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Optimal selection of third-party logistics service providers using quality function deployment and Taguchi loss function

Satyendra Kumar Sharma Vinod Kumar

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Satyendra Kumar Sharma
Management Department Birla Institute of Technology and Science (BITS) Pilani, Rajasthan, India, and
Vinod Kumar
Sprott School of Business, Carleton University, Ottawa, Canada

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Abstract

Purpose – Selection of logistics service provider (LSP) (also known as Third-party logistics (3PL) is a critical decision, because logistics affects top and bottom line as well. Companies consider logistics as a cost driver and at the time of LSP selection decision, many important decision criteria's are left out. 3PL selection is multi-criteria decision-making process. The purpose of this paper is to develop an integrated approach, combining quality function deployment (QFD), and Taguchi loss function (TLF) to select optimal 3PL.

Design/methodology/approach – Multiple criteria are derived from the company requirements using house of quality. The 3PL service attributes are developed using QFD and the relative importance of the attributes are assessed. TLFs are used to measure performance of each 3PL on each decision variable. Composite weighted loss scores are used to rank 3PLs.

Findings – QFD is a better tool which connects attributes used in a decision problem to decision maker's requirements. In total, 15 criteria were used and TLF provides performance on these criteria.

Practical implications – The proposed model provides a methodology to make informed decision related to 3PL selection. The proposed model may be converted into decision support system.

Originality/value – Proposed approach in this paper is a novel approach that connects the 3PL selection problem to practice in terms of identifying criteria's and provides a single numerical value in terms of Taghui loss.

Keywords Selection, QFD, LSP, Taguchi loss

Paper type Research paper

1. Introduction

Logistics is the one of the important driver in supply chain management (SCM). In the recent past, third-party logistics (3PL), also termed as logistics outsourcing (Knemeyer *et al.*, 2003) has received considerable attention from logistics scholars. 3PL is known as using external companies to perform some or all logistics functions, like transportation, distribution, warehousing, inventory management, order processing, and material handling (Isıklar *et al.*, 2007). In today's globalized and competitive environment, 3PL allows firms to focus on core competencies and bring substantial cost savings and improved efficiency to outsourcing firm. CSCMP research states that 68 percent surveyed firms outsource their logistics function. Three important research themes that have been researched by logistics scholars are: the examination of primary motivations for logistics outsourcing; the assessment of the contribution of logistics outsourcing to a firm's competitiveness; and the evaluation and selection of 3PLs. Evaluation and selection of 3PL plays a critical role in SCM because an appropriate 3PL will help the

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outsourcing firms to reduce capital investment in facilities, equipment, information technology and manpower, increase the flexibility of outsourcing firms in adapting to market volatility, improve inventory turnover rate, improve on-time delivery, reduce the transportation cost, and so on. The 3PL selection decision is a complex task due to a high number and varying type of 3PLs in the market (Liu and Wang, 2009). Scope of the logistics services also range from simple, routine transportation tasks (e.g. freight bill payment and auditing) to integrated logistics services (e.g. logistics finance, consulting, asset management, human resource management) (Alessandra, 2008).

Considering the inherent complexity and strategic importance of 3PL selection, the main objective of this research paper is to develop a systematic decision-making tool that helps the outsourcing firm identify and select the most desirable 3PL partner(s) with best strategic fit, needed expertise, proven efficiency, and greatest flexibility for customization among many alternative choices.

3PL selection problem has been researched as a multi-criteria decision-making (MCDM) problem that contains both qualitative and quantitative factors. These criteria may include 3PL's price, expertise, reputation, financial stability, service flexibility, and service reliability. Many types of MCDM approaches have been proposed for the 3PL selection, such as analytic hierarchy process (AHP), fuzzy AHP, analytic network process (ANP), artificial neural networks, case-based reasoning, data envelopment analysis (DEA), rule-based reasoning, technique for order preference by similarity to ideal solution (TOPSIS), and so on. Though these techniques are good enough to deal with number of qualitative and quantitative factors and these factors may be conflicting in nature also. In practice 3PL selection depends more on business requirements, guided by business strategy. The capabilities of logistics service provider (LSP) should match with service required by the customer. The proposed model is developed in order to address this issue. This paper develops an integrated approach, combining QFD and Taguchi loss function (TLF) method for selecting 3PL strategically. Through QFD, voice of customer is translated into service requirements that may include certain variables, that will be decision variables in 3PL selection. The performance of each LSP with respect to the variables identified through QFD are measured by a common value, Taguchi's loss score. The composite weighted loss scores are calculated for each potential LSP. The LSP are then ranked according to their composite weighted loss scores. The LSP with the smallest loss score is recommended to perform the outsourcing function.

The rest of the paper is organized as follows: the background and an overview of the literature are provided in Section 2. The development of the proposed model is detailed in Section 3. A case-based numerical example is provided in Section 4 to illustrate the application of the proposed model. The paper concludes with summary and recommendations for future research in Section 5.

