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A fuzzy QFD methodology to improve logistics service

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C H R O N I C L E

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A B S T R A C T

Customer service is increasingly being recognized as a source of competitive advantage. The keys to provide effective customer service are determining the customer needs, accurately, and meeting and exceeding the needs in a consistent manner. Companies should adapt a strategic, proactive focus on customer service based on understanding logistic processes and designing the logistics system to meet their needs. This paper proposes an approach based on the quality function deployment (QFD), for ranking strategic actions to improve logistics service. The paper addresses the issue of how to deploy the house of quality (HOQ) to effectively and efficiently improve logistics processes and thus customer satisfaction. For data collection, fuzzy logic is used to deal with the ill-defined nature of the qualitative linguistic judgments required in the proposed HOQ. The methodology has been tested by means of a real case application, which refers to an Iranian company operating in the manufacturing industry.

1. Introduction

Among leading firms, logistics has evolved over the past few years to the point where logistical competency is frequently viewed as a strategic resource (Mentzer et al., 1989). Properly exploited, logistical performance can help gain and retain profitable customers. Service quality enhancements have been proven to consistently result in an increased market share and revenue gains. Studies by Little (Shycon, 1992) indicate that the quality of a company's service may lead to gain or lose as much as 10 per cent in sales revenue. Service may well be the competitive arena of the future. According to (Chase & Garvin, 1989) "Competition is shifting away from how companies build their products to how well they service customers before and after they build them. The manufacturers that thrive into the next generation, will compete by anticipating and responding to a truly comprehensive range of customer needs". Meeting customers' needs is the core objective of any firm, many of

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today's most progressive and successful firms emphasize on logistics service as a competitive differentiator (Livingstone, 1992; Stern et al., 1993). These firms concentrate on creating or adding value for the customer.

Customer service represents the output of the logistics system and the place component of the firm's marketing mix. It is a measure of the effectiveness of the logistics system in creating time and place utility for a product (Lambert and Stock, 1993). A number of service elements are commonly related to logistics customer service, although the degree of importance attached to them differs from case to case depending on the specific customer needs (see e.g. LaLonde & Zinszer, 1976; Sterling & Lambert, 1987; Lambert & Harrington, 1989; Sharma & Lambert, 1991; Semeijn 1995). There is general agreement that excellent logistics customer service can be considered as a primary source of competitive advantage, and the keys to provide effective customer service are determining customer requirements accurately and responding to them in a consistent manner (e.g. Lambert & Stock, 1993; Christopher, 1983; Fuller et al., 1993; Global Logistics Research Team). Therefore, logistics customer service planning ought to be carried out at the strategic level, and to be the most effective the planning process have to follow a systematic framework (Pirttilä & Huiskonen, 1996).

Researchers have presented several planning frameworks (Lambert & Stock, 1993; Christopher, 1983; Fuller et al., 1993; Byrne & Markham, 1991), and they have similarities in what stages a comprehensive logistics customer service planning process have to include, and what analyses need to be performed. To manage logistics customer service as a strategic competitive weapon, three issues must be evaluated including customers' requirements, company's performance, and competitors' performance (Lambert & Stock, 1993).

According to VanHuss (1993), there are some general agreements where excellent customer service can be considered as a source of competitive advantage for firms and the keys to provide effective customer service are determining customer needs accurately and meeting and exceeding the requirements in a consistent manner. O'Neil and Iveson (1991) defined the most cost-effective methods of providing required customer service levels as a part of logistics strategic management. Schary (1992) argued that customer service could become a dominant objective for logistics management in the 1990s. High levels of customer service have become a basic requirement for establishing and maintaining a presence in the market, and, although important, managing cost is secondary to service objectives. DeRoulet (1993) supported Schary by stating that instead of being just the other side of the cost trade-off, customer service is the primary key of a firm's marketing. In the competitive environment of today, each company should have a well-thought-out customer service strategy (Korpela et al., 1996).

In Section 2, we review the concept of customer service, customer service strategy, QFD and fuzzy QFD. In section 3, we describe the proposed methodology, and In Section 4, we demonstrate with a real example the use of the fuzzy QFD approach to support the strategic management process.

2. Literature review

2.1 Customer service and customer service strategy

The concept of customer service has gone through a profound evolution during the last decades. Before 1970, physical distribution was approached from a mechanistic and firm-oriented point of view, and satisfaction to customers was provided by creating time and place utility to the product (Manrodt & Davis, 1992). In the 1970s and 1980s, customer service was still considered reactive and firm oriented while, in the late 1980s, the definition of customer service was changed towards the development of customer value (Manrodt & Davis, 1992). Cooper et al. (1988) defined customer service as "a process for providing significant value-added benefits to the supply chain in a cost-effective way". Thus, the importance of customer service in creating value for the whole supply chain as well as for the end customer was recognized (Carothers, Adams, 1991; Langley, Holcomb). Schary (1992) called for a strategic, proactive focus on customer service based on understanding logistic processes and designing the logistics system to meet their requirements. The objective was to create value for the customers. According to Manrodt and Davis (1992), the recent trends in customer service can be described as follows: (1) firms are becoming proactive in their method to customer service, and considerable attention is concentrated on how to provide the customer with value-creating service before, during, and after the product is delivered, (2) the change is happening especially in response to aggressive customers who ask that suppliers take formal steps to detect the customer's requirements and to provide the desired value, (3) the key to providing breakthrough levels of customer service is to manage information flows effectively, (4) a shift to contractual-driven systems is happening, and (5) firms are under increasing pressure to generate value through enhanced customer service, and the firms with the necessary capabilities are evidencing an ability to reach sustainable competitive advantages (Korpela et al., 1996).

