# An Intelligent Approach to Prioritize Logistics Requirements in Food Industry

Zeki Ayağ

*Industrial Engineering Department, Kadir Has University*
*Kadir Has Campus, Cibali 34083, Fatih, İstanbul, TURKEY*
zekia@khas.edu.tr

***Abstract*— The aim of this study is to analyze dairy food industry and to determine the priorities of important logistics requirements (LR) based on customer requirements as a part of a supply management system. For product or service development, quality function deployment (QFD) is a useful approach to maximize customer satisfaction. The determination of the priorities of the LR is an important issue during QFD process for product or service design. For this reason, in this work, an integrated approach integrating fuzzy logic and QFD methods is proposed to identify and prioritize the LR in dairy food industry for the improvement of customer satisfaction. In addition, a case study in Turkish dairy food industry is given to illustrate the proposed approach for potential readers. In short, the main contribution of the proposed approach with the case study is to help managers understand their customer requirements, determine the related LR and rank them by weight in order to prioritize (i.e. determining the sequences of putting into action) for improving the level of customer satisfaction.**

***Keywords*—***Supply chain management; food industry; dairy customer needs; dairy logistics requirements; fuzzy logic, fuzzy QFD*

## 1. Introduction

Customer service management has become a strategic issue in the logistics and supply chain management. Companies may increase customer satisfaction and gain market shares by improving logistics and supply chain performances. As the producing lines of dairy products increase daily, the logistics of milk, cheese and yoghurt-like products continues to gain more importance. The dairy industry is characterized by hyper-competition with average margins of 1-2 per cent of sales, deals with highly perishable products that also tend to be fragile and have a low value to size ratio, widely varying consumer tastes and consumer fixation on price.

This complex business environment has led to an analysis of logistics needs in dairy industry and an understanding of dairy logistics environment leading to the determination of logistics requirements (LR) [1].

The aim of this paper is to propose a new integrated approach to determine and prioritize the most suitable LR for the improvement of customer satisfaction. The approach is based on the fuzzy logic and the quality function deployment (QFD) methods, a methodology which has been successfully adopted in new products, process or system development.

QFD is a comprehensive quality system aimed at satisfying the customer. The intents of applying QFD are to incorporate the voice of the customer into the various phases of the product, process or system development cycle and to assume the achievement of customer required quality. However, it is more difficult to assess the performance of this process with accurate quantitative values; due to its uncertain nature. For this reason, this work concentrates on a fuzzy QFD approach to improve the quality of the responsiveness to customer requirements. Fuzzy logic's use is preferred to remove the uncertainty, vagueness, and impreciseness from data obtained to assess customers' spoken and unspoken needs. In the proposed fuzzy QFD methodology, qualitative information is converted firstly into quantitative parameters.

## 2. Related Literature

In literature, some researchers have applied fuzzy theory to quantitatively formulate problems for optimizing the improvements of design requirements. Ref. [2] proposed a fuzzy inference system of customer requirements which allowed product attributes to be mapped out. Ref. [3] used a fuzzy theoretical modelling approach to QFD by developing fuzzy multi-objective models under the assumption that the function relationships among design requirements and between customer requirements and design requirements could be

***International Journal of Supply Chain Management***
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

recognized based on the benchmarking data set of customer competitive analysis. Some researchers, such as Ref. [4]-[7] developed some fuzzy approaches, including fuzzy sets, fuzzy arithmetic, and/or defuzzification techniques, to address complex and often imprecise problems regarding customer requirement management.

To the best of our knowledge, no many works have dealt with the development and commercial introduction of new products or processes using QFD in the food industry. The existing research includes the work carried out by Ref. [8], who described the structure of the product development process using the HOQ method in the case of a Danish butter cookie company. To improve the integration between sensory analysis and market analysis in food product development, Ref. [9] suggested a new structure for HOQ in which the relationships between sensory attributes, technical attributes and consumer requirements are highly detailed. Ref. [10] conducted a case study regarding the practical implementation of QFD in a quality improvement project, and the conclusion was that there was a lack of truly quantitative relationships between consumer requirements and food product characteristics, both physically and extrinsically. Ref. [11] developed a model in which food technological innovations can be quantitatively evaluated and compared in terms of how well they meet pre-designed consumer segment requirements.

