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# DETERMINATION OF CRITICAL SUCCESS FACTOR FOR LIBRARY PERFORMANCE: AN APPLICATION OF FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

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## ABSTRACT

*Proposing a novel framework for evaluating performance based on the combination of fuzzy AHP and fuzzy comprehensive evaluation method. Determining the factors and sub-factors in the evaluation index system, and then calculating the factor and subfactor weights by the extent analysis fuzzy AHP method. By the constructed system, evaluating performance can be conducted by the fuzzy comprehensive evaluation method. The approach can provide an effective, reasonable and accurate results of the assessment. Evaluating performance is the main means to improve Service quality and can play a major role in strengthening the management of institutions. For this purpose, a fuzzy analytic hierarchy process (FAHP) method integrating the fuzzy logic and AHP methods is used to determine performance indexing criteria more effectively, easily and applicable for a Universities libraries. Shortly, the objectives of the research are; to define a step-by-step approach for an efficient performance indexing variable selection in Measuring library performance.*

**KEYWORDS**: *Performance Evaluation, Critical Factors, FAHP, Library Performance*

## 1. INTRODUCTION

Analytic Hierarchical Process is one of the most popular Multi-Criteria Decision Making Techniques while the Fuzzy set theory is extensively incorporated into original AHP to address vagueness in human judgment. There are no of algorithms proposed for Fuzzy AHP. However, Fuzzy extent Analysis is one of the most frequently used models. AHP is a mathematical technique used for multi-criteria decision-making. In a way, it is better than other multi-criteria techniques, as it was designed to incorporate tangible as well as non-tangible factors particularly when the subjective judgments of different individuals constitute an important part of decision making (Saaty, 1980). Over the period no of researchers use Fuzzy-AHP in various decision-making situations. Few of those are stated below;

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Tang and Beynon (2005) apply Fuzzy-APH in the capital investment decision-making process. They use FAHP method utilized to consider the preference results with differing levels of precision in the pairwise judgments made. While, Mehregan, Jamporazmey, Hosseinzadeh, and Mehrafrouz (2011) apply Fuzzy-AHP to e-learning system assessment by identifying and prioritizing the preliminary e-learning critical success factors (CSFs) or enablers that need to be concentrated by universities and educational institutes. The result of such performance evaluation subsequently. Ahmed and Kilic (2015) apply FAHP to assess the performance of the organization and determine the variables which may assist in the decision-making process and eventually increase organizational performance. Vatanserver and Akgul (2014) use fuzzy analytic hierarchy process (FAHP) approach for evaluating the e-commerce websites, which can tolerate vagueness and uncertainty of judgment. Therefore, the insufficiency and imprecision problems associated with the conventional AHP can be solved. Hence, websites can be evaluated more reasonably. Liu, Kwon, and Kang (2007) a fuzzy analytic hierarchy process (FAHP) approach was designated to evaluate the e-commerce websites, which can tolerate vagueness and uncertainty of judgment. Authors divided a website's quality into four aspects as follows: Website basic technique, Web page design, Website information/content, Website function/service.

Harrison and Waite (2006) proposed fuzzy analytical hierarchy process (FAHP) approach to evaluate online bookstores. Research consists of five major criteria that are identified to achieve the overall goal. Specifically, the five major criteria are price, reputation, website features, service, and quality. Ellatif and Saleh (2008) developed an assessment method to evaluate the critical achievement factors of E-bank portals employing Fuzzy AHP & VBA, and convey an evaluation method to analyses five quality dimensions: access, website interface, trust, attention, and credibility. Deng and Wang (2011) analyzed the characters of the E-commerce information system, and built up an evaluation indices which can be divided into 3 levels, 4 aspects, includes 20 detail indices after that, it designated AHP and fuzzy evaluation method, carried out an integrative assessment.

Jun and Yu (2008) presented fuzzy analytic hierarchy process model to measure the e-commerce websites' performance. The study has investigated three websites the relative significance of the site quality, information quality, transaction capability. Li and Pang (2011) proposed an AHP-based multi-level fuzzy comprehensive evaluation model for business website assessment. The effectiveness of the firm, Information of business, Design of business, Availability of system, the efficiency of the system as the first indexes in the study.