Besides, when speaking about service management, a dynamic perspective has to be adopted. Customer service is not a steady concept, but is continually in a state of change, and evolves through a continuous improvement cycle (Morris, 1996; Baines, 1996). Therefore, the quantitative measure of logistics performances delivered and expected has to be repeated over time, periodically monitoring gaps between expectations and perceptions. When a lack of correspondence happens, viable logistics areas and factors of intervention have to be detected, pondered and ranked in terms of efficiency and effectiveness. Since interventions imply expenditures, before taking steps toward implementation, a costs/benefits analysis is needed to undertake necessary actions starting from those factors with the highest effect on customer service. To conclude, providing logistics service, which meets customer expectations is a continuous process, which can be summarized in the following steps (Bottani & Rizzi, 2005):

- understanding the customer's voice, that is requirements and expectations in terms of relevant logistics performances;
- evaluating customer's service perception;
- if a gap between perception and requirements happens, detecting viable steps implemented to improve customer satisfaction;
- identifying costs and benefits related to each step;
- implementing the most efficient actions for customer satisfaction by means of a cost/benefit analysis.

The quality function deployment (QFD) methodology has been found as a viable tool, which can be successfully implemented for this purpose (Akao, 1990). QFD is defined by the American Supplier Institute as ''A system for translating consumer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing/sales and distribution'' (Bottani & Rizzi, 2005).

The QFD is a technique for product or service development, brand marketing, and product management (Celik et al., 2008). By concentrating on listening to the customers, QFD has been a successful tool to help a company's product development team systematically translate customer requirements (CRs) to appropriate product features. The success of QFD applications may be the result of some of its advantages, such as high customer satisfaction, greater customer focus, shorter lead time, development of cross-functional teamwork, and preservation of knowledge (Bossert, 1991; Eureka, 1987).

A preliminary review of the literature has highlighted only few references where QFD has been associated with service assessment. Lapidus and Schibrowsky (1994) described the QFD applicability as a method for improving service starting from customer complaints. In their approach, customer complaints become the ''whats'' to be considered in the house of quality (HOQ). Conversely, we propose a proactive approach to be adopted before complaints occur: thus, ''whats'' do not emerge from complaints but from logistics and supply chain management literature.

Behara and Chase (1993) presented the QFD process in matching customer requirements to specific topic areas in service management. However, these applications do not provide a general tool to plan and to manage the trade-offs and correlations associated with customer requirements and firm viable actions. Stuart and Tax (1996) applied the QFD application to manage the service design phase. They recommended the implementation of HOQ as an effective tool to plan processes for a successful execution of services. Their approach is of general purpose and describes the general traits of a QFD method to design service strategies. However, the authors did not provide much detail on how the approach may be deployed for a practical in-field application. In conclusion, the works cited above deal with service management under a general perspective, and do not concentrate the approach on service performances which stem from logistics processes and activities.

Starting from the work of Bottani and Rizzi (2006), we develop a tool suitable to be adopted in the logistics and customer service. In addition, the primary objective is to introduce a methodology that could be directly adopted by practitioners in the logistics field. A cost/benefit analysis is also introduced to detect and to rank the most efficient steps towards improvement of logistics processes and customer satisfaction. A fuzzy approach is adopted since the methodology mainly relays on qualitative judgments given by panel of experts and by customers.

2.2. QFD and fuzzy QFD

2.2.1. QFD

The QFD, originated in 1972 in Japan, has been a successful tool to help the product design and development team systematically in translating market research and customer requirements into the technical requirements for product design. According to Bottani and Rizzi (2006), QFD is composed of four successive matrices: customer requirement planning matrix, product characteristics deployment matrix, process and quality control matrix, and operative instruction matrix. Here, the current research concentrates on the first matrix (customer requirement planning matrix). The customer requirement planning matrix, also known as ''house of quality" (HOQ), is the first step in investigating customer needs and market requirements. HOQ begins with customer requirements (CRs) which are usually obtained from market survey or customer interview. The acquired CRs are translated into a list of measureable ECs. Based on the acquired CRs and ECs, the team can determine the relationships between CRs and ECs, the competitive analysis, and the correlations between ECs. The obtained information can be used to calculate the importance of ECs (Hauser & Clausing, 1988). The components of HOQ are illustrated in Fig. 1. The fundamental rationale of HOQ is introduced in several publications (Cohen, 1995; Revelle et al., 1998).

2.2.2. Fuzzy QFD

Fuzzy set theory, introduced by Zadeh (1965), was developed for solving problems in which descriptions of activities, observations, and judgments are subjective, vague, and imprecise (Liu, 2009). A number of scholars have applied the fuzzy set theory to QFD and developed various fuzzy QFD approaches. For instance, Khoo and Ho (1996) proposed the concept of fuzzy QFD and fuzzified linguistic variables to make them more reasonable. Besides, they also considered the correlations among CRs and the correlations among ECs. Chan et al. (1999) applied fuzzy number and entropy methods to derive the importance of CRs, respectively, and combined the results to obtain the final importance of CRs. Shen et al. (2001) found it necessary to translate customer requirements into trends of future analysis. They added a future tendency index to the importance of CRs to compute the final importance of CRs. Shen et al. (2001) mentioned that the importance ranking of ECs may be influenced by various factors, including types of fuzzy numbers, defuzzification methods, and the number of fuzzy numbers. It was found that defuzzification methods have relatively larger impact on the ranking result. Sohn and Choi (2001) applied fuzzy QFD to supply chain and included reliability in the assessment. They applied a fuzzy MCDM method to select a design with an optimal combination of reliability and customer satisfaction.

Chen et al. (2006) integrated fuzzy weighted average method and fuzzy expected value method to evaluate the importance of ECs. Bottani and Rizzi (2006) applied QFD in logistics and supply chain management. They translated linguistic values of customer requirements into fuzzy numbers and computed the importance of ECs using the conventional QFD method. Kahraman et al. (2006) employed the analytic network process (ANP) method to determine the importance of each EC and incorporated resource constraints, such as cost budget, to form a multi-objective programming problem and derived important ECs. Kwong et al. (2007) developed a fuzzy expert system approach to measure the importance of ECs and the correlations among ECs. These two measures were integrated to calculate the aggregated importance of ECs, etc. (Liu, 2010).

