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Abstract

Purpose – As the modern manufacturing twining seamlessly with logistics operations for value adding services, logistics service is becoming more and more significant. Under this research background, the purpose of this paper is to introduce an innovative evaluation model for customer satisfaction using fuzzy analytic hierarchy process (FAHP).

Design/methodology/approach – This model uses triangular fuzzy concept to determine the weight of each index so that subjective or objective weighting is addressed. A case study from two large express companies in China is used to demonstrate the feasibility and practicality of the proposed model for examining customer satisfaction.

Findings – One of the key findings is that Company B has higher customer satisfaction than Company A due to its quick response and flexible logistics strategy. This paper has several contributions. First, A FAHP-based customer satisfaction evaluation model is proposed for the logistics service. Second, the triangular fuzzy concept is introduced to determine the weight of each index so as to addresses the limitation of subjective or objective weighting method. Third, a case study demonstrates the implementation of the model.

Research limitations/implications – First, this paper considers the fuzzy AHP for the customer satisfaction evaluation. Comparing with other multi-criteria decision-making methods like data envelopment analysis, evidential reasoning approach , and multi-attribute value theory will be carried out in the near future. Second, the manufacturing modes like make-to-order, make-to-stock, and mass-customized production may have different logistics support so that the final products may reach the final targets quickly. How to evaluate various mode-based logistics and their customer satisfactions have great significance. Finally, Big Data-enabled customer satisfaction evaluation approaches may be a possible solution.

Practical implications – Based on the data from questionnaire, it is found that, in practical applications, manufacturing enterprises should amend the index system according to the specific business scope and the production characteristics. Manufacturing enterprises need to collect large

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amounts of data through market research and conduct the measurement on the related coefficient between the measurement indicators and customer satisfaction degree. After that, they can make sorting and filtering on the measurement index according to the measurement results.
Social implications – Customer satisfaction is very important to manufacturing and logistics enterprises due to its time constraints. The physical products with services like logistics are paid close attention to by the final customers.
Originality/value – The contribution of this paper is as follows: a FAHP-based customer satisfaction evaluation model is proposed for the logistics service; triangular fuzzy concept is introduced to determine the weight of each index so as to addresses the limitation of subjective or objective weighting method; a case study was used to demonstrate the implementation of the model. One of the key findings is that Company B has higher customer satisfaction than Company B due to its quick response and flexible logistics strategy.
Keywords Fuzzy analytic hierarchy process, Customer satisfaction evaluation, Logistics service
Paper type Research paper

Manufacturing, referring to the production of merchandise by utilizing various resources like manpower, machines, tools, etc., plays an important role in supporting our lives and developments (Chryssolouris, 2013; Ruiz-de-Arbulo-Lopez *et al.*, 2013). Modern manufacturing includes all intermediate processes and other value adding procedures such as assembly and shipping (Dai *et al.*, 2012; Grošelj *et al.*, 2015; Hilmola *et al.*, 2015). The manufactured products should be delivered to suitable destinations so that the values of the manufacturing could be enabled. Take electronic products, for example, they must be delivered to targeted market areas as soon as possible once issued so as to take up the profit margin. Therefore, logistics is very critical to the manufacturing sector.

Currently, as the distributed manufacturing factories are in different areas, modern manufacturing heavily relies on logistics because different parts are produced in different locations or countries then all of them must be shipped to final assembly site from where the final products could be manufactured. Customized products like cars, furniture, and luxury electronic devices are mainly based on large number of producers which manufacture various components once a customer places an order for certain types of merchandise (Mourtzis *et al.*, 2014; Liu *et al.*, 2015). In such manufacturing mode, logistics efficiency and effectiveness are very important to ensure the products' delivery due date. That is crucial to meet the customer satisfaction due to their high priorities (Cui *et al.*, 2015).

Customer satisfaction is very important to manufacturing and logistics enterprises due to its time constraints. The physical products with services like logistics are paid close attention to by the final customers. Thus, manufacturing companies widely use product service system which focusses on the customer value and satisfaction more than traditional products (Geng and Chu, 2012). Logistics service thus is proposed under different production mode so as to improve the customer satisfaction (Luisa dos Santos Vieira *et al.*, 2013). For example, the mass production and customized production may use different logistics strategies to meet customer satisfaction. For customized production, logistics is very important to ship the final qualified products to the customers before or on the deadline basis. In this case, logistics will be flexible to improve the customer satisfaction (Dotoli *et al.*, 2014).

In order to evaluate customer satisfaction, large numbers of research have been carried out (Bellingkrodt and Wallenburg, 2015; Cao *et al.*, 2015; Abdolvand *et al.*, 2015). However, existing approaches have some challenges under manufacturing-driven scenarios. First, the entire supply chain management focusses on evaluating customer satisfaction. Manufacturing-driven logistics services are paid less attention so that the evaluation models are mainly used for selecting and examining the logistics providers (Tracey and Tan, 2001; Meade and Sarkis, 2002). Second, evaluation models are usually based on some criteria quantified as weights for judging the key impact factors. Unfortunately, these weights are subjective due to different interpretation of different cases (Khan *et al.*, 2015). That may greatly influence the evaluation results. Finally, most of the studies focus on theoretic aspects such as behavioral analysis, alignable mechanism, and qualitative investigation (Li *et al.*, 2014; Miao *et al.*, 2014). Real-life cases and implementation applications are scarcely reported.

