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Application of Fuzzy Quality Function Deployment Model, Group Decision Making and Choquet Integral to Improve Service Quality in Engineering Education*

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This paper considers ways to increase service quality levels at engineering programs and actions to be taken for accomplishing this. The aim of this paper is to develop and implement a Quality Function Deployment (QFD) model for engineering programs in Turkey. The research determines the most important technical requirements based on considering Voice of the Student (VOS), which is measured with a Service Quality (SERVQUAL) application-based measurement model. The students' responses to SERVQUAL survey are considered by a group decision-making approach. Group decision-making approach is used to attach importance to the ideas of students. The Choquet integral as an aggregation operator is used firstly for aggregating the weights of each response in order to determine the weight of each dimension of SERVQUAL application and secondly for aggregating the SERVQUAL weights and relationship matrix. Finally key factors for increasing qualified and sustainable education are proposed.

Keywords: fuzzy quality function deployment; choquet integral; large column large row (LCLR); voice of student (VOS); SERVQUAL

1. Introduction

After psychological, safety needs and the need to belong, people need motivational factors in order to be satisfied at work and in their lives. Education is one of the most important motivational factors for an individual. University education, as a valuable investment in a person's life, is a very important point to satisfy motivational needs. The mission of a university is to facilitate the achievement of a personalized education in coordinating the adaptability and generating knowledge for both individuals and society [1]. During this achievement process, the university education provides many benefits such as market, private non-market, external social and indirect benefits [2, 3].

Today, due to ever increasing variety of services offered by companies, the measurement of quality of those services has become more important [4, 5]. An important objective in service sectors to match customer needs with sufficient resources at the right time. Universities as service institutions provide an education service to their customers, namely students. Students, after taking national university placement tests, desire to be placed in one of the most qualified universities. Because the quality of education affects the quality of a graduate as an engineer, teacher, doctor etc. Therefore, service quality at universities has become important.

Quality in education is important to ensure skilled manpower and has attracted greater interest for socio-economic development and well-being. Higher education is crucial to an economy in creating and maintaining a competitive edge over its competitors [6]. High quality higher education enables a university to become more competitive. In the literature, studies have been conducted in this field. For example, Raharjo et al. [7] proposed a model using QFD and Analytic Hierarchy Process (AHP) to improve the quality of higher education quality. Quinn et al. [8] emphasize that customer satisfaction at an educational establishment is one of the greatest challenges of the quality movement.

Engineering education is defined as the activity of teaching the knowledge and principles pertaining to the practice of engineering. It includes an initial education (bachelor's and/or master's degree), and any advanced education and specializations that follow [9]. In this educational journey, engineering candidates are equipped with technical and social abilities. Sakthivel and Raju [10] emphasize the need for developing of quality models in engineering education, propose a new educational excellence model. Their approach is based on total quality management principles. In another study, Lakal et al. [11] developed a service quality assessment model for engineering education. It included 8 dimensions for measuring quality: Research orientation, personal growth, higher-order learning, effective teaching, support processes, project opportunities, workload and infrastructure. They state that out of the eight dimensions, research orientation, project opportunities, personal growth and higher-order learning are the unique contribution to service quality models as these were not explored by the past studies. As highlighted in the aforementioned studies, service quality in engineering education plays an important role for cultivating professional

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engineers, and service quality models are needed for this field.

Understanding customers' expectation and desires exactly is the most crucial step in defining and delivering high quality service [12, 13]. Service Quality Model (SERVQUAL) is one of the most effective and comprehensive models in service quality literature developed by Parasuraman, Zeithaml and Berry in 1988. Partial revisions of its design make up the most basic service quality dimensions that can be applied to different service businesses and sectors [14]. SERVQUAL has a perfectionist approach that advocates that the key to achieving excellent service quality is to fully meet or exceed customer expectations. A measurement model has been devised by taking this perfectionist viewpoint in designing and constructing the conceptual structure of the method [15]. SERVQUAL is used for defining the size of the difference between the customer's expectation and service provider's performance. If performance exceeds expectations, this is the best situation for customers and it is called as quality surprise. If performance equals expectations it is called as satisfactory service quality. However, if performance does not meet expectations, this is called low service quality, and in this situation, service provider must improve the quality level. In this respect, SERVQUAL is an efficient tool for defining the level of service quality for a service institution. The SERVQUAL method proposed by Parasuraman et al. [14] is one of the best evaluation methods for assessing the expectations and perceptions. SERVQUAL has five dimensions to measure service quality, including the tangibles, reliability, responsiveness, assurance and empathy [12, 16].

In this study, SERVQUAL is used for determining students' needs. For decades, researchers have acknowledged a positive relationship between service quality and customer satisfaction, often using the SERVQUAL model of service quality [17]. Besides, Quality Function Deployment (QFD) has been widely known to be one of the most useful tools in customer-driven products or service quality development and for application of concurrent engineering and implementing total quality management [18, 19]. In this study, QFD is used for understanding and determining how students' needs will be met.