2. Literature review

Firm's success depends on its ability to achieve effective integration of worldwide organizational relationships within a supply chain (Shepherd and Gunter, 2006). Importance of the integrated SCM is growing worldwide, due to increased pressure to fill customer's orders on time as well as efficiently. Reflecting on the growing popularity of logistics outsourcing and a subsequent growth of the 3PL industry, there exist an extensive body of literature related to logistics outsourcing including 3PL evaluation and selection. McGinnis and Ackerman stated that 3PL's perceived performance and capability are more important determinants for 3PL selection than prices charged for 3PL services. Also, Meade and Sarkis (2002) discovered that 3PL's capability to handle end-of-life product disposal and reverse distribution played a role in 3PL selection. Other prior studies responded to a growing need for modeling the 3PL selection process. These studies include 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. Efendigil *et al.* (2008) proposed an integrated approach, combining fuzzy AHP and ANN, to select the best third-party reverse logistics provider. Thakkar *et al.* (2005) who developed an ANP and interpretive structural model (ISM) to select the best 3PL option among various alternatives.

Extending these studies, Perçin (2009) proposed a two-phase AHP and TOPSIS method combined with the Delphi method to select the appropriate 3PL in a real-world setting. Qureshi *et al.* (2008) developed an ISM model to identify and classify the key criteria relevant for the assessment of 3PLs. There criteria were – service quality, size, 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 operational flexibility. Zhou *et al.* (2008) proposed a DEA to measure the operating efficiency of ten leading 3PLs in China and then identified the various sources of efficiencies and inefficiencies in 3PL operations. Saen (2009) also used DEA, that could handle both cardinal and ordinal data to select the 3PL with reverse logistics service offerings. A mathematical programming model which minimizes the total processing cost of multiple types of waste electrical and electronic products was presented by Dat *et al.* (2012). A QFD-based framework which integrated ANP and the goal programming models was presented by Buyukozkan and Berkol (2011). Buyukozkan and Cifci (2012) also proposed a hybrid fuzzy MCDM model which assisted in evaluating green suppliers. Barker and Zabinsky (2011) presented a model using AHP that establishes preferences among eight alternative network configurations, considering various flow processes. Pishvaee *et al.* (2012) developed a new hybrid credibility-based fuzzy mathematical programming for green logistics network design. Kannan (2011) used fuzzy extent analysis for selecting third-party reverse logistics provider for the battery industry. Table I presents the various methods or techniques used by logistics researchers in 3PL evaluation and selection decisions.

Numerous 3PL selection models are uncovered in the literature. Suitability of these models depends on context chosen. The suitability of these models depends on three criteria.

Complexity of the context, amount of information available on the performance of the suppliers, and the Importance of the context (De Boer *et al.*, 2001). These model are good enough to explore 3PL selection variables and finding their weights through MCDM techniques. The hybrids methods are uncovered in literature to overcome the problems of one technique by combining with other techniques.

Following Table II provides all hybrids models developed for 3PL selection and evaluation.

In the most of above mentioned models, very few models have included the risks and benefits of outsourcing in the evaluation process. Even fewer studies have been made to provide a systematic approach for quantifying the intangible factors. Although methods that use AHP methodology by itself are easier to implement, they do not provide a quantitative approach for inclusion of all the relevant factors. The hybrid approaches for 3PL selection combining AHP methodology with other MCDM

S. No.	Method	Key features	Reference
1	AHP	Considered a set of 3PLs to be integrated and managed by the 4PL	Zhang *et al.* (2004)
2	ANP	Considered both tangible and intangible performance criteria for 3PL selection	Thakkar *et al.* (2005)
3	Case-based reasoning	Considered the fuzziness of the 3PL selection criteria Incorporated the professional expertise and experience into the 3PL selection decision	Isıklar *et al.* (2007)
4	DEA	Evaluated the comparative operating efficiency of 10 Chinese 3PLs Identified the sources of 3PL inefficiency through the correlation analysis	Zhou *et al.* (2008)
5	Chance-constrained data envelopment	A new chance-constrained data envelopment analysis (CCDEA) approach is proposed to assist the decision makers to determine the most appropriate third-party reverse logistics (3PL) providers	Azadi and Saen (2011)
6	ISM	Interpretive structural modeling (ISM) methodology is adopted in this model summarizing relationships among specific attributes for selecting the best third party	Govindan *et al.* (2012)
7	AHP	The number of experts is high enough	Daim *et al.*
8	Generic balanced scorecard	Managers need a balanced set of financial and non-financial measures that represent different requirements, strategic goals, strategies, resources, and capabilities and the causal relationships between these domains	Kumar and Singh (2012)

Table I.
A summary of the selected analytical studies on 3PL evaluation and selection

S. No.	Method	Key features	Reference
1	Fuzzy TOPSIS Fuzzy AHP	Extended the work of Bottani and Rizzi (2006) Focussed on the 3PL selection for strategic alliance	Buyikozkan *et al.* (2008)
2	Two-phase AHP TOPSIS Delphi method	Solved the actual problem Used the multiple phase and hybrid 3PL selection procedures	Percin (2009)
3	Delphi method Fuzzy inference Fuzzy linear assignment	Used the three-phase 3PL selection procedures Considered the vagueness of the 3PL selection criteria	Liu and Wang (2009)
4	QFD and fuzzy AHP	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	Ho *et al.* (2011)
5	Fuzzy and TOPSIS	Fuzzy AHP is integrated with TOPSIS for preference ranking of 3PL	Kumar and Singh (2012)
6	QFD and fuzzy regression	QFD is utilized to structure-specific customer service needs Fuzzy linear regression is then employed to determine a functional relationship between the 3PL user's logistics service needs and the 3PL characteristics	Percin and Min (2013)

Table II.
A summary of the selected hybrid models on 3PL evaluation and selection

quantitative techniques do not address the problem of relevant criteria identification and then variation of performance of 3PLs on selected criteria.

