International Journal for Quality research
UDK - 005.6:02
Original Scientific Paper (1.01)

INTEGRATING FACTOR ANALYSIS AND ANALYTIC HIERARCHY PROCESS FOR LIBRARY SERVICE QUALITY

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Abstract: *In this paper an attempt has been made to propose a methodology for identifying and prioritizing the user needs pertaining to library services. In order to categorize the user needs into quality dimensions, Factor analysis has been carried out on user responses obtained through questionnaire survey. Analytic Hierarchy Process (AHP) is employed to determine the priority ratings of the library quality dimensions. The priority structure of the quality dimensions provides an idea for the library management to allocate the resources in an effective manner to achieve more user satisfaction. A case study is presented to demonstrate the proposed methodology.*
Keywords: *Library service quality, Factor analysis, Analytic Hierarchy Process*

1. INTRODUCTION

Well equipped library in an engineering educational institution is the rich springs of knowledge, from where knowledge flows to irrigate the field of engineering education. It is the fountain-head of innovativeness and inspiration for the users such as students and faculty in any engineering educational institution. In the present technological environment, modernization of the library leads to enhancing user satisfaction through the improved service quality (Durga Prasad et al., 2007). Traditionally, the quality of an academic library has been described in terms of its collection and measured by the size of the library's holding and various counts of its use (Nitecki, 1996). But the quality of the library services is not merely depending on the collection of books. Service quality is a measure of how well the service level delivered matches the customer expectations. The concept of quality is not a new phenomenon for library and information science professionals as it is rooted in library principles, practices, and activities. Ranganathan's five laws of library science, particularly the fourth law (save the time of reader) implies the importance of quality in library services. The law emphasises that library administration be simple and efficient to save user's time (Dash and Padhi, 2010). In the Indian library scenario, the concept of assessing service quality from customer's perspective is still in its infancy (Manjunadha and Shivalingaiah, 2004). Over the years, the researchers have studied the user wants and user perceptions about the value of library services. The services offered by a library should meet the expectations of the various users of the library.

The concept of service quality in the context of a library can be defined as the difference between users' expectations and perceptions of service performance and the reality of the service(Sahu, 2007). Therefore, the management of the libraries has to focus on the identification of needs and expectations of the users. Satoh et al. (2005) addressed the important considerations to the service quality assessment in university libraries by conducting the focus group interviews. Bayraktaroglu and Ozgen (2008) investigated most strategically important user requirements using the integration of Kano, AHP and QFD methods. Ahmed and Shoeb (2009) reported a study on examining the overall service quality of a library in Bangladesh from its user's perceptions and also they determined the dimensions of service quality. Jamali and Tooranloo (2009) adopted fuzzy – TOPSIS technique to prioritize the academic library service quality indicators to meet the requirements of the students as customers of the academic libraries.

Kiran (2010) carried a study using a survey methodology to assess the impact of library services on

the academic staff work and their perceived level of satisfaction. He demonstrated the methodology to obtain the priority structure of service quality dimensions through a case study. Garibay et al. (2010) adopted QFD-Kano model to prioritize the customer requirements of the digital library. They captured the voice of users of the library through online questionnaire survey and prioritized the user needs. In this paper, Exploratory Factor analysis is employed to explore the library service quality dimensions and Analytic Hierarchy Process (AHP) is adopted to prioritize the quality dimensions. The rest of the paper is organized as follows. The proposed methodology is discussed in the section 2. A case study is presented in Section 3. In section 4, conclusions are presented.

2. METHODOLOGY

The outline of the proposed methodology is shown in figure 1. Questionnaire survey is a service evaluation tool, which reveals the expectations and opinions of the users of a library. Factor analysis is carried for the responses data through questionnaire survey to establish the library service quality dimensions.

