International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 9 (2015) pp. 21633-21645

http://www.ripublication.com

Prioritization Of Students' Needs For Education Service Design And Development By Embedding AHP And Fuzzy Set Theory: A Case Study

Lupo Toni

Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica (DICGIM), Università degli Studi di Palermo, Viale delle Scienze, 90128, Palermo, Italy
Email: toni.lupo@unipa.it

Abstract

Student satisfaction represents a strategic factor for many universities towards increasing competition concerning students recruitment. Thus, nowadays many universities take into account typical customer-oriented industry's approaches for the education service design and development. In such a condition, prioritization of students' needs represents a crucial step to appropriately adopt these approaches. This paper proposes an effective way to evaluate importance of students' needs based on the Analytic Hierarchy Process (AHP) method, in which linguistic variables are parameterized by means of triangular fuzzy numbers, to deal with uncertainty, subjectivity and vagueness. Finally, a case study concerning the degree program in Management Engineering at the University of Palermo (Italy) is performed with detailed considerations on the most responding service aspects on students' need.

Keywords: education service quality; AHP; fuzzy set theory; student's needs evaluation

1. Introduction

In the last few years, universities have been characterized by an increasing competition in terms of students recruitment and financial appropriations. For such reasons, student-oriented design and development of the education service represent critical aspects at many universities characterized, during the last years, by the so called "*rankings war*". As a consequence, nowadays universities pay great attention to typical customer-oriented industry's approaches and tools, such as Quality Function Deployment (QFD), to convert students' needs into quantified education service

attributes (Chen, 2014; Muda et al, 2013).In general, these approaches provide a visual process to support decision makers and managers to design new services as well to improve existing ones, on the basis of established customers' requirements. The latter are pointed out on the basis of recognized "customers' needs" in reference of their importance weights (Easton, 2010; Di Trapani et. al., 2014; Sgroi, et al., 2014a; 2014b). Thus, prioritization of students' needs becomes a crucial activity since it represents a mandatory step in applying customer-oriented industry's approaches.

Over the time, several methods have been developed in this regard (Cristiano et al, 2001; Cohen & Cohen, 1995; Li et al, 2011). In the present work, a novel approach based on the Analytic Hierarchy Process (AHP) method (Saaty, 1980; 1990) is considered to obtain the importance weights of students' needs given that the customers' needs prioritization can be seen as a multi-criteria decision making problem, as shown in recent works (Bana e Costa & Oliveira, 2012; Certa et al, 2015). In particular, AHP allows to overcome many critical factors characterizing the typically employed evaluation approaches, such as: the well-documented tendency of respondents to select central categories to express their judgments, influence of the linguistic categories number in the evaluation process, the form and the type of the adopted linguistic variables and, also, the transformation from cardinal to metric data (Lupo, 2013a).

AHP has been introduced about 30 years ago and, nowadays it is one of the most considered MCDM methods. This fact is probably due to some aspects characterizing AHP, such as: opportunity to conduct a sensitivity analysis on obtained ranking results; possibility to integrate both quantitative and qualitative and also conflicting criteria and it is well supported by office software. Moreover, AHP is particularly appreciated by many researchers for its advantageous mathematical structure and easiness in acquiring the required input data, which can be obtained by simply pairwise comparisons. Another typical issue in applying AHP is to measure consistency in group decisions. In fact, as stressed by Dong et al (2010), consistency measures represent a substantial aspect for consensus in group decision making.

AHP has been widely considered in the higher education field for different purposes. For instance, Feng et al,(2004) considered a composite approach based on AHP and Data Envelopment Analysis (DEA) to evaluate efficiency of Research & Development management activities, with reference to 29 research-oriented universities in China. Lukman et al (2010) performed a comparative study by means of AHP to rank various universities with reference to several performance criteria. In detail, importance weights of established performance indicators are obtained by means of AHP on the basis of collected data by way of a questionnaire formulated by pairwise comparisons. Wu et al, (2010) adopted the VIKOR method combined with AHP to analyze and to measure the intellectual capital of universities on the basis of several established indicators of innovation capital. More recently, the same Authors (Wu et al,2012) proposed a mixed approach in which AHP and VIKOR are considered, under a fuzzy evaluation environment, to rank 12 private universities. In this study, the Authors consider a set of performance indices deriving from the official performance evaluation structure developed by the Taiwan Assessment and Evaluation Association (TWAEA).Very recently, Lupo (2013a) proposed the

employment of AHP in a service quality study to overcome weakness of the ServQual model concerning estimation of customer expectations. In particular, the Author considers AHP to point out improvement priorities on higher education service attributes, with reference to the degree program in Management Engineering at the University of Palermo (Italy).

