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*Corresponding author: Berna Bulgurcu, Department of Business Administration, Cukurova University, Adana, 01330, Turkey
E-mail: bkiran@cu.edu.tr

Reviewing editor:
Shaofeng Liu, University of Plymouth, UK

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OPERATIONS MANAGEMENT | RESEARCH ARTICLE

An extent analysis of 3PL provider selection criteria: A case on Turkey cement sector

Berna Bulgurcu[1]* and Gulsun Nakiboglu[1]

Abstract: Outsourcing has become an increasingly popular means for businesses to improve their efficiency. Logistics outsourcing can be described as transferring some of the logistics functions to an external firm. This paper aims to identify the selection criteria that are used by logistics service providers in Turkey's cement sector in choosing the third-party service provider. By drawing focus on Chang's Extent Analysis on Fuzzy Analytical Hierarchy Process (FAHP), the present paper evaluates cost, service/operation quality, competencies, general attributes of firms and relational factors as the main criteria, and considers explanatory 29 sub-criteria. In doing so, a questionnaire that was prepared in the pairwise comparison model was used as a large sample to collect data from a total of 25 experts working in 14 cement companies. As a result, the analysis identifies service/operation quality as the most important one among the main criteria, and determines the service price as the most preferred criterion among the sub-criteria. The study and results both provides particular insight into a specific sector as it is based on the data collected from a large number of experts in one sector, and offers an opportunity for other sectors from the same point of view.

Subjects: Operations Research; Business; Management and Accounting; Operational Research / Management Science; Operations Management; Supply Chain Management; Manufacturing Industries; Transport Industries; Service Industries

ABOUT THE AUTHORS

Berna Bulgurcu is a researcher and holds a PhD in Management Science from Cukurova University. She works as an Assistant Professor at Business Department of the same university since 2016. Her research interests are Multi-Criteria Decision Making Techniques, Fuzzy Logic, Artificial Neural Network and Adaptive Neuro Fuzzy Inference Systems (E-mail: bkiran@cu.edu.tr; Tel: 090-322 338 72 54, ext 273).

Gulsun Nakiboglu is assistant professor in Production Management at Cukurova University, Business Department. She received her PhD in Industrial Engineering Department from same university. Her teaching and research interests include supply chain management, logistics and production planning in sustainability perspective (E-mail: ngulsun@cu.edu.tr; Tel: 090-322 338 72 54, ext 277).

PUBLIC INTEREST STATEMENT

Outsourcing of logistics process is a frequently preferred practice of enterprises to focus on their core competencies. Deciding the appropriate logistics service provider (LSP) should be done for the continuous and smooth progress of the logistics process. For this reason, the decision makers determines the criteria in the best way, which is appropriate to the sector, product, distribution network and own business characteristics. In this study, important LSP criteria for a sector (cement sector) have been identified. The criteria used for the LSP were searched from literature, the list was shortened in the interviews made by experts, and the form that includes 29 pairwise comparisons of criteria was asked to 25 experts from 14 cement firms. In the comparison of the criteria, the multi-criteria decision method fuzzy AHP was used and the criteria were evaluated. Because it has been done with a large number of experts from the same sector, it will be able to give ideas to similar sectors and LSPs.

Keywords: 3PL; logistics service provider; selection criteria; fuzzy AHP; Chang's extent analysis; cement industry; outsourcing

1. Introduction

Logistics is one of the most important parts of supply chain management that has a significant effect on the success, efficiency and cost of the entire supply chain. More specifically, logistics involve the tasks of planning, implementing, and controlling the efficient, effective forward, and reversing the flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements (Council of Supply Chain Management Professionals, 2016). This function typically includes inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management (CSCMP, 2016).

In today's global and competitive world, firms wish to focus on their best areas and core competencies and prefer to use outsourcing for other activities and processes. Transactional, operational and repetitive activities are largely outsourced (Langley & Capgemini, 2016). The purpose of outsourcing is to create value from an expert firm on the chosen area (Liou, Wang, Hsu, & Yin, 2011), and thus to help that firm to reduce operating costs and improve competitiveness (Uygun, Kacamak, & Kahraman, 2015). The logistics process has been identified as an important function that may be used in outsourcing to reduce the costs and increase the efficiency. Transferring the entire or some part of the logistics function process to (an) external firm(s) can be defined as logistics outsourcing. In the entire supply chain, these logistics service providers (LSPs) perform the activities between the supplier and the buyer as a third party (Hwang, Chen, & Lin, 2016) and hence these external firms are referred to as third party logistics (3PL).

3PL can be defined as the outsourcing of all or much of a company's logistics operations to a specialized company (CSCMP, 2016) and 3PL provider (hereafter referred to as LSP) is an external provider who manages, controls and delivers logistics activities for firms (Hertz & Alfredsson, 2003). LSPs may carry out transportation, warehousing, inventory management, order processing, consolidate shipments, select carriers, information system, packaging activities, and returns handling (Aghazadeh, 2003; Aguezzoul, Rabenasolo, & Jolly-Desodt, 2006; Liu & Wang, 2009). Globally, the most outsourced logistics processes are domestic transportation (80%), warehousing (66%), international transportation (60%), freight forwarding (48%), customs brokerage (45%) and reverse logistics (34%) (Langley & Capgemini, 2016).