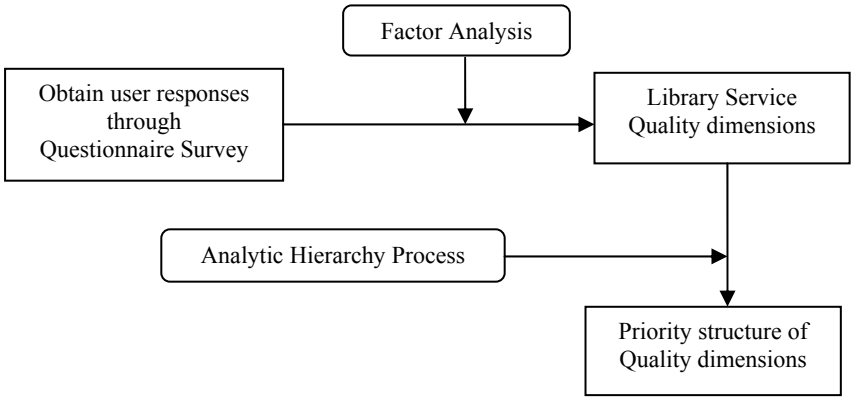

Figure 1: Outline of the proposed methodology

In order to allocate the library resources effectively, priority structure of the quality dimensions is needed. Analytic Hierarch Process is used in the study to obtain the priority ratings.

2.1 Factor Analysis

Factor analysis (FA) is a multivariate statistical technique primarily used for data reduction and summarization. To conduct factor analysis, there must be substantial number of variables correlated among each other. Formal statistics such as Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity are used for testing the appropriateness of the data to proceed for factor analysis. KMO measure is an index that compares the size of the observed correlation coefficients to the sizes of the partial correlation coefficients. The value of KMO in between 0.5 and 1.0 indicates the factor analysis is appropriate. Values below 0.5 imply that factor analysis may not be appropriate for the data (Abidin et al., 2009). The Bartlett's Test of Sphericity is a test statistic used to test the null hypothesis that variables are uncorrelated to each other. The test statistic is based on chi-square transformation of the determinant of the correlation matrix. A large value of chi-square indicates the rejection of the null hypothesis. If this hypothesis cannot be rejected, then the appropriateness of factor analysis should be questioned. The significance level gives the result of the test. Very small values of significance (below 0.05) indicate a high probability that there are significant relationships between the variables, whereas higher values (0.1 or above) indicate the data is not appropriate for factor analysis. Once it has been determined that factor analysis is an appropriate technique for analyzing the data, adopt the factor analysis procedure that consists of selecting the method of extracting the components, the number of components to be extracted and the method of rotation for interpretation of the factors. Principal component analysis is the most commonly used method for extracting factors. Scree plot indicates the eigen values against the number of factors in order of extraction. It helps to determine the number of factors (Durga Prasad et al., 2010). The rotation of factors is done in order to improve the meaningfulness, reliability and reproducibility of factors. The goal of rotation is to simplify and clarify the data structure. There are two types of rotations, namely orthogonal rotation, which produce uncorrelated factors, and oblique rotation, which produce correlated factors. It is advisable to use orthogonal rotation as it produces more easily interpretable results (Costello and

Osborne, 2005). Varimax, quartimax and equamax are commonly available orthogonal methods of rotation. In this paper, principle component method followed by the varimax rotation is adopted by using SPSS17.0 package. The outcome of factor analysis shows the pattern of the new factors in accordance with respective variables that describe each factor.

2.2 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method developed by Saaty. It aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision-maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process (Kamal, 2001). AHP methodology (Karlsson and Ryan, 1997) for decision-making involves four main steps such as setup the pair-wise comparison matrix, perform pair-wise comparisons of all the elements, estimation of eigen values of the matrix and checking the consistency of pair-wise judgments .

Step 1: Establishment of pair-wise comparison matrix

Setup the pair-wise comparison matrix of order $n \times n$ consists of n elements (requirements) in the rows and columns whose priorities are to be determined.

