International Journal of Information Technology & Decision Making
Vol. 16, No. 1 (2017) 225–244
© World Scientific Publishing Company
DOI: 10.1142/S0219622015500406

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A Fuzzy Linguistic Extended LibQUAL+ Model to Assess Service Quality in Academic Libraries

F. J. Cabrerizo

Department of Software Engineering and Computer Systems
Universidad Nacional de Educación a Distancia (UNED)
Madrid 28040, Spain
cabrerizo@issi.uned.es

J. López-Gijón

Department of Library Science
University of Granada, Granada 18071, Spain
jgijon@ugr.es

M. A. Martínez

Department of Social Work and Services
University of Granada, Granada 18071, Spain
mundodesilencio@ugr.es

J. A. Morente-Molinera

Department of Computer Science and Artificial Intelligence
University of Granada, Granada 18071, Spain
jamoren@decsai.ugr.es

E. Herrera-Viedma

Department of Computer Science and Artificial Intelligence
University of Granada, Granada 18071, Spain
and
Department of Electrical & Computer Engineering
King Abdulaziz University, Jeddah 21589, Saudi Arabia
viedma@decsai.ugr.es

Published 6 January 2016

LibQUAL+ model is the best-known method for the quality evaluation of library services, but it has two major drawbacks. First, to measure the quality, it is devised on a cardinal scale: the service levels range from 1 to 9. However, the standard representation of the concepts used by humans for communication is the natural language and, hence, users should express their judgments by using words instead of numbers. Second, it considers that all users' opinions are equally important. Nevertheless, users do not play an equal role in assessing the service quality, i.e., the opinion given by some users should be more relevant than the opinion provided by others. To solve these drawbacks, we present an extended LibQUAL+ model representing the

users' perceptions by using a fuzzy linguistic modeling and taking into account that users' opinions on the library services are not equally important.

Keywords: Academic library; quality evaluation; LibQUAL+; fuzzy linguistic modeling.

1. Introduction

The essential reason of the existence of an academic library, and at the same time its main role, is to support the research and educational work conducted within an Academic Institution.[1] It is difficult to imagine a University without an academic library as it is such a functional, integral part of the University.[2] Therefore, it is fundamental to improve the services offered by an academic library.[3,4] In addition, since funding for universities and higher education is being decreased year after year,[5] and an academic library is increasingly becoming in a resource center for research and permanent learning, the quality evaluation of the library services is more relevant than ever.[6]

The quality of an academic library has tended to be defined in terms of richness of resources. Measures such as the number of patrons served or the size of the academic library collection have traditionally been used. However, quality measures based exclusively on collections have become antiquated.[7] As the goal of an academic library is to meet users' expectations, service quality must be assessed with a new approach considering users' needs.[8–10] In such a way, one of the appropriate evaluation methods of the academic library services is the one based on the opinions given by the users. An academic library is a service institution and, therefore, better service will be offered if the needs and nature of its users are known. According to users' judgments, observed strengths and weaknesses can be understood and, with the aim of developing strengths and eliminating defects, proposals can be offered to this end.

The survey method is one of the most important methods for evaluating the library service quality using users' perceptions as detailed information is offered about users' opinions, it makes visible the problems, it clarifies the concept of service, and it provides feasible solutions. Furthermore, environment variables cannot be manipulated and the environment is less controlled.[8]

LibQUAL+ model[11] is the most popular and the best-known library survey. More than 1,100 libraries have taken part in LibQUAL+ since 2000, including community college libraries, academic law libraries, health sciences libraries, public libraries, and university and college libraries.[8,12–15] It was created in the US with the aim of collecting data on the library service quality. The objective of its designers was to create an instrument which would assist libraries better understand their users' judgments of service quality and to utilize this knowledge in planning their operations. The information obtained from the survey allows the identification of areas needing improvement. Furthermore, it has also been used to recognize best practices and reallocate resources in accordance.[14]

Despite its popularity, the LibQUAL+ model has some drawbacks. On the one hand, users respond to each question providing a value from 1 to 9 on a 9-points Likert scale.[16] Nevertheless, since the process of quality evaluation is centered on humans, coming with their intrinsic vagueness, subjectivity and imprecision in the verbal expression of impressions, the theory of fuzzy sets,[17] which was introduced by Zadeh, is a more suitable instrument to represent often not well-defined preferences found in most practical situations. Furthermore, as the information expressed by humans is by nature nonnumeric, opinions, preferences, and evaluations are commonly provided linguistically.[18–21] Therefore, a more flexible, realistic, less specific, and suitable form to articulate the opinions on each question is by using sentences or words rather than numerical values. On the other hand, LibQUAL+ model considers that all users have the same importance in evaluating each question on the library service levels. However, in the quality evaluation of library services, the information managed by the users is not equally important, that is, it is a heterogeneous framework.[22,23] For instance, when the users provide their judgments on the community space for group learning and group study, their assessments must not be considered with equal relevance, given that, there are users, such as students, with more knowledge on the community space for group learning and group study than others, such as professors, and, as a consequence, all the judgments are not equally trustworthy. Anyway, a global and final assessment must be obtained utilizing the individual and initial assessments.

The objective of this study is to present a fuzzy linguistic extended LibQUAL+ model, overcoming the above drawbacks of the LibQUAL+ model, to evaluate the quality of the services offered by an academic library according to users' perceptions. Our extended LibQUAL+ model utilizes the ordinal fuzzy linguistic modeling[24] to represent the users' judgments and takes into account that users' opinions on the library services are not equally important. To do so, tools of computing with words based on the Linguistic Ordered Weighted Averaging[24] (LOWA) aggregation operator and the Linguistic Weighted Averaging[25] (LWA) aggregation operator are used to obtain the quality assessments.