For most of the manufacturing firms, logistics is neither their core competency nor a core business function, but an essential function for them to gain competitive advantage. This brings logistics function to the fore as a very suitable candidate for outsourcing. Total business spending for logistics activities, which is very important for competitiveness may be very high (Banomyong & Supatn, 2011). Outsourcing may facilitate the reduction of the cost and achievement of effectiveness in logistics activities (Hwang et al., 2016). The main benefits of logistics outsourcing include the following: concentrating on core competencies, improving performance, receiving a higher level of service quality, achieving cost saving opportunities, reducing logistics costs, reducing asset base, gaining flexibility in supply chain, shortening average order-cycle lengths, extending the market boundaries, gaining access to leading edge technology, achieving flexibility in adapting to changes in the market, increasing the market knowledge and data access, enhancing innovation performance, reaching a greater level of flexibility to respond to the customer needs, achieving expertise and experience, increasing customer satisfaction, making better use of resources, improving service quality and restructuring supply chain (Aghazadeh, 2003; Alkhatib, Darlington, & Nguyen, 2015a; Alkhatib, Darlington, Yang, & Nguyen, 2015b; Hsiao, Kemp, Van Der Vorst, & Omta, 2010; Hwang et al., 2016; Jharkharia & Shankar, 2007; Kumar, Singh, & Dureja, 2012; Langley & Capgemini, 2016; Li et al., 2012; Liu & Wang, 2009; Percin & Min, 2013; Razzaque & Sheng, 1998; Selviaridis & Spring, 2007; Wong & Karia, 2010). In other words, logistics outsourcing enhances the efficiency and strengthens the business. LSPs are viewed as strategic partners who play a vital role in improving the performance and achieving the competitive advantage (Jothimani & Sarmah, 2014).

Historically, transportation and warehouse management processes are largely outsourced, but today LSPs have more strategic roles in achieving effective intra- and inter-firm relationships and integration (Zacharia, Sanders, & Nix, 2011). Since their service area is widened, the wrong choice of service provider causes ineffective activities, low-quality logistics services and some several problems, such as delayed shipments, higher costs, risks related to exposure and damaged reputation. Logistics outsourcing has a lot of advantages that are mentioned earlier. However, it also has problematic aspects and risks mainly related to long-term commitments and failures of service providers in performing their tasks (Alkhatib et al., 2015b). Therefore, selecting the right service provider represents an important decision to make. There is a lot of related research in literature that focus on LSP selection, as well as a great deal of academic papers that work solely on a firm's decision problem. Unlike existing papers in literature, this study focuses on the perspective of one sector rather than on a firm's selection of service provider. In other words, this paper aims to pinpoint the criteria that play a significant role in the selection of LSP from a single industry's point of view.

This paper is organized in four sections. Section 1 delineates the need for and importance of supplier evaluation and selection criteria. Section 2 provides an overview of the literature on the selection of supplier or LSP. Section 3 summarizes supplier selection criteria. Section 4 explains the methodology used in this research and explains Chang's extent analysis based on Fuzzy Analytical Hierarchy Process (FAHP) method step by step. Section 5 present important outcomes about selection criteria for Turkey's cement industry. This is finally followed by Section 6, which contains inferences based on the findings of this research.

2. Literature review

Boyson et al. (1999) state that the research topics in logistics outsourcing may be explored as the motivational factors for logistics outsourcing, evaluating the contribution of logistics outsourcing to competitiveness of the buyer firm and selection and evaluation of logistics service suppliers (as cited in Percin & Min, 2013).

There is a great deal of literature related to the supplier selection the earliest of which is Dickson (1966)'s study. Considering the LSP and its selection problem, Maloni and Carter (2006) provide a review of 45 surveys based on LSP papers between 1989 and 2004. Their paper analyze many factors, such as the functions of outsourcing, analysis approach, success factors and barriers of LSP. Selviaridis and Spring (2007) who provide an overview of the literature on the topic focus on research purposes, methods of use, theoretical approaches and levels of analysis based on 114 articles within the period between 1990 and 2005. Additionally, Marasco (2008) reviewed 152 articles published between 1989 and 2006. In this paper, the frameworks are constructed at five phases as the context within the third-party logistics relationship takes place (external or internal), the relationship's structural characteristics, the process, the outcomes that result from the relationship (at internal level and external level) and comprehension. Aguezzoul (2014) provides a comprehensive literature review related to the methods and criteria by analyzing 67 articles that were published between 1994 and 2013. Cost, relationship, services, quality and information and equipment system are determined as the criteria that are most commonly used in the selection of LSP. The methods applied were categorized under five groups, such as multi-criteria decision making (MCDM) techniques, statistical approaches, artificial intelligence, mathematical programming and hybrid methods. Further, Alkhatib et al. (2015a) provide a literature review for the decisions in selecting and evaluating LSP by using MCDM methods to determine the methods and criteria based on 56 articles published between 2008 and 2013. This study finds out that cost/price, quality and reliability, flexibility and compatibility, services and financial measures are the five criteria mostly used in the literature.

