$ with the principle proposed by Zadeh (1965) and the features of triangular fuzzy numbers presented by Liang and Wang (1991), the extended algebraic operations on triangular fuzzy numbers can be expressed as follows:

$$\text{Addition}: \tilde{F}_1 \oplus \tilde{F}_2 = (t_1 + r_1, t_2 + r_2, t_3 + r_3) \tag{3-2}$$

$$\text{Subtraction}: \tilde{F}_1 - \tilde{F}_2 = (t_1 - r_1, t_2 - r_2, t_3 - r_3) \tag{3-3}$$

$$\text{Multiplication}: \tilde{F}_1 \otimes \tilde{F}_2 = (t_1 * r_1, t_2 * r_2, t_3 * r_3) \tag{3-4}$$

$$\text{Division}: \tilde{F}_1 \div \tilde{F}_2 = (t_1/r_1, t_2/r_2, t_3/r_3) \tag{3-5}$$

$$\text{Reciprocal}: \frac{1}{\tilde{F}_1} = \left(\frac{1}{t_3}, \frac{1}{t_2}, \frac{1}{t_1}\right) \tag{3-6}$$

The triangular fuzzy numbers are easy to use and interpret. For example, in the 9-point scale, "approximately moderate or 3" can be represented by (2.8,3.0,3.1), "approximately between strong and very strong" can be represented by (4.5,6,7.5), and the non-fuzzy number 9 can be represented by (9,9,9).

As to the triangular fuzzy numbers which are continuous weights, this paper employs the center of gravity method to defuzzify them using Eq. (3-7):