In order to precisely evaluate the customer satisfaction under manufacturing-driven logistics, this paper introduces a model using fuzzy analytic hierarchical process (FAHP) that is proposed to quantize the accessing indexes. Triangular fuzzy concept is introduced to determine the weight of each index which addresses the limitation of subjective or objective weighting method. Thus customer satisfaction of express enterprises or third-party logistics enterprise can be reasonably evaluated.

Based on the data from the questionnaire, it is found that, in practical applications, manufacturing enterprises should amend the index system according to their specific business scopes and production characteristics. They need to collect large amount of data through market research and conduct the measurement on the related coefficient between the measurement indicators and customer satisfaction degree. After that, they can make sorting and filtering on the measurement index according to the measurement results.

The rest of this paper is organized as follows. Section 1 briefly reviews the related work in terms of logistics service, customer satisfaction evaluation models, and FAHP. Section 2 presents the proposed model for logistics service using FAHP. Section 3 introduces a case study which illustrates two scenarios to evaluate the customer satisfaction. Conclusions are presented in Section 4 for giving our findings and future work.

1. Literature review

This section briefly reviews the related work including logistics service, customer satisfaction evaluation models, and FAHP.

1.1 Logistics service

Logistics usually refers to management of flow of things from one point to another so as to meet customer requirements or corporations (Christopher, 1998). In the manufacturing sector, logistics is heavily integrated to its operations and value adding points that the manufacturing activities are closed related to the movements of materials and workers (Lee *et al.*, 2012). Driven by the manufacturing operations or finished products, logistics could be presented through different approaches or models. Wy *et al.* (2011) introduced a generic simulation model for considering the assembly manufacturing lines to optimize the logistics based on a data-driven method.

Logistics currently, for manufacturing companies, is regarded to add values to traditional products. Thus, the manufacturing and logistics activities are homogeneous at the operational level which makes the final products reach the customers as soon as possible (Nilsson and Darley, 2006). Lai and Wong (2012) introduced some empirical evidence from Chinese manufacturing professionals that logistics service not only improve the productivity, but also could be beneficial to the environmental improvement. For a manufacturing company, a quality control game model is introduced to examine the logistics service supply chain (Liu and Wang, 2015). In order to support logistics services, some models are used such as knowledge-based logistics approach using ontology, event-driven multi-agent ubiquitous manufacturing execution model, lean manufacturing and distribution, as well as service-oriented manufacturing and logistics (Makris *et al.*, 2012; McFarlane *et al.*, 2012; Panetto *et al.*, 2012; Zhang *et al.*, 2012; Zhong *et al.*, 2013).

1.2 Customer satisfaction evaluation models

Customer satisfaction evaluation is usually carried out by the performance analysis approach which aims to improve the production activities and increase the profit margin. The linkage of customer satisfaction and manufacturing and logistics operations is evaluated by a genetic algorithm-based learning model using past experiences (Simon and Honore Petnji Yaya, 2012; Zhao *et al.*, 2012). Since the manufacturing and logistics behaviors largely influence the customer satisfaction, a behavioral simulation model is used to analyze their impacts using numerical examples (Oliver, 2014). It is found that the frontline behaviors like machine operations, quality check, and package will largely influence the customer satisfaction.

As driven by the integration of modern manufacturing and logistics, customer satisfaction mainly focusses on logistics since it is the exact interface to the final customers who always want the ordered products delivered by deadline basis. A shortened delivery time means it is harder for manufacturing firms to produce the customized products (Griffin *et al.*, 2012). In order to improve the customer satisfaction in this case, a switching intention model is proposed to evaluate the role of service performances about manufacturing enterprises and logistics companies (Estampe *et al.*, 2013). The participants' performance may influence the customer satisfaction in logistics service (Turkyilmaz *et al.*, 2013). To examine the influence, Xiong *et al.* (2014) introduced a structural equation model which considers the client's clarity of objectives and promptness of payments, designer carefulness, construction risk management, the effectiveness of their contribution and mutual respect and trust. For the whole business strategy, most of the studies focus on the manufacturing and supply chain management to evaluate the customer satisfaction using different models such as profitability-based model, balanced scorecard-based analytic network process model, fuzzy linear programming model, AHP, etc. (Lun *et al.*, 2015; Tjader *et al.*, 2014; Ko and Chen, 2014; Hwang *et al.*, 2005).