This paper is organized as given next; a fuzzy QFD methodology described briefly and its illustration through a case study. Finally, some concluding remarks are given in last section.

## 3. Proposed Fuzzy QFD Approach

### 3.1 Quality Function Deployment (QFD)

Quality function deployment (QFD is a comprehensive quality tool specifically aimed at satisfying customers' requirements [12]. QFD is defined as a method and technique used for developing a design quality aimed at satisfying the consumer and then translating the consumer's demands into design targets and major quality assurance points to be used throughout the production stage [12].

The QFD process involves four phases: (1) product planning: house of quality, (2) product design: parts deployment, (3) process planning, and (4) process control (quality control charts). A chart (matrix) represents each phase of the QFD process. The complete QFD process requires at least four charts, called houses, to be built that extend throughout the entire system's development life cycle and to clearly establish relationships between company functions and customer satisfaction. These matrices explicitly relate the data produced in one stage of the process to the decisions that must be made at the next process stage. In the product planning matrix, customer’s desires, in customers' own words (WHATs), are determined and translated into technical description (HOWs) or proposed performance characteristics of the product. The second QFD matrix relates potential product features to the delivery of performance characteristics. Process characteristics and production requirements are related to engineering and marketing characteristics with the third and fourth matrices. The house of quality concept is shown briefly in Figure 1. The reader may refer to Ref. [12], [13] for a detailed discussion of the traditional QFD methodology and implementation of house of quality.

In this study, dairy customer needs are treated as the voice of the customer (WHAT), as these are the requirements of an improved logistics process. All logistics practices that affect each customer need must be identified as the HOWs in a QFD matrix. Following this procedure, a house of quality focus on dairy industry can be built, containing WHATs and HOWs, and their correlations.

This generic QFD matrix in Figure 2 allows dairy organizations to assess how effective their current logistics practices are, how they can improve them, and to what levels they can improve.

### 3.2 Fuzzy Logic

The fuzzy set theory is a mathematical theory designed to model the vagueness or imprecision of human cognitive processes that was pioneered by Ref. [14]. This theory is basically a theory of classes with unsharp boundaries. What is important to recognize is that any crisp theory can be fuzzified by generalizing the concept of a set within that theory to the concept of a fuzzy set [15]. Fuzzy set theory and fuzzy logic have been applied in a great variety of applications, which are reviewed by several authors [16], [17]. The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set [17], [18].