To overcome this problem, the proposed approach in this paper 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, identifying, analyzing, and responding to relevant decision variables in 3PL selection proactively are critical in minimizing disruption and losses in supply chains. In addition, some of the techniques discussed in literature require the users to have highly sophisticated mathematical skills. The high levels of knowledge requirements often make these techniques not so desirable in the eyes of the supply chain managers. So 3PL selection first requires a comprehensive list of decision variables, which will be critical in 3PL selection. These decision variables will be identified through a systematic techniques, that is QFD. A long list of decision variables make the selection task complex for SCM managers. Comparing the performance of all 3PLs on many criteria is tedious and risk prune decision. TLFs are used as a mechanism to quantitatively represent the 3PL' scores by measuring their performances with respect to these criteria. By employing QFD and TLFs, in a integrated manner presents a superior approach to 3PL selection.

3. Research methodology

QFD concept and the house of quality (HOQ) tools are used to better understand and transform customer requirements into designs of service, and process to ensure the service quality (Sullivan, 1986). This paper expects that QFD/HOQ, applied in logistics service design, will help better selection of 3PLs and also provide a mechanism to improve their performance (service quality) in effectively establishing linkages between customer requirements and service specifications (design target values) (Mehrjerdi, 2010).

TLF has been applied in the manufacturing industry like the spring coil manufacturing process (Caporaletti *et al.*, 1993) and also in service industry like airlines (Li and Chen, 1998). Taguchi uses a common value, quality loss, to measure the performance of the suppliers with respect to various factors. Quality loss that is measured by Taguchi loss is a common language and easy to understand in decision making. As a result, its use makes the comparison of the suppliers' or service providers' performances easy and meaningful. The lower and the upper customer tolerance levels are customer-defined limits of the lack in performance. In addition, since the loss function is quadratic and nonlinear, it allows higher values to be placed on measurements that show lower variation from the target value. In calculating TLF, the quadratic loss function was adopted in our study, as the quadratic loss function is perhaps better suited to present customer's evaluation. There is evidence that customers tend to penalize a service company in an increasingly stronger manner as the company's service moves away from target value. This feature of TLF makes evaluating the performance of the suppliers more meaningful as those who perform very close to the target level have considerably lower loss score compared to others. These unique features of the TLF make it appropriate for use in the development of our model for 3PL selection.

3.1 Quality function deployment

QFD is a technique which transforms customer needs (CNs) or the voice of customers into technical requirements (TRs) using the matrix called HOQ (Hauser and Clausing, 1988). HOQ basically summarizes what customer wants in terms of customer attributes and their relative importance to product characteristics. As shown in Figure 1, the horizontal portions (rows) of HOQ matrix contain customer attributes reflecting what a CNs, whereas its vertical portions (columns) describe detailed TRs technically required by the customer (Kim *et al.*, 2000).

As shown in Figure 1, the typical HOQ contains the following components (Alptekin and Karsak, 2011):

(1) identify customer requirements (WHATs) and evaluate those weights in the left wall of the house;

(2) compare the competitiveness of the service in the right wall;

(3) translate customer requirements into service design characteristics (HOWs) just below the roof;

(4) define the relationship between WHATs and HOWs in the central deployment matrix or called relationship matrix;

(5) define the relationships between the various service design characteristics in the correlation matrix in the roof; and

(6) design the target values of the service on the ground floor of the house, which is the absolute importance for each service design characteristic.

3.2 TLF

Current research on service quality has shown that customers think in terms of adequate and desired expectations and develop a "zone of tolerance" when evaluating service quality. This is the extent to which customers recognize and are willing to accept a variation in the service. Taguchi states that increasing deviation from the expected values causes increasing loss to customers. TLFs are used as a means to quantify the performance of the suppliers with respect to the criteria. The rationale for the use of TLFs is twofold. First, all the characteristics having different units of

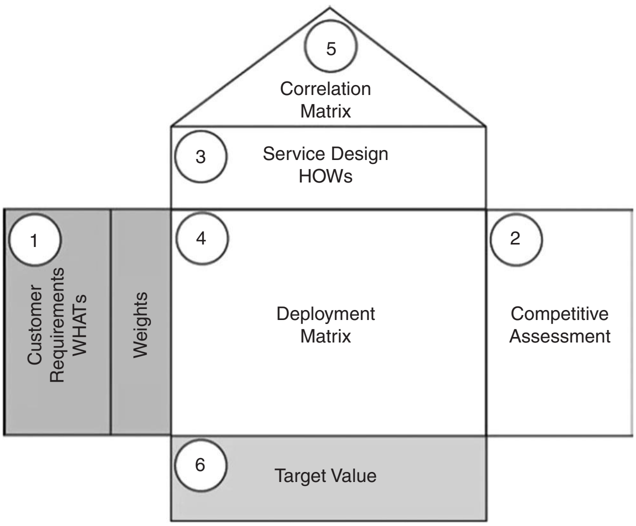

Figure 1.
House of Quality

measurement and varying magnitude of scale can be converted into a common measurement, that is loss score. Second, since the loss function is quadratic and nonlinear, the loss becomes increasingly large as the value deviates from the target value. This second feature allows higher values to be placed on measurements that show lower variation from the target value.