As the subject of selecting supplier service providers is expanded, selecting the best appropriate service provider becomes more important because businesses differ from one another in terms of properties, activities and quality levels, and a lot of enterprises decided to use outsourcing at logistics activities. This subject has generated a great deal of academic discussion as it attracted the attention of many researchers (Percin & Min, 2013). So far, different types of methods (mainly, multi criteria decision making methods, statistical techniques, data analysis techniques and mathematical modelling techniques) have been designed and applied to address the supplier selection. It is possible to find a greater number of techniques used for selecting and evaluating LSPs in literature, such as AHP, DEA, ANP, TOPSIS, ELECTRE, mathematical models, service quality approach, discriminant analysis, expert systems, QFD, case based reasoning, rule based reasoning, Interpretive Structural Model (ISM), factor analysis, etc. (Ho, Xu, & Dey, 2010; Isiklar, Alptekin, & Buyukozkan, 2007; Kumar & Singh, 2012; Liu & Wang, 2009; Percin & Min, 2013; Vijayvargiya & Dey, 2010).

Particularly, some of the papers that investigate the selection of LSPs are discussed later.

In their research, Bottani and Rizzi (2006) present fuzzy TOPSIS method to select the most appropriate LSP based on the criteria such as compatibility, financial stability, flexibility, performance, price, physical equipment and information system, quality, strategic attitude, trust and fairness. Aguezzoul et al. (2006) apply the ELECTRE method for sorting service providers based on the selection criteria. Jharkharia and Shankar (2007) represent ANP based LSP selection. In this paper, overall weighted index determinants are compatibility, cost, quality and reputation with dimensions of long-term relations, operational performance, financial performance and risk management. Gol and Catay (2007) apply AHP in Turkish automobile company's problem of selecting LSP with respect to 27 criteria and five main criteria, which are general company considerations, capabilities, quality, client relationship and labour relations.

In 2009, Liu and Wang implement fuzzy Delphi, fuzzy inference and fuzzy linear assignment techniques for the selection of provider. Percin (2009) introduces Delphi for determining the evaluation criteria, AHP for determining the weights and TOPSIS for service providers' preference order. Bhatti, Kumar, and Kumar (2010) implements AHP to determine the criteria used by a lead logistics provider (LLP) in selecting the 3PL. As the main criteria, they looked at vendor status, logistics competence of service provider, quality of service and IT competencies. Soh (2010) uses FAHP and finds that information technology capability is the most important selection criterion among the others, which include finance, service level, relationships, management and infrastructure.

Vijayvargiya and Dey (2010) identify the best logistics providers among six automobile components firms by using AHP. Kumar and Singh (2012) use FAHP and TOPSIS methods for evaluating the performance of LSP. They consider nine criteria as logistics cost, service quality, compatibility, consignment tracking capability, time delivery, information systems, total revenue, geographical coverage, range of service provided, concluding that cost and logistics service quality are two most important factors. Falsini, Fondi, and Schiraldi (2012) propose a model that combines AHP, DEA and linear mathematical model to select the LSP.

In their paper, Li et al. (2012) establish a model for the evaluation of LSP by using fuzzy sets that have the criteria of management success, business strength, service quality and business growth. Kumar et al. (2012) introduce VIKOR and CFPR (consistent fuzzy preference relation) method for the selection of 3PLs providers in firms manufacturing automobile parts. Ho, He, Lee, and Emrouznejad (2012) develop an integrated approach based on using QFD for determining the criteria and FAHP methods for prioritizing the criteria to select the LSP.

Gupta, Sachdeva, and Bhardwaj (2012) apply fuzzy MCDM methods for selecting LSP in a cement industry by means of five criteria, which are price, geographic location, reliability, flexibility and environmental conditions. Daim, Udbye, and Balasubramanian (2012) investigate the selection of LSP for international business by implementing AHP with the five main criteria, which are cost, service, global capabilities, information technology, experience and local presence. Percin and Min (2013) propose a QFD and fuzzy linear regression methodology to select the service provider.

Bansal, Kumar, and Issar (2013) apply their approach at a glass manufacturing firm. To select the LSP, they have consensus with management based on eight criteria, which are transportation cost, quality of services, number of value added services, reliability of services, flexibility, geographic coverage, market reputation and infrastructure. Akman and Baynal (2014) implement FAHP and fuzzy TOPSIS methods for examining the LSP selection problem at a tire manufacturing company in Turkey. Alkhatib et al. (2015b) state that LSP selection is important especially for developing countries. They use fuzzy DEMATEL and fuzzy TOPSIS methods and consider tangible and intangible logistics resources based on resource-based view in order to overcome uncertainty related to the data. In a recent paper, Hwang et al. (2016) use qualitative and quantitative approaches to determine the LSP selection on IC manufacturing sector in Taiwan and obtain the sequencing of the main criteria, which are performance, cost, service and quality. For LSP selection, Awasthi and Balezentis (2017) used a hybrid approach based on BOCR (benefits, costs, opportunities and risks) and fuzzy MULTIMOORA. Raut, Kharat, Kamble, and Kumar (2018) interested with the LSP problem from environmental sustainability and implemented DEA and ANP methods. In Bianchini (2018)'s paper, which is applied on a company, AHP is used to determine the relative weights of the evaluation criteria and TOPSIS is used to rank the potential LSP.

3. Supplier selection criteria

Global competition and fluctuations in short-term demands make it necessary to meet customer's needs very quickly, which cause pressure on firms to improve their logistics activities in terms of cost and service quality. Effective and efficient logistics services help firms to gain competitive advantage. Therefore, it is vital to select the appropriate service provider and it is not enough to select less costly LSP.