## 2. METHODOLOGY OF THE STUDY

AHP is widely used for multi-criteria decision making and has successfully been applied to many practical problems (Saaty, 1980). In spite of its popularity, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the DM's perceptions to exact numbers. Traditional AHP requires exact or crisp judgments (numbers). However, due to the complexity and uncertainty involved in real world decision problems, decision makers might be more reluctant to provide crisp judgments than fuzzy ones. Furthermore, even when people use the same words, individual judgments of events are invariably subjective, and the interpretations that they attach to the same words may differ. Moreover, even if the meaning of a nutshell is well-defined (e.g., the linguistic comparison labels in the standard AHP questionnaire responses), the boundary criterion that determines whether an object does or does not belong to the set defined by that word is often fuzzy or vague. That is why fuzzy numbers and fuzzy sets have been introduced to characterize linguistic variables. A linguistic variable is a variable whose values are not numbers but words or sentences from a natural or artificial language. Linguistic variables are used to represent the imprecise nature of human cognition when we try to translate people's opinions into spatial data. The preferences in AHP are essentially human judgments based on human perceptions (this is particularly the case for intangibles), so fuzzy approaches allow for a more accurate description of the decision-making process (Murtaza, 2003).

Decision-making expert systems are often complex and multifaceted. In recent years, tools for modeling decision making have improved significantly, and multi-criteria decision making (MCDM) models are widely considered to be very useful in resolving conflicts related to the decision making process. Since (Biemans & Vissers, 1991) developed the theory of decision behavior in a fuzzy environment, various methods have been developed for handling multi-criteria decision-making systems (Lee, 1999)& (Zimmermann, 1985).

In this study, triangular fuzzy numbers, $\tilde{1}$ to $\tilde{9}$ , are used to represent subjective pairwise comparisons of the selection process to capture the vagueness. A fuzzy number is a special fuzzy set, where x takes it values on the real line, $-\infty < x < +\infty$ and $\mu_F(x)$ is a continuous mapping from R to the closed interval [0, 1].

A triangular fuzzy number denoted as $\tilde{M} = (l, M, U)$ , where $l \leq m \leq u$ has the following triangular type membership function;

**Table 1. Definition and Membership Function of Fuzzy Number (Ayag, 2005)**

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

$$\mu_F(x) = \begin{cases} 0 & x < 1 \\ x - l/m - i & l \leq m \leq u \\ u - x/u - m & m \leq x \leq u \\ 0 & x > u \end{cases}$$

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

$$\forall \alpha \in [0,1] \;\; \tilde{M} = [\, l^{\alpha} \; u^{\alpha} \,] = [(m - l)\,\alpha + l, - (u - m)\,\alpha + n]$$

The triangular fuzzy numbers (TFNs), $\tilde{1}$ to $\tilde{9}$, are utilized to improve the conventional nine-point scaling scheme. To take the imprecision of human qualitative assessments into consideration, the five TFNs are defined with the corresponding membership function as shown in figure 2