1.3 FAHP

FAHP is a very useful method for multiple criteria decision-making. It has been widely studied and used for various decision models. It uses a crisp point estimation approach such as the extent analysis or the fuzzy preference programming based on nonlinear manner for FAHP priority derivation (Xu and Liao, 2014). In manufacturing and logistics implementations, FAHP has been successfully applied for a knowledge-based system for automotive production line design incorporating quality function deployment (Qattawi *et al.*, 2013). The system is based on the knowledge and presents the ability to deal with the manufacturing and logistics decision-makings. For selecting suitable suppliers, an improved voting AHP and data envelopment analysis (DEA) was introduced to extend the LH-model for multi-criteria supplier selection (Hadi-Vencheh and Niazi-Motlagh, 2011). Through an illustrative example, this paper exhibits the outperformance of the proposed model compared with LH-model for addressing the supplier selection problems.

Recently, FAHP has been used for assessing customer satisfaction. Lu *et al.* (2014) introduced a model for evaluating the customer satisfaction of mobile telecommunication enterprises based on FAHP. The results show that China Mobile's customer satisfaction index evolved to a much higher level, and followed by China Unicom and China Telecom. Gao *et al.* (2013) introduced a knowledge-based FAHP approach which uses the mathematics fuzzy theory to analyze the customer satisfaction for China Mobile. In this approach, the method of establishing and analysis of satisfaction evaluating system is given by determining index weight by AHP and FAHP. In the manufacturing and logistics decision-makings such as intelligent machine tool selection, new service production, and evaluation of third-party logistics performance, FAHP has been widely used (Ayağ and Özdemir, 2011; Lee *et al.*, 2012; Wang *et al.*, 2012; Tseng *et al.*, 2015).

From the literature review, several research gaps are apparent. First, logistics service mainly focusses on the optimization models in reducing the cost and optimizing logistics planning. Customer satisfaction is scarcely reported. Second, the customer satisfaction evaluation models mainly consider the business operations. While, the manufacturing and logistics perspective are limited. Third, FAHP is widely used for decision-making. However, its application in evaluating customer satisfaction under manufacturing-driven logistics service is limitedly reported.

2. A customer satisfaction model using FAHP

In order to fulfill these research gaps, this paper introduces a customer satisfaction evaluation model for logistics service using FAHP. Customer satisfaction is a complex factor that is made up of a hierarchical simple factor. Due to different influential degrees, the index weight attached to each simple variable should be evaluated (Hossain *et al.*, 2014). The determination of weight is pivotal to assessment of customer satisfaction and plays an important role in reflecting customer satisfaction in an objective way (Lin and Wang, 2011). Besides, choosing appropriate survey methods is very important to achieve effectiveness. Thus, this paper employs the method of Triangular FAHP based on triangular fuzzy number to confirm weights. The employment of FAHP for this research is based on several considerations. First, it is suitable for multi-criteria decision problems with imprecise or fuzzy ratio-scale preference measurements (Avikal *et al.*, 2014). By full use of the fuzzy logic, FAHP is able to handle the partial truth concept where the range of truth value may be between completely true and false (Tyagi, 2015). Second, when the human decision-making from some degrees, the criteria may be subjective. FAHP uses the fuzzy definition of the degrees in the scale values which will be more objective (Kamvysi *et al.*, 2014). Third, the advantages of computational simplicity and meaningful representation in a fuzzy environment make FAHP to be a suitable approach for the manufacturing-driven customer satisfaction evaluation. With the triangular fuzzy concept, the incompleteness of pairwise judgment will be allowed (Tang and Lin, 2010).

2.1 Triangular fuzzy concept

Theorem 1. If $M_1=(l_1,m_1,u_1)$ and $M_2=(l_2,m_2,u_2)$ are two triangular fuzzy numbers and marks $V(M_1 \geqslant M_2)=\mu(d)$, d as abscissa of M_1, M_2 intersection, then:

$$V(M_1 \geqslant M_2) = \mu(d) = \begin{cases} \frac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & l_1 \leqslant u_2 \\ 1, & m_1 \geqslant m_2 \\ 0, & \text{others} \end{cases} \quad (1)$$

Theorem 2. Bases on Theorem 1, the following equation is available:

$$V(M \geqslant M_1, M_2, \ldots, M_k) = V[(M \geqslant M_1)(M \geqslant M_2), \ldots, (M \geqslant M_k)]$$
$$= \min V(M \geqslant M_i)\, i = 1, 2, \ldots, k$$

If $x_{ij}^t = (l_{ij}^t, m_{ij}^t, u_{ij}^t), \quad i,j = 1, 2, \ldots, n_k, \quad t = 1, 2, \ldots, T$ means the fuzzy evaluation $A = (\alpha_{ij}^t)_{n_k \times n_k}$, degree provided when comparing the no. t decision maker on the factors i and j. Therefore, the evaluations of all decision-makers form the fuzzy matrices. The fuzzy matrix is plus-minus inverse matrix:

$$\alpha_{ij}^{-1} = \alpha_{ji} = \left(\frac{1}{u_{ji}}, \frac{1}{m_{ji}}, \frac{1}{l_{ji}}\right) \tag{2}$$