The study is arranged into five sections. In Sec. 2, the bases of the fuzzy linguistic extended LibQUAL+ model, that is, the ordinal fuzzy linguistic modeling for computing with words and the LibQUAL+ model, are presented. Section 3 describes the extended LibQUAL+ model presented in this study. To illustrate the application of this model, a Spanish academic library is evaluated in Sec. 4. Finally, we point out some concluding remarks in Sec. 5.

2. Preliminaries

In this section, we describe both the fuzzy linguistic approach for computing with words and the LibQUAL+ model, which are necessary to design the fuzzy linguistic extended LibQUAL+ model presented in this study.

2.1. *A fuzzy linguistic approach for computing with words*

In real-life situations, there are many cases in which the information has to be assessed in a qualitative form instead of a quantitative one. On the one hand, the phenomena related to human perception are better qualified using words in natural language instead of numbers. On the other hand, exact quantitative information cannot be expressed as either the cost for its calculation is too high or it is unavailable. In both cases, an approximate value may be appropriate. For modeling qualitative information, the theory of fuzzy sets[17] has provided good outcomes and it has conclusively been demonstrated to be helpful in many problems, e.g., in quality evaluation,[26,27] recommender systems,[28–30] decision making,[31–33] and so on.

To deal with vague and fuzzy qualitative features of problems, the fuzzy linguistic approach may be used. It models linguistic information by using linguistic terms supported by linguistic variables,[34–36] whose values are sentences or words in a natural language instead of numbers. In addition, a syntactic rule and a semantic rule are used to define a linguistic variable. Although the numerical approach is more precise than the fuzzy linguistic one, this last one presents the following advantages:

(i) Even when the context is changing or the concepts are abstract, the linguistic description is understood with ease by human beings.
(ii) The more refined assessment scale are the more sensitive to noise. Therefore, because of linguistic scales being less refined than numerical ones, they are less sensitive to the appearance of errors and their propagation.

In this study, among the different linguistic approaches proposed in the literature,[18,19] the ordinal fuzzy linguistic approach[24,25] is used because it simplifies the definition of the syntactic and semantic rules, and, therefore, the fuzzy linguistic modeling is made very much easier. To do so, a finite and totally ordered linguistic term set $S = \{s_i\}$, $i \in \{0, \ldots, \mathcal{T}\}$, in the usual sense, that is, $s_i \geq s_j$ if $i \geq j$, and with odd cardinality, is considered. Usually, the values of the cardinality are odd values, with an upper limit of granularity of 11 or no more than 13. Furthermore, the mid term represents an assessment of "approximately 0.5", being the rest of linguistic terms situated symmetrically around it. These values fall in line with Miller's observation about the fact that human beings can rationally manage to bear in mind seven or so items.[37] According to the ordered structure of the linguistic term set, the semantics of the linguistic terms are established by considering that each linguistic term for the pair $(s_i, s_{\mathcal{T}-i})$ is equally informative. For instance, the following set of nine linguistic terms may be used to express the users' opinions: {N = None, EL = Extremely Low, VL = Very Low, L = Low, M = Medium, H = High, VH = Very High, EH = Extremely High, T = Total}.

The simplicity and quickness of the computational model of the ordinal fuzzy linguistic approach is one of its advantages. The computational model is based on the symbolic computation[24,25] and operates by direct calculation on linguistic terms by considering the order of such linguistic terms in the ordered structure of the set.

Using a fuzzy linguistic approach, this symbolic tool is natural as the linguistic evaluations are simply approximations provided and handled when it is unnecessary or impossible to get more precise values. As a consequence, the use of membership functions associated to the linguistic terms is not necessary in this case.

The ordinal fuzzy linguistic model is usually determined by establishing (i) a negation operator, (ii) comparison operators that are based on the ordered structure of linguistic terms, and (iii) suitable aggregation operators of ordinal fuzzy linguistic information. On the one hand, the negation operator is habitually defined from the semantics associated to the linguistic terms as $Neg(s_i) = s_j \mid j = \mathcal{T} - i$. On the other hand, two comparison operators of linguistic terms are defined as follows:

- Maximization operator: $\max(s_i, s_j) = s_i$ if $s_i \geq s_j$.
- Minimization operator: $\min(s_i, s_j) = s_i$ if $s_i \leq s_j$.

To complete the ordinal fuzzy linguistic computational model, two aggregation operators based on symbolic calculation are presented in the following sections.

2.1.1. *The LOWA aggregation operator*

This aggregation operator is based on symbolic computation to aggregate ordinal linguistic values with equal importance.[24]

Definition 2.1. Let $A = \{a_1, \ldots, a_m\}$ be a set of linguistic terms to be aggregated, then the LOWA operator, ϕ, is defined as follows:

$$\begin{aligned}\phi(a_1, \ldots, a_m) &= W \cdot B^T = \mathcal{C}^m\{(w_k, b_k),\ k = 1, \ldots, m\} \\ &= w_1 \odot b_1 \oplus (1 - w_1) \odot \mathcal{C}^{m-1}\{(\beta_h, b_h),\ h = 2, \ldots, m\}, \end{aligned} \tag{2.1}$$

where $W = [w_1, \ldots, w_m]$ is a weighting vector, such that, $w_i \in [0, 1]$ and $\Sigma_i w_i = 1$. $\beta_h = w_h / \Sigma_2^m w_k$, $h = 2, \ldots, m$ and $B = \{b_1, \ldots, b_m\}$ is a vector associated to A, such that, $B = \sigma(A) = \{a_{\sigma(1)}, \ldots, a_{\sigma(m)}\}$, where $a_{\sigma(j)} \leq a_{\sigma(i)}\ \forall\ i \leq j$, with σ being a permutation over the set of linguistic terms A. $\mathcal{C}^m$ is the convex combination operator of m linguistic terms and if $m = 2$, then it is defined as follows:

$$\mathcal{C}^2\{(w_i, b_i),\ i = 1, 2\} = w_1 \odot s_j \oplus (1 - w_1) \odot s_i = s_k, \tag{2.2}$$

such that, $k = \min\{\mathcal{T},\ i + round(w_1 \cdot (j - i))\}$, $s_j, s_i \in S$, $(j \geq i)$, where "*round*" is the usual round operation, and $b_1 = s_j$, $b_2 = s_i$. If $w_j = 1$ and $w_i = 0$, with $i \neq j$, $\forall i$, then the convex combination is defined as: $\mathcal{C}^m\{(w_i, b_i),\ i = 1, \ldots, m\} = b_j$.