Step 2: Perform pair-wise comparisons of all the elements

Saaty's fundamental scale of absolute numbers (Tsinidou et al., 2010) to perform pair-wise comparison between the elements. This comparison scale enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion. The decision-maker can express his preference between each pair of elements verbally as equally preferred, moderately preferred, strongly preferred, very strongly preferred and extremely preferred. These descriptive preferences would then be translated into numerical values 1, 3, 5, 7, 9 respectively, with 2, 4, 6 and 8 as intermediate values for comparisons between two successive judgments. Reciprocals of these values are used for the corresponding transposed judgments. For a matrix of order n , $n(n-1)/2$ comparisons are required. After the pair-wise comparisons are completed, proceed for the next step to estimate the eigen values of the matrix.

Step 3: Estimation of the eigen values of the matrix

Averaging over normalized columns method proposed by Thomas Saaty is used to estimate the eigen values. In this method, first sum the values in each column of the pair-wise comparison matrix and then divide each element in a column by the sum of its respective column. The resultant matrix is termed as the normalized pair-wise comparison matrix. Finally sum the elements in each row of the normalized pair-wise comparison matrix and divide the sum with the number of elements. The result of this computation is referred to as the priority matrix and is an estimation of the eigen values of the matrix.

Step 4: Checking the consistency of pair-wise judgments

In order to verify the consistency of the pair-wise comparison matrix, Saaty proposed consistency index (CI) and consistency ratio (CR). The CI and CR are defined as follows.

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1}$$

and

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

Where $\lambda_{\max}$ = maximum principal eigen value of the comparison matrix

n = number of elements (order of the pair-wise comparison matrix)

The value of $\lambda_{\max}$ is obtained by first multiplying the pair-wise comparison matrix with the priority matrix. Then divide the first element of the resulting matrix by the first element of the priority matrix, the second element of the resulting matrix by the second element in the priority matrix, and so on. A single column matrix is obtained and the average of the elements of the matrix gives the value of $\lambda_{\max}$. The RI in the above equation represents the average consistency index for numerous random entries of same-order reciprocal matrices. The value of RI for matrices of order n are given in table 1.

Table 1: Average value of RI for corresponding matrix order (Saaty, 1980)

n	RI	*n*	RI	*n*	RI	*n*	RI
1	0	5	1.12	9	1.45	13	1.56
2	0	6	1.24	10	1.49	14	1.57
3	0.58	7	1.32	11	1.51	15	1.59
4	0.90	8	1.41	12	1.48		

If CR ≤ 0.1, then the estimate is accepted; otherwise, a new comparison matrix is solicited until CR ≤ 0.1 (Chang et al., 2007).

3 CASE STUDY

In view of demonstrating the methodology, a case study has been undertaken in an engineering educational institution located in Visakhapatnam,

Andhra Pradesh, India. The institution has been offering under graduation courses of five different branches of engineering.

The institution is planning to offer post graduation courses in the near future. The authorities of the institution have taken step to restructure the library to meet the highest level of the satisfaction of the users. In order to assist the management of the institution in the effective allocation of the resources of the library, study is carried with the proposed methodology.

3.1 Questionnaire Survey

After the several discussions made with the users of the library, a questionnaire was developed on the expectations of the user's of the library shown in table 2. The questionnaire was administered to 220 users include students, faculty members, supporting staff and administrative staff.

Table 2: Questionnaire

Kindly indicate the degree of importance of service quality characteristics in a university library to ensure qualitative services to the users. Mention your response with a tick mark in the appropriate box on the basis of the following scale.
Note: 1- Not Important ; 2- Slightly Important ; 3- Somewhat Important ; 4- Important ; 5-Very Important