QFD is a structured method that allows systematic evaluation of the capabilities of the proposed products and services in order to clearly identify and meet customer needs and requirements. QFD is a process that performs product development and improvement process through a matrix system called "house of quality". In this context, "QFD can be defined as a quality improvement method carried out by a team of functions that enables the transformation of customer needs into goods or service characteristics" [20]. The basic concept of QFD is to translate the desires of customers, in other words, voice of the customer, into technical requirements or engineering characteristics, and subsequently into parts characteristics, process plans and production requirements. In recent times, some studies have been conducted with QFD method. For example, Presley et al. [21] proposed a methodology for organizational product and process innovation based on Soft System Methodology theory incorporating QFD and IDEF0 techniques. This methodology is based on a series of phases that elicit information from complex and amorphous real-world practices and processes. Sireli et al. [22] proposed a simultaneous multiple product design study based on the QFD methodology to surmount the confusions in understanding customer needs accurately. They considered Kano's model of customer satisfaction associated with the QFD literature. The proposed methodology has been applied to a part of NASA's Aviation Weather Information project on cockpit weather information design. Ertay et al. [23] proposed implementation of QFD based on analytic network process with linguistic data in automotive industry. Besides, Hoyle and Chen [24] proposed the Product Attribute Function Deployment method extending the qualitative matrix principles of QFD while utilizing the quantitative decision-making processes of DBD (Decision Based Design). Their methodology is used for the conceptual design of an automotive manifold's absolute pressure sensor. As indicated in this study, in reality, the decision-making process in QFD emphasizes using multifunctional teams for integrating all corporate functions to be responsive to the customer's requirements so that product planning, product design, process planning, and production planning provide a coherent response to Customer Needs (CNs). In other words, QFD can be seen as a set of planning tools, which helps to introduce new or improved products faster to the market by focusing on customer satisfaction. QFD analysis is carried out with a Chart, called the "house of quality" (HoQ). This chart contains information on "what to do related to CNs", "how CNs are related to Technical Requirements (TRs)", relationships between CNs and TRs and among the TRs, and benchmarking data [25]. The model architecture, partly different from House of Quality (HoQ), used in this study is displayed in Fig 1.

For this diagram "House" term is used, because the diagram resembles and looks like a house. Customer needs look like windows of the house. There is a correlation matrix at the top as its roof. Customer needs versus technical requirements (rela-

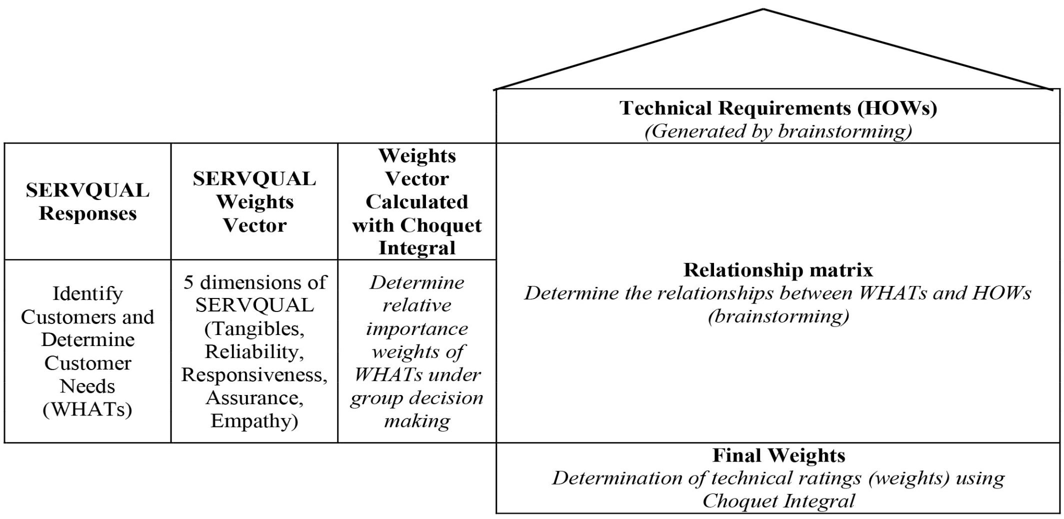

Fig. 1. Model Architecture.

tionship matrix) can be considered as the main part of the house, etc. The first three columns show the VOS analysis of WHATS (customer needs) and weights of each of them. This part of the house is explained in Steps 1, 2 and 3 of Section 2 of the paper. Relationship matrix shows the importance level of relations between voice of students and technical requirements. This part of the house is explained in Steps 4 and 5 of Section 2. Inner-dependences among technical requirements and inner-dependence between voice of student elements namely SERVQUAL dimensions are not used in this study. Because, in this study, the objective is to find importance weights for CNs and TRs. For calculating these, inner-dependencies are not required.

There have been some studies on quantifying the planning subjects in HoQ in QFD within the past decade. Kim et al. [26] used Analytical Hierarchy Process (AHP) method to prioritize the functions in QFD for developing a service-oriented product development system. Some of these studies focused on employing fuzzy set theory for prioritizing TRs or CNs [27]. Fuzzy QFD is used in several fields such as product design and product selection [28], routing of shipment investments [29], supplier selection [30] and determining service management requirements [31]. In addition, QFD method is combined with different techniques in the literature. It is combined with fuzzy linear programming [32–34], entropy weights [35, 36], Analytic Network Process (ANP) [37] and group decision making [38].

In this study, a linguistic scale is used to determine the strength relationship between "*Whats*" and "*Hows*". Fuzzy numbers were used since fuzzy set theory [39] is generally found to be better-suited to real life than the binary logic system [40]. Binary logic—in other words classical logic, is based on certainty theory. However, real life is quite uncertain by its nature [41]. Results obtained by evaluating a situation or a system related particularly with human factor and human thought from a certain and absolute perspective prove inadequate in reflecting reality [42, 43].

This study proposes a hybrid methodology by evaluating SERVQUAL results at the beginning of QFD application. The problem is analyzed with a hybrid methodology using SERVQUAL to determine the weights of VOS and using generalized Choquet integral to calculate overall scores for TRs. As an aggregation tool, in the literature, the Choquet integral with respect to a fuzzy measure has been used in information fusion and data mining such as decision-making, nonlinear multi-regressions and nonlinear classifications [44–46]. SERVQUAL application reflects the student requirements. The student views are considered under a group decision-making approach.