Example of application of the LOWA aggregation operator: Let us consider the above set of nine linguistic terms and suppose that we want to aggregate by means of the LOWA aggregation operator the following four linguistic terms, {EL, VL, EH, T}. Assuming this weighting vector $W = [0.3, 0.2, 0.4, 0.1]$ the general expression of the aggregation of linguistic terms is:

$$\begin{aligned}\phi(\text{EL}, \text{VL}, \text{EH}, T) &= [0.3, 0.2, 0.4, 0.1](T, \text{EH}, \text{VL}, \text{EL}) \\ &= C^4\{(0.3, T), (0.2, \text{EH}), (0.4, \text{VL}), (0.1, \text{EL})\}.\end{aligned}$$

Then, we obtain the final result applying the recursive definition of the convex combination, C^4, as follows. First, we develop C^4 until its simpler expression in the following steps:

(i) For $m = 4$,

$$C^4\{(0.3, T), (0.2, \text{EH}), (0.4, \text{VL}), (0.1, \text{EL})\} = 0.3 \odot T \oplus (1 - 0.3) \odot C^3\{(0.29, \text{EH}), (0.57, \text{VL}), (0.14, \text{EL})\}.$$

(ii) For $m = 3$,

$$C^3\{(0.29, \text{EH}), (0.57, \text{VL}), (0.14, \text{EL})\} = 0.29 \odot \text{EH} \oplus (1 - 0.29) \odot C^2\{(0.80, \text{VL}), (0.20, \text{EL})\}.$$

Now, we are going to go back solving the simpler cases until obtaining the final result:

(i) For $m = 2$,

$$C^2\{(0.80, \text{VL}), (0.20, \text{EL})\} = 0.80 \odot \text{VL} \oplus (1 - 0.80) \odot \text{EL} = \text{VL},$$

since $\text{VL} = s_2$ and $\text{EL} = s_1$ then

$$\min\{8, 1 + \mathit{round}(0.80 \cdot (2 - 1))\} = \min\{8, 2\} = 2.$$

(ii) For $m = 3$,

$$C^3\{(0.29, \text{EH}), (0.57, \text{VL}), (0.14, \text{EL})\} = 0.29 \odot \text{EH} \oplus (1 - 0.29) \odot C^2\{(0.80, \text{VL}), (0.20, \text{EL})\} = L,$$

since $\text{EH} = s_7$ and $\text{VL} = s_2$ then

$$\min\{8, 2 + \mathit{round}(0.29 \cdot (7 - 2))\} = \min\{8, 3\} = 3.$$

(iii) Finally, we obtain the final result for $m = 4$,

$$C^4\{(0.3, T), (0.2, \text{EH}), (0.4, \text{VL}), (0.1, \text{EL})\} = 0.3 \odot T \oplus (1 - 0.3) \odot C^3\{(0.29, \text{EH}), (0.57, \text{VL}), (0.14, \text{EL})\} = H,$$

since $T = s_8$ and $L = s_3$ then

$$\min\{8, 3 + \mathit{round}(0.3 \cdot (8 - 3))\} = \min\{8, 5\} = 5.$$

The LOWA aggregation operator is an "or-and" operator[24] and its behavior may be regulated by means of the weighting vector W. Yager[38] presented a measure of *orness*, associated with any weighting vector W : $\mathit{orness}(W) = \frac{1}{m-1} \sum_{i=1}^{m} (m - i) w_i$, with the aim of classifying Ordered Weighted Averaging (OWA) operators regarding to their localization between "or" and "and". The *orness* describes the degree to which the aggregation is like an "or" (max) operation: an OWA operator with $\mathit{orness}(W) < 0.5$ will be an *andlike* operator, and with $\mathit{orness}(W) \geq 0.5$ will be an *orlike* operator.

The determination of the weighting vector W is an important issue of the LOWA aggregation operator. In Ref. 38, an expression to obtain the weighting vector W, allowing to represent the concept of fuzzy majority[39] by means of a fuzzy linguistic nondecreasing quantifier Q,[40] was proposed:

$$w_i = Q(i/n) - Q((i-1)/n), \ \ i = 1, \ldots, n. \tag{2.3}$$

When a fuzzy linguistic quantifier Q is utilized to calculate the weights of LOWA operator ϕ, it is represented by ϕ_Q.

2.1.2. *The LWA aggregation operator*

This aggregation operator, which is based on the LOWA aggregation operator, is another important aggregation operator of ordinal linguistic values.[25] Unlike the LOWA aggregation operator, the LWA aggregation operator is defined to aggregate linguistic information values with not equal importance.

The aggregation of information with not equal importance, i.e., weighted information, is carried out by involving two activities. First, the weighted information is transformed under the importance degrees by using a transformation function h, which is determined by the type of aggregation of weighted information that is going to be performed. In Ref. 38, the effect of the importance degrees on the "max" and "min" types of aggregation was discussed by Yager. He also suggested a class of functions for importance transformation in both types of aggregation. On the one hand, for the "min" aggregation, Yager proposed a family of t-conorms acting on the weighted information and the negation of the importance degree, which presents the nonincreasing monotonic property in these importance degrees. On the other hand, for the "max" aggregation, Yager proposed a nondecreasing monotonic property in these importance degrees. Second, the transformed weighted information is aggregated by using an aggregation operator of nonweighted information f.