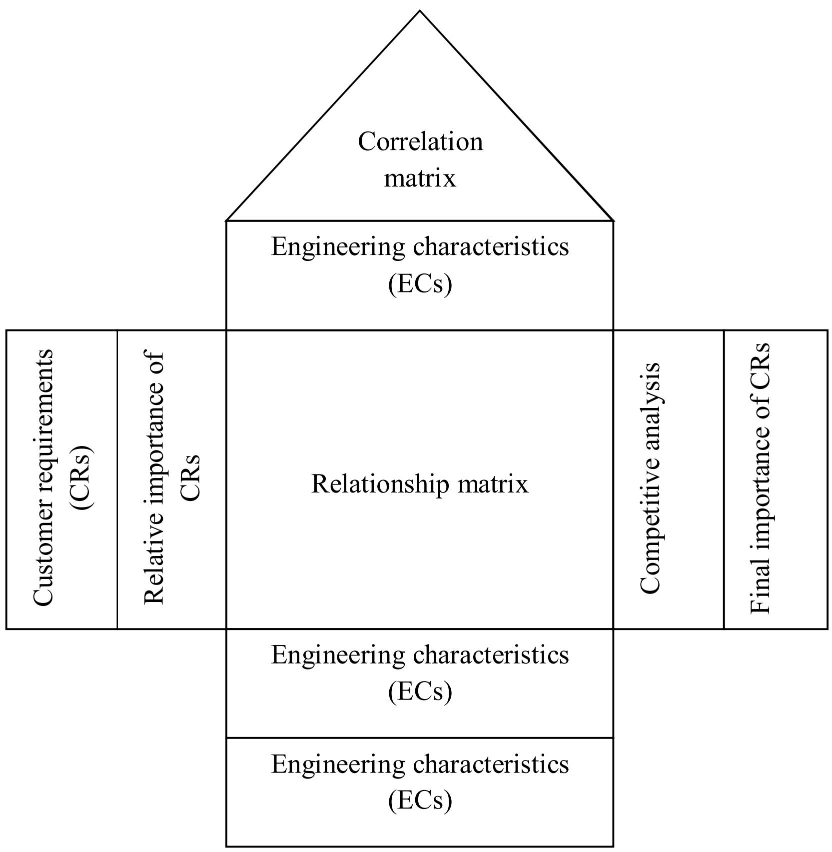


Fig. 1. Components of HOQ

3. The proposed fuzzy QFD approach

The methodology proposed is based on the translation of HOQ principles from product development field to logistics service management. While the traditional HOQ correlates customer requirements (''whats'') with engineering characteristics of new product under development (''hows''), in our approach customer service requirements in terms of logistics performances (''whats'') are crossed over with viable strategic actions, either technical or managerial, that could be undertaken by the firm's top management to improve logistics processes (''hows''). The related customer service HOQ is shown in Fig. 2.

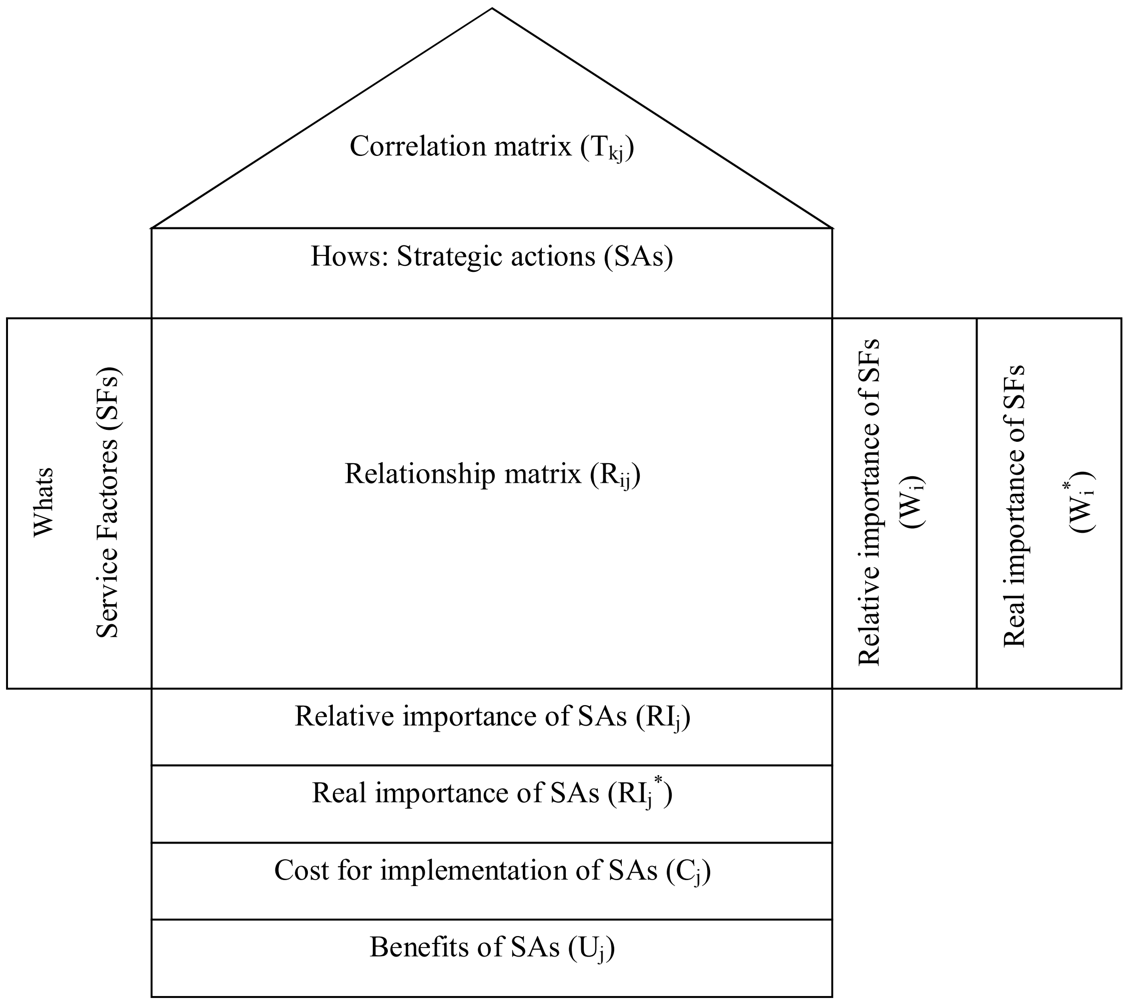


Fig. 2. The house of quality for the strategic management of logistics service (Bottani & Rizzi, 2005)