This study evaluates the quality characteristics of undergraduate engineering education program in Turkey from the perspective of industrial engineering students. Survey data obtained from 129 undergraduate engineering students at a university in Turkey are used for model architecture based on QFD analysis. QFD can be accepted as a very suitable tool for identifying significant quality characteristics valued by students and determining the most important and the least important student quality requirements and technical requirements. The first stage of this study is designing a comprehensive questionnaire. In order to complete this stage, a project management team, consisting of a student focus group constituted according to GPA and lecturers, directed their efforts first on identifying the "Whats" of high-quality industrial engineering education and then on identifying the "Hows". "Whats" are customer needs which are adapted from dimensions of SERVQUAL model. As an example, the physical appearance of campus, faculty, classrooms and labs is one of the main components of customer needs (This is "Tangibles" dimension in SERVQUAL model). "Hows" represent ways of performing activities for meeting customer needs. As an example, environmental planning of faculties is defined as a technical requirement for meeting customer needs in Tangibles dimension. The focus group used brainstorming to identify the "Voice of the Students", in other words, the quality characteristics that undergraduate industrial engineering students in Turkey desire in their engineering education program. At the beginning of the focus group discussion, the participants are oriented in their role as customers of the education program and derived VOS-based application of the classical SERVQUAL technique. After identifying the "Whats", the focus group determined the "Hows" to translate VOS into educational service elements, in other words, TRs.

The organization of this paper is as follows: in the second section, the steps of the methodology are discussed, the third section is about the application of the model and the last section is about the results and discussion.

2. A service quality model for engineering education

In this study, two models are proposed and the results are compared. These are "Basic Methodology" and "Hybrid Methodology". Quality Function Deployment (QFD) approach is used in both of the methodologies. In the basic methodology approach, group decision making model and fuzzy Choquet integral were not used. However, in hybrid methodology approach, a six-step QFD-based model is developed for evaluating customer needs by group decision making and Choquet integration operator with fuzzy data. In Fig. 2, two methodologies, namely the hybrid and basic methodologies, for implementing the model are summarized and the differences between them are presented.

Each part of Fig. 2 is discussed below in detail. First step (Determination of customer needs and data collection for customer needs) is the same for both of the methodologies. This is discussed in Step 1 below. Second step is calculating weights of customer needs. In the simple methodology, it is carried out with weighted averages and in the hybrid methodology it is carried out by using the LCLR method. This is discussed in Step 2 below. Third step is the determination final weights. This is conducted in hybrid methodology but not in the basic one. It is discussed in Step 3 below. Technical requirements and their relations with customer needs are discussed in Steps 4 and 5, respectively. And finally, weights of each technical requirement are calculated in the last (6th.) Step.

Step 1. *Deriving customer needs according to five dimensions of SERVQUAL application.*

Firstly the service quality dimensions are determined, which are adapted from Zeithaml et al. (1990).

In SERVQUAL model, 5 dimensions are defined which are explained below. These are general definitions of the dimensions. In the 3rd. Section, at the first application step, specific definitions of dimensions can be found for university education.

(i) Tangibles: The physical appearance of used instruments, communication materials, personnel and service area,
(ii) Reliability: Having the necessary knowledge and skills to provide services, excellence,
(iii) Responsiveness: Providing prompt service, enthusiasm and helpfulness,
(iv) Assurance: Avoiding danger, risk and maintaining the security,
(v) Empathy: Trying to understand the needs of customers with courtesy and a friendly approach.

Step 2. *Calculating relative weights for voice of the students with SERVQUAL scores under a group decision making approach based on assuming no inner-dependence.*

The classical SERVQUAL questionnaire is designed in four parts. The first part of the questionnaire is the explanation part. Here a brief explanation is given to the respondents. In addition, in this part the users determine the degree of importance of each dimension for him or her, which is called as the coefficient factors, $w_{f_{i_l}}$, where all

$$\sum_{l=1}^{5} w_{f_{i_l}} = 1.$$

The second part of the SERVQUAL model is composed of 22 questions asking the respondent to rate (from 1 to 7; 1: least-7: most) the properties of expected services in a university, which is called as expected quality (E_{ilt}).

The third part of the questionnaire is composed of similar questions but here the respondents are asked about the properties of the university where the SERVQUAL application is conducted. The answer of each respondent is modeled as perceived quality (P_{ilt}). *(i:student, l:dimension, t:question number).* The last part of the questionnaire is