In other research fields, such as: software selection (Lai et al 2002), evaluation of transport quality (Lupo, 2013b), maintenance optimization (Certa et al 2013) and so on, AHP has been successfully considered to support individual and group decisions when several stakeholders with conflicting interests are affected.

On the basis of aforementioned considerations, this paper proposes an easy and effective way based on AHP to evaluate prioritization of customers' needs and demonstrates its application in higher education sector. In addition, a fuzzy evaluation environment is considered to address issues arising from uncertainty, subjectivity and vagueness of judgments expressed by way of linguistic variables (Zadeh, 1996; Zimmermann, 1985).

The remainder of this paper is organized as follows: a detailed description of the developed approach is reported below. in Section 3 the hierarchical service structure of the Engineering program at the Palermo University (Italy) is described. Section 4 reports on the application of the method to evaluate importance weights of students' needs. Finally, Section 5 recapitulates the work by providing conclusions and speculating on directions for future research.

2. Fuzzy AHP for evaluating prioritization of students' needs

With referring to the fundamental service aspects characterizing the quality structure of higher education service, importance weights of students' needs are assessed under a fuzzy evaluation environment. Fig. 1 shows a general hierarchical structure of service quality composed by service dimensions, sub- dimensions and items

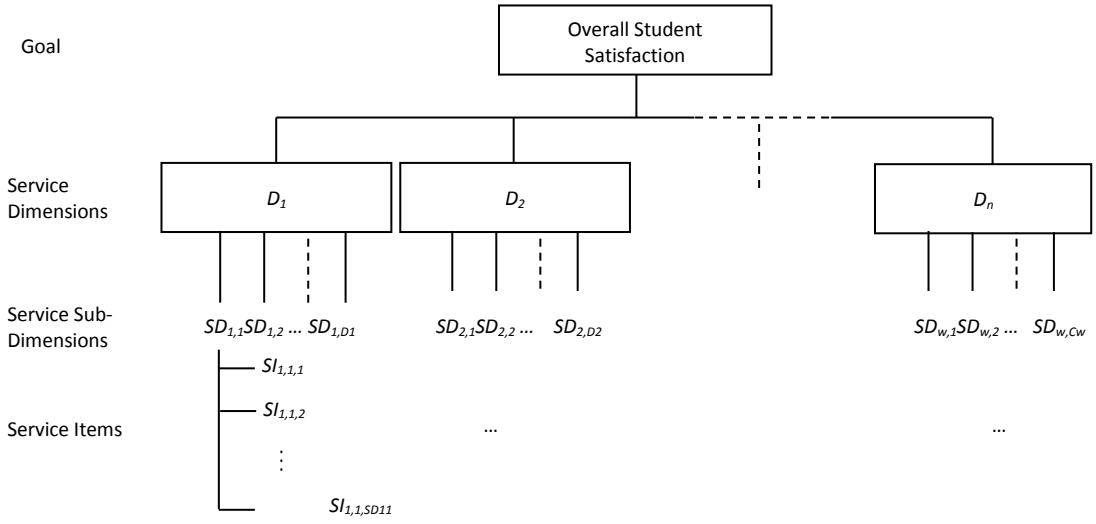


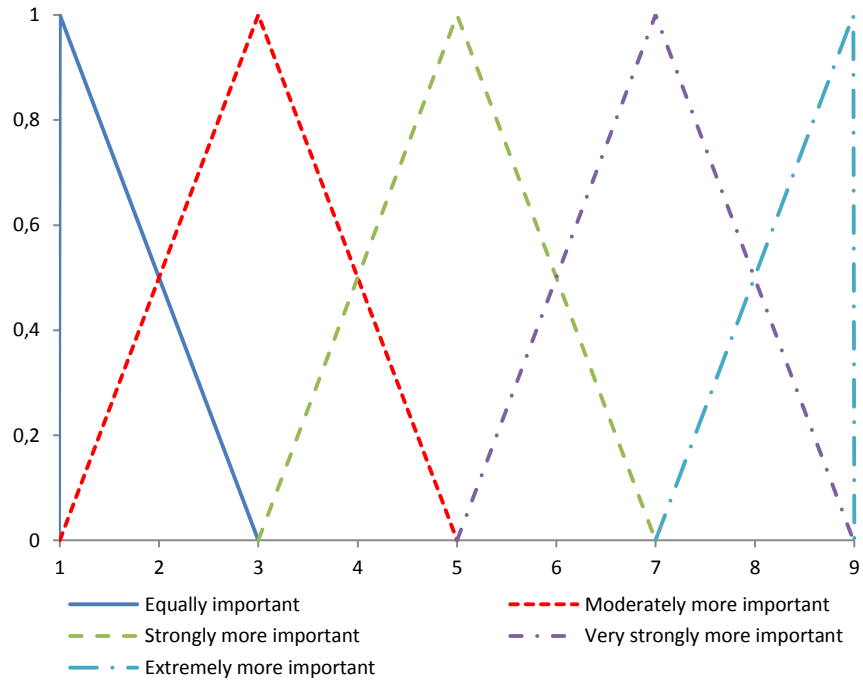
Fig. 1. General hierarchical structure of service quality

Linguistic terms, used to express the relative importance of each pair of

service aspects in the same hierarchical level (Fig. 1), are quantified by triangular fuzzy numbers (TFNs)(Klir1999). In detail, the membership function of a TFN $\tilde{A}$ is $\mu_{\tilde{A}}(x)$: $R \rightarrow [0, 1]$ and it can be represented by the set of equations (1), where $l_A<m_A<u_A$. The parameter m_A corresponds to the maximum value of $\mu_{\tilde{A}}(x)$, whereas l_A and u_A are respectively the lower and upper bounds of the definition interval.

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - l_A}{m_A - l_A} & for \;\; l_A \le x \le m_A \\ \dfrac{u_A - x}{u_A - m_A} & for \;\; m_A \le x \le u_A \\ 0 & otherwise \end{cases} \qquad 1$$

Fig 2 shows the fuzzy-linguistic pairwise comparisons scale here considered.



a

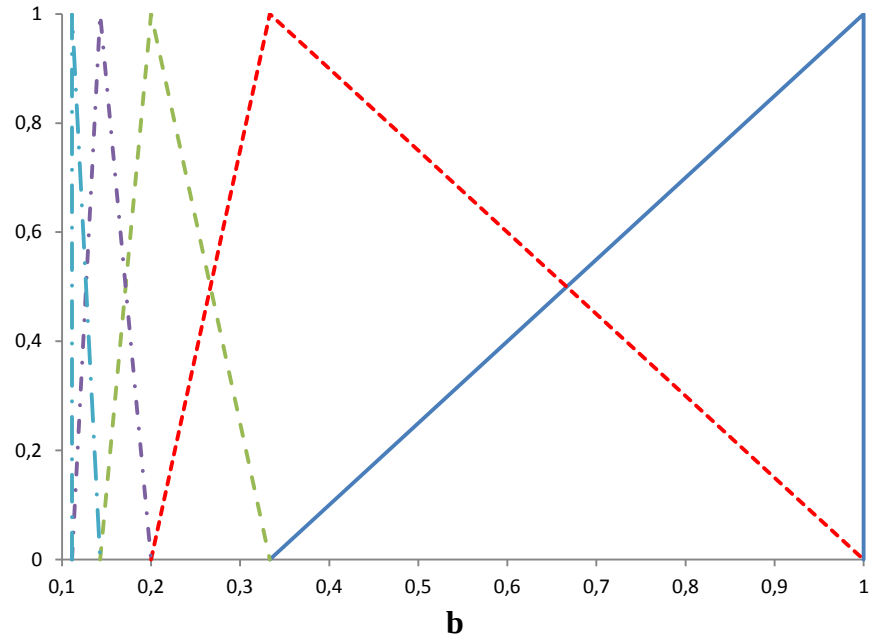


Fig. 2: Fuzzy linguistic pairwise comparisons scale (a) and related reciprocal values (b)