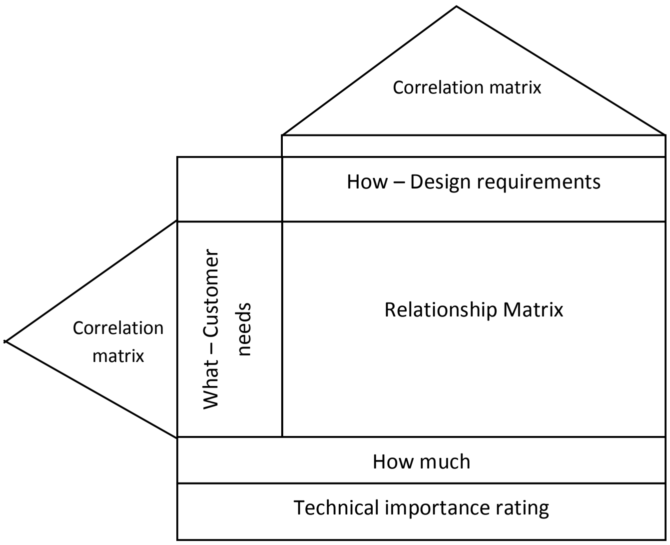


**Figure 1.** General characteristics of a House of Quality (HOQ)

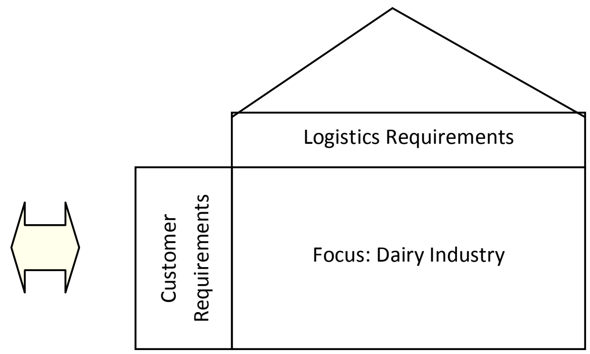


**Figure 2.** Applied HOQ

The membership function represents the grade of membership of an element in a set. The membership values of an element vary between 1 and 0. Elements can belong to a set in a certain degree and elements can also belong to multiple set. Fuzzy set allows the partial membership of elements. Transition between membership and non membership is gradually. Membership function maps the variation of value of linguistic variables into different linguistic classes. The adaptation of membership function for a given linguistic variable under a given situation is done in three ways; a) experts previous knowledge about the linguistic variable; b) using simple geometric forms having slopes (triangular, trapezoidal or s-functions) as per the nature of the variable; and c) by trial and error learning process.

**Table 1**.Definition and membership function of fuzzy number [19]

| Intensity of Importance [1] | Fuzzy number | Definition | Membership function |
|---|---|---|---|
| 1 | $\tilde{1}$ | Equally important/preferred | (1, 1, 2) |
| 3 | $\tilde{3}$ | Moderately more important/preferred | (2, 3, 4) |
| 5 | $\tilde{5}$ | Strongly more important/preferred | (4, 5, 6) |
| 7 | $\tilde{7}$ | Very strongly more important/preferred | (6, 7, 8) |
| 9 | $\tilde{9}$ | Extremely more important/preferred | (8, 9, 10) |

[1] Fundamental scale used in pair wise comparison [20]

In this study, triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$, are used to represent subjective pair wise comparisons of selection process in order to capture the vagueness. A fuzzy number is a special fuzzy set $F = \{(x, \mu_F(x)), x \in R\}$, where x takes it values on the real line, $R: -\infty < x < +\infty$ and $\mu_F(x)$ is a continuous mapping from $R$ to the closed interval [0, 1]. A triangular fuzzy number denoted as $\tilde{M} = (l, m, u)$, where $l \le m \le u$, has the following triangular type membership function;

$$\mu_F(x) = \begin{cases} 0 & x < l \\ \frac{x-l}{m-l} & l \le x \le m \\ \frac{u-x}{u-m} & m \le x \le u \\ 0 & x > u \end{cases} \quad (1)$$

Alternatively, by defining the interval of confidence level $\alpha$, the triangular fuzzy number can be characterized as:

$$\forall \alpha \in [0,1]$$

$$\tilde{M}_\alpha = [l^\alpha, u^\alpha] = [(m-l)\alpha + l, -(u-m)\alpha + u] \quad (2)$$

Some main operations for positive fuzzy numbers are described by the interval of confidence, by Ref. [21] as given below;

$$\forall m_L, m_R, n_L, n_R \in R^+, \tilde{M}_\alpha = [m_L^\alpha, m_R^\alpha], \tilde{N}_\alpha = [n_L^\alpha, n_R^\alpha], \alpha \in [0,1]$$

$$\tilde{M} \oplus \tilde{N} = [m_L^\alpha + n_L^\alpha, m_R^\alpha + n_R^\alpha],$$

$$\tilde{M} \Theta \tilde{N} = [m_L^\alpha - n_L^\alpha, m_R^\alpha - n_R^\alpha]$$

$$\tilde{M} \otimes \tilde{N} = [m_L^\alpha n_L^\alpha, m_R^\alpha n_R^\alpha],$$

$$\tilde{M} / \tilde{N} = [m_L^\alpha / n_L^\alpha, m_R^\alpha / n_R^\alpha]$$

$\alpha - cut$ is known to incorporate the experts or decision maker(s) confidence over his/her preference or the judgments. Degree of satisfaction for the judgment matrix $\tilde{A}$ is estimated by the index of optimism $\mu$. The larger value of index $\mu$ indicates the higher degree of optimism. The index of optimism is a linear convex combination [22] defined as:

$$\tilde{a}_{ij}^\alpha = \mu a_{iju}^\alpha + (1-\mu) a_{ijl}^\alpha, \quad \forall \mu \in [0,1] \quad (3)$$

$\alpha - cut$: It will yield an interval set of values from a fuzzy number. For example; assigning $\alpha = 0.5$ will yield a set $\alpha_{0.5} = (2,3,4)$. The triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$, are utilized to improve the conventional nine-point scaling scheme. In order to take the imprecision of human qualitative assessments into consideration, the five triangular fuzzy numbers are defined with the corresponding membership function as shown in Figure 3.