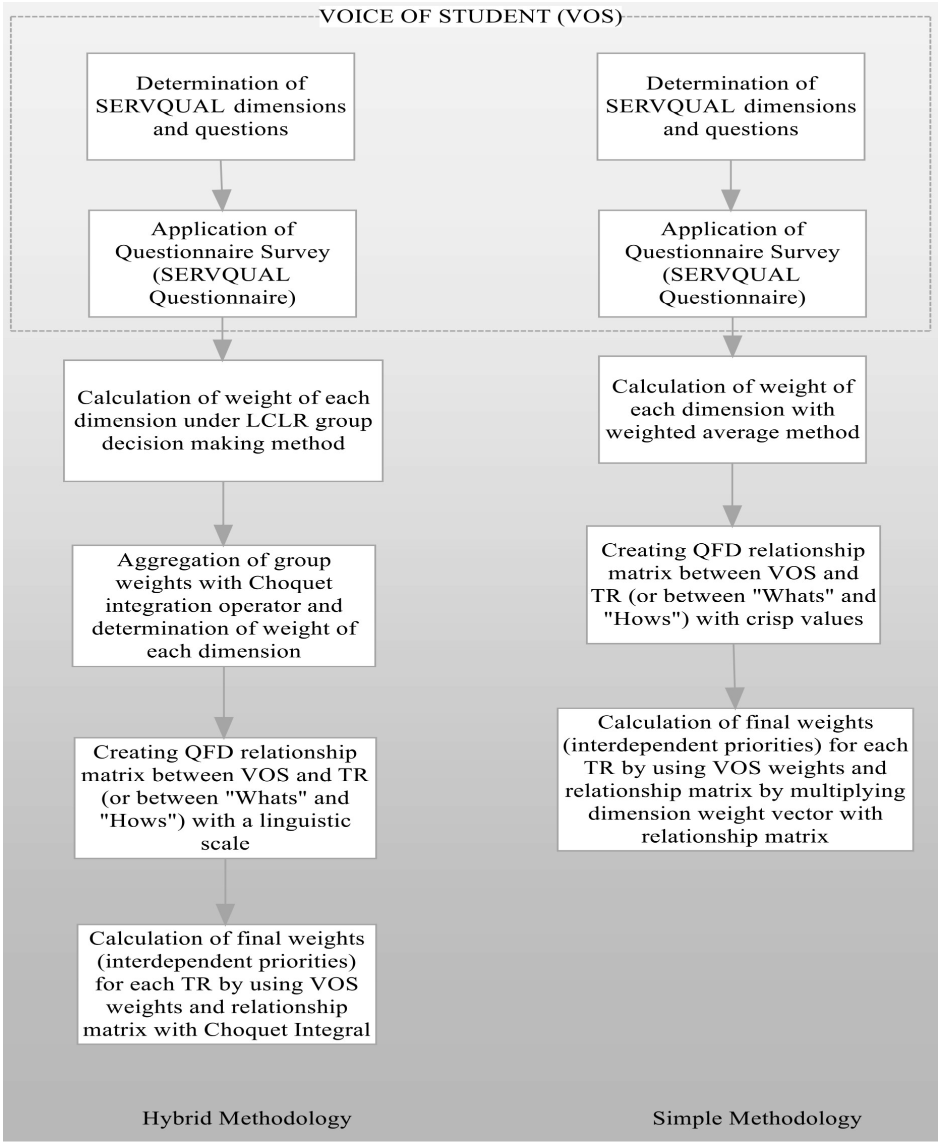

Fig. 2. Steps of the hybrid and basic methodologies.

about the demographic characteristics of the respondents.

In this step, firstly, for all dimensions, an overall SERVQUAL score (SS_l) is calculated as given in Equation (1). (k: total number of questions at dimension l ($l = 1,2, \ldots 5$), n: total number of students, $w\,f_{il}$:factor coefficient of dimension l for student i).

$$SS_l = \frac{1}{k} \cdot \sum_{i=1}^{n} \sum_{t=1}^{m} (|P_{ilt} - E_{ilt}|) \cdot w_{f_i l} \quad (1)$$

According to the SERVQUAL method, both expectations and realized service quality performance are questioned. Here in Equation (1) E_{ilt} and P_{ilt} represent expected service quality and realized performance of service quality, respectively (They can take scores between 1 and 7). The gaps between the expectations and the performances indicate the levels at which the service institution can meet the expectations.

Overall SERVQUAL scores are not used as the final score of each customer need. Here a group-decision approach is used to integrate the group decision effect. The main purpose of using group decision is to emphasize the degree of importance of some student groups. Calculation of relative weights with group decision-making approach is based on Large Column Large Row (LCLR) method. The properties and steps of LCLR algorithm is discussed in the study of Chen et al. [47]. The LCLR method determines the degree of importance of the respondents who have more powerful influence on the results.

Experiences and knowledge backgrounds of individual decision makers are usually different and sometimes the information is incomplete, thus the judgment matrix being constructed by an individual decision maker cannot avoid the disagreements [47, 48]. Students who have low grades have less effect on determining the importance degree of factors (dimensions) than those with higher grades. This is concluded from questionnaire results and it is observed that reliability coefficient (Cronbach alpha value) of lower-grade groups was lower than that of higher-grade groups. And this shows that students who have higher grades are more knowledgeable and more interested with academic and educational factors. Because of these reasons, SERVQUAL scores for each SERVQUAL dimension which are found with Equation (1) are modified according to h functions of Choquet integral.

Equation (2) shows the calculation of h functions of Choquet integral where z represent the groups ($z = 1,2,3$). φ_z is the group decision weights.

$$SS_l \cdot \varphi_z = h(x_{lz}) \tag{2}$$

Step 3. *Calculating interdependent priorities of customer needs with Choquet integral.*

In this step, weights of each dimension in the SERVQUAL model (these can also be called as "customer needs") are calculated. As previously mentioned, there are 5 dimensions in the model. Each dimension has a different importance degree in the customer's point of view. Choquet Integral is used here for aggregating these weights, as it is an efficient aggregation tool for fuzzy variables. Human evaluations are subjective, especially when assessing service quality. Therefore, these assessments are fuzzy in nature. To determine final weights of fuzzy factors, Choquet Integral calculation is required. Properties and technical details of Choquet Integral is discussed below:

Definition of Choquet Integral [49]: Fuzzy integral, which is developed by Tzeng [49], can be defined as follows:

Let $(X, \aleph, g)$ be a fuzzy measure space. The Choquet integral of a fuzzy measure $g : \aleph \rightarrow [0, 1]$ with respect to a simple function h is defined by:

$$\int h(x) \cdot dg \cong \sum_{i=1}^{n} [h(x_i) - h(x_{i-1})] \cdot g(H_i) \tag{3}$$

with the same notions as above, and $h(x_{(0)}) = 0$.