According to it, the LWA aggregation operator was proposed in Ref. 24. However, in this study, it is redefined with the aim of simplifying its expression. In such a way, we use the *orness* measure and the LOWA aggregation operator ϕ as f.

Definition 2.2. According to the LWA aggregation operator, Φ, the aggregation of a set of weighted linguistic terms, $\{(c_1, a_1), \ldots, (c_m, a_m)\}$, $c_i, a_i \in S$, is defined as follows:

$$\Phi[(c_1, a_1), \ldots, (c_m, a_m)] = \phi(h(c_1, a_1), \ldots, h(c_m, a_m)), \tag{2.4}$$

where a_i stands for the weighted linguistic term, c_i represents the importance degree of a_i and h is the transformation function defined depending on the weighting vector W utilized for the LOWA aggregation operator ϕ, such that $h = \min(c_i, a_i)$, if $orness(W) \geq 0.5$, and $h = MAX(Neg(c_i), a_i)$, if $orness(W) < 0.5$.

Example of application of the LWA operator: Let us consider the above set of nine linguistic terms. We want to aggregate by means of the LWA aggregation operator the following seven labels, {H, N, M, VH, M, L, L} with the

following linguistic importance degrees {H, L, VH, VH, T, H, L}. Supposing the weighting vector $W = [0.28, 0.28, 0.28, 0.16, 0, 0, 0]$, we have an *orness(W)* ≥ 0.5, and, therefore, $h = \min(c_i, a_i)$. Then, using the LWA aggregation operator we obtain:

$$\begin{aligned}\Phi((H,H),(L,N),(\text{VH},M),(\text{VH},\text{VH}),(T,M),(H,L),(L,L)) \\ = \phi_Q(\min(H,H),\min(L,N),\min(\text{VH},M),\min(\text{VH},\text{VH}), \\ \min(T,M),\min(H,L),\min(L,L)) = \phi_Q(H,N,M,\text{VH},M,L,L).\end{aligned}$$

Using the LOWA operator as in the above example, we obtain the following value: $\phi_Q(H, N, M, \text{VH}, M, L, L) = H$.

Finally, we should point out that the fuzzy linguistic extended LibQUAL+ model proposed in this study is based on the LOWA and LWA aggregation operators. These two aggregation operators have been chosen because of the following reasons:

(i) They are complementary. The LWA aggregation operator is defined from the LOWA aggregation operator and, therefore, the design of the evaluation model is simplified.
(ii) Linguistic approximation processes are not necessary as these aggregation operators operate by symbolic computation. In such a way, the processes of computing with words are simplified.
(iii) The concept of fuzzy majority, which is represented by linguistic quantifiers, operates in the computation process of the LOWA and LWA aggregation operators. Therefore, the assessments of the library service quality are obtained according to the majority of the evaluations given by the users.

2.2. *The LibQUAL+ model*

LibQUAL+ model[11] is a survey that is administered by the Association for Research Libraries (ARL) to measure users' perceptions of library service quality and to assist libraries recognize service areas that need improvement. Its basis is the attribute-based gap model SERVQUAL,[41] which was created for being used in the for-profit business sector in the 1980s.[41–44] Built upon the "Gap Theory of Service Quality", SERVQUAL claims that "only customers judge quality; all other judgments are essentially irrelevant".[45] In SERVQUAL, the gap between customer's perceptions and expectations defines the service quality: when expectations exceed experiences, the service quality is low, and vice versa.[14] Modified SERVQUAL instruments were used by the Texas A&M University Libraries and other libraries for several years. It revealed the need for an adapted tool that would work for the particular needs of libraries. Then, ARL joined with Texas A&M University Libraries to develop the LibQUAL+ model, which seeks to investigate original ways for libraries to measure their value.

To do so, the LibQUAL+ survey is composed of 22 core questions measuring perceptions that concern three dimensions of library service quality[12]:

(i) *Affect of service*: This dimension assesses responsiveness, empathy, reliability and assurance of library employees. It includes the following nine questions:

- q_1: Employees who instill confidence in users.
- q_2: Giving users individual attention.
- q_3: Employees who are consistently courteous.
- q_4: Readiness to respond to users' questions.
- q_5: Employees who have the knowledge to answer user questions.
- q_6: Employees who deal with users in a caring fashion.
- q_7: Employees who understand the needs of their users.
- q_8: Willingness to help users.
- q_9: Dependability in handling users' service problems.

(ii) *Library as place*: This dimension measures the library as a refuge for work of study, the symbolic value of the library, and the usefulness of space. It includes the following five questions:

- q_{10}: Library space that inspires study and learning.
- q_{11}: Quiet space for individual activities.
- q_{12}: A comfortable and inviting location.
- q_{13}: A getaway for study, learning or research.
- q_{14}: Community space for group learning and group study.

(iii) *Information control*: This dimension assesses how users want to interact with the modern library and includes timeliness and convenience, scope, modern equipment, ease of navigation and self-reliance. It contains the following eight questions:

- q_{15}: Making electronic resources accessible from my home or office.
- q_{16}: A library Web site enabling me to locate information on my own.
- q_{17}: Printed library materials I need for my work.
- q_{18}: The electronic information resources I need.
- q_{19}: Modern equipment that lets me easily access needed information.
- q_{20}: Easy-to-use access tools that allow me to find things on my own.
- q_{21}: Making information easily accessible for independent use.
- q_{22}: Print and/or electronic journal collections I require for my work.