As can be seen from the Fig. 2, ''whats'' elements express service factors SFi, i=1;...; n affecting logistics service perception. These factors have been extensively described by logistics and supply chain management literature. The reader will find a comprehensive list of the main criteria that can be used for the evaluation of the logistics service in Franceschini and Rafele (2000). For the sake of clarity, the service factors proposed by the authors are shown in Table 1, together with a brief description.

Table 1
List of viable factors for the evaluation of logistics service, adapted from Franceschini and Rafele (2000)

Service factors ''whats''	Description
Lead-time	Time period elapsing from customer's order until receipt
Regularity	The dispersion around the mean value of the delivered lead-time
Reliability	Capability to deliver orders within the due date
Completeness	Capability to deliver full orders when required
Flexibility	Capability to modify orders in terms of due date and quantity when required
Correctness	Avoidance of mistakes in orders delivered
Harmfulness	Avoidance of damages in orders delivered
Productivity	Number of item produced in a given time period

Obviously, service factors listed in table do not give an absolute description of all viable factors that could be considered when perceived service has to be assessed. Depending on particular circumstances, factors could be either added or removed. Once customer service has been assessed, viable strategic actions $SA_j, j = 1, \cdots, m$, the firm can undertake in the logistics field to improve service performances have to be identified and ranked in terms of both effectiveness and efficiency with regard to customer service improvement. Those actions correspond to ''hows'' in the proposed customer service HOQ. A list of possible ''hows'' when customer service performance related to logistics activities has to be improved is shown in Table 2. Again, Table 2 does not provide a definitive framework of all the options available, which depend on the particular circumstances.

The roof of correlations, the weights W_i [n×1], the relationships matrix R_{ij} [n×m] and the relative importance of SAs vector RI_j [1×m] complete the HOQ. It is worth stressing that the weight vector, the correlations matrix and the relationships matrix translate linguistic judgments given by human beings. Therefore, an effective mean to deal with them would appear to be fuzzy logic.

Table 2
List of viable strategic actions (Bottani & Rizzi, 2005)

Strategic actions ''hows''	Description
Just-In-Time implementing	JIT helps to streamline the logistics pipeline through the efficient flow of materials and information, i.e. by providing the right materials, in the right quantities and quality, in the right place at the right time.
Warehouse management optimization	The efficiency and the effectiveness of the logistics flows are deeply affected by optimized warehouse & distribution centers management policies. Shipping & receiving, storage, picking activities can largely benefit from ad hoc optimization tools.
Transport management	Transportation has been recognized as a paramount factor affecting effectiveness and efficiency of logistics processes. Through transportations, the product value is increased by making it available where and when it is required. However, transports add significant costs, which could jeopardize the profitability of the supply chain. Therefore specific optimization tools can be considered as viable actions to improve logistics performances perceived by customers.
Information Technology	Information technology is generic term used to include hardware, software and networking technologies, such as servers, computer networks, expert systems, software for communication, such as Enterprise Requirement Planning (ERP), Electronic Data Interchange (EDI), etc. All these tools play a significant role in synchronizing the flow of goods with the flow of information, which affects the logistics performance of the supply chain.
Demand forecasting Methods	Accurate forecasting methods make it possible to match supply and demand, smoothing uncertainty, reducing safety stocks and stock outs. The setup of collaborative programs, such as CPFR, VMI, or consignment aimed at reducing uncertainties may be encompassed in this category.
Other	Depending on the particular circumstance, other strategic actions in the logistics field may be considered.

To well cope with vagueness of linguistics judgments required in building the HOQ, we propose to express importance weights, as well as relationships and correlations, with fuzzy triangular numbers. Thus, unless specified, all terms computed should be considered as fuzzy numbers. According to this premise, the importance weights W_i is a fuzzy vector expressing the relative importance of SFs based on a defined fuzzy linguistic scale (Bottani, 2006). The reader may refer to Zadeh (1965), and Zimmermann (1991), for a complete description of fuzzy numbers and related algebra. In our approach, four new fuzzy elements have been added to the traditional HOQ, namely:

- the weighted importance of service factors;
- the weighted importance of strategic actions;
- the cost for the implementation of strategic actions;
- the marginal benefit of strategic actions.

These elements, as well as their role in ranking SAs, are detailed below.

3.1. Weighted importance of service factors

The weighted importance W_i^* of SFs is a [n×1] vector which expresses the real importance of each SF. The introduction of W_i^* is required to weight each service factor considering not only the importance the customer gives it, which is expressed by the value W_i, but also the performance delivered by the firm for that factor. To gain a competitive advantage, the firm must provide superior service to the customers on critical service factors, that is either those that are perceived as the most important ones or where service perceived is inferior. Conversely, improving service either for a factor whose importance is trivial or where the firm already delivers a superior service is useless. The weighted importance W_i^* is computed by assessing the distance d_i between firm performance and that which is perceived by customers as superior, the latter being the performance that allows the firm to achieve customer satisfaction. Both the performance delivered and the target superior value could be retrieved from customer service surveys by asking the customer directly. Since both performance values are fuzzy, a distance between fuzzy numbers has to be assessed. To this extent, the Hamming procedure is suggested to be adopted (Chien & Tsai, 2000). This procedure identifies the distance between two fuzzy numbers as the distance between the centers of gravity of the respective membership functions. From a mathematical point of view, given two fuzzy sets A and B, the Hamming distance $d(\mu_A(x), \mu_B(x))$ between two fuzzy numbers belonging to A and B respectively, can be computed as:

$$d(\mu_A(x), \mu_B(x)) = \int_X |\mu_A(x) - \mu_B(x)| dx, \tag{1}$$

where X is the universe of discourse. Due to the calculation method, the resulting Hamming distance is a crisp value. The d_i parameters are then calculated according to Eq. (1). Then, the weighted importance W_i^* of SFs can be derived as follows:

$$W_i^* = d_i \otimes W_i, \quad i = 1, \ldots, m. \tag{2}$$

3.2. Weighted importance of strategic actions

This element strives to determine which strategic action has the highest impact on customer satisfaction. It takes into account the weighted importance of service factors, the relationships matrix and the correlations matrix. As already detailed, the generic position R_{ij} in the relationships matrix expresses the relationship between the j^{th} SA with the i^{th} SF. Again, a fuzzy linguistic scale may be usefully adopted by DMs to interpret the vagueness and incomplete understanding of the relationships between ''hows'' and ''whats''. The importance RI_j of each strategic action can then be calculated applying the following equation:

$$RI_j = \sum_{i=1}^{n} W_i^* \otimes R_{ij}, \quad j = 1, \ldots, m \tag{3}$$

where W_i^* is the fuzzy weighted importance of i^{th} service factor, while R_{ij} is the fuzzy number expressing the impact of the j^{th} SA versus the ith SF. In a similar manner, the generic position T_{kj}, j, k=1,…,m, k≠j, in the correlations matrix expresses the correlation between the k^{th} and the j^{th} ''hows''. In order to quantitatively ponder the correlation between ''hows'', we adopt the approach of Tang et al. (2002). According to the authors, the correlation T_{kj} can be interpreted as the incremental changes of the degree of attainment of the j^{th} ''how'' when the attainment of the k^{th} one is unitary increased. Using this definition, the weighted importance RI_j^* can be computed as follows:

$$RI_j^* = RI_j \otimes \sum_{k=j} T_{kj} \otimes RI_k, \quad j = 1, \ldots, m \tag{4}$$

3.3. Cost and marginal benefit of strategic actions

In order to complete the assessment and ranking of strategic actions, their cost of implementation should be considered. In this situation fuzzy logic becomes a fundamental tool in dealing with ill-defined issues such as the evaluation of costs. While a DM may find objective difficulties in quantitatively assessing the costs of implementation of strategic actions, he/she can more easily give a judgment on a linguistic scale, ranging for instance from Very High to Very Low. This is why, in the lower part of the HOQ a fuzzy parameter C_j has been added to ponder the cost of implementing the j^{th} strategic action. The marginal benefit U_j of strategic actions can be calculated through the ratio between benefits and costs, as expressed by the following equation:

$$U_j = RI_j^* \otimes \frac{1}{C_j}, \quad j = 1,\dots,m \tag{5}$$

Since both RI_j^* and C_j parameters are fuzzy numbers, Eq. (5) describes an operation between fuzzy numbers; the resulting U_j is thus a fuzzy number. In order to make SAs comparable and rank the results, defuzzified values should be computed. Due to its simplicity, the Yager method (Yager, 1981) is suggested as a viable tool to adopt in order to obtain final crisp marginal benefits. Starting from a fuzzy triangular number *a(l,m,u)*, the defuzzified value is computed as:

$$\frac{l + 2m + u}{4} \tag{6}$$

Once crisp values have been computed, SAs can be finally ranked. In particular, according to Trappey et al. (1996), the greater the crisp U_j parameter, the higher the implementation priority of the corresponding strategic action. Strategic action which scores the highest is the one which has the highest impact on customer service, and therefore whose implementation should be considered by the firm top management to improve the logistics performance.

4. Case study

4.1. The company

In this section, the methodology developed is applied to a real industrial case, which refers to a major Iranian company operating in the manufacturing industry. HEPCO Company was established & registered in March 1974, with the intention of assembly & production of road construction equipment. In 1975 Hepco resumed operation in its premises in Arak consistory of 1000000 square meters of land & 40000 square meters of production hall in collaboration with licencors; namely : International Harvester, Dynapac, Poclain, Sakai & Lokomo. In 1984, Hepco development project was designed in collaboration with Liebherr & Volvo companies, aiming at fabrication of steel structures of road construction equipment. The capabilities thus gained , was later consolidated in a new Company in 2002 Energy Equipment Production Co. (Teta), fully owned by Hepco Today, Hepco, together with its subsidiaries, and in collaboration with its world famous partners is active in production, supply and support of road construction mining and industrial projects .

The main customers of the firm are major manufacturers, which have recently set up programs to streamline the supply processes. Buyers have been requiring adequate logistics performances from their suppliers to reduce inventory, avoid control of orders accuracy and turn the supplying process from a traditional approach to a JIT one. As a consequence, the firm has been asked not only for remarkable products from a technical point of view, but also for remarkable logistics performances, basically in terms of lead time, reliability and accuracy of shipments. Operating in a very competitive scenario from a logistics point of view, the firm needs to proactively manage customer service to retain its customers and gain new market shares. To this extent, the QFD approach proposed in this paper has been recognized by experts in logistics as a valid tool to control logistics performances and promptly tune service delivered to match customer requirements.

4.2. Results and discussion

When applying the proposed HOQ to the real case, appropriate ''whats'' have to be identified. To this extent, four firm main buyers were asked to take part in the application. In the following, they will be indicated as C_1, C_2, C_3, C_4. First of all, the importance of each customer has been weighted through the percentage of profit margin generated, as shown in Table 3.