One of the unique features of TLF is its versatility; it can easily be applied to various different contexts. Numerous applications of TLF were uncovered in the literature. Health care application of TLF is illustrated in two separate studies by Taner and Anthony (2000, 2006). They have used quadratic loss function to model the loss to society in health care industry as well as assessing the quality in medical diagnostic tests. TLF has also been used to improve customer service in the real estate industry by helping brokers to identify the property that most closely matches the buyer's needs (Festervand *et al.*, 2001). In the manufacturing sector, TLF has been used to model the cost of deviation in the tool's quality.

Generally, three types of loss functions are used to calculate Taguchi loss (Taguchi and Hsiang, 1989; Besterfield *et al.*, 2003, Ealey, 1994). First, two-sided loss function is used where nominal value is the target and deviation from either side of the target is allowed as long as it remains within the specification limits. Any deviation from the target value will result in a loss and zero loss occurs only when the characteristic measurement is equal to the target value. The second and third types of loss functions are one-sided functions where deviations from the target are allowed only in one direction. These loss functions are referred to as "larger is better" and "smaller-is-better" with target values of infinity and zero, respectively. Quality loss function is formulated as $L(X)=k\ (X-T)^2$ where X is a measurable quality characteristic with a specific target value, T is the target value, k is the proportionality constant (loss coefficient), and $L(X)$ is loss in dollars for specific value of X (Ealey, 1994).

In this research, the quality loss functions are used to quantify the impact of the outsourcing of 3PL. However, the target values are different for the different performance characteristics. About 100 percent possibility of receiving an outsourcing benefit over the in-house performance is the target value. The loss function for each performance characteristic can be determined by calculating the loss coefficient k. k is the costumer's loss/functional tolerance. Functional tolerance is defined as the maximum permissible deviation from the target value. Consumer's loss is the loss generated when the value of the quality characteristic exceeds the functional tolerance.

The decision maker sets the specification limits to indicate the allowable deviation from the target value for each performance characteristic. The loss coefficient k can then be determined for the performance characteristics based on these specification limits (Figure 2).

4. Case study application

The main purpose of this research is to build a decision-making model for 3PL selection. An in-depth case study approach is adopted for this research. Case studies are suitable for exploring issues that are too complex for empirical survey or experimental research (Yin, 1994).

In order to demonstrate the practicality and usefulness of the proposed methodology in a 3PL selection problem, we applied it to the actual problem. The company, which became a subject of the current case study is National Engineering Industry (NEI), is a manufacturing firm and was founded in 1947. Between 1947 and 2012, it grew rapidly owing to the manufacturing industry boom in India. Company NEI now has more than

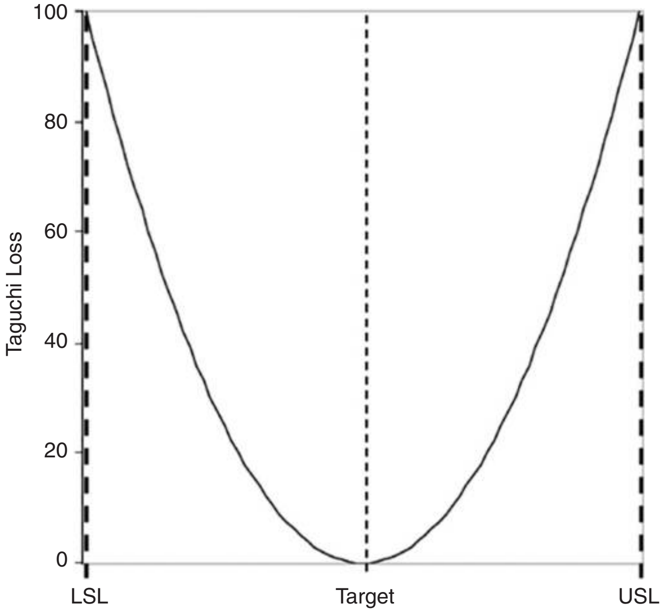

Figure 2.
Two-sided equal specifications Taguchi loss function

1,700 full-time employees and wants to position itself as one of the leading company in Ball bearings manufacturing industry, India. It has generated approximately 780 million dollars of the sales revenue for the year ending 2012. Its main customers are world-class auto-makers such as Toyota, Renault, Ford, Fiat, Tata motors, Maruti and Hyundai/Kia. It serves both Indian domestic and foreign markets (e.g. Europe, Asia, and USA) all across the world and coordinates global supply chain activities using advanced information technology solutions such as ERP. To focus on its core competency (manufacturing), it needs to hire a 3PL for handling collaborative planning, forecasting and replenishment, warehousing, electronic order entry, real-time data access, spare parts distribution, inventory and materials management, automated billing and payment, packaging services, and inbound and outbound transportation management.

NEI wants to have a decision support system for logistics partner selection, so that company can respond to dynamically changing customer requirements. Managers believe that the establishment of a flexible and scalable logistics network with the 3PL will be essential for achieving lower logistics costs, shorter market response time, and greater flexibility. Also, Company NEI believes that logistics outsourcing through the 3PL can be a competitive differentiator and thus considered 3PL selection as one of the most important strategic managerial decision.