## 4. Case Study

The proposed approach was applied to a Company producing dairy products in the Turkish food industry. This case study was inspired from a work from the literature [1]. 16 CR are identified and to respond these needs, 14 LR are determined through review of literature, our expertise and validation of the case company logistics managers. These data is shown in Table 2 and Table 3.

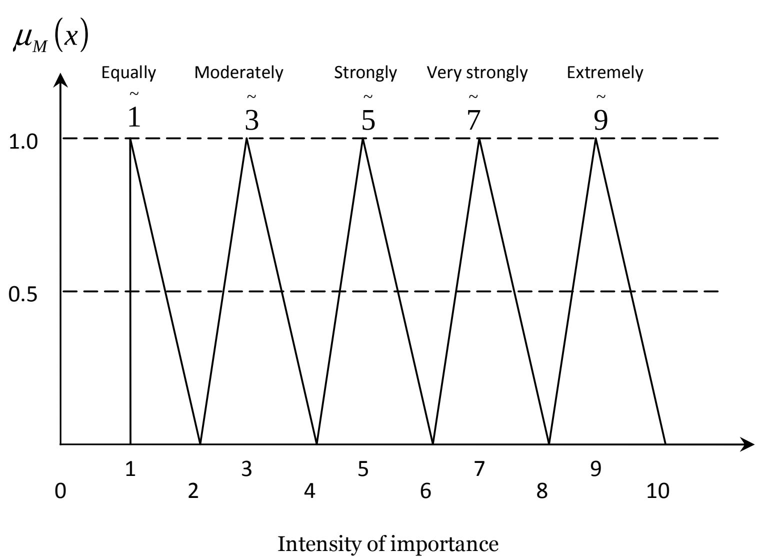


**Figure 3.** Fuzzy membership function for linguistic values for attributes or alternatives

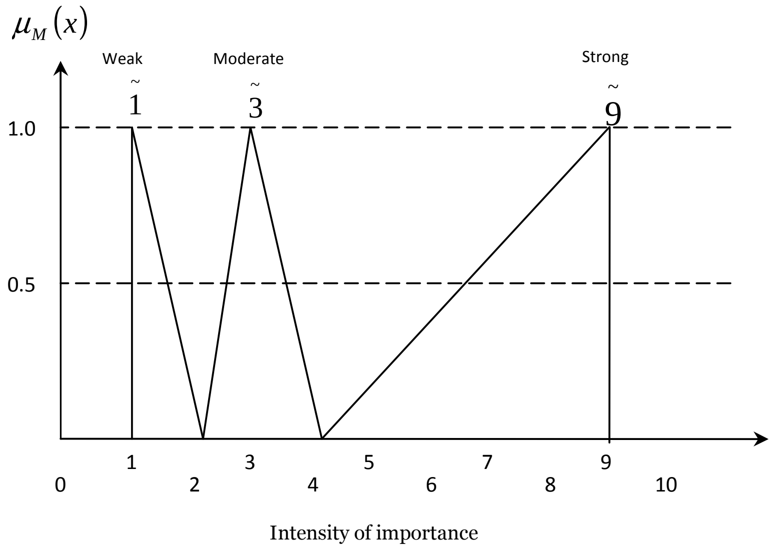


**Figure 4.**Fuzzy membership function for linguistic values for customer and logistics requirements [1]

**Table 2.**Customer Requirements for the Turkish Dairy Industry: "Performance Aspects "Customer Requirements (CR)"

| Code | Definition |
|---|---|
| **CR1** | Quality |
| **CR2** | Price |
| **CR3** | Freshness of Protection |
| **CR4** | Expiry Date |
| **CR5** | Volume |
| **CR6** | Product Variety |
| **CR7** | Lead Time |
| **CR8** | On-time Delivering |
| **CR9** | Supplier Reliability |
| **CR10** | Meeting the Orders Regularly and Correctly |
| **CR11** | Efficiency of Barcode System |
| **CR12** | Efficient Performance Management System |
| **CR13** | Picking the Return Products |
| **CR14** | Consolidation of Orders |
| **CR15** | Payment Options |
| **CR16** | Effective Customer Management System |