Logistics outsourcing is different from traditional purchasing in terms of time frame and relations. The firms that want to use logistics outsourcing are faced with the inevitable need to select the best suitable service provider to meet their needs. Despite the benefits involved, it is not necessarily easy to implement the outsourcing in logistics function and apply successful coordination with the service provider (Hwang et al., 2016). Due to the complexity of the selection process, it is necessary to develop a framework related to the selection and evaluation of LSP.

The criteria list and indexing construction is very important for the selection of LSPs. The research done in this area draws on a wider range of criteria, including operational, organizational and relational factors (Coltman, Devinney, & Keating, 2011). Table 1 gives a brief list of the criteria that are used in the studies related to logistics outsourcing.

The characteristics of the supplier selection procedure vary depending on the country (culture, economic conditions, etc.) in general and on the firm, in particular. Further, different industries have unique characteristics and specific requirements and priorities. Therefore, the selection criteria and the importance of these criteria may be different (Aghazadeh, 2003; Liu & Hai, 2005; Liu & Wang, 2009). Previous studies show that firms from different industries have different logistics service provider selection decisions (Hwang et al., 2016). This study selects Turkey's cement industry as the application area of the supplier selection problem.

4. Methodology

MCDM methodologies serve as effective decision support tools to analyze complex decision problems, which involves multiple criteria, goals or objectives of conflicting nature (Kahraman, Onar, & Oztaysi,

Table 1. The list of the criteria mostly used in the selection of logistics service provider in the literature

Main criteria	Sub-criteria	Literature on the selection of logistics supplier
Cost/ Financial criteria	Price Continuous cost reduction Flexibility in payment	Gol and Catay (2007), Liu and Wang (2009), Soh (2010), Kumar et al. (2012), Ho et al. (2012), Gupta et al. (2012), Bansal et al. (2013), Akman and Baynal (2014), Jothimani and Sarmah (2014), Hwang et al. (2016), Jharkharia and Shankar (2007)
Operations and service quality	Customer satisfaction Flexibility in operations Capability to handle specific business requirements Transportation safety Range of service provided Number of value added services Geographical coverage Key performance indicators tracking ISO compliance Location Asset ownership Accuracy in operations On time delivery Reliability of services Data security Infrastructure Document accuracy	Ho et al. (2012), Li et al. (2012), Kumar et al. (2012), Aguezzoul et al. (2006), Gupta et al. (2012), Liu and Wang (2009), Soh (2010), Akman and Baynal (2014), Bansal et al. (2013), Daim et al. (2012), Gol and Catay (2007), Hwang et al. (2016), Jothimani and Sarmah (2014), Kumar and Singh (2012)
Technology and information	Information system, IT capability Information sharing	Aguezzoul et al. (2006), Isiklar et al. (2007), Gol and Catay (2007), Jharkharia and Shankar (2007), Liu and Wang (2009), Vijayvargiya and Dey (2010), Soh (2010), Kumar and Singh (2012), Ho et al. (2012), Daim et al. (2012), Li et al. (2012), Akman and Baynal (2014)
Intangibles, business related	Responsiveness Problem solving capability Experience Trust Financial stability Reputation Past performance Cultural fit	Gol and Catay (2007), Liu and Wang (2009), Hwang et al. (2016), Soh (2010), Jharkharia and Shankar (2007), Kumar et al. (2012), Daim et al. (2012), Isiklar et al. (2007), Percin (2009), Li et al. (2012), Ho et al. (2012), Bansal et al. (2013), Akman and Baynal (2014), Aguezzoul et al. (2006), Kumar and Singh (2012)

For detailed information about the definitions of the criteria please see Akman and Baynal (2014), Gol and Catay (2007), Hwang et al. (2016), Kumar and Singh, (2012).

2015). They have been widely accepted and used in academic and industrial circles since they were developed by Keeney and Raiffa in (1976). LSP selection and evaluation process is a typical complex multi-criteria decision problem in which both qualitative and quantitative factors are involved. These factors provide an opportunity to use both kinds of criteria. Thus, MCDM methods enable decision makers to reach a specific judgement as a collective group idea (Liou et al., 2011). FAHP, which is one of MCDM methods, can be used to improve an acceptable way of understanding complex decision selection process where there are many decision makers and when there is a need for ideas. FAHP as an advanced version of Saaty's widely used AHP technique first appeared in Van Laarhoven and Pedrycz (1983).

AHP is based on the decision maker's preferences to find the best decision (Vijayvargiya & Dey, 2010). By using AHP, decision makers make a pairwise comparison and determine the numerical quantification of weights of the criteria. In practice, for the reasons, such as incomplete data, ambiguous nature of decision making process where people are involved as well as the complexity and uncertainty of business environment, decision makers have difficulty making exact comparisons between the levels of importance for criteria (Soh, 2010). Therefore, it is very suitable to use FAHP as a methodological framework in this study.

Although AHP is a popular method, it may be inadequate for analyzing complex decision problems in terms of fuzziness and uncertainness attributes. To handle these mutual attributes, FAHP combines the Fuzzy Set Theory (FST) with AHP under uncertain conditions and fuzzy data set is used for the evaluation of a simplified decision model. FST is a very powerful tool to process imprecise data and fuzzy expressions that are more natural for humans than constant mathematical rules and equations (Kreng & Wu, 2007).