Table 3
Importance ranking of the firm's main customers

Customer	Importance judgment
C_1	Very high
C_2	Very high
C_3	High
C_4	High

The main service factors ''whats'' to be considered in the real case application have emerged from a preliminary survey phase, which has been performed through direct interviews carried out by academicians with the customers involved in the project. A survey has been adopted because it emerged as one of the most efficient and effective ways to ponder the performance perceived for each factor affecting customer satisfaction (see Keller et al., 2002). The relevant logistics ''whats'' are shown in Table 4, together with a brief description.

Table 4
Service factors considered in the real case application

Service factors	Description
Lead-time	Time period elapsing from customer's order until receipt
Flexibility	Capability to modify orders in terms of due date and quantity when required
Accuracy	Avoidance of mistakes and damages in orders delivered.
Reliability	Capability to deliver orders within the due date
Fill rate	Common indicator of customer service performance related to inventory. It can be defined as the percentage of units available when requested by customers.
Frequency	Number of deliveries accomplished in a given time period.
Organization accessibility	Customer's opportunity to establish a contact with firm's staff.
Complaints management	Process subsequent to the recognition of some errors in service provided, that allows service quality standards to be reestablished.

The second part of the application focused on the assessment of viable SAs ''hows'', their mutual correlations, as well as of the relationships judgments between SAs and customer SFs. We agreed to adopt a linguistic approach. In a similar manner, appropriate linguistic scales were set up for the evaluation of relative and weighted importance of SFs, the relative and weighted importance of SAs, the costs for the implementation of SAs, together with values in the relationships and correlations matrixes. Strategic actions ''hows'' were identified based both on literature analysis and the firm characteristics, whose peculiarities have emerged from group thinking by experts in Hepco copany. Results are shown in Table 5 with a brief description for each point.

Table 5
Strategic actions considered in HEPCO Company

Strategic actions	Description
Transport management	Transportation has been recognized as a paramount factor affecting effectiveness and efficiency of logistics processes. Through transportations, the product value is increased by making it available where and when it is required. However, transports add significant costs, which could jeopardize the profitability of the supply chain.
Just-In-Time	JIT helps to smooth the production process through the efficient flow of materials, i.e. by providing the right materials, in the right quantities and quality, Just-In-Time for production.
Information technology	Information technology is generic term used to include hardware, software and networking technologies, such as servers, computer networks, expert systems, software for communication, such as Enterprise Requirement Planning (ERP), Electronic Data Interchange (EDI), etc.
Demand forecasting methods	Forecasting methods are tools that aim at foreknow customers' demand, in order to reduce its uncertainty.
Warehouse management optimization	Warehouses lay-out embrace the optimal assignment of items to storage locations, the arrangement of the functional areas of the warehouse, the number and location of docks and input/output (I/O) points, the number of aisles, etc.
Inventory management	Inventory management is a tool that aims at planning and controlling the act of determining and allocating the products inventory to customers.
Customer relationship management	CRM is a generic term, which encompasses methodologies, software, and Internet capabilities that help the firm to manage customer relationships in an organized way.

During the survey phase, the four customers have also been asked about the importance of service factors, in order to determine the relative importance of service factors, as well as to assess the distance between the service delivered for each factor and the performance that is perceived as superior. The four customers have been asked to rank the relative importance of each SF on a 4-point linguistic rating scale, ranging from VL (Very Low) to VH (Very High). The fuzzy scale is shown in Table 6.

Table 6
Linguistic judgments and corresponding fuzzy numbers

Judgment	Fuzzy number
Very high (VH)	(0.7; 1; 1)
High (H)	(0.5; 0.7; 1)
Low (L)	(0; 0.3; 0.5)
Very low (L)	(0; 0; 0.3)

$w_{i,x}$ is the fuzzy triangular number which is adopted to translate the linguistic importance judgment given to the i^{th} SF by the x^{th} customer. $w_{i,x}$ fuzzy numbers have been pooled to determine an aggregate value to be used in the HOQ, that is the relative importance W_i previously defined. To this extent, the relative importance W_i of service factor i^{th} can be computed as a weighted average of $w_{i,x}$, being weight the importance of customers. The weighted average takes into account the issue that not all customers are equal: being resources limited, the firm should tend to provide best class service for those factors, which are important for key customers. In the specific case, the following equation is applied.

$$W_i = \sum_{x=1}^{4} I_x \otimes w_{i,x,} \quad i = 1,\dots,n \tag{7}$$

where I_x is the importance of x^{th} customer surveyed ($x = 1,\dots,4$). Based on values shown in Table 3, the work group has expressed a fuzzy importance judgment using the same 4-point linguistic scale. The resulting fuzzy numbers have been used in the computation of W_i. Results are shown in Table 7.
As can be seen from the table, the four customers consider lead-time, accuracy and reliability as the most important factors. Once W_i were calculated, the weighted importance W_i^* [n × 1] of SFs was computed in accordance with Eq. (2). As regards to the crisp distance d_i between the firm's performance and the one that is perceived by customer as superior, the parameter has been computed as the average of crisp distances $d_{i,x}$ the generic x^{th} customer perceives against i^{th} service factor, as shown in the following equation:

$$d_i = \frac{\sum_{x=1}^{4} d_{i,x}}{4}, \quad i = 1,\dots,n. \tag{8}$$

Table 7
Fuzzy importance $w_{i,x}$ assigned to service factors by each customer and the relative importance of service factors W_i

Service factors	Importance judgment				Relative importance $w_{i,x}$				Relative Importance of service factors w_i
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	
Lead-time	VH	VH	VH	VH	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(1.68,3.4,4)
Flexibility	VH	H	H	L	(0.7,1,1)	(0.5,0.7,1)	(0.5,0.7,1)	(0,0.3,0.5)	(1.09,2.4,3.5)
Accuracy	VH	VH	VH	VH	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(1.68,3.4,4)
Reliability	VH	VH	VH	VH	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(1.103,3.4,4)
Frequency	VH	H	H	H	(0.7,1,1)	(0.5,0.7,1)	(0.5,0.7,1)	(0.5,0.7,1)	(1.34,2.68,4)
Fill rate	VH	VH	H	VH	(0.7,1,1)	(0.7,1,1)	(0.5,0.7,1)	(0.7,1,1)	(1.58,3.19,4)
Organization accessibility	VH	VH	H	VH	(0.7,1,1)	(0.7,1,1)	(0.5,0.7,1)	(0.7,1,1)	(1.58,3.19,4)
Complaints management	VH	L	H	H	(0.7,1,1)	(0,0.3,0.5)	(0.5,0.7,1)	(0.5,0.7,1)	(0.99,2.28,3.5)