Our proposed methodology, explained below, was used to solve the problem of NEI (Figure 3).

4.1 Building HOQ model for 3PL selection

To identify CN's, a focus group interview was conducted at NEI. Four managers: two from manufacturing company and two from its buyers agreed to participate in focus group interview. Buyers were selected in consultation with NEI people. Researcher, who was focus group moderator initiated the discussion about what buyers expect related to logistical services, what are the key logistics service quality parameters.

These meetings are intended to get every affected party involved in conversation, regarding 3PL selection and then facilitate interactive brainstorming that are needed for conflict resolution and consensus build-ups. Based on these interviews and meetings, we identified the most prioritized multiple decision criteria pertaining to CNs significantly affecting 3PL decision.

In addition, the author took into account various 3PL service requirements by examining the past 3PL literature such as the ones conducted by McGinnis *et. al.* (1995), Menon *et. al.* (1998), Meade and Sarkis (2002), Vaidyanathan (2005), Bottani and Rizzi (2006), Boran *et al.* (2009), Liu and Wang (2009), Chen (2011), Liou *et al.* (2011), Buyukozkan and Cifci (2012) and Chen and Chao (2012). Several criteria for LSP choice have been discussed in the literature by Senthil *et al.* (2014) typically, these include cost, service reliability, flexibility, responsiveness to requests and financial stability. Some criteria are developed with specific client's needs in mind, while others are common for all circumstances (Selviaridis and Spring, 2007). There is contrasting evidence on the relative importance of price; some authors (Van Laarhoven and Sharman, 1994) rank it as top criterion, while others argue that service performance and quality requirements are the topmost criteria used by firms for supplier selection.

Qualitative factors such as supplier reputation, references from clients and response to information requests are used for the initial screening of potential service providers (Sink and Langley, 1997). Moreover, prior experience of the customer's industry, its work policies and products types are perceived as important selection factors by buyers (Sink *et al.*, 1996). Overall, the criteria cited seem to apply to all 3PL purchasing circumstances, irrespective of buyer characteristics and special requirements. Research by Meade and Sarkis (2002), who present special factors pertaining to third-party reverse logistics services. Centrality of the logistics function, risk and control, cost/service trade-offs, information technologies and relationships with LSPs are also considered to be criteria's in 3PL selection. The concept of logistics complexity is also introduced to incorporate a number of critical drivers that impact on the above identified factors. Product-related (e.g. special handling needs), process-related (e.g. cycle times) and network-related (e.g. countries served) drivers are believed to have an indirect influence in the 3PL selection decision (Rao and Young, 1994). By combining the results of both the interviews and the literature review, we identified five CNs: costs, timeliness (including on-time order fulfillment and delivery), service quality (reliability scope of services, personalized service), flexibility (special and emergency need related to product types or packaging), and reputation (brand recognition).

Then the author synthesized the focus group meetings and 3PL service attributes were identified with their relative importance. Focus group participants were asked to distribute 100 points among identified customer requirements. Final weightings of CR's

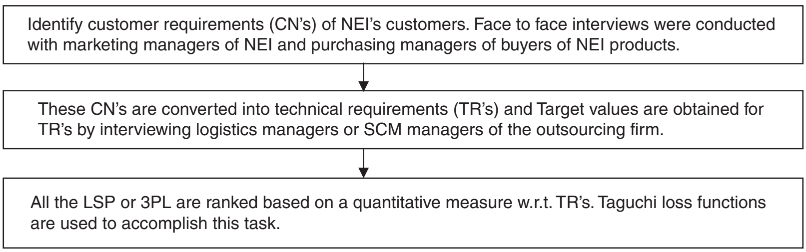

Figure 3.
Proposed methodology for 3PL selection

were calculated using averages of all four participants. This methods was quite simple and less time consuming.

Next step is to identify technical (design and service requirements) from the identified customer requirements. A focus group interview consisting logistics managers or SCM managers, who are responsible for 3PL selection was constituted to identify TR's associated with CR's. Author identified TR's in discussion with focus group and through literature review.

These TR's are: price; industry experience; on-time delivery record; asset ownership; capacity utilization; logistics information system; technological integration like EDI; optimization capability; financial growth rate; strength of customer base; international scope; capability to handle special requirements; responsiveness; managerial staff level; and general reputation.

To elaborate, the focus group believed that the 3PL's cycle time reduction capability, delivery service performance, and logistics equipments and their ownership were essential for JIT's lead time management, while capacity utilization and managerial staff level might reflect the 3PL's flexibility. Also, the focus group believed that the 3PL's understanding of the unique nature of the customer's industry was directly related to its industry experience. Furthermore, the focus group felt that the 3PL's technological integration capability helped to facilitate communication via EDI, while the 3PL's financial growth rate reflected its financial stability and the subsequent reliability (Gol and Catay, 2007).

A triangular-shaped matrix placed over the engineering design requirements corresponds to the correlations between them. Using Figure 1 we can say that $CR_{1,}$ … CR_m are the m identified customer requirements, while $TR_{1,}$ …, TR_n are the n identified TRs known as "whats" and "hows," respectively. The degrees of the importance of customer requirements are shown by the vector of $W_{1,}$ …, W_m, where m is the number of customer requirements. The relationship matrix between whats and hows is shown by matrix in Table III.