**Table 3.**Logistics Requirements (LR) for the Turkish Dairy Industry; Enablers "Logistics Requirements"

| Code | Definition |
|---|---|
| **LR1** | Qualified Employement and Traning |
| **LR2** | Usage of IT and Decision Support Systems |
| **LR3** | Customer Relations Management System |
| **LR4** | Inventory Stock and Management |
| **LR5** | Automation of Manufacturing and Warehouse Processes |
| **LR6** | Usage of Outsourcing Company |
| **LR7** | Having Different Kind of Temperature Degree Stock Parts in the Cold Stock Warehouse |
| **LR8** | Real-time Tracking of Trucks with Satellite |
| **LR9** | Usage Demand Forecasting System for Correct Demand Forecast |
| **LR10** | Having Quality Certification and Suppliers Pool with Quality Certifications |
| **LR11** | Effective Reverse Logistics |
| **LR12** | Picking Orders Fastly and Loading Trucks in the Warehouse |
| **LR13** | Usage Distribution Network Effectively |
| **LR14** | Having Strong Financial Status |

In conventional QFD, the pair wise comparison is made by using a ratio scale. We defined a three point scale $(\tilde{1},\tilde{3},\tilde{9})$ integrated fuzzy logic as in given in Figure 4, which shows the participants` judgments or preferences among the options such as strong, moderate and weak. In this study, triangular fuzzy numbers (Eq.(1)) are used to represent subjective pair wise comparisons of evaluation in order to capture the vagueness. A fuzzy number is a special fuzzy set; where x takes it values on the real line, and is a continuous mapping from R to the closed interval [0, 1].

Based on the scale $(\tilde{1},\tilde{3},\tilde{9})$, first the fuzzy QFD comparison matrix was constructed as seen in Table 4. Then, $\alpha - cut$ analysis was used to construct the second QFD matrix showing the interval values for each element of the matrix. The lower limit and upper limit of the fuzzy numbers with respect to the $\alpha$ were defined as follows by applying Eq. (2);

$$\tilde{1}_\alpha = [1, 3-2\alpha]$$

$$\tilde{3}_\alpha = [1+2\alpha, 5-2\alpha]$$

$$\tilde{3}_\alpha^{-1} = \left[\frac{1}{5-2\alpha}, \frac{1}{1+2\alpha}\right]$$

$$\tilde{5}_\alpha = [3+2\alpha, 7-2\alpha]$$

$$\tilde{5}_\alpha^{-1} = \left[\frac{1}{7-2\alpha}, \frac{1}{3+2\alpha}\right]$$

$$\tilde{7}_\alpha = [5+2\alpha, 9-2\alpha]$$

$$\tilde{7}_\alpha^{-1} = \left[\frac{1}{9-2\alpha}, \frac{1}{5+2\alpha}\right]$$

$$\tilde{9}_\alpha = [7+2\alpha, 11-2\alpha],$$

$$\tilde{9}_\alpha^{-1} = \left[\frac{1}{11-2\alpha}, \frac{1}{7+2\alpha}\right]$$

Then, we substituted the values, $\alpha = 0.5$ and $\mu = 0.5$ above expression into fuzzy comparison matrices, and obtained all the $\alpha - cuts$ fuzzy comparison matrices (Table 5).

As a final step, Eq.(3) was used to calculate eigenvectors for all comparison matrices) as follows; the judgment matrix $\tilde{A}$ is estimated by the index of optimism $\mu$, and confidence value $\alpha$ ($\mu = 0.5$, $\alpha = 0.5$). Table 6 shows the QFD matrix after $\alpha - cut$ analysis. As seen in Table, the rankings of the all LR are given, and priorities of the LR are determined by weight as follows; LR6, LR4, LR13, L14, LR5, LR8, LR3, LR12, LR2, LR7, LR10, LR11, LR9, LR1.