Q. No	Items (User attributes)	1	2	3	4	5
Q1	Staff members of the library should be courteous with the users consistently	☐	☐	☐	☐	☐
Q2	Providing photo copy, internet and audio-visual facilities	☐	☐	☐	☐	☐
Q3	Behavior of the library staff should be suitable to instill confidence in users	☐	☐	☐	☐	☐
Q4	Providing library services in the promised time	☐	☐	☐	☐	☐
Q5	Facility for providing access to the external visitors	☐	☐	☐	☐	☐
Q6	Availability of adequate text books, reference books and refereed journals	☐	☐	☐	☐	☐
Q7	Qualified library staff with a knowledge to answer the queries of the users	☐	☐	☐	☐	☐
Q8	Facility to train the library staff periodically to update their knowledge	☐	☐	☐	☐	☐
Q9	Maintaining the records pertaining to administration should be error free	☐	☐	☐	☐	☐
Q10	In-time response to the user enquires	☐	☐	☐	☐	☐
Q11	Individual attention to the users	☐	☐	☐	☐	☐
Q12	Sincere interest in guiding the users to fulfill their needs	☐	☐	☐	☐	☐
Q13	Library staff are able to understand the specific needs of the users	☐	☐	☐	☐	☐

Table 3: Sample demographics

Sl. No	Characteristic		Freq.	%
1	Gender	Male	112	62.2
		Female	68	37.8
2	Age (years)	18-25	135	75.0
		26-45	25	13.9
		46-50	20	11.1
3	Designation	Students	128	71.1
		Faculty members	25	13.9
		Support. staff	17	9.4
		Adminis. staff	10	5.6

The respondents (users) were asked to indicate the degree of importance of service quality characteristics in terms of a five point Likert scale. The demographics of the respondents are presented in table 3. The 182 responses were received from the respondents and in which 2 responses are invalid as the respondents filled the questionnaires not properly. However, 180 responses were considered for carry out the factor analysis. The response rate for the questionnaire survey is 81.8%.

3.2 Factor Analysis to obtain the service quality dimensions

The factor analysis begins with the correlation matrix, in which the inter-correlations between the studied variables (user attributes) are presented. Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's Test of Sphericity were used to examine the appropriateness of factor analysis. In this work, the

factor analysis of the data received from the questionnaire survey was carried out using Statistical Package for Social Sciences (SPSS) Version17.0. The Bartlett's test produces a chi-square of 528.541 with a significance level of 0.000, which shows that the sample taken from the total population under study is adequate.

The KMO test produces a measure of 0.568 (≈ 0.6), which further confirms the adequacy of the sample. The results obtained from the Bartlett's test and KMO test also indicate the suitability of the application of factor analysis. Hence factor analysis is considered as an appropriate technique for further analysis of the data.

The subsequent steps in factor analysis are selecting the method of extracting the factors, determine the number of factors to be extracted, and the method of rotation for interpretation of the factors. Principal component method of extraction and the varimax method of rotation are employed in this work. In the language of factor analysis, the proportion of variance of a particular variable that is due to common factors (shared with other variables) is called communality. Initial communalities are estimates of the variance in each variable accounted for by all components or factors.

Extraction communalities are estimates of the variance in each variable accounted for by the factors (or components) in the factor solution. Small values indicate variables that do not fit well with the factor solution, and should possibly be dropped from the analysis. Table 4 shows the communalities. The eigen value represents the total variance explained by each factor. The eigen values associated with each linear component before extraction, after extraction and after rotation are listed in table 5. From the table 5, it should be clear that the first five factors explain relatively large amounts of variance where as the subsequent factors explain only small amounts of variance. The extraction sums of squared loadings group gives information regarding the extracted factors or components. For principal components extraction, these values will be the same as those reported under Initial eigen values. The variance accounted for by rotated factors or components may be different from those reported for the extraction but the cumulative percentage for the set of factors or components will always be the same.

Table 4: Communalities

Communalities		
	Initial	Extraction
Q1	1.000	.760
Q2	1.000	.503
Q3	1.000	.736
Q4	1.000	.784
Q5	1.000	.650
Q6	1.000	.599
Q7	1.000	.767
Q8	1.000	.552
Q9	1.000	.784
Q10	1.000	.757
Q11	1.000	.738
Q12	1.000	.739
Q13	1.000	.419

A Scree plot is shown in figure 2 which indicates the eigen values against the number of factors in order of extraction. From the Scree plot, a distinct break occurs at five factors. The plot suggests that the five factors appear to be reasonable. In order to easily interpret the factors, the rotated component matrix is obtained by using varimax rotation. The partitions of five mutually exclusive groups are formed, which are shown in table 6.