Library users are requested, for each question, to provide their desired service level (DSL), their minimum acceptable service level, and the perception of the actual service offered by the library. To do so, a score from 1 to 9 is given. The importance that the service has to the library user is reflected by the minimum service level (MSL) and the DSL: a high level means that it is considered very important, and when the desired or MSL receives a low score, it is not considered important. A superiority gap (the perceived quality regarding the DSL by the

library users) and an adequacy gap (the perceived quality regarding the MSL that is accepted by the library users) are determined according to the responses given by the library users.[14]

The survey also asks supplementary queries on overall satisfaction and information literacy, and some queries concerning other information sources and the use of libraries. In this case, library users are asked for their impressions about queries on overall satisfaction and information literacy by giving a score from 1 to 9, while the queries concerning the other information sources and the use of libraries are answered by giving a value among "Daily", "Weekly", "Monthly", "Quarterly" or "Never". Finally, library users may express an open feedback and are also requested to provide their demographic profile, including sex, age group, status, and discipline. It makes easy a group-wise analysis of the results.[14]

3. An Extended LibQUAL+ Model Based on Fuzzy Linguistic Information to Assess Service Quality in Academic Libraries

In this section, we present the extended LibQUAL+ model based on fuzzy linguistic information to assess the service quality in academic libraries according to users' perceptions, which is developed by using the LibQUAL+ model as basis of it.

As aforementioned, the drawbacks of the LibQUAL+ model are: (i) for each question, users give a score from 1 to 9 on a 9-points Likert scale to provide the MSL that they accept, their DSL, and their perception of the current service provided by the academic library, and (ii) it considers that all the users' opinions on the library services are equally important. To overcome these drawbacks, we adapt the LibQUAL+ model to develop our fuzzy linguistic extended LibQUAL+ model. To do so, a quality evaluation model of academic libraries is defined. It presents two elements: (i) an evaluation scheme containing the 22 questions related to the three dimensions of library service quality and (ii) a computation method that generates quality assessments and is able to obtain the weaknesses and strengths of the academic libraries.

3.1. *Evaluation scheme*

The evaluation scheme developed as a part of the evaluation model presents the following characteristics:

(i) *It is user driven*: Since the quality of academic libraries is obtained from the judgments expressed by their users, the evaluation scheme should be user driven in place of design driven. Hence, the evaluation scheme necessarily requires the inclusion of questions about library service quality easily understandable to any user rather than questions that can objectively be measured independently of users. As the basis of our model is the LibQUAL+ model, we use the same 22 questions concerning the three dimensions of library service quality (see Sec. 2.2 for more details), which are easily understandable to any user. Furthermore, as

this number of questions is not excessive, it helps users in understanding it. As it is known, long and complex evaluation schemes bring about user idleness and limit their own application possibilities.

(ii) *It is weighted*: The users of the academic library do not play an equal role in evaluating library service quality, i.e., some users should be more influential than others in some questions. It is because the degree of knowledge, relevancy, and experience, may not be equal among them. Therefore, it is not always valid that all users have equal importance in regard to the decision being made. For instance, the students' opinions on the community space for group learning and group study should be more important that the professors' opinion. In such a way, there must be an allowance for such differences in weight or importance as the framework is heterogeneous.[22,23]

3.2. *Computation method*

The computation method of the evaluation model proposed in this study resembles a multi-person multi-criteria decision-making problem.[46–48] In this kind of problems, the objective is to obtain the best alternatives according to the evaluations given by a group of decision makers concerning a set of evaluation criteria. To do so, by means of the aggregation of the assessments expressed by the decision makers, the quality of the alternatives is obtained and, next, the exploitation of the quality values leads to the choice of the best alternatives. Here, the aim is to compute quality assessments of library services, but as in a multi-criteria decision context, these values are calculated in accordance with the evaluations given by the library users.

The aggregation operator that is chosen has a direct influence on the success of the decision process in a multi-person multi-criteria decision-making problem. In our computation method, we use quantifier guided aggregation operators based on the LOWA operator. We select them as they constitute a successful tool to aggregate information because of their flexibility, that is, they allows the representation of different interpretations of the concept of majority by means of fuzzy linguistic quantifiers.[38]

The computation method presents the following two main characteristics:

(i) *It is a user-centered computation method*: Instead of using assessments obtained objectively by means of direct observation of the academic library characteristics, the quality assessments are obtained from the opinions given by the library users.

(ii) *It is a majority guided computation method*: The quality assessments represent the majority of individual opinions given by the users of the academic library. To do so, the LOWA and LWA aggregation operators are used.

Considering the above aspects, a quality evaluation questionnaire, which is based on the 22 questions of the LibQUAL model, is defined. With respect to the software aspects of the quality evaluation questionnaire, we want to comment that it is based

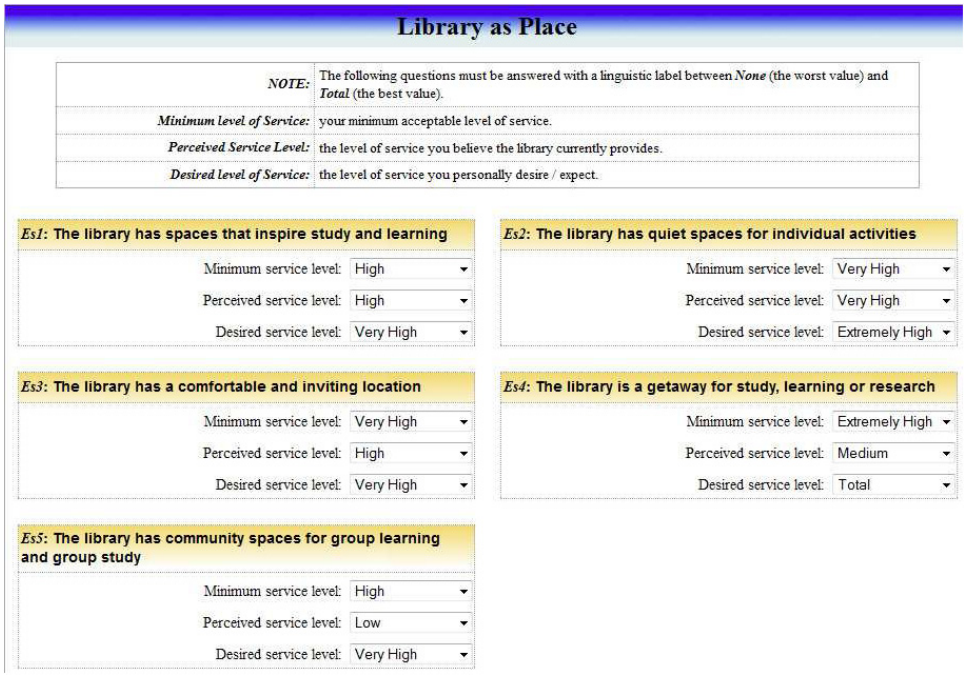

Fig. 1. Snapshot of the quality evaluation questionnaire.