So, the comprehensive triangular fuzzy in tier k is:

$$M_{ij}^k = \frac{1}{T} \times \left(\alpha_{ij}^1 + \alpha_{ij}^2 +, \ldots, +\alpha_{ij}^T\right) \tag{3}$$

Based on (3), comprehensive fuzzy number concludes:

$$S_i^k = \sum_{j=1}^{n} M_{ij}^k \cdot \left(\sum_{i=1}^{n_k} \sum_{j=1}^{n_k} M_{ij}^k\right)^{-1}, \quad i = 1, 2, \ldots, n_k \tag{4}$$

By means of Theorem 2:

$$V\left(S_i^k \geqslant S_j^k\right) = \min\left[\left(V\left(S_i^k \geqslant S_j^k\right), \ldots, V\left(S_i^k \geqslant S_j^k\right), \ldots, V\left(S_i^k \geqslant S_{n_k}^k\right)\right)\right], \quad i,j$$
$$= 1, 2, \ldots, n_k : i \neq j \tag{5}$$

Order $d^k(A_i^k) = V(S_i^k \geqslant S_j^k)$, A_i stands for the i factor in tier k, then, weight vector is:

$$W_k' = \left(d^k\left(A_1^k\right), d^k\left(A_2^k\right), \ldots, d^k\left(A_n^k\right)\right)^T \tag{6}$$

Then, the weight in tier k–1 concludes:

$$W_k = \left(d^k\left(A_1^k\right), d^k\left(A_2^k\right), \ldots, d^k\left(A_n^k\right)\right)^T \tag{7}$$

When conducting partied comparison on one factor in tier k–1 and all n_k factors in tier k, $a_{ij} = (l_{ij}, m_{ij}, u_{ij})$ in fuzzy judgment matrix is a closed interval with m_{ij} as mid-value (Nia *et al.*, 2014). m_{ij} is an integer from 1 to 9 to make comparative judgment (Table I).

2.2 Fuzzy matrix

According to (2), to calculate integrated value degree $\chi_{ij}^t = (l_{ij}^t, m_{ij}^t, u_{ij}^t)\ i,j = 1, 2, \ldots, n_k$, $t = 1, 2, \ldots, T$, fuzzy number is given through comparing the i factor with the j factor in the t decision maker.

Comprehensive triangular fuzzy number of tier k is worked out. Therefore, comprehensive determination matrix of all factors in tier k on h factor in tier $k-1$ could be works out based on formula (4).

Based on Theorem 1, it is possible to calculate $V(S_i^k \geqslant S_j^k), \quad i,j = 1, 2, \ldots, n_k: i \neq j$ and $P_{ih}^k = \min V(S_i^k \geqslant S_j^k), \quad i,j = 1, 2, \ldots, n_k: i \neq j$ which show the single order in the h factor in tier k–1 of factors in tier k. That means the i factor in tier k can be $P_h^k = (P_{1h}^k, P_{2h}^k, \ldots, P_{nh}^k)^T, \quad i,j = 1, 2, \ldots, n_k: i \neq j$. It follows synthetic judgment matrix between all factors in kth layer and the hth factor in kth–1 layer. The weight vector for the sequencing of general objective in tier k is:

$$W_h^k = \left(W_1^k, W_2^k, \ldots, W_n^k\right)^T \tag{8}$$

According to the above illustration, we can carry on the overall qualification to customer satisfaction and make a comparison on customer satisfaction between logistics companies and its competitors so as to examine their positions in particular industry. It is observed that the greater the grade of membership, the topper the relative position will be (Niazmand *et al.*, 2014). It is closer to leading level in the customer satisfaction. Comparatively speaking, the weaker the grade of membership, the lower the relative position will be. It is necessary for enterprises to improve the logistics service through measurement indices in accordance with evaluation results of customer satisfaction (Zhang and Awasthi, 2014). The application of FAHP to calculate customer satisfaction is endowed with advantages of high efficiency, less date required and clearer problems revealed (Yayla *et al.*, 2015; Zhong *et al.*, 2015). This method has strong practicability, which guarantees evaluation to be hierarchical and availability to solve more complex problems (Babić and Perić, 2014; Zhong *et al.*, 2015).

3. Case study

Based on the proposed model, this section takes two big express companies A and B as an example for demonstrating the customer satisfaction evaluation based on a customized logistics service. They are responsible for delivery of typical electronic devices from XM which is a very fast-growing high-tech firm in China. This research takes the smartphone which is manufactured and assembled national wide. The manufactured smartphones are delivered to different cities by A and B as soon as possible so that the inventory in each manufacturing company will be reduced and the final products could reach the market immediately. Given the manufacturing-driven case, a questionnaire is designed to research A and B:

- Company A.