Among several techniques, which are used in FAHP, one of them is van Laarhoven and Pedrycz's logarithmic least squares method (LLSM) to get triangular fuzzy weights from a triangular fuzzy comparison matrix in 1983. This method has serious uncertainties even under certain conditions because of approximate calculation of the triangular fuzzy numbers (Wang, Elhag, & Hua, 2006). In the chronological list of weighting methods, Buckley's method (1985) comes after LLSM. Therefore, this method was later used to calculate fuzzy weights in a rather simple manner. Despite the advantage of utilising this method, high computational requirements and geometric row calculation cause disadvantages when a perfect consistency is not provided (Csutora & Buckley, 2001).

Finally, Chang (1996) suggested the Extent Analysis Method and made a comparison using triangular fuzzy numbers to obtain the priorities of alternatives from pairwise comparisons. Among all, Chang's Extent Analysis on FAHP became popular due to the simplicity of steps and intelligibility and successful application in many fields (Ding, Yuan, & Li, 2008). It evaluates different possible weight values obtained by different decision makers by using the pairwise comparison matrix, which includes corresponding triangular fuzzy numbers. Furthermore, if one criterion is not important in Chang's method, it can get a weight of 0. Wang, Luo, & Hua (2008) argue that making zero-weight assignments to any of the main and sub criteria results in making incorrect decisions. On the contrary, according to Meixner (2009), the zero-weight assignment to any of the criteria indicates that the method has a strong representation of reality. Meixner (2009) also notes that it is an advantage to emphasize the most important criterion.

According to the extended analysis method, each object is handled to achieve an aim. With the extended statement, it expresses how much this object fulfils its purpose. Accordingly,

$X = \{x_1, x_2, \ldots, x_n\}$ is accepted as a set of object, and $U = \{u_1, u_2, \ldots, u_m\}$ is accepted as a set of goal. Every objective is obtained and extent analysis is applied for every goal g_i in turn. Thus, m expansion analysis values for each object are calculated with Equation (1).

$$\mathrm{M}^1_{g_i}, \mathrm{M}^2_{g_i}, \ldots\ldots\ldots. \mathrm{M}^m_{g_i} \;(i = 1,\ 2,\ 3 \ldots\ldots n) \tag{1}$$

All $\mathrm{M}^j_{g_i}$ $(j = 1,\ 2,\ 3 \ldots\ldots m)$ show triangular fuzzy numbers. The following steps are based on the Chang's Extent Analysis Method.

Step 1. Determine the fuzzy synthetic extent values for object i.

$$S_i = \sum_{j=1}^{m} \mathrm{M}^j_{g_i} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \mathrm{M}^j_{g_i} \right]^{-1} \tag{2}$$

While S_i shows synthesis value of i^{th} goal, $\mathrm{M}^j_{g_i}$ shows a triangular fuzzy number, which represents the significance ratio among i and j in comparison with the goal k. With $\mathrm{M}^j_{g_i}$, the comprehensive member of a fuzzy pairwise comparison matrix is obtained. To get $\sum_{j=1}^{m} \mathrm{M}^j_{g_i}$, fuzzy calculation for specific matrix of m extent analysis is as in the following matrix (Equation (3)):

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{3}$$

To find $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$, the operation of fuzzy addition of $M_{g_i}^{j}$ $(j = 1, 2, 3 \ldots\ldots m)$ values are carried out and then the reverse of vector in Equation (4) is calculated.

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{4}$$

Step 2. Compare the fuzzy numbers of $\widetilde{M}_1 = (l_1, m_1, u_1)$ and $\widetilde{M}_2 = (l_2, m_2, u_2)$

While $\widetilde{M}_1$ and $\widetilde{M}_2$ represent a fuzzy number, the rank of probability $\widetilde{M}_2 \geq \widetilde{M}_1$ is shown as

$$V\left(\widetilde{M}_2 \geq \widetilde{M}_1\right) = sup_{y \geq x}\left[min\left(\mu_{\widetilde{M}_1}(x), \mu_{\widetilde{M}_2}(y)\right)\right] \tag{5}$$

For this equation, $y \geq x$ is expressed by expansion principle. This equality shows the magnitude relation between the pairs of numbers (x, y) with relation, such as $y \geq x$ and $\mu_{\widetilde{M}_1}(x) = \mu_{\widetilde{M}_2}(y)$.

$$V\left(\widetilde{M}_2 \geq \widetilde{M}_1\right) = \text{height}\left(\widetilde{M}_1 \cap \widetilde{M}_2\right) = \mu_{\widetilde{M}_2}(d) = \begin{cases} 1, \text{if } m_2 \geq m_1 \\ 0, \text{ if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{otherwise} \end{cases} \tag{6}$$

The probability of being greater than $\widetilde{M}_1$, the middle value of $\widetilde{M}_2$ is equal to 1 as seen in Figure 1. When something else is not the case, the probability calculation must be done. For this calculation, the rates of $V\left(\widetilde{M}_1 \geq \widetilde{M}_2\right)$ and $V\left(\widetilde{M}_2 \geq \widetilde{M}_1\right)$ has to be calculated and compared. d denotes the final intersection point among $\mu_{\widetilde{M}_1}$ and $\mu_{\widetilde{M}_2}$.