Considering service dimensions 1, 2, …, *n* (see Fig. 1), the fuzzy comparison matrix $\tilde{A}$ is defined as:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{1,2} & \dots & \tilde{a}_{1,n} \\ \tilde{a}_{2,1} & 1 & \dots & \tilde{a}_{2,n} \\ \dots & \dots & \dots & \dots \\ \tilde{a}_{n,1} & \dots & \dots & 1 \end{bmatrix} \quad 2$$

where the generic term $\tilde{a}_{k,w} = \left(l_{a_{k,w}},\ m_{a_{k,w}},\ u_{a_{k,w}}\right)$ denotes TFN measuring the relative importance of the k^{th} service dimension *vs* the w^{th} one. Particularly, $l_{a_{k,w}}$, $m_{a_{k,w}}$, $u_{a_{k,w}}$ are the minimum value, most plausible value and maximum value, respectively, obtained by aggregating students' judgments via geometric mean, which is commonly used for aggregating group decisions in AHP applications (Lupo, 2013b):

$$l_{a_{k,w}} = \left(\prod_{j=1}^{J}\left(l_{a_{k,w}}\right)_j\right)^{\frac{1}{J}}, m_{a_{k,w}} = \left(\prod_{j=1}^{J}\left(m_{a_{k,w}}\right)_j\right)^{\frac{1}{J}}, u_{a_{k,w}} = \left(\prod_{j=1}^{J}\left(u_{a_{k,w}}\right)_j\right)^{\frac{1}{J}} \quad 3$$

where $\left(\tilde{a}_{k,i}\right)_j = \left(\left(l_{a_{k,w}}\right)_j, \left(m_{a_{k,w}}\right)_j, \left(u_{a_{k,w}}\right)_j\right)$ indicates FST related to the judgment of the j^{th} student (j = 1, 2, …, J).

From the fuzzy comparison matrix $\tilde{A}$, fuzzy importance weights are obtained via the Logarithm Least-squares method (Chen et al,2005), which is selected here for its easiness and effectiveness. In particular, the importance level expressed in fuzzy form for the k^{th} service dimension $\tilde{E}_k$, is obtained as:

$$\tilde{E}_k = \left(l_{E_k}, m_{E_k}, u_{E_k}\right) \quad k = 1,2,..,n \qquad 4$$

in which:

$$s_{E_K} = \frac{\left(\prod_{i=1}^{n} s_{a_{k,w}}\right)^{\frac{1}{n}}}{\sum_{k=1}^{n}\left(\prod_{i=w}^{n} s_{a_{k,w}}\right)^{\frac{1}{n}}} \quad s \in \{l, m, u\} \qquad 5$$

The related crisp importance weight is obtained with reference to the confidence level α (α-cut) (Klir, 1999), which includes students' uncertainty over their judgments, and the index of optimism ρ on fuzzy results (Lee, 1999), by the following relationship:

$$\begin{aligned} &E_k^{\alpha} = \rho \cdot u_{E_k}^{\alpha} + (1-\rho) \cdot l_{E_k}^{\alpha} \\ &k = 1,\ 2,..,n \\ &\forall \rho \in [0,1] \end{aligned} \qquad 6$$

in which,

$$\begin{cases} u_{E_k}^{\alpha} = u_{E_k} - \left(u_{E_k} - m_{E_k}\right) \cdot \alpha \\ l_{E_k}^{\alpha} = \left(m_{E_k} - l_{E_k}\right) \cdot \alpha + l_{E_k} \end{cases}$$
$$\alpha \in [0,1] \qquad 7$$

A larger α value is considered when students are confident in choosing a crisp value to represent their judgments, whereas ρ: $R \rightarrow [0, 1]$ reflects students' attitude towards risk on fuzzy assessment results (Chang, Da-Yong, 1996). Optimistic students are inclined to prefer higher crisp values derived from fuzzy intervals, while pessimistic ones tend to favor lower ones (Lupo, 2013a).

Finally, importance weights of service sub-dimensions and items are evaluated by multiplying their local importance weights, which are obtained via the above described procedure, by the importance weights of the related service aspects placed in the above levels of the hierarchical structure.

3. Hierarchical tree of the higher education service

There are a large number of interested parties in the higher education sector, such as: students, graduates, faculty staff and professors, parents of the students, alumni, domestic and international partners, government, industries (recruiters), etc. In particular, they interact with university institutions in different ways and, thus, their specific needs may be different. For such a reason, before implementing any quality improvement program, it is necessary to identify which interested part is mainly taken into consideration for the improvement program.