Parameters $d_{i,x}$ have been obtained basing on the survey results and by applying Eq. (1). To this extent, a section of the survey was dedicated to performance judgments about the service delivered by the firm to its customers. The customers were asked to judge the service level they were receiving for each service factor, using the linguistic scale shown in Table 6. Moreover, for each SF, the customers had to indicate the judgment which best matched their perception of a superior service. $d_{i,x}$ parameters as they result from the survey, d_i values, and the corresponding weighted importanceW_i^* are shown in Table 8 and Table 9.

Table 8

Distances d_i from the optimum performance and weighted importance Wi* of each service factor

	Performance judgments				Optimum performance				Distance di,x			
	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
Lead-time	H	L	L	L	VH	VH	VH	VH	0.1	0.6	0.6	0.6
Flexibility	H	L	L	L	VH	H	VH	VH	0.1	0.5	0.6	0.6
Accuracy	H	H	H	H	VH	VH	H	VH	0.1	0.1	0	0.1
Reliability	L	L	L	H	VH	VH	VH	VH	0.6	0.6	0.6	0.1
Frequency	H	L	L	L	VH	VH	VH	VH	0.1	0.6	0.6	0.6
Fill rate	L	H	L	L	VH	VH	VH	VH	0.6	0.1	0.6	0.6
Organization accessibility	VH	VH	H	H	VH	VH	H	H	0	0	0	0
Complaints management	H	H	L	H	VH	VH	H	H	0.1	0.1	0.5	0

Table 9

Weighted importance W_i^* of each service factor

	Distance di	Relative importance Wi	Weighted importance Wi*
Lead-time	0.475	(1.68, 3.4, 4)	(0.798, 1.615, 1.9)
Flexibility	0.45	(1.09,2.4, 3.5)	(0.491, 1.08, 1.575)
Accuracy	0.075	(1.68, 3.4, 4)	(0.126, 0.255, 0.3)
Reliability	0.475	(1.103, 3.4, 4)	(0.524,1.615, 1.9)
Frequency	0.475	(1.34, 2.68, 4)	(0.637, 1.273, 1.9)
Fill rate	0.475	(1.58, 3.19, 4)	(0.751, 1.515, 1.9)
Organization accessibility	0	(1.58, 3.19, 4)	(0, 0, 0)
Complaints management	0.175	(0.99, 2.28, 3.5)	(0.173, 0.399, 0.613)

From outcomes analysis, it emerges that customers perceive a significant difference between the firm's service performance and optimum one in terms of lead-time, accuracy, reliability, frequency & fill rate. Considering crisp values gained for W_i^*, we found that lead-time factor has the highest priority in customer's opinion, and organization accessibility has the lowest priority. The next step in the construction of the HOQ was the assessment of the relationships matrix R_{ij} $[n \times m]$. To this extent, strategic actions SAs for customer satisfaction have been listed in columns, while service factors SFs have been crossed over in rows. The degree of relationship (weak, medium, strong) between SAs and SFs has been expressed with linguistic judgments. Since fuzzy logic is exploited to well cope with the ill-defined nature of linguistics judgements, these judgments have been translated to corresponding fuzzy numbers according to Table 10.

Table 10

Degree of relationship, graphic symbols and corresponding fuzzy numbers

Degree of relationship	Fuzzy number
Strong	(0.7; 1; 1)
Medium	(0.3; 0.5; 0.7)
Weak	(0; 0; 0.3)

During this phase, we benefited from a preliminary literature survey phase, which strived to highlight the relationships between service factors and strategic actions. The resulting relationships matrix is shown in the center of Table 12. The roof of correlations was built up in a similar manner. Again, linguistic judgments have been used to express the correlations between strategic actions (strong negative, negative, positive, strong positive) then they have been translated into fuzzy triangular numbers, as shown in Table 11.

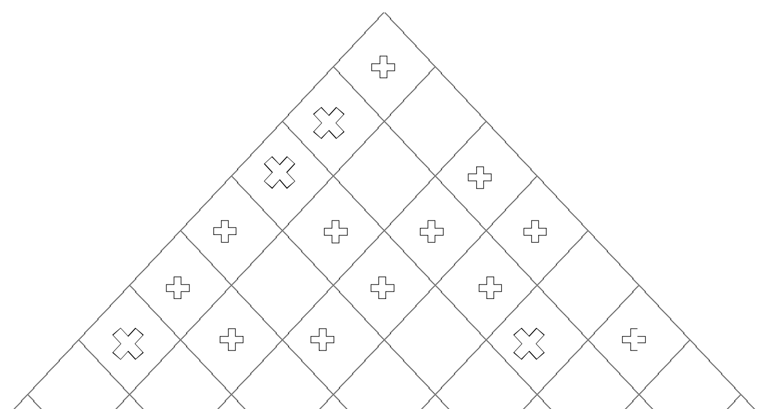
Table 11
Degree of correlation, graphic symbols and corresponding fuzzy numbers

Degree of correlation	Fuzzy number
Strong positive	(0.7; 1; 1)
Positive	(0.5; 0.7; 1)
Negative	(0; 0.3; 0.5)
Strong negative	(0; 0; 0.3)

Once the relationships matrix and the roof of correlations were compiled, the relative importance RI_j and the weighted importance RI_j^* of each strategic action were computed in accordance with Eq. (3) and Eq. (4) respectively. Results are shown in Table 12. Then, the cost C_j for the implementation of each strategic action was determined to evaluate the marginal benefit U_j. To this extent, experts were asked to express a linguistic judgment about the investment required for each strategic action, by using the same 4 value fuzzy scale previously shown in Table 6. Results are shown in Table 12. It should be remarked that fuzzy logic was found to be a very consistent and easy to use tool to handle such a vague, imprecise and ill-defined issue as costs estimation for strategic actions. Then, the fuzzy resulting benefits U_j have been computed according to Eq. (5). Finally, fuzzy U_j parameters were de-fuzzified applying Eq. (8). Crisp U_j obtained can be regarded as synthesis parameters, expressing the overall efficiency of implementing the jth strategic action. The final ranking of strategic actions together with the fuzzy and crisp U_j values are shown in the last two rows of Table 12.