Step 3. Determination of the degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $\widetilde{M}_i (i = 1, 2, \ldots\ldots, k)$.

$$\begin{aligned} V\left(\tilde{M} \geq \widetilde{M}_1, \widetilde{M}_2, \ldots\ldots \widetilde{M}_k\right) &= V\left[\left(\tilde{M} \geq \widetilde{M}_1\right), \left(\widetilde{M} \geq \widetilde{M}_2\right), \ldots \left(\tilde{M} \geq \widetilde{M}_k\right)\right] = \min V\left(\tilde{M} \geq \widetilde{M}_1\right) \\ &= 1, 2, ..k \end{aligned} \tag{7}$$

Under the assumption of $d'(A_i) = \min V(\tilde{S}_i \geq \tilde{S}_k)$, the weight vector is calculated for all S_j, $k = 1, 2, .., n; k \neq j$.

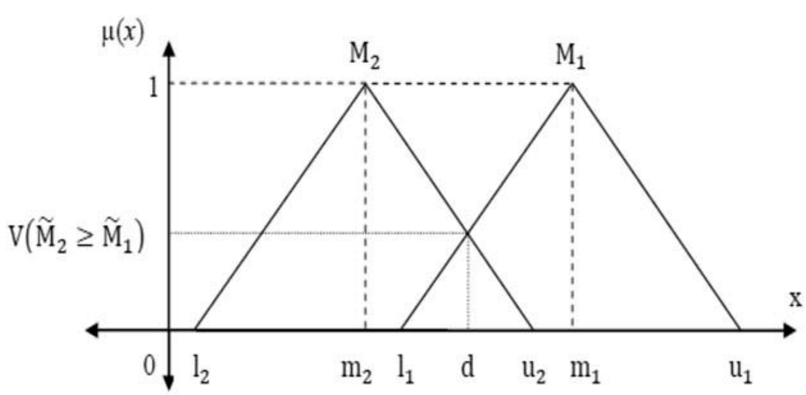

Figure 1. *Intersection between $\widetilde{M}_1$ and $\widetilde{M}_2$.*

$$W' = (d'(A_i))^T, (i = 1, 2 \ldots, n) \tag{8}$$

Step 4. Get the normalized weight vector W by using normalization.

$$W = (d(A_i))^T, \ (i = 1, \ 2, \ldots n) \tag{9}$$

where W is now not a fuzzy number.

5. Application and findings

There are few sectors related to LSP selection studies, such as automotive, telecommunications, direct selling, retailing, consumer goods and general manufacturing industries (Hwang et al., 2016).

The projections related to the period between 2013 and 2023 in Turkey also show that during this period both the production and the consumption will be increased in one of the biggest manufacturing industry. This attracting manufacturing industry is cement industry (ATIG, 2015). Turkey is one of the most important cement producing countries in the world. According to cement industry reports, Turkey is the leading cement producing country in Europe (Ministry of Economy, 2016). It was the fifth largest cement producer of the world in 2014. Further, Turkey is among the top five exporting countries (Cevik, 2016). The profit margin of the cement firms listed in Istanbul Stock Exchange Market is around 33% and their net profit is around 21% (Turkish Yatirim, 2014).

Logistics play a key role in the cement sector in terms of both production and the delivery of final product. LSP also have a role to play in every step of the whole procedure due to the high-tonnage raw materials and semi-finished products used in the manufacturing process. The tasks of LSP involve the inclusion of raw materials to the process, transportation of admixtures from their source to the endpoint, transfer of intermediate products, transportation of coal as the fuel of use, transfer of the final product to domestic and foreign markets. There is only few, if any, firms in the cement sector which have in-house professionals to carry out all these tasks. These services are generally outsourced through annual contracts. These services affect the cost by about 15%, which is in turn reflected in the prices. In addition to the regional supply/demand ratio and competition levels, transportation expenditures also have a determining role in the prices of services in the cement sector (Cevik, 2016). Therefore, in case logistics outsourcing is not efficiently managed, the failures about logistical activities can increase and cause higher costs and loss of reputation. Consequently, the selection criteria for LSP, which reflect strategic and operational needs, should be accurately evaluated.

This study aims to determine the most important criteria for LSP at the cement industry in Turkey by applying Chang's Extent Analysis on FAHP model. Generally speaking, there are many different criteria for the selection of the present LSP. The study analyses the literature on the selection of relevant LSP to provide a comprehensive framework for identifying the criteria for supplier selection and, especially LSP selection that are generally used in the literature. Due to its focus on a specific industry, the present study chooses the decision criteria that are applicable to the cement sector and relevant to the concerns that are strategically and practically important in this sector.

The FAHP method requires pairwise comparisons of criteria. If there is *n* criteria, it means that the number of combinations will be (n*(n–1)/2), for 15 criteria it will be 105 pairwise questions, which may cause confusion on the receiving end and relatedly may yield inconsistent results. At this point, it becomes important to reduce the number of criteria and make an accurate decision on consensus-based criteria. In order to provide a very reliable picture, high-level decision makers created a sample size for this study. Therefore, the list of criteria is first evaluated and then shortened based on the results of the interviews with purchasing and logistics experts from cement industry as well as academicians as can be seen in Table 2. Since this method does not have framework based on statistics, a statistically significant sample size of decision makers is not required (Dias & Ioannou, 1996).