Since students are the primary customer of the education system, in this work their suggestions have been used to describe the hierarchical structure of fundamental education service needs. In particular, with reference to the degree program in Management Engineering at the University of Palermo (Italy), the hierarchical structure of the delivered education service has been pointed out by using the Critical Cases Approach (CCA) (Cronin, 1992), on the basis of preliminary focus groups covering both service experts (decision makers and managers) and a significant number of students and alumni. The obtained structure is divided into 4 service dimensions, 10 service sub-dimensions and 36 fundamental service items as shown in Fig 3.

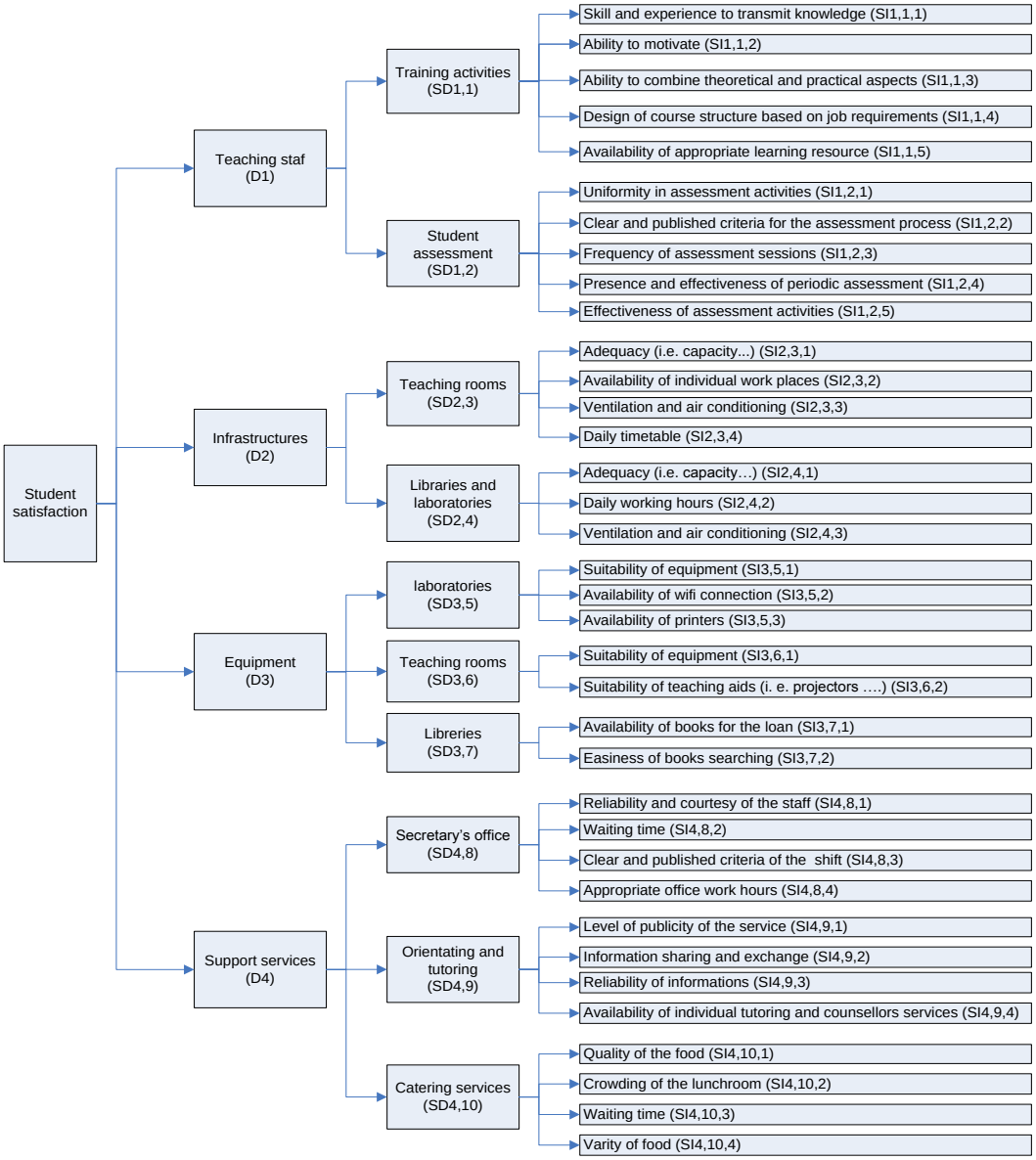


Fig 3: Quality structure of the analyzed higher education service. Such quality structure is considered in the subsequent developed case study.