Table I. Paired compared fuzzy scale chart to judge matrix

Implication	Scale	Scale reciprocal
Factor i and factor j is equally importance when compared	(1,1,1)	(1,1,1)
Factor i and factor j is weak importance when compared	(2/3,1,3/2)	(2/3,1,3/2)
Factor i and factor j is marked importance when compared	(3/2,2,5/2)	(2/5,1/2,2/3)
Factor i and factor j is equally important when compared	(5/2,3,7/2)	(2/7,1/3,2/5)
Factor i and factor j is equally important when compared	(7/2,4,9/2)	(2/9,1/2,2/3)

Company A, is the first supplier of express service, the largest express carrier currently and the industry leader in China, mainly engaged in express mail service. Company A's business covers nearly 2,000 cities in China and more than 200 countries and regions all over the world. The most extensive coverage of network system gives it a strong support to achieve the "Next Morning Delivery and the Next Day Delivery" in more than 300 cities in China.

- Company B.

Company B established in March 1993, is a private express enterprise mainly dealing with express delivery, custom declaration, inspection declaration and other services. Up until 2009, it has more than 2,400 online shops, covering more than 85 percent of region's GDP. Among all the express delivery enterprises in China, it is ranked the second after Company A in operation scale, network coverage and market share. It focusses on "customer concern, promotion of the economy and development of national express industry." Exploring customer needs, B has introduced new services that provide customers with fast and secure distribution channels available to help customers give faster and better response to the market, launched new products and adjusted strategy to shorten trade cycle, reduce operating costs, and promote competitiveness.

3.1 The implementation of customer satisfaction evaluation system

As both companies are responsible for delivering the electronic products from XM, the customer satisfaction measurement is carried out. First, appropriate index is selected to establish an index system. Second, a survey is implemented on index and then statistical analysis may be worked out. Index system of this study is shown in Table II. The selected index is mainly based on the significant impacts considering the logistics services in manufacturing-driven cases. For example, the quality of logistics service highly relate to the quick response and flexible availability of the company so that the customers are able to get the services with better customer satisfaction.

To develop the index system, three experts are invited to conclude relative importance of secondary index compare with primary index. The overall triangular fuzzy number is calculated, i.e. the fuzzy weight matrix with paired comparison as shown in Table III.

According to the triangular fuzzy weight matrix in Table III, overall fuzzy degree of the secondary index compared with the primary index is shown in Table IV.

According to the overall fuzzy degree in Table IV, we can obtain hierarchy sorting and overall combined sorting of the secondary indices compared to the primary index:

$$V(S1 \geqslant S2) = V(S1 \geqslant S3) = V(S1 \geqslant S4) = V(S1 \geqslant S5)$$
$$= V(S1 \geqslant S6) = V(S1 \geqslant S7) = V(S1 \geqslant S8) = 1;$$
$$V(S2 \geqslant S1) = 0.63, V(S2 \geqslant S3) = 0.81, V(S2 \geqslant S4) = V(S2 \geqslant S5)$$
$$= V(S2 \geqslant S6) = V(S2 \geqslant S7) = V(S2 \geqslant S8) = 1;$$
$$V(S3 \geqslant S1) = 0.82, V(S3 \geqslant S2) = V(S3 \geqslant S4) = V(S3 \geqslant S5)$$
$$= V(S3 \geqslant S6) = V(S3 \geqslant S7) = V(S3 \geqslant S8) = 1;$$
$$V(S4 \geqslant S1) = 0.5, V(S4 \geqslant S2) = 0.85, V(S4 \geqslant S3) = 0.67,$$
$$V(S4 \geqslant S5) = V(S4 \geqslant S6) = V(S4 \geqslant S8) = 1, V(S4 \geqslant S7) = 0.95;$$

Primary index	Secondary index	Tertiary index	Quaternary index
Customer satisfaction	Corporate image	Corporate brand	Corporate reputation
		Affinity of corporate	Communication
	Expected quality	Expected quality of reliability	Service error rate
			On-time-delivery Rate
		Expected quality of integrity	Services
	Perceived quality	Perceived quality of response	Rapid response on orders, inquiries, and proceedings from customers
			Rapid response on elimination breakdown
		Perceived quality of availability	Coverage of transportation network
			Ability to provide services at any time
	Perceived value	Perception of prices under given quality	Transaction cost
		Perception of services under given prices	Value-added service capabilities of enterprises
	Perceived fairness	Fairness compared with logistics service providers	Equality of investment
	Customers' trust	Reliability of logistics enterprises services	Error rate of cargo damage
	Customers' satisfaction	Gaps between expected quality and actual experiences	Comparison with the expected quality of service
		Gaps compared with other enterprises of actual experiences	Comparison in the service quality with other companies
	Customers' loyalty	Possibility of repeated consumption	Time span of repeated consumption