Let g be a fuzzy measure which is defined on a power set $P(x)$. The following characteristic is evidently,

$$\forall A, B \in P(X), A \cap B = \phi \Rightarrow g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B) \;\; for \; -1 \leq \lambda \leq \infty \tag{4}$$

For a set $X = \{x_1, x_2, \cdots, x_n\}$, the density of fuzzy measure $g_i = g_\lambda(\{x_i\})$ can be formulated as follows:

$$g_\lambda(\{x_1, x_2, \cdots, x_n\}) = \sum_{i=1}^{n} g_i + \lambda \sum_{i_1=1}^{n-1} \sum_{i_2=i_1+1}^{n} g_{i_1} \cdot g_{i_2} + \cdots + \lambda^{n-1} \cdot g_1 \cdot g_2 \cdots g_n = \frac{1}{\lambda} \left| \prod_{i=1}^{n} (1 + \lambda \cdot g_i) - 1 \right| \;\; for \; -1 \leq \lambda \leq \infty \tag{5}$$

The Choquet integral can be used to aggregate partial evaluations of a decision. Different clusters are aggregated with a systematic procedure. It plays an important role in this kind of models of multiple evaluations. In this study, different views of different customer groups exist and customers' views are fuzzy.

Step 4. *Deriving Technical Requirements (TRs) according to Voice of Student (VOS).*

A brainstorming team composed of 10 professors and 10 students was formed for deriving the TRs of the desirable university education from the VOS. A Technical Requirement (TR) can be defined as planning of an activity for meeting customer desires. In order to define correct technical requirements for correct customer expectations, expectations and technical requirements must be compatible. This means, technical requirements must be defined according to customer needs. During the brainstorming session, the team members defined necessary service actions for meeting student needs. Then suggestions are evaluated and scored. Finally, essential and applicable actions are determined with final score of each suggestion. These actions are services that are presented by the service system to meet customer needs. In addition, technical requirements are grouped. In the next Section, at the fourth application step, specific definitions of technical requirements are discussed.

Step 5. *Creating a relationship matrix between WHATs and HOWs and defining fuzzy densities for Choquet Integral assuming no inner dependence of TRs.*

The fuzzy evaluation scale for creating the relationship is shown in Table 1. This scale is developed by Yuksel and Dagdeviren [40]. The linguistic values, the related scale and the mean of fuzzy numbers are shown in Table 1.

Step 6. *Calculating interdependent priorities with Choquet aggregation operator.*

In this step, the degree of importance for each technical requirement is calculated. Thus, the service institution can sort the technical requirements according to importance degrees and can consider which technical requirement is prior. Here $h(x_i)$ shows the weight of each dimension (ranges) of

Table 1. Linguistic values and mean of fuzzy numbers [40]

Linguistic values	Triangular fuzzy scale	The mean of fuzzy numbers
Very Low (VL)	(0,0,0.25)	0.00
Low (L)	(0,0.25,0.50)	0.25
Medium (M)	(0.25,0.50,0.75)	0.50
High (H)	(0.50,0.75,1)	0.75
Very High (VH)	(0.75,1,1)	1.00

Table 2. Reliability Coefficients

SERVQUAL Dimensions	Reliability coefficients (Cronbach alpha value)
1. Tangibles	0.823
2. Reliability	0.893
3. Responsiveness	0.701
4. Assurance	0.750
5. Empathy	0.758

VOS. The g expressions (fuzzy densities) are derived from the same method applied in Step 3.

$$\int hdg = \sum_{i=1}^{n} (h(x_i) - h(x_{i-1})) \cdot g\{A_i\} = h(x_1) \cdot g\{x_1, x_2, x_3, x_4, x_5\} + (h(x_1) - h(x_2)) \cdot g\{x_2, x_3, x_4, x_5\} + (h(x_3) - h(x_2)) \cdot g\{x_3, x_4, x_5\} + (h(x_4) - h(x_3)) \cdot g\{x_4, x_5\} + (h(x_5) - h(x_4)) \cdot g\{x_5\} \quad (6)$$

3. Application of the model for a university education program

The SERVQUAL study was conducted with university students in Turkey. Before analyzing the SERVQUAL results, a reliability test was performed with the SPSS 11.5 software [50]. The survey responses were reliable. The reliability coefficients for each dimension are given in Table 2. George and Mallery [51] provided the following rules for Cronbach alpha (CA) value: If 1>CA≥0.9: Excellent, if 0.9 > CA ≥ 0.8: Good, if 0.8 > CA ≥ 0.7: Acceptable, if 0.7 > CA ≥ 0.6: Questionable, if 0.6 > CA ≥ 0.5: Poor, and if CA < 0.5 – Unacceptable".

Application of Step 1. *Deriving customer needs from five dimensions of SERVQUAL application.*

In the SERVQUAL model, there are 5 dimensions which are i. Tangibles, ii. Reliability, iii. Responsiveness, iv. Assurance and v. Empathy. Because we consider education service quality in this study, 5 dimensions of the SERVQUAL model [52] is modified by redefining explanation of each dimension and the 22 default questions of the original model considering specific requirements of university education. Table 3 and 4 show the modified explanations and question items.

Application of Step 2. *Calculating relative weights for Customer Needs (CNs) with SERVQUAL scores under LCLR method assuming no inner-dependence:* The students are grouped according to their GPA scores. Table 5 shows the groups and relative evaluations.

Application of Step 3. *Calculating interdependent priorities (weights) of CNs with Choquet integral.* In this step, weights (importance degrees) are calculated for each dimension with results of the SERVQUAL questionnaire and the results of the Large Column Large Row method. There are 3 different weights for each service quality dimension. However, a single weight is needed for each dimension. It is accomplished by applying the Choquet Integral in this step. First, h and g function values are calculated for the first dimension (namely Tangibles).