on a LAMP stack[49] (GNU/Linux, Apache Web server, MySQL database and PHP programming language). In addition, it is fully web-based and, therefore, all its options and components may be accessed through a web interface. In Fig. 1, a snapshot of the quality evaluation questionnaire, which shows the questions related to the library as place dimension (LPD), is presented.

The MSL, the performance level, and the DSL behind each question are rated on a linguistic term set S. Here, the linguistic term set presented in Sec. 2.1 is utilized. Furthermore, as it is assumed that each user does not have the same importance in the evaluation scheme, a linguistic importance degree, $I(e_l, q_i) \in S$, for each library user, e_l, on each question, q_i, is assigned. It should be pointed out that this importance degree may be obtained from either a set of decision makers or the staff members of the academic library. In addition, it may be different for each academic library.

Once the library users, $\{e_1, \ldots, e_L\}$, have filled all the questionnaires for a given academic library, A_m, the model calculates the quality assessments of the academic library and obtains its weaknesses and strengths using the LWA and LOWA aggregation operators in the following way:

(i) For each question, q_i, all the evaluation judgments given by the library users are aggregated by means of the LWA aggregation operator, Φ, in order to obtain its global quality assessment of the MSL, MSL_i^m, its global quality assessment of the perceived performance level (PPL), PPL_i^m, and its global quality assessment of

the DSL, DSL_i^m:

$$\begin{aligned}
\mathrm{MSL}_i^m &= \Phi_Q((I(e_1, q_i), e_1(q_i^{MSL})), \ldots, ((I(e_L, q_i), e_L(q_i^{MSL}))),\\
PPL_i^m &= \Phi_Q((I(e_1, q_i), e_1(q_i^{PPL})), \ldots, ((I(e_L, q_i), e_L(q_i^{PPL}))),\\
\mathrm{DSL}_i^m &= \Phi_Q((I(e_1, q_i), e_1(q_i^{DSL})), \ldots, ((I(e_L, q_i), e_L(q_i^{DSL}))),
\end{aligned} \tag{3.5}$$

where $e_l(q_i^{\mathrm{MSL}}) \in S$ stands for the MSL provided by the library user e_l on question q_i, $e_l(q_i^{\mathrm{PPL}}) \in S$ stands for the PPL provided by the library user e_l on question q_i, $e_l(q_i^{\mathrm{DSL}}) \in S$ stands for the DSL provided by the library user e_l on question q_i and $I(e_l, q_i) \in S$ is the linguistic importance degree assigned to the user e_l on question q_i. Therefore, MSL_i^m, PPL_i^m and DSL_i^m, represent the MSL, the PPL, and the DSL, respectively, regarding to question q_i for the academic library A_m, according to the majority, which is represented by the fuzzy linguistic quantifier Q, of the linguistic assessments given by the library users $\{e_1, \ldots, e_L\}$.

When assessing user's satisfaction, the gap is the most interesting aspect. It is defined as the distance between the accepted MSL, the perceived performance service level and the DSL. Then, the gap between user's expectations and perceptions represents the service quality according to the gap model. That is, when experiences exceed expectations, the service quality is high, and vice versa.[14] LibQUAL+ model distinguishes four gaps: negative and positive adequacy, and negative and positive superiority. A positive adequacy gap is obtained when the perceived performance service level exceeds the generally accepted MSL. It indicates the extent to which the service exceeds the lowest possible level that users will accept. A negative adequacy gap appears when the offered service is below the accepted minimum one. A negative superiority gap opens up when the perceived service level does not reach the DSL but exceeds the accepted minimum one, and a positive superiority gap means that the perceived service level exceeds the DSL by the user.

Taking into account these considerations, two scores obtaining the strengths and weaknesses of an academic library A_m, according to the users' answers, are defined as follows:

$$SA_i^m = \begin{cases} + & \text{if } \mathrm{PPL}_i^m > \mathrm{MSL}_i^m \\ - & \text{if } \mathrm{PPL}_i^m < \mathrm{MSL}_i^m, \end{cases} \tag{3.6}$$

$$SS_i^m = \begin{cases} + & \text{if } \mathrm{PPL}_i^m > \mathrm{DSL}_i^m \\ - & \text{if } \mathrm{PPL}_i^m < \mathrm{DSL}_i^m, \end{cases} \tag{3.7}$$

where SA_i^m stands for the service adequacy score on question q_i for the academic library A_m and SS_i^m stands for the service superiority score on the question q_i for the academic library A_m.

On the one hand, SA_i^m is an indicator of the extent to which an academic library is meeting the minimum expectations of its users. A negative score means that the user's perceived service level is below its MSL. It may be used by the academic library

to identify areas needing improvement. On the other hand, SS_i^m is an indicator of the extent to which an academic library is exceeding the desired expectations of its users. It may be used to identify services satisfied outstandingly by the academic library.

(ii) Finally, for the academic library A_m, the following quality assessments are calculated:

(a) Its quality assessment on the affect of service dimension, $\text{ASD}^m \in S$, by aggregating the PPL, PPL_i^m, from questions q_1 to q_9, by means of the LOWA aggregation operator ϕ:

$$\text{ASD}^m = \phi_Q(\text{PPL}_1^m, \ldots, \text{PPL}_9^m), \tag{3.8}$$

where ASD^m is a measure representing the quality assessment of the affect of service dimension according to the majority, which is represented by the fuzzy linguistic quantifier Q, of linguistic assessments given by the library users about questions $\{q_1, \ldots, q_9\}$.