Table II.
Index system

$$V(S5 \geqslant S1) = 0.21, V(S5 \geqslant S2) = 0.54, V(S5 \geqslant S3) = 0.35, V(S5 \geqslant S4) = 0.7,$$
$$V(S5 \geqslant S6) = 0.83, V(S5 \geqslant S7) = 0.7, V(S5 \geqslant S8) = 1;$$
$$V(S6 \geqslant S1) = 0.15, V(S6 \geqslant S2) = 0.58, V(S6 \geqslant S3) = 0.33, V(S6 \geqslant S4) = 0.81,$$
$$V(S6 \geqslant S5) = V(S6 \geqslant S8) = 1, V(S6 \geqslant S7) = 0.79;$$
$$V(S7 \geqslant S1) = 0.57, V(S7 \geqslant S2) = 0.91, V(S7 \geqslant S3) = 0.73,$$
$$V(S7 \geqslant S4) = 1, V(S7 \geqslant S5) = V(S7 \geqslant S6) = V(S7 \geqslant S8) = 1;$$
$$V(S8 \geqslant S4) = 0.2, V(S8 \geqslant S5) = 0.51, V(S8 \geqslant S6) = 0.34, V(S8 \geqslant S7) = 0.33.$$

Then:

$$P(S1) = 1, P(S2) = \min(0.63, 0.81, 1, 1, 1, 1, 1) = 0.63, P(S3) = 0.82,$$

$$P(S4) = 0.5, P(S5) = 0.21, P(S6) = 0.15, P(S7) = 0.57, P(S8) = 0.2$$

Normalized overall combined sorting is:

$$W' = (1, 0.63, 0.82, 0.5, 0.21, 0.15, 0.57, 0.2)T$$

Using the same method, we can obtain the weight of each index in the tertiary level and quaternary level, and finally calculate the weight of each index as shown in Table V.

Table III. Matrix of triangular fuzzy weight

Index	Corporate image	Expectation quality	Perception quality	Perception value	Perception fairness	Customer trust	Customer satisfaction	Customer loyalty
Corporate image	(1,1,1)	(1.22,1.67,2.17)	(0.4,0.5,0.67)	(1.5,2,2.5)	(0.67,1.67,2.17)	(2.56,3,3.5)	(0.67,1,1.5)	(3.5,4,4.5)
Expectation quality	(0.49,0.67,0.94)	(1,1,1)	(1,1,1)	(1.13,1.5.1.89)	(1,1,1)	(0.67,1,1.5)	(1.22,1.67,2.17)	(2.5,3,3.5)
Perception quality	(1.5,2,2.5)	(1,1,1)	(1,1,1)	(1.5,2,2.5)	(1,1,1)	(1.22,1.67,2.17)	(0.67,1,1.5)	(2.5,3,3.5)
Perception value	(0.4,0.5,0.7)	(0.77,1,1,28)	(0.4,0.5,0.67)	(1,1,1)	(0.67,1,1.5)	(0.4,0.5,0.67)	(2.5,3,3.5)	(1.5,2,2.5)
Perception fairness	(0.54,0.78,1.1)	(1,1,1)	(1,1,1)	(0.67,1,1.5)	(1,1,1)	(0.4,0.5,0.67)	(0.78,1,1.33)	(0.67,1,1.5)
Customer trust	(0.37,0.5,0.7)	(0.67,1,1.5)	(0.49,0.67,0.94)	(1.5,2,0.4)	(1.5,2,2.5)	(1,1,1)	(0.29,0.33,0.4)	(1,1,1)
Customer satisfaction	(0.67,1,1.5)	(0.49,0.67,0.94)	(0.67,1,1.5)	(0.29,0.33,0.4)	(0.78,1,1.33)	(0.67,3,3,5)	(1,1,1)	(1.5,2,2.5)
Customer loyalty	(0.22,0.25,0.3)	(0.29,0.33,0.4)	(0.29,0.33,0.4)	(0.4,0.5,0.67)	(0.67,1,1.5)	(1,1,1)	(0.4,0.5,0.67)	(1,1,1)

3.2 Discussions and analysis

For developing the customer satisfaction measurement index system, the questionnaire is divided into two parts, with 20 small problems totally. In total, 100 questionnaires were released in the course of the investigation, 91 were reclaimed, of which 82 were valid:

(1) Questionnaire Results Analysis

A. Survey on personal information and service information:

- Age distribution: among 82 valid respondents, ones aged between 20 and 29 years old accounted for 73 percent of all respondents. It is because customers at this age group directly use express service with the age distribution is shown in Table VI and Figure 1.
- Profession distribution: there are 22 students, eight unemployed or retired among 82 valid respondents. With regard to certain relevance and value of the survey,

Table IV.
Comprehensive fuzzy

Index	Comprehensive fuzzy degree
Corporate image S_1	(0.122,0.189,0.292)
Expected quality S_2	(0.096,0.138,0.211)
Perceived quality S_3	(0.110,0.161,0.246)
Perceived value S_4	(0.082,0.121,0.191)
Perceived fairness S_5	(0.064,0.093,0.148)
Customers' trust S_6	(0.072,0.108,0.137)
Customers' satisfaction S_7	(0.064,0.127,0.205)
Customers' loyalty S_8	(0.045,0.063,0.096)