Table 2. List of criteria for the selection of logistics service provider

Main criteria	Sub-criteria
C_1 : Cost	C_{11} : Price of the service
	C_{12} : Continuous cost reduction efforts
	C_{13}: Flexibility in payment
C_2: Service/operation quality	C_{21} : Customer satisfaction
	C_{22} : Operational performance based on speed
	C_{23} : Operational performance based on time
	C_{24} : Operational performance based on accuracy
	C_{25} : Problem solving capability
	C_{26} : Customer orientation
C_3 : Competencies (business competence)	C_{31} : Function coverage
	C_{32} : Geographical coverage of operations
	C_{33} : Asset ownership for operations
	C_{34} : Technological infrastructure for operations
	C_{35} : Capacity adequacy
	C_{36} : Flexibility
	C_{37} : Information technology, IT capability
C_4 : General attributes of firm	C_{41} : Location
	C_{42} : Documents (ISO etc.)
	C_{43} : Reputation
	C_{44} : Experience
	C_{45} : Financial stability
C_5 : Relational factors	C_{51} : Compatible culture
	C_{52} : Customer relationship
	C_{53} : Willingness to information sharing

A survey questionnaire which is created by using this list includes pairwise comparisons between all the selection criteria and sub-criteria. In selecting the firms, this study draw on the list of Turkey's Biggest 500 Companies (2016) published every year by Istanbul Chamber of Commerce (Istanbul Ticaret Odasi, ITO). Out of the total number of 21 cement firms included in this list, 14 cement firms agreed to fill out the survey and thus the questionnaire was sent to 25 experts in the field of logistics procurement and transportation related to the third-party logistics provider selection. These firms were selected because they had a more institutional character, had a higher amount of production and hence adopted a systematic approach to achieve an effective logistics process and select the best service provider. Chang's scale as shown in Table 3 was used in order to identify the decision maker's preferences (Kahraman, Cebeci, & Ruan, 2004).

Table 3. Triangular fuzzy scale by Chang

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

After the evaluation of 25 expert decision makers on main criteria and sub-criteria, each judgement is brought together only as a matrix. Aczel and Saaty (1983) propose the use of geometric mean method to combine each decision maker's pairwise comparison to synthesize judgments instead of using weighted arithmetic mean method to maintain reciprocal property. In this study, the geometric mean method is used to aggregate decision makers' preferences as in Equation (9).

$$\left(\prod_{k=1}^{n} a_{ij}^{k}\right)^{1/n} \tag{9}$$

Table 4 shows a pairwise comparison matrix that is established by using the aggregation of decision makers' preferences among the main criteria before the evaluation of the sub-criteria. The pairwise comparison matrices for the sub-criteria are constructed in the same manner.

All calculations as seen in Table 5-10 of synthetic extent values are considered as a kind of normalization operation performed on fuzzy numbers.

S_C can be calculated by Equations (6) and (8). The degrees of possibility of superiority of S_C, which is denoted by$V\left(\tilde{S}_I \geq \tilde{S}_k\right)$, are calculated and shown in Table 11.

By using these values, the weight vector of the main criteria $W' = (0.63423,\ 1,\ 0.345936,\ 0.173669,\ 0.345936)$ is obtained. However, the normalized value of this vector has to be calculated to decide the priority weights of each main criterion over another. The normalized weight vectors $W = (0.254,\ 0.4,\ 0.138,\ 0.069,\ 0, 138)$ is calculated.

Table 4. Fuzzy aggregate pairwise comparison matrix of main criteria

	C_1	C_2	C_4	C_4	C_5
C_6	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(1, 1, 1)
C_2	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(3/2, 2, 5/2)
C_3	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)
C_4	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)
C_5	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)

Table 5. Fuzzy aggregate pairwise comparison matrix of cost sub-criteria

	C_{11}	C_{12}	C_{13}
11	(1, 1, 1)	(1, 1, 1)	(3/2, 2, 5/2)
C_{12}	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)
C_{13}	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(1, 1, 1)

Table 6. Fuzzy aggregate pairwise comparison matrix of service/operation quality sub-criteria

	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}
C_{21}	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)
C_{22}	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)
C_{23}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)
C_{24}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)
C_{25}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)
C_{26}	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)

Table 7. Fuzzy aggregate pairwise comparison matrix of competencies sub-criteria

	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}
C_{31}	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)
C_{32}	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)
C_{33}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)
C_{34}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)
C_{35}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)
C_{36}	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)
C_{37}	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)

Table 8. Fuzzy aggregate pairwise comparison matrix of general attributes of firm sub-criteria

	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}
C_{41}	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(1, 1, 1)
C_{42}	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(3/2, 2, 5/2)
C_{43}	(1, 1, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)
C_{44}	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)
C_{45}	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)

Table 9. Fuzzy aggregate pairwise comparison matrix of relational factors of sub-criteria

	C_{51}	C_{52}	C_{53}
C_{51}	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)
C_{52}	(1, 1, 1)	(1, 1, 1)	(3/2, 2, 5/2)
C_{53}	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(1, 1, 1)

Table 10. Fuzzy synthetic extent values of main criteria

S_{C1}	(0.16, 0.22, 0.31)
S_{C2}	(0.19, 0.30, 0.45)
S_{C3}	(0.11, 0.17, 0.25)
S_{C4}	(0.105, 0.1481, 0.22)
S_{C5}	(0.113, 0.167, 0.25)

Table 11. The degree of possibility for fuzzy synthetic extent values of main criteria

$\min V(S_{C1})$	0.63423
$\min V(S_{C2})$	1
$\min V(S_{C3})$	0.345936
$\min V(S_{C4})$	0.173669
$\min V(S_{C5})$	0.345936

The same steps are followed to make an evaluation and obtain these weight values for sub-criteria.