(b) Its quality assessment on the library as place dimension (LPD), $\text{LPD}^m \in S$, by aggregating the PPL, PPL_i^m, from questions q_{10} to q_{14}, by means of the LOWA aggregation operator ϕ:

$$\text{LPD}^m = \phi_Q(\text{PPL}_{10}^m, \ldots, \text{PPL}_{14}^m), \tag{3.9}$$

where LPD^m is a measure representing the quality assessment of the LPD according to the majority, which is represented by the fuzzy linguistic quantifier Q, of linguistic assessments expressed by the library users about questions $\{q_{10}, \ldots, q_{14}\}$.

(c) Its quality assessment on the information control dimension (ICD), $\text{ICD}^m \in S$, by aggregating the PPL, PPL_i^m, from questions q_{15} to q_{22}, by means of the LOWA aggregation operator ϕ:

$$\text{ICD}^m = \phi_Q(\text{PPL}_{15}^m, \ldots, \text{PPL}_{22}^m), \tag{3.10}$$

where ICD^m is a measure representing the quality assessment of the ICD according to the majority, which is represented by the fuzzy linguistic quantifier Q, of linguistic assessments given by the library users about questions $\{q_{15}, \ldots, q_{22}\}$.

(d) Its global quality assessment, $r^m \in S$, by aggregating the PPL, PPL_i^m, from all questions, by means of the LOWA aggregation operator ϕ:

$$r^m = \phi_Q(\text{PPL}_1^m, \ldots, \text{PPL}_{22}^m), \tag{3.11}$$

where r^m is a measure indicating the global quality assessment according to the majority, which is represented by the fuzzy linguistic quantifier Q, of linguistic assessment expressed by the library users about all the questions $\{q_1, \ldots, q_{22}\}$.

4. A Real Case of Application

In this section, we illustrate the application of extended LibQUAL+ model proposed in this study. To do so, the academic library at the Higher Technical School of Information Technology and Telecommunications Engineering at the University of Granada is evaluated. This school has a comprehensive range of study programmes in Computer Sciences and Telecommunications Engineering, with a total number of approximately 2500 students working for a degree. The web survey was opened for three weeks in March 2014. All members at the school received an email inviting them to fill the survey, and they could reply in either Spanish or English. Two follow-up emails were sent reminding them to complete the survey.

The group of users was divided into professors (E_p), staff members (E_s), graduate students (E_g) and undergraduates (E_u). A total of 229 people completed the web survey, including 145 undergraduates ($\{e_1, \ldots, e_{145}\} \in E_u$), 35 graduate students ($\{e_{146}, \ldots, e_{180}\} \in E_g$), 40 professors ($\{e_{181}, \ldots, e_{220}\} \in E_p$) and 9 staff members ($\{e_{221}, \ldots, e_{229}\} \in E_s$). The linguistic importance degrees associated with each type of user on each question, q_i, are shown in Table 1. They were provided from the staff members of the academic library although, as aforementioned, they may be different for each academic library. For example, the importance degree of the professors on question q_{10}, *library space that inspires study and learning*, is low as it is naturally not important to the professors. However, this library service is very important for graduate students and undergraduates.

Table 1. Weaknesses and strengths of the academic library.

	$I(E_p, q_i)$	$I(E_s, q_i)$	$I(E_g, q_i)$	$I(E_u, q_i)$	MSL_i^m	DSL_i^m	PPL_i^m	SA_i^m	SS_i^m
q_1	EH	VL	T	T	H	VH	VH	+	
q_2	EH	VL	T	T	H	VH	VH	+	
q_3	EH	VL	T	T	H	EH	VH	+	−
q_4	EH	VL	T	T	VH	EH	EH	+	
q_5	EH	VL	T	T	VH	EH	EH	+	
q_6	EH	VL	T	T	VH	EH	EH	+	
q_7	EH	VL	T	T	VH	EH	VH		−
q_8	EH	VL	T	T	H	EH	EH	+	
q_9	EH	VL	T	T	VH	EH	EH	+	
q_{10}	L	EH	T	T	VH	T	EH	+	−
q_{11}	L	EH	T	T	VH	T	H	−	−
q_{12}	L	EH	T	T	VH	T	EH	+	−
q_{13}	L	EH	T	T	H	T	EH	+	−
q_{14}	L	EH	T	T	H	EH	L	−	−
q_{15}	T	M	T	H	VH	T	EH	+	−
q_{16}	T	M	T	H	VH	T	EH	+	−
q_{17}	T	M	T	T	VH	T	EH	+	−
q_{18}	T	M	T	H	VH	EH	EH	+	
q_{19}	T	M	T	H	VH	EH	EH	+	
q_{20}	T	M	T	T	VH	EH	T	+	+
q_{21}	T	M	T	T	VH	EH	T	+	+
q_{22}	T	M	T	H	H	VH	VH	+	

Assuming these linguistic importance degrees, the linguistic quantifier *most of* defined as $Q(r) = r^{1/2}$, and using the LWA aggregation operator, Table 1 shows the global quality assessment of the MSL, MSL_i^m, the global quality assessment of the DSL, DSL_i^m, the global quality assessment of the PPL, PPL_i^m, the service adequacy score, SA_i^m and the service superiority score, SS_i^m, on each question q_i for the academic library A_m at the Higher Technical School of Information Technology and Telecommunications Engineering.