Table V.
Index weight

Tertiary index	Weight	Quaternary index	Weight
Corporate brand	0.146	Corporate reputation	0.146
Affinity of corporate	0.099	Communication	0.099
Expected quality of reliability	0.111	Service error rate	0.075
		On-time-delivery rate	0.036
Expected quality of integrity	0.043	Services	0.043
Perceived quality of response	0.087	Rapid response on orders, inquiries, and proceedings from customers	0.059
		Rapid response on elimination breakdown	0.028
Perceived quality of availability	0.114	Coverage of transportation network	0.065
		Ability to provide services at any time	0.049
Perception of prices under the given quality	0.062	Transaction cost	0.062
Perception of services under the given prices	0.062	Value-added service capabilities of enterprises	0.062
Fairness compared with logistics service providers	0.051	Equality of investment	0.051
Reliability of logistics enterprises services	0.037	Error rate of cargo damage	0.037
Gaps compared with the expected quality of the actual experience	0.088	Comparison with the expected quality of service	0.088
Gaps compared with other enterprise of actual experience	0.052	Comparison in service quality with other companies	0.052
Possibility of repeated consumption	0.049	Time span of repeated consumption	0.049

respondents are mostly the waged youth. The number of people (NOP) in specific occupation distribution is shown in Table VII and Figure 2.

- Distribution on annual average charges for express service: from the results of the survey questionnaire (Table VIII), it can be seen that the use of express services are still very frequent. The average annual use of express services (1-10 times) accounted for 76 percent, the average annual use of express services (50+ times)

Age range	Below 20	20-29	30-50	50+
Number of people	2	60	16	4

Table VI. Age distribution

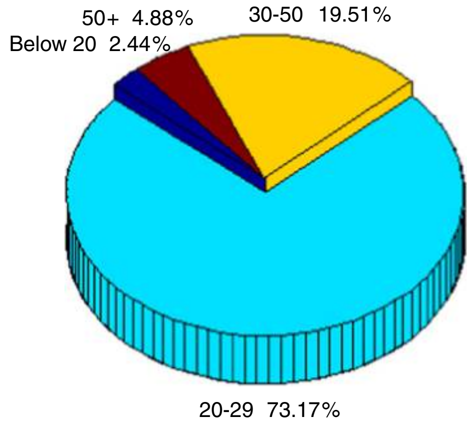

Figure 1. Age distribution

Occupation	Student	In-service staff	Unemployed/retired	Others
Number of people	22	50	8	2

Table VII. Occupation distribution

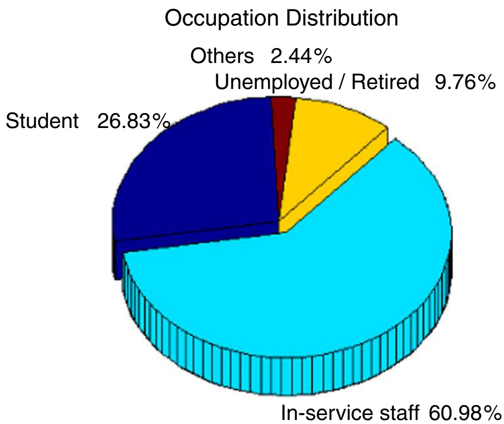

Figure 2. Distribution of occupation

accounted for 7 percent. The distribution diagram of average annual use of express services is shown in Figure 3.

- Selection of express delivery enterprises

Through the questionnaire, it is found that 54 percent of the respondents tend to select Company A and the balance (i.e. 46 percent) tends to Company B.

Corresponding to the remaining 16 questions in the questionnaire, Figures 4 and 5 (NOP) show the respective analysis on the survey results of Companies A and B. These

Table VIII. Annual average charges distribution

Annual average charges	0	1-3	4-10	11-50	50+
Headcount	4	32	30	10	6

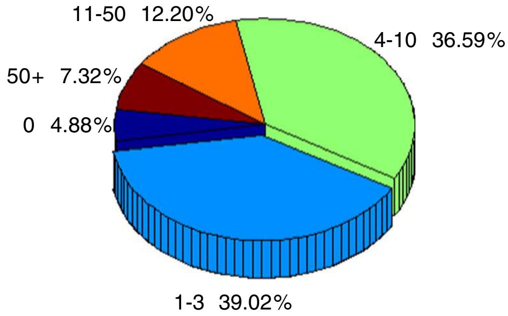

Figure 3. Annual average charges distribution

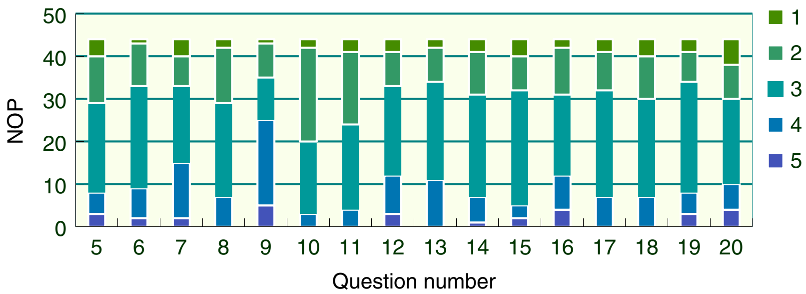

Figure 4. Questionnaire – headcount distribution of scores for issues of Company A