Table 5: Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.394	18.417	18.417	2.394	18.417	18.417	2.140	16.464	16.464
2	2.086	16.047	34.464	2.086	16.047	34.464	1.870	14.384	30.848
3	1.533	11.789	46.253	1.533	11.789	46.253	1.693	13.020	43.868
4	1.414	10.874	57.128	1.414	10.874	57.128	1.594	12.264	56.132
5	1.361	10.467	67.595	1.361	10.467	67.595	1.490	11.462	67.595
6	1.025	7.884	75.479						
7	.686	5.275	80.754						
8	.541	4.160	84.914						
9	.490	3.770	88.684						
10	.432	3.325	92.009						
11	.398	3.065	95.074						
12	.357	2.742	97.816						
13	.284	2.184	100.000						

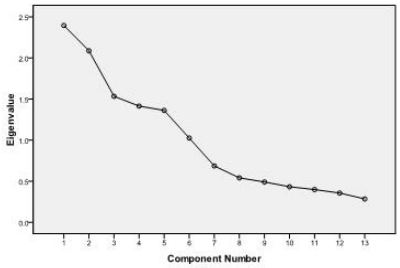

Figure 2: Screen plot

Table 6: Rotated component matrix

	Component				
	1	2	3	4	5
Q6	.767				
Q5	.746				
Q8	.705				
Q2	.681				
Q10		.868			
Q11		.856			
Q13		.577			
Q7			.867		
Q3			.852		
Q4				.882	
Q9				.877	
Q1					.868
Q12					.844

The first group of variables signifies the facilities offered by the library. The variables in the second group and third group are pertaining to responsiveness and assurance. The aspects related to service reliability and compassion come under the fourth, fifth groups respectively. The factors obtained from 1 to 5 are labeled as Adequate facilities (AF), Responsiveness (RES), Assurance (AS), Service reliability (SR) and Compassion (CO) respectively. These are the library service quality dimensions which are shown in table 7.

Table 7: Survey questions and service quality dimensions

Sl. No	Variables in the questionnaire	Service quality dimensions (Factors)
1	Availability of adequate text books, reference books and refereed journals (Q6)	Adequate Facilities (AF)
	Facility for providing access to the external visitors (Q5)	
	Facility to train the library staff periodically to update their knowledge (Q8)	
	Providing photo copy, internet and audio-visual facilities (Q2)	
2	In-time response to the user enquires (Q10)	Responsiveness (RES)
	Individual attention to the users (Q11)	
	Library staff members are able to understand the specific needs of the users (Q13)	
3	Behavior of the library staff should be suitable to instill confidence in users (Q3)	Assurance (AS)
	Qualified library staff with a knowledge to answer the queries of the users (Q7)	
4	Providing library services in the promised time (Q4)	Service Reliability (SR)
	Maintaining the records pertaining to administration should be error free (Q9)	
5	Staff members of the library should be courteous with the users consistently (Q1)	Compassion (CO)

3.3 Priority structure of service quality dimensions through AHP

The brainstorming sessions conducted with the experts in the field of library and information services to prepare the pair-wise comparison matrix of library service quality dimensions. The pair-wise comparison matrix and the normalized pair-wise comparison matrices of the service quality dimensions are shown in tables 8 and 9.