This final table 12 indicates that **service/operations quality** is the most important main criterion (0.4) in selecting an optimal LSP, being followed by cost (0.254), competencies and relational

Table 12. The weights of main and sub-criteria

Main criteria	Weight	Sub-criteria	Local weight	Global weight
Cost **(C_1)**	0.254	Price of the service (C_{11}) Continuous cost reduction efforts (C_{12}) Flexibility in payment (C_{13})	0.548 0.282 0.170	0.14 0.07 0.04
Service/ Operation quality **(C_2)**	0.4	Customer satisfaction (C_{21}) Operational performance based on speed(C_{22}) Operational performance based on time (C_{23}) Operational performance based on accuracy (C_{24}) Problem solving capability (C_{25}) Customer orientation (C_{26})	0.164 0.166 0.189 0.130 0.189 0.162	0.066 0.067 0.076 0.052 0.076 0.065
Competencies (C_3)	0.138	Function coverage (C_{31}) Geographical coverage of operations (C_{32}) Asset ownership for operations (C_{33}) Technological infrastructure for operations (C_{34}) Capacity adequacy (C_{35}) Flexibility (C_{36}) Information technology, IT capability (C_{37})	0.142 0.141 0.160 0.115 0.160 0.142 0.139	0.020 0.019 0.022 0.016 0.022 0.020 0.019
General attributes of firm (C_4)	0.069	Location (C_{41}) Documents (C_{42}) Reputation (C_{43}) Experience (C_{44}) Financial stability (C_{45})	0.267 0.430 0.101 0.062 0.139	0.018 0.03 0.007 0.004 0.01
Relational factors (C_5)	0.138	Compatible culture (C_{51}) Customer relationship (C_{52}) Willingness to information sharing (C_{53})	0.282 0.548 0.170	0.039 0.076 0.023
	1			1

factors (0.138), and general attributes of firm (0.069). Following the same procedure, the sub-criteria can be compared with respect to their corresponding main criteria, to find that the most preferred sub-criterion is price of service (0.14).

6. Conclusion

As the markets become more global and competitive, logistics emerge as an important area in customer service and costs. As a rising trend, logistics outsourcing help organizations to reduce logistical costs and assets, improve customer satisfaction and focus on core activities in addition to other benefits. Failures that are related to logistical service providers cause problems such as late shipments, higher costs and loss of reputation. Therefore, service provider selection is an extensively discussed topic both in practice-based and academic research.

The present study focused on the issue of evaluation and selection of LSP. After determining the specific criteria for the cement sector, the extent analysis on FAHP method was used to weight these criteria. The results show that the most important criterion is service/operations quality. Considering the cement sector in terms of all the criteria shown in the list, service/operations quality stands out in the main criteria whereas service cost is noted as a significant sub-criterion.

In this research, the decision framework is composed of six main criteria and 20 sub-criteria. These criteria selected by a team of academics with expertise on the provider selection and experts from the cement sector who deal with purchasing, manufacturing and quality control.

These criteria are selected from among a more extended list, drawing on the literature on supplier selection and LSP, as well as a discussion with professionals.

Although the present paper provides a comprehensive framework to guide the decision makers at LSP selection, it also has certain limitations as in the previous research. Firstly, the decision weights depend on the decision makers because of the AHP method. Secondly, the application could not consider all possible selection and evaluation criteria that may be added to the model. Since the application is based on a sample industry, the authors intended to overcome this limitation by preparing a list that contains the main criteria that were used in the literature and discussed by experts. The final list was used in the survey. This study can be further extended by using outranking methods, such as ELECTRE, PROMETHEE, ARAS, OCRA, MOORA, MOOSTRA to determine the best LSP for a specific cement firm.

This study concerned with calculating the weights of the selection criteria for LSP. Following this step, no choice was made between the outcome and alternatives to LSP. The reason is both that the study aimed to make a general evaluation on the sector and that it was not feasible to reach a similar group of providers since some firms in the sector work with local providers while some others work with providers who provide service across the country. The main contribution of this paper is to fill the gap in the literature by identifying and determining the supplier selection criteria in cement industry. Therefore, this paper can serve as a guideline for cement industry to plan their logistics strategies and applications, help them to build a LSP performance evaluation system. Additionally, the logistics organizations which serve to cement firms can benefit from the results of this paper to understand the customer needs and adapt themselves accordingly. Therefore, from the standpoint of a manager, this paper provides insights to not only decision makers from cement industry but logistics providers as well.

As an application, this research which is based on cement industry as a sample may serve as a model to be applied to other industries which have same logistical needs for selecting service providers. Further, the results may help the logistics providers that also serve to other industries which have the same properties.

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Author details
Berna Bulgurcu[1]
E-mail: bkiran@cu.edu.tr
ORCID ID: http://orcid.org/0000-0002-9695-2668
Gulsun Nakiboglu[1]
E-mail: bkiran@cu.edu.tr
ORCID ID: http://orcid.org/0000-0002-6835-744X
[1] Department of Business Administration, Cukurova University, Adana, Turkey.

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