$h(x_1) = 0.173; h(x_2) = 0.252; h(x_3) = 0.349$ and
$g_\lambda(x_1) = 0.173; g_\lambda(x_2) = 0.292; g_\lambda(x_3) = 0.397$

Equation 7 shows the calculation of the value of λ.

$$\lambda + 1 = \prod_{i=1}^{n} (\lambda \cdot g_i + 1) \quad (7)$$

λ+1 = (0.173λ + 1)(0.292λ + 1)(0.397λ + 1) (One root of λ equals to 0)

if $\lambda = 0$ additive measure can be used [53].

$$g_\lambda (x_1, x_2) = g_\lambda (x_1) + g_\lambda (x_2) = 0,465 \quad (8)$$

$$g_\lambda (x_1, x_3) = g_\lambda (x_1) + g_\lambda (x_3) = 0,570 \quad (9)$$

$$g_\lambda (x_2, x_3) = g_\lambda (x_2) + g_\lambda (x_3) = 0,689 \quad (10)$$

$$g_\lambda (X) = g_\lambda (x_1, x_2, x_3) = g_\lambda (x_1) + g_\lambda (x_2) + g_\lambda (x_3) = 0,862$$

Table 3. Customer Needs (CNs)

SERVQUAL Dimensions	Explanations
1. Tangibles	The physical appearance of campus, faculty, classrooms and labs must be well enough.
2. Reliability	Academic staff (the professors) and administrative staff must be reliable in terms of class applications such as exams, quizzes etc. and in terms of other administrative applications.
3. Responsiveness	The complaints or other requests to the staff must be evaluated promptly.
4. Assurance	University personnel must be confident.
5. Empathy	The staff must give importance to communication with students.

Table 4. Service quality dimensions (22 SERVQUAL questions)

SERVQUAL Dimensions and sub-dimensions	Parameter
1. Tangibles	S_T
Land spacing	S_{T1}
Outlook of classrooms and buildings	S_{T2}
The cleanliness of janitors	S_{T3}
Outlook of laboratories	S_{T4}
2. Reliability	S_R
Reliability of academicians	SR_1
Student Affairs Office, Library services	S_{R2}
Punctuality of professors in class	S_{R3}
Grading	S_{R4}
The interest of administrative personnel	S_{R5}
3. Responsiveness	S_{RES}
Quick response to problems	S_{RES1}
The support for student social activities	S_{RES2}
Eagerness of administrative and academic staff	S_{RES3}
Tackling problems with students fairly	S_{RES4}
4. Assurance	S_A
Feeling of trust with academic personnel	S_{A1}
Feeling of trust with administrative staff	S_{A2}
Politeness of personnel	S_{A3}
Mastery in field of study	S_{A4}
Self-confidence	S_{A5}
5. Empathy	S_E
The equity of time-schedules for each separate department	S_{E1}
Advisory of professors	S_{E2}
The ease of communication	S_{E3}
Sensibility to problems	S_{E4}

Table 5. Relative Weights of Group Evaluations

Groups	Relative Weights of Groups for Each SERVQUAL Dimension under LCLR Method				
	1. Tangibles	**2. Reliability**	**3. Responsiveness**	**4. Assurance**	**5. Empathy**
Group 1 *(GPA< 2.50)*	0.173	0.165	0.118	0.126	0.087
Group 2 *(2.50 ≤ GPA <3.00)*	0.252	0.241	0.172	0.184	0.127
Group 3 *(3.00 ≤ GPA≤ 4.00)*	0.349	0.334	0.238	0.254	0.176

Calculation of weight for Tangibles is performed with Equation (11):

$$\int hdg = \sum_{i=1}^{n} (h(x_i) - h(x_{i-1})) \cdot g\{A_i\} \qquad (11)$$

$$= h(x_1)\cdot g_\lambda (x_1, x_2, x_3) + (h(x_2) - h(x_1)) \cdot g_\lambda (x_2, x_3) + (h(x_3) - h(x_2)) \cdot g_\lambda (x_3) = 0.242$$

Other weights for SERVQUAL dimensions are calculated by using Equations (7-11) with their own h and g values. The results are shown in Table 6.

Application of Step 4. *Deriving TRs according to CNs. TRs are created with brainstorming team. Technical requirements are group under basic service components and explained below:*

In this step, when creating technical requirements of the system, main components of a service system are taken into consideration by the brainstorming team. A service system is composed of 4 components in general [54]. Therefore, an education system can also be characterized as a composition of i. Direct services, ii. Facilities, iii. Auxiliary goods and services and iv. Indirect services.

i. Direct Services are benefits that are easily observable with senses and serve as essential features of service. In this group administrative personnel and academic personnel are considered as basic service providers of the system. Administrative Personnel (ADP) criterion is composed of the sub-criteria listed below:

- *To participate in the management system as the supervisory personnel,*

Table 6. Weights for SERVQUAL dimensions

	SERVQUAL Dimensions				
g expressions	**1. Tangibles**	**2. Reliability**	**3. Responsiveness**	**4. Assurance**	**5. Empathy**
$g_\lambda(x_1)$	0.173	0.165	0.118	0.126	0.087
$g_\lambda(x_2)$	0.292	0.279	0.199	0.213	0.147
$g_\lambda(x_3)$	0.397	0.381	0.271	0.290	0.200
$g_\lambda(x_1, x_2)$	0.465	0.445	0.317	0.339	0.234
$g_\lambda(x_1, x_3)$	0.570	0.546	0.389	0.416	0.287
$g_\lambda(x_2, x_3)$	0.689	0.660	0.470	0.502	0.347
$g_\lambda(x_1, x_2, x_3)$	0.862	0.825	0.588	0.628	0.434
Choquet weights	**0.242**	**0.222**	**0.113**	**0.129**	**0.061**
Normalized Weights*	**0.316**	**0.289**	**0.147**	**0.168**	**0.080**

** Normalized weights are used in this study to make the sum of the weights equal to 1. An example of 0,316 for tangibles is calculated as:* 0.316 = 0.242 / (0.242 + 0.222 + 0.113 + 0.129 + 0.061). Other weights are also calculated likewise.