## 5. Conclusions

In this study, a Turkish dairy product company was analyzed and important dairy logistics requirements using QFD was identified and prioritized through an integrated approach bringing the following methods; fuzzy logic and QFD together. The QFD method is a useful approach to maximize customer satisfaction. To determine the priorities of logistics requirements is an important issue during QFD processes for product or service design. This study aims to improve customer satisfaction by identifying logistics requirements in dairy industry. The proposed approach was applied to a Turkish firm in a dairy food sector, and the results of the study were presented to the Company management so they can improve its sales and profits with having advantages in the market.

**Table 4.**Fuzzy QFD comparison matrix using triangular fuzzy numbers

| | **Weight/ Importance** | | **LR1** | **LR2** | **LR3** | **LR4** | **LR5** | **LR6** | **LR7** | **LR8** | **LR9** | **LR10** | **LR11** | **LR12** | **LR13** | **LR14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Performance Aspects "Customer Demands"** | 8 | **CR1** | $\tilde{5}$ | | | | | | $\tilde{9}$ | $\tilde{9}$ | | $\tilde{9}$ | | | | |
| | 10 | **CR2** | | | | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | | | | | | $\tilde{9}$ | | $\tilde{9}$ |
| | 7 | **CR3** | | | | | | | $\tilde{9}$ | $\tilde{9}$ | | | | | | |
| | 10 | **CR4** | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{5}$ | | $\tilde{9}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ |
| | 6 | **CR5** | $\tilde{9}$ | | | | $\tilde{9}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{9}$ | | | | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ |
| | 10 | **CR6** | $\tilde{1}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ |
| | 5 | **CR7** | | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{5}$ | | | $\tilde{1}$ | | | | $\tilde{9}$ | |
| | 10 | **CR8** | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ |
| | 7 | **CR9** | | $\tilde{9}$ | | $\tilde{5}$ | | | | | | | | | $\tilde{9}$ | |
| | 10 | **CR10** | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ |
| | 8 | **CR11** | $\tilde{1}$ | $\tilde{9}$ | $\tilde{1}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{1}$ | $\tilde{9}$ | $\tilde{1}$ | $\tilde{9}$ |
| | 10 | **CR12** | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ |
| | 10 | **CR13** | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{1}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ |
| | 8 | **CR14** | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{5}$ |
| | 10 | **CR15** | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{1}$ |
| | 6 | **CR16** | | | $\tilde{9}$ | | | | | | | | $\tilde{9}$ | | | $\tilde{9}$ |

**Table 5.** $\alpha - cuts$ fuzzy QFD comparison matrix for the interval values

| | **Weight/ Importance** | | **LR1** | **LR2** | **LR3** | **LR4** | **LR5** | **LR6** | **LR7** | **LR8** | **LR9** | **LR10** | **LR11** | **LR12** | **LR13** | **LR14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Performance Aspects “Customer Demands”** | 8 | **CR1** | [4,6] | | | | | | [8,10] | [8,10] | | [8,10] | | | | |
| | 10 | **CR2** | | | | [8,10] | [8,10] | [8,10] | | | | | | [8,10] | | [8,10] |
| | 7 | **CR3** | | | | | | | [8,10] | [8,10] | | | | | | |
| | 10 | **CR4** | [4,6] | [8,10] | [8,10] | [8,10] | [8,10] | [4,6] | | [8,10] | [4,6] | [8,10] | [8,10] | [4,6] | [8,10] | [8,10] |
| | 6 | **CR5** | [8,10] | | | | [8,10] | [8,10] | [4,6] | [8,10] | | | | [4,6] | [8,10] | [8,10] |
| | 10 | **CR6** | [1,2] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] |
| | 5 | **CR7** | | [8,10] | [8,10] | [8,10] | [8,10] | [4,6] | | | [1,2] | | | | [8,10] | |
| | 10 | **CR8** | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] |
| | 7 | **CR9** | | [8,10] | | [4,6] | | | | | | | | | [8,10] | |
| | 10 | **CR10** | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] |
| | 8 | **CR11** | [1,2] | [8,10] | [1,2] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [8,10] | [1,2] | [8,10] | [1,2] | [8,10] |
| | 10 | **CR12** | [4,6] | [4,6] | [8,10] | [4,6] | [4,6] | [8,10] | [4,6] | [4,6] | [4,6] | [4, 6] | [4,6] | [4,6] | [8,10] | [4,6] |
| | 10 | **CR13** | [4,6] | [4,6] | [8,10] | [4,6] | [1,2] | [8,10] | [4,6] | [4,6] | [8,10] | [4, 6] | [8,10] | [4,6] | [4,6] | [8,10] |
| | 8 | **CR14** | [4,6] | [4,6] | [8,10] | [8,10] | [4,6] | [8,10] | [4,6] | [4,6] | [4,6] | [4, 6] | [4,6] | [4,6] | [8,10] | [4,6] |
| | 10 | **CR15** | [8,10] | [4,6] | [4,6] | [8,10] | [8,10] | [8,10] | [4,6] | [4,6] | [4,6] | [4, 6] | [4,6] | [8,10] | [8,10] | [1,2] |
| | 6 | **CR16** | | | [8,10] | | | | | | | | [8,10] | | | [8,10] |