Next, the focus group analyzed the attributes that believed to be the most important for 3PL companies in order to satisfy the buying firm's needs. These CN's were then arrayed in the first HOQ against the LSP attributes (TR's) which are necessary to satisfy the buying firm's requirements. Next, each CR's was assigned a rating in the range of 1 through 5, depending upon the relative importance of each requirement to the others: 5 being the most important, and 1 the least important. Following the requirement ratings, each TR's was rated as to its influence on each buying firm's needs (CNs). The rating scale for this was shown in Table III. Each 3PL attribute rating was then multiplied by each buying firm's needs importance rating. The products from these multiplications reflected the importance of each 3PL attribute in satisfying required CNs. Finally, the products for each 3PL attribute were added down and average of these were shown in their respective rows named as weighted average in Table III and normalized to obtain an overall relative importance for each 3PL attribute in satisfying required buying firm's needs. Table III clearly shows relative importance of 3PL attributes (termed as TR in HOQ). It is evident form Table III that first six attributes namely: price; industry experience; on-time delivery record; asset ownership; capacity utilization; logistics information system; are vital and more important for 3PL selection rather than remaining nine attributes, that are technological integration like EDI; optimization capability; financial growth rate; strength of customer base; international scope; capability to handle special requirements; responsiveness; managerial staff level; and general

Table III. House of quality for 3PL selection

TR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CN																
Cost	0.26	5	3	2	1	4	2	0	3	1	0	0	0	3	2	0
Time	0.22	2	3	4	3	1	3	2	0	0	0	2	0	1	2	0
Quality	0.28	2	3	2	2	2	2	0	3	2	2	2	4	3	4	0
Flexibility	0.16	0	0	0	3	4	4	2	1	0	2	4	4	3	3	0
Reputation	0.08	0	2	2	3	0	2	0	0	0	3	2	2	3	4	5
Weighted avg.		0.460	0.488	0.424	0.440	0.492	0.508	0.152	0.356	0.164	0.224	0.360	0.384	0.512	0.576	0.080
Normalized avg.		0.0020	0.0021	0.0018	0.0019	0.0021	0.0022	0.00066	0.00015	0.00071	0.00097	0.0015	0.0016	0.0023	0.0022	0.00034

reputation. Asset ownership and efficiency of 3PL companies affects their reliability and capability of operations. Similarly OEMs also see that price quotation and industry experience also are important attributes.

4.2 Using TLF to rank 3PL

HOQ presents the CNs and associated TRs. This matrix also shows the relative importance of the CNs from customers perspective and possible relationship between CNs and TRs and relative importance of TR's that is best possible importance of 3PL attributes in fulfilling specified customer requirements.

Next step is to get the target value for TRs. A focus group was constituted consisting logistics managers or SCM managers, who are responsible for 3PL selection in outsourcing firm. HOQ matrix was presented to them and then discussion was started on how much target value, decision-making company is seeking for each TR. This decision depends on type of customer segment served by decision-making firm and this is clear by HOQ. 3PL selection also depends on company's business strategy as well as SCM strategy. Based on the relative importance of the CR's and relationship between CR and TR, discussion happens on possible target values, type of loss function (two side or one side). Minimum limit and maximum limits for all TRs are determined by reaching on consensus among focus group members. Snow (1993) lists four types of loss functions that may be used to determine a metric's utility. The determination of the proper function depends on the type and magnitude of variation allowed from the target value. With the two-sided equal specification limit function, variation is allowed in both directions from the target value. Zero loss will occur at the target value and any deviation from the target value will generate a loss that will follow a quadratic function up to a 100 percent loss at specification limits.

Delineation of target values with their specification limits is done by logistics managers and these values have been shown in following Table IV.

All the 3PL characteristics values may be objective or subjective. For example target experience for 3PL is five years that is desired experience by outsourcing firm. This target value is taken equaling to 100 and shown in Table IV. Similarly specification limits are expressed in Table IV.

The constant "K" is developed such that, when the calculated value of "K" is entered into the loss function equation, the loss will be zero at the target value and 100 percent at the specification limit:

$$L = Kx^2$$

$$K = 100/(\text{USL or LSL})^2$$

where L is the loss generated by the process for the characteristic measured, x is the characteristic measurement, USL is the upper specification limit and LSL lower specification limit. In the loss function K is a constant to return and a 100 percent loss is considered at the USL or LSL specification limit.

Computed value of K for each 3PL attribute has been shown in last column of the Table IV.