In order to allow us to better know the quality and performance of each academic library service, the system, through a web interface, generates a radar plot (see Fig. 2). It shows the global quality assessment of the replies to all 22 questions on minimum, desired and perceived levels. It has a coded axis for each question, $\{q_1, \ldots, q_{22}\}$, and questions measuring the same service dimension are next to each other in the radar plot. Questions about affect of service dimension, $\{q_1, \ldots, q_9\}$, are colored light grey, questions about LPD, $\{q_{10}, \ldots, q_{14}\}$, are colored grey, and questions about ICD, $\{q_{15}, \ldots, q_{22}\}$, are colored black in the radar plot. Moreover, it allows to distinguish the different gaps: (i) the positive adequacy gap is marked with black and white vertical rectangles in the radar plot, (ii) the negative adequacy gap is marked with black and white squares in the radar plot and (iii) the positive superiority gap is marked with wavy lines.

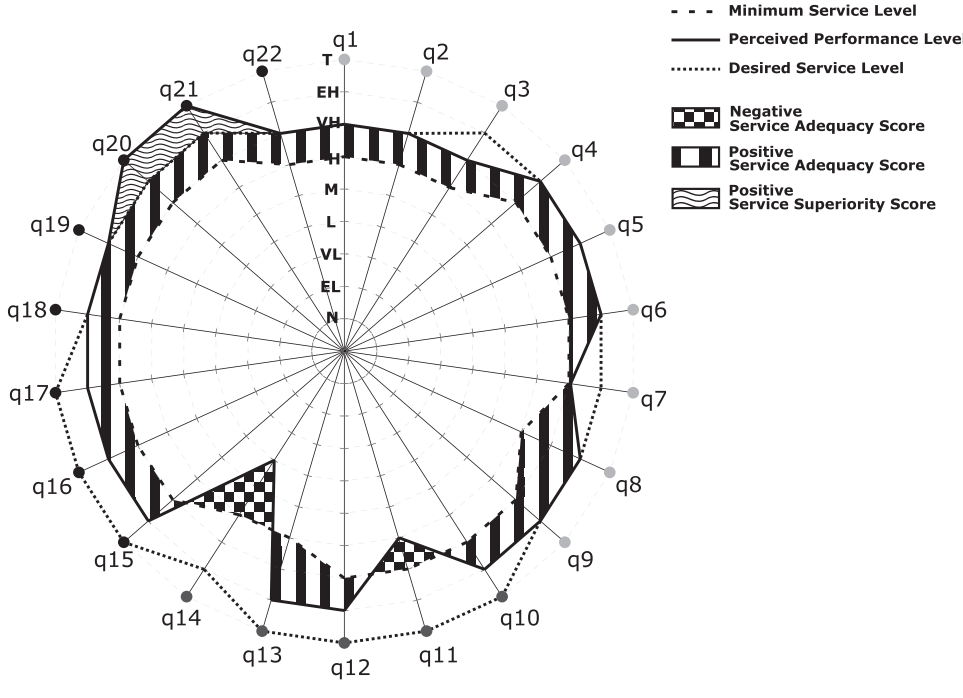

Fig. 2. Radar plot.

Table 2. Quality assessments of the academic library.

	ASD^m	LPD^m	ICD^m	r^m
A_m	EH	EH	EH	EH

In this particular example (see Fig. 2), we can see that the weaknesses of the academic library, according to user's perceptions, are the library services *quiet space for individual activities* (q_{11}) and *community space for group learning and group study* (q_{14}), where the largest negative adequacy gap scores were obtained as the perceive performance level was lower than the MSL demanded by the users. Whereas a positive superiority gap emerged in the responses to questions concerning *easy-to-use access tools that allow me to find things on my own* (q_{20}) and *making information easily accessible for independent use* (q_{21}), being these library services the strengths of the academic library.

The quality assessment on the affect of service dimension, ASD^m, the quality assessment on the LPD, LPD^m, the quality assessment on the ICD, ICD^m, and the global quality assessment, r^m, of the academic library are shown in Table 2. In this case, the LOWA aggregation operator uses the same linguistic quantifier *most of* defined previously in the LWA aggregation operator.

Finally, with the aim of evaluating the performance of the fuzzy linguistic extended LibQUAL+ model in regard to the LibQUAL+ model, we asked to the people that completed the web survey if they had answered the survey in 2013, and if they did, they had to remark if they preferred to use the fuzzy linguistic extended LibQUAL+ model or the LibQUAL+ model. We should point out that in 2013, to evaluate the academic library at the Higher Technical School of Information Technology and Telecommunications Engineering, the LibQUAL+ model was used. In that occasion, a total of 153 people completed the LibQUAL+ survey. The result was the following: 97 people completed the survey both in 2013 and in 2014, and a 87% of them said that they preferred the linguistic terms to the numerical ones. Furthermore, in 2013, only 46% of the initial respondents completed it, while in 2014, the survey was completed by the 67% of the initial respondents. This increase in the number of initial respondents that completed the survey may be due that the respondents felt more comfortable using words in natural language than numerical values.

5. Concluding Remarks

In this study, a fuzzy linguistic LibQUAL+ model to evaluate the quality of academic libraries according to user satisfaction has been presented. It contributes to overcome the drawbacks of the LibQUAL+ model using the ordinal fuzzy linguistic modeling to represent the users' perceptions and taking into account that the users' opinions on the library service levels are not equally important. Considerable use has

been made of fuzzy set technology to offer the ability to describe the information by using linguistic terms in a way that is particularly user friendly. Our results reveal that people feel more comfortable using linguistic terms than numerical values to evaluate the service quality. In addition, automatic tools of fuzzy computing with words based on the LOWA and LWA aggregation operators have been applied to compute quality assessments of academic libraries and to identify their strengths and weaknesses.

In the future, we propose to improve our fuzzy linguistic LibQUAL+ model by incorporating multi-granular linguistic information with the aim of providing to the library users a highest flexibility in the expression of opinions.[21,22]

Acknowledgments

The authors would like to acknowledge FEDER financial support from the Project TIN2013-40658-P, and also the financial support from the Andalusian Excellence Project TIC-5991.

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