As a result, JIT implementation emerged as the strategic action with the highest implementation priority, since it makes it possible to improve most of service factors: lead time, flexibility, reliability, frequency and fill-rate. Also JIT has been proved to have positive correlations against other strategic actions. Finally, we can rank strategic actions as follows:

JIT implementation, inventory management, demand forecasting methods, customer relationship management, warehouse lay-out optimization, information technology, and transport management.



Service factors	Strategic actions	JIT implementation	Transportation management	Information technology	Demand forecast methods	Warehouse layout optimization	Inventory management	CRM	Rij	Rij*
	Lead time	(0.7,1,1)	(0.7,1,1)	(0.3,0.5,0.7)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(1.68,3.4,4)	(0.798,1.615,1.9)
	Flexibility	(0.7,1,1)	(0.7,1,1)	(0.3,0.5,0.7)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(0.7,1,1)	(1.09,2.4,3.5)	(0.491,1.08,1.575)
	Accuracy	(0.3,0.5,0.7)	(0.7,1,1)	(0.7,1,1)				(0.3,0.5,0.7)	(1.68,3.4,4)	(0.126,0.255,0.3)
	Reliability	(0.7,1,1)	(0.7,1,1)	(0,7,1,1)	(0.7,1,1)	(0,0,0.3)	(0.7,1,1)	(0.3,0.5,0.7)	(1.103,3.4,4)	(0.524,1.615,1.9)
	Frequency	(0.7,1,1)			(0.7,1,1)	(0,0,0.3)	(0.7,1,1)	(0.3,0.5,0.7)	(1.34,2.68,4)	(0.751,1.515,1.9)
	Fill rate	(0.7,1,1)			(0.7,1,1)		(0.7,1,1)	(0.3,0.5,0.7)	(1.58,3.19,4)	(0,0,0)
	Organization accessibility							(0.7,1,1)	(1.58,3.19,3.5)	(1.73,0.3999,0.613)
	Complains management							(0.7,1,1)	(0.99,2.28,4)	
Relative importance Rij		(2.277,7.226,9.385)	(1.357,4.565,5.675)	(0.936,3.617,5.245)	(2.24,7.098,9.175)	(0.902,2.695,4.615)	(2.24,7.098,9.175)	(1.634,5.423,8.288)	(5.494,32.79,91.77)	
Real importance Rij*		(7.845,46.97,103.1)	(3.88,23.16,49.84)	(6.288,27.49,73.65)	(5.797,33.5,82.54)	(5.224,32.49,68.19)	(6.883,40.4,91.77)	(5.494,32.79,82.54)		
Cost of implementation Cj		(0.5,0.7,1)	(0.5,0.7,1)	(0.7,1,1)	(0.5,0.7,1)	(0.5,0.7,1)	(0.5,0.7,1)	(0.5,0.7,1)		
Utility factor U		(7.845,46.97,103.1)	(3.883,16.21,24.92)	(6.288,27.4,73.65)	(5.797,33.5,82.54)	(5.224,32.49,68.19)	(6.888,40.45,91.77)	(5.494,32.79,91.77)	(5.494,32.798,2.54)	
Crisp Value		51.23	25.01	33.73	38.83	34.6	44.89	38.4		

+: (0.5, 0.7, 1)
×: (0.7, 1, 1)

5. Conclusion

This paper has discussed the way of strategic management of logistics services and processes for a big manufacturer. It has proposed an approach based on the quality function deployment (QFD), for ranking strategic actions to improve logistics service. The paper has addressed the issue of how to deploy the house of quality (HOQ) to effectively and efficiently improve logistics processes and thus customer satisfaction. For data collection, fuzzy logic has been used to deal with the ill-defined nature of the qualitative linguistic judgments required in the proposed HOQ. The methodology has been tested by means of a real case application, which refers to an Iranian company operating in the manufacturing industry.

The approach proposed could be considered as a useful tool for selecting the most efficient and effective logistics leverages to reach customer satisfaction. In particular, the methodology allows the identification of the service factors that are perceived to affect logistics performances from the customer's point of view, enabling the assessment of possible gaps between customers' and firm's perception of logistics service. As a matter of fact, this is why firm's perception should not be considered as the starting point in developing service strategies, while direct interviews with customers are required. In order to assess and rank viable strategic actions, in the approach proposed we have introduced a utility factor, which considers the costs of implementation for each ''how''. The utility factor can be directly adopted as a synthesis parameter to select the most suitable strategic action to implement. Ultimately, the strategic actions have been ranked as follows:

1)JIT implementation, 2)Inventory management, 3) Demand forecasting methods, 4) Customer relationship management, 5)Warehouse lay-out optimization, 6)Information technology, and 7)Transport management.

As we can see, JIT implementation has the highest priority, and it can be the result of strong relationship between JIT and the most important service factors. After JIT implementation, inventory management and demand forecasting method has the highest priority. It could be the result of strong relationship between these two strategic actions and fill-rate.

Although information technology has a strong effect on service improvement, its priority is low, because according to HEPCO's experts, organization needs high budget for implementing information technology. Therefore, if top management of the company plan to implement strategic actions according to the results above, can access customer satisfaction, higher market share and more benefit.

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