Following Table V provides the characteristics values for all the 15 3PL attributes for all six potential 3PL service providers. These six 3PL are the possible alternatives for this decision. The characteristics values for all the 15 3PL attributes for all six

TR (3PL attribute)	Target value	Range	Specification limit	Value of K	Loss function
Price	100	100-130	30	1,111.11	$L(X) = 1{,}111.11\ (X-T)^2$
Industry experience	100	100-195	05	40,000	$L(X) = 40{,}000\ (X-T)^2$
On time delivery record	100	100-185	15	4,444.44	$L(X) = 4{,}444.44\ (X-T)^2$
Asset ownership	100	100-160	40	625	$L(X) = 625\ (X-T)^2$
Capacity utilization	100	100-180	20	2,500	$L(X) = 2{,}500\ (X-T)^2$
Logistics information system	100	100-190	10	10,000	$L(X) = 10{,}000\ (X-T)^2$
Technological integration	100	100-180	20	2,500	$L(X) = 2{,}500\ (X-T)^2$
Optimization capability	100	100-190	10	10,000	$L(X) = 10{,}000\ (X-T)^2$
Financial growth rate	100	100-170	30	1,111.11	$L(X) = 1{,}111.11\ (X-T)^2$
Strength of customer base	100	100-175	25	1,600	$L(X) = 1{,}600\ (X-T)^2$
International scope	100	100-165	35	816.33	$L(X) = 816.33\ (X-T)^2$
Capability to handle special requirements	100	100-185	15	4,444.44	$L(X) = 4{,}444.44\ (X-T)^2$
Responsiveness	100	100-190	10	10,000	$L(X) = 10{,}000\ (X-T)^2$
Managerial staff level	100	100-170	30	1,111.11	$L(X) = 1{,}111.11\ (X-T)^2$
General reputation	100	100-190	10	10,000	$L(X) = 10{,}000\ (X-T)^2$

Table IV. Target values with their specification limits of all TRs

TR (3PL attribute)	A	B	C	D	E	F
Price	120	125	110	105	110	95
Industry experience	95	110	105	105	98	95
On-time delivery record	90	85	95	80	95	80
Asset ownership	90	85	85	70	70	65
Capacity utilization	90	95	85	95	90	95
Logistics information system	90	100	95	98	98	100
Technological integration	85	85	90	95	90	90
Optimization capability	85	90	90	95	95	90
Financial growth rate	85	70	90	75	85	95
Strength of customer base	80	80	85	95	90	75
International scope	95	95	90	85	75	65
Capability to handle special requirements	90	100	95	85	85	80
Responsiveness	90	100	95	90	95	90
Managerial staff level	80	80	85	95	90	75
General reputation	90	90	95	95	85	85

Table V. 3PL characteristic value

potential 3PL service providers were collected from the experts in the domain of logistics and supply chain in respective companies.

Using the relative value from Table V, which presents the deviation from the target value, the next step is to convert the raw performance measurements into TLFs. This conversion illustrates two valuable features of TLFs. First, all of the raw measurements are transformed into the common Taguchi unit of measure, the percentage of loss for that characteristic. The decision maker is asked to state his perception of the delivery of the particular characteristics by each of the six providers. The decision maker chooses the bases for such judgments on the historical data, reputation of the provider, and the specifics of the situation at hand. For instance, the decision maker believes that possibility of delivery of the benefit "responsiveness" by provider A is 90 percent while this possibility is 100 percent for provider B. The decision maker's perception of performance of the six providers with respect to all the attributes is delineated in Table V. Next Table VI provides the loss scores for all six 3PL on all 15 decision variables. To explain the calculations in the Table VI, loss score for price attribute for company A is like this:

$$L = Kx^2$$

where value of K is given in Table IV, that is 1,111.11:

$$L = 1{,}111.11^{*}(120-100)^2$$

Loss scores obtained by loss equation are multiplied with the attribute weights to get the weighted loss scores, these have been shown in Table VI. Loss scores on a particular attribute imply that deviation from target value results into increasing loss to customers. TLF methodology is used to measure level of customer satisfaction. Loss scores provides the performance scores of 3PL companies on different attributes. Loss score for company A has been shown in column 3 of Table VI. These scores indicate that company has high loss scores (44.44) on price, strength of customer base and managerial staff attributes. Company A does well on industry expertise and international scope. A look on company C loss scores on all attributes are not more than 25 and this commensurates with weighted loss score of company C (that is 0.176) is least among all 3PL companies.

Table VI.
3PL characteristic Taguchi loss

TR (3PL attribute)	Weight of attribute	A	B	C	D	E	F
Price	0.0010	44.44	69.44	11.11	2.78	11.11	2.78
Industry experience	0.0021	2.78	11.11	2.78	2.78	0.44	2.78
On-time delivery record	0.0018	11.11	25	2.78	44.44	2.78	44.44
Asset ownership	0.0019	11.11	25	25	100	100	136.11
Capacity utilization	0.0021	11.11	2.78	25	2.78	11.11	2.78
Logistics information system	0.0022	11.11	0	2.78	0.44	0.44	0
Technological integration	0.00066	25	25	11.11	2.78	11.11	11.11
Optimization capability	0.00015	25	11.11	11.11	2.78	2.78	11.11
Financial growth rate	0.00071	25	100	11.11	69.44	25	2.78
Strength of customer base	0.00097	44.44	44.44	25	2.78	11.11	69.44
International scope	0.0015	2.78	2.78	11.11	25	69.44	136.11
Capability to handle special requirements	0.0016	11.11	0	2.78	25	25	44.44
Responsiveness	0.0023	11.11	0	2.78	11.11	2.78	11.11
Managerial staff level	0.0022	44.44	44.44	25	2.78	11.11	69.44
General reputation	0.00034	11.11	11.11	2.78	2.78	25	25
Composite Weighted Taguchi loss	1.00	0.276	0.332	0.176	0.301	0.380	0.601
Rank		2	4	1	3	5	6