**Table 6.**QFD matrix after $\alpha - cut$ analysis for the values; $\mu = 0.5, \alpha = 0.5$

| Performance Aspects "Customer Demands" | Weight/ Importance | | LR1 | LR2 | LR3 | LR4 | LR5 | LR6 | LR7 | LR8 | LR9 | LR10 | LR11 | LR12 | LR13 | LR14 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | **CR1** | 5 | | | | | | 9 | 9 | | 9 | | | | | |
| | 10 | **CR2** | | | | 9 | 9 | 9 | | | | | | 9 | | 9 | |
| | 7 | **CR3** | | | | | | | 9 | 9 | | | | | | | |
| | 10 | **CR4** | 5 | 9 | 9 | 9 | 9 | 5 | | 9 | 5 | 9 | 9 | 5 | 9 | 9 | |
| | 6 | **CR5** | 9 | | | | 9 | 9 | 5 | 9 | | | | 5 | 9 | 9 | |
| | 10 | **CR6** | 1.5 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 5 | **CR7** | | 9 | 9 | 9 | 9 | 5 | | | 1.5 | | | | 9 | | |
| | 10 | **CR8** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 7 | **CR9** | | 9 | | 5 | | | | | | | | | 9 | | |
| | 10 | **CR10** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | 8 | **CR11** | 1.5 | 9 | 1.5 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 1.5 | 9 | 1.5 | 9 | |
| | 10 | **CR12** | 5 | 5 | 9 | 5 | 5 | 9 | 5 | 5 | 5 | 5 | 5 | 5 | 9 | 5 | |
| | 10 | **CR13** | 5 | 5 | 9 | 5 | 1.5 | 9 | 5 | 5 | 9 | 5 | 9 | 5 | 5 | 9 | |
| | 8 | **CR14** | 5 | 5 | 9 | 9 | 5 | 9 | 5 | 5 | 5 | 5 | 5 | 5 | 9 | 5 | |
| | 10 | **CR15** | 9 | 5 | 5 | 9 | 9 | 9 | 5 | 5 | 5 | 5 | 5 | 9 | 9 | 1.5 | |
| | 6 | **CR16** | | | 9 | | | | | | | | 9 | | | 9 | |
| | | **Max.** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | |
| | | **ATIR** | 581 | 730 | 773 | 864 | 816 | 903 | 697 | 811 | 630 | 694 | 656 | 742 | 836 | 826 | **10559** |
| | | **RTIR*100** | 5.50 | 6.91 | 7.32 | 8.18 | 7.73 | 8.55 | 6.60 | 7.68 | 5.97 | 6.57 | 6.21 | 7.03 | 7.92 | 7.82 | |
| | | **Rank** | **14** | **9** | **7** | **2** | **5** | **1** | **10** | **6** | **13** | **11** | **12** | **8** | **3** | **4** | |

**Note:** ATIR is calculated by multiplying the values of each LR column by those in the weight/importance column. RTIR is also calculated by dividing the total ATIR (10559) by the ATIR value of each LR.