- *To be an expert in Management Science,*
- *Counselor Group consisting of members for different areas of management (Education Programs; Project Management; Cooperation with Industry. . . . . etc.),*
- *To be visionary in development of education programs,*
- *To contribute to both researcher groups and lecturer groups.*

Academic Personnel (ACP) criterion is composed of the sub-criteria listed below:

- *To be compatible in the design and development of education programs and curriculums,*
- *To be active researcher in his/her own subject area,*
- *To serve as an active lecturer.*

ii. Facility: Physical resources are indispensable for the offered services. A service system includes buildings, parking area, green space, landscaping, offices, indirect service areas, corridors, furnishing, forms etc. Physical planning and maintenance of facilities plays an important role for achieving and sustaining a high quality engineering education system. Therefore, TRs for Sufficiency and Reliability of Class and Lab. Materials (SRC&CLM) and Environmental Planning of Faculties (EPF) are developed, accordingly. SRC&CLM criterion is composed of the sub-criteria listed below:

- *To procure and maintain projection devices, computers, connection cables etc. in classrooms,*
- *To take protective measures for laboratories, staff members and students against safety risks.*

Environmental Planning of Faculties (EPF) criterion is composed of the sub-criteria listed below:

- *To form an environmental sustainability board in faculties,*
- *To use Green Building Techniques in buildings in order to provide healthy living conditions,*
- *To form an environmental conservation board,*
- *To conduct regional planning efforts including representatives from local governments in order to address air quality.*

iii. Auxiliary Goods and Services: These are the goods and services needed to increase the effectiveness of the direct services. The associated TRs developed are Information Technologies used at a University (IT) and Accessibility to the Campus (ATC) are developed in this concept.

Information Technologies used at a University (IT) is composed of the sub-criteria listed below:

- *To support the use of computers and software to manage information,*
- *To establish and enrich the cooperation with units referred to as Management Information Services (or MIS) and to give training program on the required software programs to the lecturer in faculties.*

Accessibility to the Campus (ATC) is composed of the sub-criteria listed below:

- *To provide easily accessible public transportation services (bus terminal, subway etc.),*
- *To procure personal service vehicles for the personnel and the students.*

iv. Indirect Services: These are psychological and indirect benefits that cannot be directly addressed by the customer but complementary for delivering a quality service. These are determined as Social and Cultural Activities (S&CA) and Campus Health Care Services (CHCS).

Social and Cultural Activities (S&CA) are composed of the sub-criteria listed below:

- *To support student club activities that are helping students in their personal growth,*
- *To organize seminars to expand the vision of the students.*

Campus Health Care Services (CHCS) are composed of the sub-criteria listed below:

- *To procure the establishment of medical units in faculties for simple treatments*,
- *To get easy medical treatment in university hospital.*

Application of Step 5. *Creating relationship matrix between WHATs and HOWs and defining fuzzy densities [55] for Choquet Integral assuming no inner dependence of TRs.*

Table 7 shows relationship matrix with no group decision effect and fuzzy modeling. Here the evaluation is based on crisp (non-fuzzy) values. Final weights of each TR are found by multiplying weights vector with TR relationship matrix of which results are discussed in the next section. Table 8 shows the relationships among VOS and

Table 7. Relationship matrix with no group decision effect and no fuzzy modeling

			Technical Requirements							
Servqual Dimensions	**Customer Needs**	**Customer Weights Determined with Servqual Technique (AVERAGE SCORES)**	**Administrative Personnel**	**Academic Personnel**	**Environmental Planning of Faculties**	**Sufficiency and Reliability of Class and Lab Materials**	**Information Technologies Used at the University**	**Accessibility to the Campus**	**Social and Cultural Activities**	**Campus Health Care Services**
Tangibles	S_{T1} S_{T2} S_{T3} S_{T4}	**0.257**	0	0	1	1	0.5	1	1	1
Reliability	S_{R1} S_{R2} S_{R3} S_{R4} S_{R5}	**0.247**	1	1	0.25	0.5	1	0	0.75	0.5
Responsiveness	S_{RES1} S_{RES2} S_{RES3} S_{RES4}	**0.176**	1	1	0.5	0	1	1	0.25	1
Assurance	S_{A1} S_{A2} S_{A3} S_{A4} S_{A5}	**0.188**	1	1	0	0	1	0	0	0.5
Empathy	S_{E1} S_{E2} S_{E3} S_{E4}	**0.130**	0.75	1	0	0	0	0.5	1	0

Table 8. Relationship matrix with group decision effect and fuzzy modeling

			Technical Requirements							
SERVQUAL Dimensions	**Customer Needs**	**Customer Weights Determined with Choquet Integration operator under Group Decision**	**Administrative Personnel**	**Academic Personnel**	**Environmental Planning of Faculties**	**Sufficiency and Reliability of Class and Lab Materials**	**Information Technology Used at the University**	**Accessibility to the Campus**	**Social and Cultural Activities**	**Campus Health Care Services**
Tangibles	S_{T1} S_{T2} S_{T3} S_{T4}	**0.316**	VL	VL	VH	VH	M	VH	VH	VH
Reliability	S_{R1} S_{R2} S_{R3} S_{R4} S_{R5}	**0.289**	VH	VH	L	M	VH	VL	H	M
Responsiveness	S_{RES1} S_{RES2} S_{RES3} S_{RES4}	**0.147**	VH	VH	M	VL	VH	VH	L	VH
Assurance	S_{A1} S_{A2} S_{A3} S_{A4} S_{A5}	**0.168**	VH	VH	VL	VL	VH	VL	VL	M
Empathy	S_{E1} S_{E2} S_{E3} S_{E4}	**0.080**	H	VH	VL	VL	VL	M	VH	VL