5. Discussion

At this point, each 3PL provider has received a weighted loss score for all pertinent attributes. However, to compare performances of the potential provider, a single loss score for each 3PL provider is desirable. To accomplish this task, the composite loss score for each provider is determined by calculating the average of the weighted loss scores for attribute categories. Taguchi loss scores are multiplied with weights of the 3PL attributes and this gives weighted loss scores. At this point, the TLFs result in 15 separate loss measurements for each 3PL. It is difficult for a manager to compare 15 loss scores and selecting optimal 3PL companies. In the application, a single value is desirable in order to allow comparison of the utility of the various 3PL. Composite loss scores are computed by taking average of all 15 loss scores for each 3PL. The providers are then ranked based on their composite loss scores. The weighted TLFs are then simply ranked from the smallest loss to the largest loss. 3PL companies that causes least loss, are given higher ranks. Thus we see the last row of Table VI, it becomes clear that third 3PL company's weighted loss score is minimum that is 0.176, among all six companies, so it is given highest rank. Similarly number sixth 3PL company is having highest loss score (0.601) and is given least rank. This combined methodology presents a tool to logistics decision makers and enhances the quality of their decisions. Though this methodology has been illustrated using a case study of Indian automotive company, but this paper provides a generalized methodology that can be used by any industry person for 3PL selection decisions.

6. Conclusion and future scope of research

In 3PL selection, the QFD process led to a rapid identification of relevant attributes that provide the product characteristics at the time of study. QFD process also provides the relationship between customer requirements and TRs and this assures the most practice oriented and context-specific decision variables to be included in product/process decisions. Cross-functional teams were able to make contributions in all steps of the development. QFD has proven to be an effective tool in managing product/service development in the manufacturing, software development, and service industries. A shortcoming of QFD in this, or for that manner any application, is that it relies upon a subjective evaluation of the factors under consideration. Thus, the numerical ratings upon which the method relies can be only quasi-objective. This situation is considerably improved by using QFD in conjunction with an experimental method such as TLF. 3PL service provider selection is strategic task in supply chain. The rankings enabled the rapid development of supplier selection, which then could be readily communicated to the numerous stakeholders for feedback. TLF is used to quantitatively measure the 3PL performance. The weighted and then composite loss scores are used to find comparative performance of 3PL. The 3PL service provider with lowest loss score is chosen for outsourcing function. The proposed model has two strengths: first all the relevant decision variables are identified through a scientific process known as QFD. Second it provides a method to quantify the providers performance in single unit, that enables managers in quick decision-making process. The managers no longer have to estimate the potential criteria of an outsourcing decision and come up with a list of their own, each time a decision needs to be made. These managers can consult the comprehensive list of the criteria categories provided in the model and customize the list to fit their specific situation. Considering the importance of the supply chain in any business, the use of the proposed tool leads to selection of the right service providers which in turn could secure competitive advantage for the company.

Several research opportunities exists. This model further can be improved in different ways. AHP or fuzzy AHP may be employed to get the relative importance of service attributes. Second target values and specification limits were mentioned in percent form, real objective values may be taken for all the attributes for potential service providers. Subjective assessment of performance of providers may removed by taking objective data. Further a sensitivity analysis may be carried out in order to check out the effects of relative importance of various attributes and specification limits on final outcome. Furthermore, the stand-alone model, the proposed methodology can be embedded within the intelligent decision support system framework where the model can be interfaced with human experts, data warehouses/repositories, and computer software.

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About the authors

Dr Satyendra Kumar Sharma is BE, MBA from MNIT Jaipur and PhD from BITS Pilani. He carried out his PhD research on supply chain risk management. He has more than nine years of experience in industry and academics. Currently he is working as a Lecturer in management department and nucleus member of planning cell in practice school division, BITS Pilani. His research interest areas are supply chain management, risk management and project management and market and supply intelligence. He has published more than nine papers in *Nati International Journals* and more than 13 papers in conferences. He has conducted several MDP's. He is a member of professional bodies like Society of operations and production management and AIMS international. Dr Satyendra Kumar Sharma is the corresponding author and can be contacted at: satyendra.sharma1979@gmail.com

Professor Vinod Kumar, the winner of the two Scholarly Achievement and three Research Achievement Awards of the Carleton University, received his Graduate education from the University of California, Berkeley and the University of Manitoba. He has just completed ten years as the Director of the Sprott School of Business – Carleton University. Vinod has also served for several years on the Board of Governors and the Senate for Carleton University and on the Board of the Ontario Network of e-Commerce. Vinod is a well-known expert sought in the field of technology and operations management. He has consulted DND, CIDA, Canada Post, Industry Canada, CHEO, Federal partners of technology transfer and Canadian Association of Business Incubator to name a few. Before joining academia in the early 1980s, Vinod worked for five electronics and manufacturing firms for over 15 years in Canada, India and the USA. in various line and staff management positions. Vinod has given invited lectures to professional and academic organizations in Australia, Brazil, China, Iran, and India among others. He has taught in Executive MBA programs in Canada and Hong Kong and in Sprott MBA in Ottawa, Iran and China where he enjoys connecting his industry and research experience with management theories.