4.0 Case study

Once the hierarchy structure of education service quality is described, the importance weights of its elements are estimated by using the above mentioned procedure (Section 2), on the basis of data collected by way of a survey. In particular, the latter was conducted over a period of six months, from July to December 2014, by using a questionnaire based on simple pairwise comparisons. Just for an example, Table 1 reports the questionnaire part relating to service elements of service dimension "Equipment".

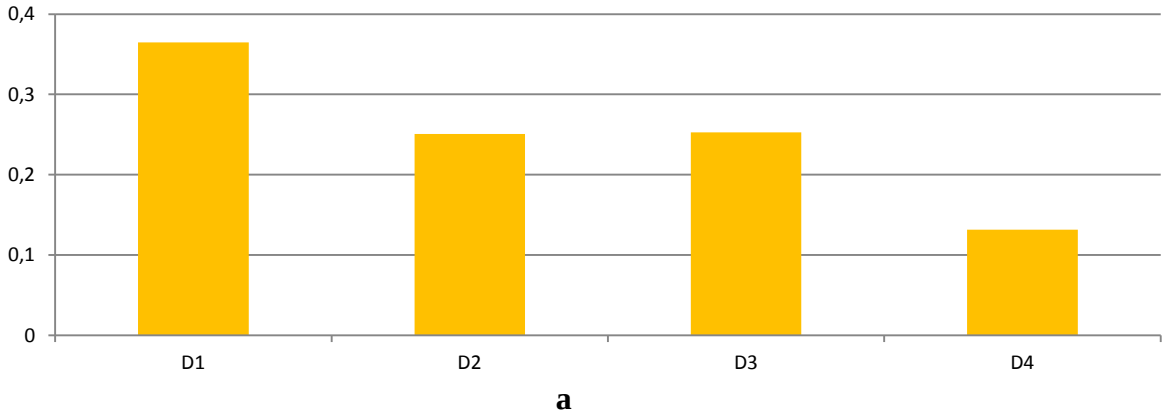
Table 1: Pairwise comparisons concerning elements of service dimension "Equipment"

How important is:

Compared with	Laboratories					Teaching rooms				
Libraries	A	B	=	a	b	A	B	=	a	b
	C	D		c	d	C	D		c	d
Teaching rooms	A	B	=	a	b					
	C	D		c	d					

D:	*Extremely more important*	**a:**	*Moderately less important*
C:	*Very strongly important*	**b:**	*Strongly less important*
B:	*Strongly important*	**c:**	*Very strongly less important*
A:	*Moderately important*	**d:**	*Extremely less important*
=:	*Equally important*		

A total of 350 questionnaires were selected for their completeness to undergo this study, from 405 totally obtained questionnaires, and for both the confidence indices α and ρ have been assumed a value equal to 0.5. Fig. 4 reports the obtained importance weights of students' needs for all the established elements of the service quality structure.