Table 9. Final Weights and Ranking TRs with no group decision effect and no fuzzy modeling

SERVQUAL Technique	ADP	ACP	EPF	SRC&CLM	IT	ATC	S&CA	CHCS
Weights	0.709	0.741	0.407	0.381	0.740	0.498	0.616	0.651
Normalized Values	0.149	0.156	0.086	0.080	0.155	0.105	0.130	0.137
Ranking	**3**	**1**	**7**	**8**	**2**	**6**	**5**	**4**

Table 10. Final Weights and Ranking Technical Requirements according to hybrid methodology

Choquet Integral	ADP	ACP	EPF	SRC&CLM	IT	ATC	S&CA	CHCS
Final Weights	0.460	0.466	0.350	0.338	0.420	0.398	0.418	0.391
Normalized	0.142	0.144	0.108	0.104	0.130	0.123	0.129	0.121
Ranking	**2**	**1**	**7**	**8**	**3**	**5**	**4**	**6**

TR (or WHATs and HOWs). The relationship matrix is created with the fuzzy scale. Values in the third column are taken from the last row Table 6.

Application of Step 6. *Calculating interdependent priorities with Choquet aggregation operator:* In this step, after determining the weights of the *student quality requirements*, in other words, VOS based SERVQUAL technique considering no group decision effect and no fuzzy modeling as in Step 3 in Table 6, the weights of *educational service elements*, in other words, TRs, can be also determined based on both SERVQUAL technique and Choquet Integration Operator under Group Decision. Table 9 shows the weights calculated for each TR based on SERVQUAL technique with no group decision effect and fuzzy modeling as in Step 3. Table 10 also indicates the weights for each TR based Choquet Integration Operator under Group Decision.

4. Results and discussion

When comparing the results of Table 9 with those of Table 10, in SERVQUAL technique with no group decision effects and no fuzzy modeling, the highest priority of TRs belongs to Academic Personnel and the least priority of TRs belongs to Sufficiency and Reliability of Class and Lab Material. This result is similar to those of Choquet integration operator under group decision. Ranking order according to SERVQUAL technique based on crisp numbers can be given as ACP > IT > ADP > CHCS > S & CA > ATC > EPF > SRC & CLM. When group decision effect, fuzzy numbers and linguistic terms are considered, this ranking order is to change as ACP > ADP > IT > S & CA > ATC > CHCS > EPF > SRC & CLM.

According to the results, academic and administrative personnel are the important requirements for a qualified university education. Jensen [56] emphasizes the importance of quality improvement tools and methods in engineering education. There are several issues taken into consideration in this study. One of the most important issues highlighted in this study is the importance of qualified personnel for a good quality engineering education system. Findings in Jensen's study coincides with findings in this study. University education can be considered as a many-sided investment for a student. Students are to attend in university for dedication and commitment towards the goal of learning and achieving. In this journey the quality of lecturers and researchers at university are very important in determining and improving the vision of students. After lecturers and researchers, the most important people are the administrative personnel. The administrative personnel help in the social education of students by supporting social activities.

Other important necessity for a good university education is the information technologies used at the university. Especially in recent years, the information technologies are rapidly growing. That is why the students prefer universities that are good at technological development.

The results also emphasize that social and cultural activities are more important than some characteristics such as accessibility and health care delivery in the campus. The least important characteristics are environmental planning and sufficiency of class and lab materials.

5. Conclusions

To provide an efficient and effective engineering education, it is important to dignify to opinions of customers, namely students, and listening to their voice. Improvement of service quality in engineering education is an important point that enables service providers to discover the gap between expected service by students and realized service activities. In addition, it is also important to explore how students' needs will be met. In this sense, SERVQUAL and QFD approaches are suitable tools for this objectives. This study uses SERVQ-

UAL for discovering what engineering students request for a quality education and this study also uses QFD for discovering how students' requests can be met. In the study, these two methods are combined and enriched with group decision effect and Choquet Integral to obtain more reliable and practical results.

Engineering students' needs are grouped under 5 dimensions of SERVQUAL model which are: Tangibles, Reliability, Responsiveness, Assurance and Empathy. In order to provide suitable services to meet students' needs, Technical Requirements of Administrative Personnel, Academic Personnel, Sufficiency and Reliability of Class and Lab. Materials, Environmental Planning of Faculties, Information Technologies used at University, Accessibility to the Campus, Social and Cultural Activities and Campus Health Care Services are determined. In addition, the importance degree of each technical requirement is calculated with two different methods and they are compared in detail. The results have shown that academic personnel, administrative personnel and information technology services play the most important 3 roles in engineering education.

Not only determining service quality requirements but also proposing actions how to fulfill these requirements, the service quality approach in this study addresses the problem in all directions. In this sense, the student-driven approach developed in this study has been useful to provide totalitarian management touch for the engineering education institutions.

In future time, inner-dependence matrixes can be studied taking into consideration the other phases of QFD. The inner dependence matrix of educational service elements, in other words, TRs, have not been considered as it is in a classic HoQ evaluation procedure. Since there is no inner-dependence among educational service elements. At least, it has not been projected in the scope of this study. The proposed methodology is flexible in manner to be able to use in the other investigation areas. This methodology has the characteristic of "Hybrid Evaluation System" because of including SERVQUAL and QFD techniques based on area survey and Group Decision Making Technique based on LCLR and Choquet Integration.

List of Acronyms

QFD: Quality Function Deployment
SERVQUAL: Service Quality Model
CN: Customer Needs
VOS: Voice of Student
TR: Technical Requirement
HoQ: House of Quality
LCLR: Large Column Large Row Method

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