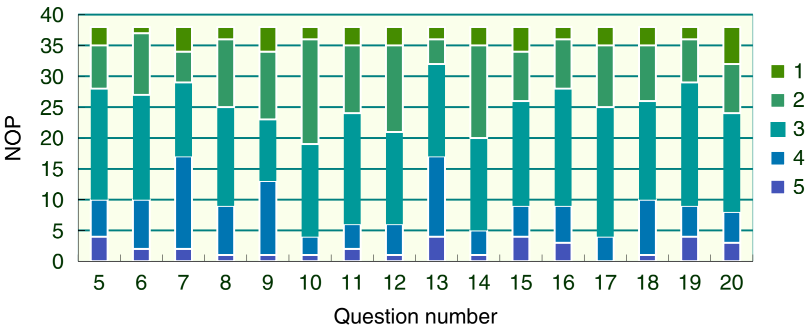

Figure 5. Questionnaire – headcount distribution of scores for issues of Company B

analysis indicate the NOP distribution in different choices and scores. It is observed in this study that customer satisfaction with services are divided into five grades, the corresponding assignment are 5, 4, 3, 2 and 1.

The evaluation scores of Companies A and B can be determined from the weighted average of single-factor evaluation matrix. The final total scores can be calculated through composite operation of index weights and evaluation scores. The results are shown in Table IX.

Based on the results from Table IX, some managerial implications are obtained. The total evaluation score on customer satisfaction of normalized Company A is lower than that of Company B. It is shown after analysis that the score of Company B was significantly higher than that of Company A. For customer satisfaction scores in service error rate, ability to provide services at any time, comparison with expected quality of service and comparison with other companies, Company B is relatively higher than that of Company A, and will maintain the existing strengths in these aspects. However, the satisfaction scores of Company B in communication, service scope, coverage of transport network, transaction costs and other aspects are lower than that of Company A. So, Company B needs to improve on these aspects, thereby enhancing its customer satisfaction, improving corporate image and competitiveness to give new impetus to the long-term development of enterprises.

4. Conclusions

This paper introduces a customer satisfaction evaluation model based on FAHP for manufacturing-driven logistics services. Based on the data from questionnaire, it is found that, in practical applications, enterprises should amend the index system according to the specific business scope and the operating characteristics. The key

Index	Weight	Company A Evaluation scores	Company A Total weight	Company B Evaluation scores	Company B Total weight
Corporate reputation	0.146	0.188	0.027	0.203	0.030
Communication	0.099	0.201	0.020	0.199	0.020
Service error Rate	0.075	0.206	0.015	0.209	0.016
On-time-delivery rate	0.036	0.186	0.007	0.192	0.007
Services scale	0.043	0.228	0.010	0.193	0.008
Rapid response on orders, inquiries, and proceedings from customers	0.059	0.167	0.010	0.173	0.010
Rapid response on elimination breakdown	0.028	0.171	0.005	0.184	0.005
Coverage of transportation network	0.065	0.201	0.013	0.177	0.012
Ability to provide services at any time	0.049	0.198	0.010	0.223	0.011
Transaction cost	0.062	0.189	0.012	0.175	0.011
Value-added service capabilities of enterprises	0.062	0.187	0.012	0.197	0.012
Equality of investment	0.051	0.201	0.010	0.201	0.010
Error rate of cargo damage	0.037	0.188	0.007	0.179	0.007
Comparison with the expected quality of service	0.088	0.183	0.016	0.195	0.017
Comparison in the quality of service with other companies	0.052	0.197	0.010	0.205	0.011
Time span of repeated consumption	0.049	0.191	0.009	0.184	0.009
Total score		0.193		0.195	
Normalized total score		0.498		0.502	

Table IX. Total scores of customer satisfaction for express delivery enterprises findings of this research is, from the case study, the total evaluation score on customer satisfaction of Company A is lower than that of Company B. The contribution of this paper is as follows:

- a FAHP-based customer satisfaction evaluation model is proposed for the logistics service;
- triangular fuzzy concept is introduced to determine the weight of each index so as to addresses the limitation of subjective or objective weighting method;
- a case study from two large express companies in China was used to demonstrate the implementation of the model; and
- one of the key findings is that Company B has higher customer satisfaction than Company A due to its quick response and flexible logistics strategy.

Future research directions will be carried out from several aspects. First, this paper considers the fuzzy AHP for the customer satisfaction evaluation. Comparing with other multi-criteria decision-making methods like DEA, evidential reasoning approach, and multi-attribute value theory will be carried out in the near future. Second, the manufacturing modes like make-to-order, make-to-stock, and mass-customized production may have different logistics support so that the final products may reach the final targets quickly. How to evaluate various mode-based logistics and their customer satisfactions are with great significance. Finally, with large number of data generated from manufacturing and logistics, Big Data-enabled customer satisfaction evaluation approaches may be a possible solution. Thus, the proposed model could be compared with Big Data-enabled solutions so that better methods may be worked out.

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