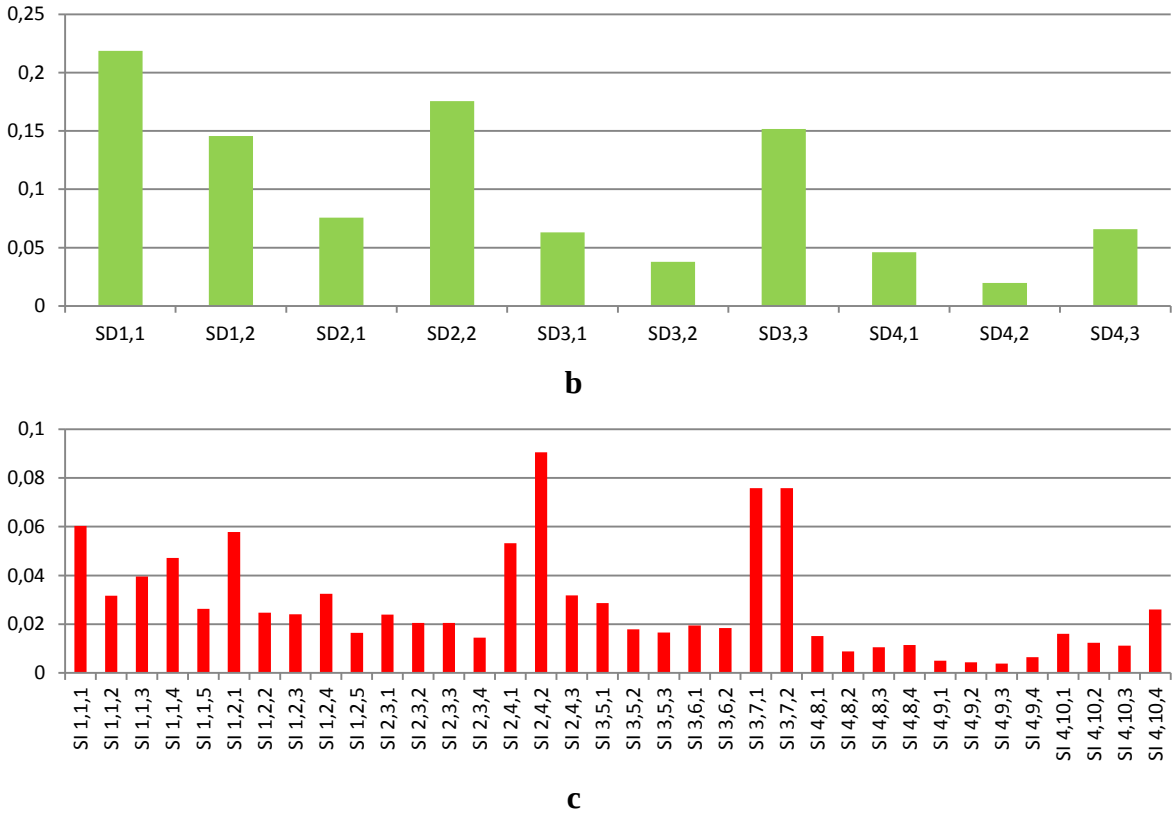


Fig 3: Prioritization of students' needs for the established service dimensions (a), sub-dimensions (b) and items (c) (α = 0.5; ρ = 0.5)

From the obtained results it is possible to point out that, from students' perspective on education service quality, the core service items are: daily working hours of the libraries and laboratories (0.0905), availability of books for the loan (0.0758), easiness of books searching (0.0758), teacher's skill and experience to transmit knowledge (0.0603) and adequacy of the libraries and laboratories (0.0532). On the other hand, the fundamental service sub-dimensions are: training activities (0.2187), libraries and laboratories infrastructures (0.1756) and libraries equipment (0.1517). Finally, the more important service dimension is teaching staff (0.3646).

5 Conclusions

This paper tackled the important issue involved in prioritization of students' needs for education service design and development by means of an easy and effective way based on AHP, in which linguistic variables are parameterized by means of triangular fuzzy numbers. In detail, as a result of the suitable mathematical structure of this approach, importance weights of students' needs are evaluated by incorporating both students' confidence over their judgments and attitude towards risk on fuzzy assessment results. Thanks to the performed service analysis concerning the degree

program in Management Engineering at the University of Palermo (Italy), the hierarchical structure of the higher education service was described, from the students perspective on service quality, and prioritization of students' needs were obtained. The achieved results constitute a fundamental step towards an operational student-oriented education service design and development. Future researches concerning higher education service quality analysis will involve the employment of the non-compensative MCDM ELimination Et Choix TRaduisant la REalitè (ELECTRE III) method (Roy,1978) to comparatively evaluate quality of fundamental education service aspects.

References

1. Bana e Costa, C.A. , Oliveira, M.D. (2012) A multicriteria decision analysis model for faculty evaluation. Omega, 40(4): 424-436;
2. Certa, A., Enea, M, and Hopps, F. (2015). A multi-criteria approach for the group assessment of an academic course: A case study. Studies in Educational Evaluation. 44: 16–22;
3. Certa, A., Enea, M., & Lupo, T. (2013). ELECTRE III to dynamically support the decision maker about the periodic replacements configurations for a multi-component system. Decision Support Systems, 55, 126–134;
4. Chang, Da-Yong. (1996) Application of the extent analysis method of fuzzy AHP, European Journal of Operational Research, 95: 649-655;
5. Chen, S.-H. (2014) Determining the service demands of an aging population by integrating QFD and FMEA method. Quality and Quantity (in Press) DOI: 10.1007/s11135-014-0148-y;
6. Chen, M.F., Tzeng, G.H. and Tang, T. (2005) Fuzzy MCDM approach for evaluation of expatriate assignments, Int. J. Information Technology & Decision Making, 4(2): 277–296;
7. Cristiano, J.J., Liker, J.K., White III, C.C. (2001) Key factors in the successful application of quality function deployment (QFD). IEEE Transactions on Engineering Management, 48 (1): 81-95;
8. Cohen, L., Cohen, L. (1995) Quality Function Deployment: How to Make QFD Work For You, p. 348;
9. Cronin J. Stenen A., (1992) Measuring service quality, Journal of marketing, 6(3): 55-68;
10. Di Trapani, A.M., R. Squatrito, M. Foderà, R. Testa, S. Tudisca and Sgroi F. (2014). Payment for environmental services for the sustainable development of the territory. Am. J. Environ. Sci., 10: 480-488. DOI: 10.3844/ajessp.2014.480.488;
11. Dong, Y., Zhang, G., Hong, W. C., & Xu, Y. (2010). Consensus models for AHP group decision making under row geometric mean prioritization method. Decision Support Systems, 49(3), 281–289;
12. Easton, G. (2010) Critical realism in case study research. Industrial Marketing Management, 39(1): 118-128;