## References

[1] Z. Ayag, F. Samanlioglu, G. Buyukozkan, *"Fuzzy QFD Approach to Determine Supply Chain Management Strategies in the Dairy Industry"*, Journal of Intelligent Manufacturing, Vol.24, No. 6, pp. 1111-1122, 2013.

[2] R.Y.K. Fung, K. Popplewell, J. Xie, *"An intelligent hybrid system for customer requirements analysis and product attribute targets determination"*, International Journal of Production Research, Vol. 36, No.1, pp.13-34, 1998.

[3] K.J. Kim, H. Moskowitz, A. Dhingra, G. Evans, *"Fuzzy multi criteria models for quality function deployment"*, European Journal of Operation Research, Vol.121, No.3, pp. 504-518, 2000.

[4] X.X. Shen, K.C. Tan, M. Xie, *"The implementation of quality function deployment based on linguistic data"*, Journal of Intelligent Manufacturing, Vol. 12, No.1, pp. 65-75, 2001.

[5] L.V. Vanegas, A.W. Labib,*"Application of new fuzzy-weighted average (NFWA) method to engineering design evaluation"*, International Journal of Production Research, Vol. 39, No.6, pp. 1147-1162, 2001.

[6] J. Wang, *"Fuzzy outranking approach to prioritize design requirements in quality function deployment"*, International Journal of Production Research, Vol. 37, No.4, pp. 899-916, 1999.

[7] M. Zhou,*"Fuzzy logic based models for quality planning and improvement"*, ASME Conference: Intelligent Engineering Systems through Artificial Neural Networks, Vol. 7, pp. 311-316, 1997.

[8] E. Holmen, P.S. Kristensen, *"Downstream and Upstream Extension of the House of Quality"*, MAPP Working Paper No. 37, MAPP, Copenhagen, 1996.

[9] A.C. Bech, E. Engelund, H.J. Juhl, K. Kristensen, C.S. Poulsen, *"QFood: Optimal Design of Food Products"*, MAPP Working Paper No. 19, MAPP, Copenhagen, 1994.

[10] A.I.A Costa, *"Development of Methodologies for Quality Modelling: An Application on Tomato Ketchup"*, MSc Thesis, Wageningen University, 1996.

[11] M. Korsten, *"Technology-initiated, Consumer-oriented Product Development"*, MSc Thesis, Wageningen University, 2000.

[12] Y. Akao, *QFD – Quality Function Deployment: Integrating Customer Requirements into Product Design*, Cambridge, MA, Productivity Press, Portland, 1990.

[13] L. Cohen, *Quality Function Deployment How to Make QFD Work for You*, Addition-Wesley, Reading, MA, 1995.

[14] F. A. Lootsma, *Fuzzy Logic for Planning and Decision Making*, Kluwer Academic Publisher, Dordrecht, 1997.

[15] L.A. Zadeh, *"Fuzzy Logic, neural Network, and Soft Computing"*, Communications of the ACM, Vol.37, No.3, pp. 77-84, 1994.

[16] G. J. Klir, B. Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice-Hall, Englewood Cliffs, NJ, 1995.

[17] H. J. Zimmermann, *Fuzzy set theory and its applications*, Kluwer, Massachusetts, 1996.

[18] C.V. Negoita, *Expert Systems and Fuzzy Systems*, The Benjamin/ Cummings, Menlo Park, California, 1985.

[19] Z. Ayag, *"A fuzzy AHP-based simulation approach to concept evaluation in a NPD environment"*, IIE Transactions, Vol. 37, No.9, pp. 827-842, 2005.

[20] T. L. Saaty, *"Decision Making, Scaling, and number crunching"*, Decision Science, Vol. 20, No.2, pp. 404-409, 1989.

[21] A. Kaufmann, M.M. Gupta, *Introduction to Fuzzy Arithmetic: Theory and Applications*, Van Nostrand Reinhold, New York, 1985.

[22] A.R. Lee, *"Application of modified fuzzy AHP method to analyze bolting sequence of structural joints"*, UMI Dissertation Services, A Bell & Howell Company, 1999.