Table 8: Pair-wise comparison matrix of the library service quality dimensions

	AF	RES	AS	SR	CO
AF	1	3	2	3	5
RES	1/3	1	4	3	2
AS	1/2	1/4	1	1/2	2
SR	1/3	1/3	2	1	2
CO	1/5	1/2	1/2	1/2	1
SUM	2.36	5.08	9.50	8.0	12.0

Table 9: Normalized Pair-wise comparison matrix

	AF	RES	AS	SR	CO	SUM
AF	0.4237	0.5906	0.2105	0.3750	0.4167	2.0165
RES	0.1398	0.1969	0.4211	0.3750	0.1667	1.2994
AS	0.2119	0.0492	0.1053	0.0625	0.1667	0.5955
SR	0.1398	0.0650	0.2105	0.1250	0.1667	0.7070
CO	0.0847	0.0984	0.0526	0.0625	0.0833	0.3816

To normalize the sum of the rows, divide the each row sum of the table 9 with the number of elements (i.e., 5). The priority matrix of the quality dimensions is obtained and given as follows.

$$\frac{1}{5}\times\begin{bmatrix}2.0165\\1.2994\\0.5955\\0.7070\\0.3816\end{bmatrix}=\begin{bmatrix}0.4033\\0.2598\\0.1191\\0.1414\\0.0763\end{bmatrix}$$

The priority ratings of the library service quality dimensions are shown in table 10.

Table 10: Priority structure of the library service quality dimensions

Sl. No	Library service quality dimension	Priority Rating	Rank
1	Adequate facilities (AF)	0.4033	1
2	Responsiveness (RES)	0.2598	2
3	Assurance (AS)	0.1191	4
4	Service reliability (SR)	0.1414	3
5	Compassion (CO)	0.0763	5

$$\begin{bmatrix}1 & 3 & 2 & 3 & 5\\1/3 & 1 & 4 & 3 & 2\\1/2 & 1/4 & 1 & 1/2 & 2\\1/3 & 1/3 & 2 & 1 & 2\\1/5 & 1/2 & 1/2 & 1/2 & 1\end{bmatrix}\times\begin{bmatrix}0.4033\\0.2598\\0.1191\\0.1414\\0.0763\end{bmatrix}=\begin{bmatrix}2.2270\\1.4462\\0.6091\\0.7511\\0.4172\end{bmatrix}$$

$$\begin{bmatrix}2.2270/0.4033\\1.4462/0.2598\\0.6091/0.1191\\0.7511/0.1414\\0.4172/0.0763\end{bmatrix}=\begin{bmatrix}5.522\\5.567\\5.114\\5.312\\5.468\end{bmatrix}$$

$$\lambda_{\max}=\frac{5.522+5.567+5.114+5.312+5.468}{5}=5.3966$$

$$\mathrm{CI}=\frac{5.3966-5}{5-1}=0.0992$$

$$\mathrm{CR}=\frac{0.0992}{1.12}=0.088$$

The consistency index (CI) and consistency ratio (CR) are calculated using the procedure discussed in the step 4 of the section 2.2 and the computations are given as follows.

The consistency ratio (CR) is 0.088, which is smaller than 0.10 proved that the AHP results were consistent. From the table 10, it is observed that highest priority is given to the adequate facilities, responsiveness and service reliability. The next priorities are given to quality dimensions namely, assurance and compassion.

In order to improve the facilities to meet the expectations of the user community, the importance of the digital library is emphasized and softwares like MARC-21 convertibility, AACR-2, OPAC etc. for supporting the cataloguing process. To enhance the responsiveness of the services, it is necessary to train the library staff through conducting staff development programs, workshops to get exposure on understanding the specific needs of the users. It is suggested that the reliability in services can be improved by adopting the search strategy in tracing the information. The implementation of Boolean logic, truncation etc. imparts assurance to the users. The need of harmonious, cordial and good human relations between the library staff and the users is essential to attain empathy. On the basis of the above suggestions, the library management has to allocate their resources to impart qualitative services in the institution.

4. CONCLUSIONS

Quality is the basic requirement of any library service and all libraries strive to deliver the highest quality of service to attain the highest satisfaction level of the users. The library management has to allocate the resources effectively to meet the highest satisfaction of the users. The methodology proposed in this paper paves the way to understand the expectations of the users and helps the management in respect of giving priority to the service quality dimensions.

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Received: 15.02.2011 Accepted: 01.06.2011 Open for discussion: 1 Year