13. Feng, Y. J., Lu, H., & Bi, K. (2004). An AHP/DEA method for measurement of the efficiency of R&D management activities in universities. International Transactions in Operational Research, 11, 181–191;
14. Klir G. J., Yuan B., *Fuzzy sets and fuzzy logic, Theory and Applications*, Prentice Hall P T R, Upper Saddle River, New Jersey (1999);
15. Lai, V. S., Wong, B. K., & Cheung, W. (2002). Group decision making in a multiple criteria environment: A case using AHP in software selection. European Journal of Operational Research, 137, 134–144;
16. Lee, A. R. Application of modified fuzzy AHP method to analyze bolting sequence of structural joints, UMI Dissertation Services. A. Bell & Howell Company (1999);
17. Li, Y.-L., Huang, M., Chin, K.-S., Luo, X.-G., Han, Y. (2011) Integrating preference analysis and balanced scorecard to product planning house of quality. Computers and Industrial Engineering, 60 (2): 256-268;
18. Lupo, T. (2013a). A fuzzy ServQual based method for reliable measurements of education quality in Italian higher education area. Expert Systems with Applications, (17), 7096–7110;
19. Lupo, T. Handling stakeholder uncertain judgments in strategic transport service analyses, Transport Policy (2013b), Vol 29: 54-63 DOI: 10.1016/j.tranpol.2013.04.002;
20. Lukman, R., Krajnc, D., &Glavicˇ, P. (2010). University ranking using research, educational and environmental indicators. Journal of Cleaner Production, 18, 619–628;
21. Muda, N. , Roji, N.S.M. (2013) A quality function deployment (QFD) in determining the critical learning outcomes. JurnalTeknologi (Sciences and Engineering). 63(2): 107-112;
22. Roy, B., (1978). ELECTRE III: un algorithme de classementsfondesurune representation floue des preference en presence de criteres multiples. Cahiers de CERO, 20 (1), 3–24;
23. Saaty, T.L. (1980). The Analytical Hierarchy Process. McGrawHill International Book Compagny, New York;
24. Saaty TL., (1990) How to make a decision: the analytic hierarchy process, European Journal of Operational Research, 48:9-26;
25. Sgroi, F., A.M. Di Trapani, R. Testa and S. Tudisca, (2014°). Strategy to increase the farm competitiveness. Am. J. Agric. Biol. Sci., 9: 394-400. DOI: 10.3844/ajabssp.2014.394.400;
26. Sgroi, F., S. Tudisca, A.M. Di Trapani, R. Testa and R. Squatrito, (2014b). Efficacy and efficiency of Italian energy policy: The case of PV systems in greenhouse farms. Energies, 7: 3985-4001. DOI: 10.3390/en7063985;
27. Wu, H. Y., Chen, J. K., & Chen, I. S. (2010). Innovation capital indicator assessment of Taiwanese universities: A hybrid fuzzy model application. Expert Systems with Applications, 37, 1635–1642;
28. Wu, H. Y., Chen, J. K., & Chen, I. S. (2012). Ranking universities based on performance evaluation by a hybrid MCDM model. Measurement, 45, 856–880;

29. Zadeh, L.A. (1996) Fuzzy logic computing with words, IEEE Transactions on Fuzzy Systems, 4, 103-111;
30. Zimmermann, H. J. (1985). Fuzzy set theory and its applications. Boston, MA: Kluwer;