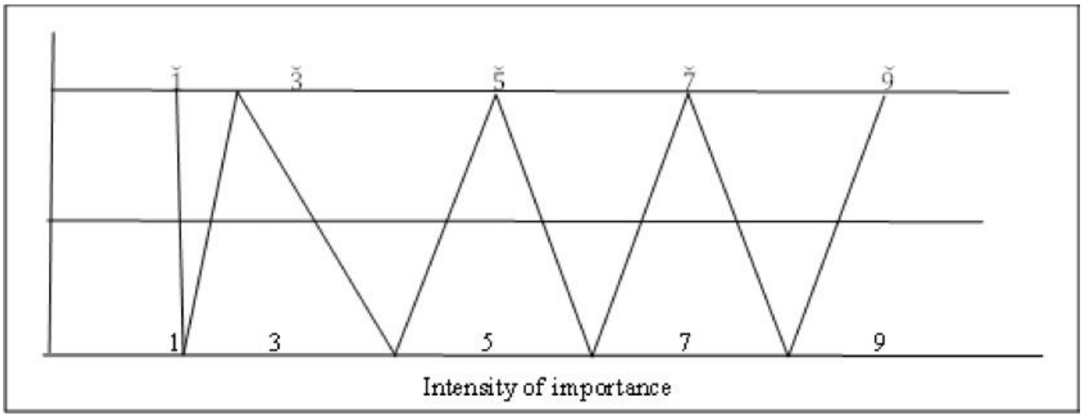


**Figure 2. Fuzzy Membership Function for Linguistic Values for Criteria or Alternatives**

### *2.1 Steps of Fuzzy AHP Approach*

The AHP method is also known as an eigenvector method (Aggarwal & Singh, 2013). It indicates that the eigenvector corresponding to the largest eigenvalue of the pairwise comparisons matrix provides the relative priorities of the factors, and preserves ordinal preferences among the alternatives. It means that if an alternative is preferred to another, its eigenvector component is larger than that of the other. A vector of weights obtained from the pairwise comparisons matrix reflects the relative performance of the various factors. In the fuzzy AHP, triangular fuzzy numbers are utilized to improve the scaling scheme in the judgment matrices, and interval arithmetic is used to solve the fuzzy eigenvector (Cheng & Mon, 1994). In this study, the five-step-procedure is defined for fuzzy AHP as follows;

***Step 1.Comparing the performance score:***

Triangular fuzzy numbers ( $\breve{1}\ \breve{3}\ \breve{5}\ \breve{7}\ \breve{9}$) are used to indicate the relative strength of each pair of elements in the same hierarchy.

***Step2.Constructing the Fuzzy compari comparison matrix:***

By using triangular fuzzy numbers, via pairwise comparison, the fuzzy judgment matrix $\left(\breve{A}\left(a_{ij}\right)\right)$ is constructed as given below;

$$\breve{A} = \begin{bmatrix} 1 & \breve{a}_{12} & .. & .. & .. & .. & .. & \breve{a}_{1n} \\ \breve{a}_{21} & & & 1 & & & & \breve{a}_{2n} \\ \breve{a}_{n1} & & & \breve{a}_{n2} & & & & 1 \end{bmatrix}$$

Where, $\widetilde{a_{ij}^{\alpha}}$ = 1, if *i* is equal *j, and* = $\breve{1}\ \breve{3}\ \breve{5}\ \breve{7}\ \breve{9}$ or $\breve{1}^{-1}$ , $3^{-1}$ , $5^{-1}$ , $7^{-1}$ , $9^{-1}$ , if *i is not equal to j*

*Step 3.Solving fuzzy eigenvalues:* A fuzzy eigenvalue, $\tilde{\lambda}$ is a fuzzy number solution to

$$\tilde{A}\,\tilde{X} = \tilde{\lambda}\,\tilde{X} \text{ ----------} \rightarrow (1)$$

Where is a *n x n* fuzzy matrix containing fuzzy numbers $\widetilde{a_{ij}}$ and $\widetilde{x}$ is a non-zero *nx1* fuzzy vector containing fuzzy numbers $\widetilde{x_i}$ . To perform fuzzy multiplications and additions using the interval arithmetic and *cut,* the equation $\tilde{A}\,\tilde{X} = \tilde{\lambda}\,\tilde{X}$ is equivalent.

$$\widetilde{A} = \left[\widetilde{a_{ij}}\right] \ , \tilde{x}^t = (\tilde{x}^1, \dots \dots \dots \tilde{x}^n),\ \widetilde{a_{ij}^{\alpha}} = \left[a_{ijl}^{\alpha,},\ \ a_{iju}^{\alpha,}\right], \tilde{x}_i^{\alpha} = \left[x_{il}^{\alpha,},\ \ x_{iu}^{\alpha,}\right], \tilde{\lambda}_i^{\alpha} = \left[\lambda_l^{\alpha,},\ \ \lambda_u^{\alpha,}\right] \text{ ----} \rightarrow (2)$$

For, $0< \alpha < 1$ and all i, j, where i=1,2,....,n, j=1,2,...,n α −τηε *cut* is known to incorporate the experts or decision maker(s) confidence over his/her preference or the judgments. The degree of satisfaction for the judgment matrix *A* is estimated by the index of optimism . The larger value of index indicates the higher degree of optimism. The index of optimism is a linear convex combination (Lee, 1999) defined as;

$$a_{ij}^{\alpha} = \mu a_{ij}^{\alpha} + (1-\mu)a_{ij}^{\alpha} , \nu\ \mu \epsilon [0,1] \text{ ----------} \rightarrow (3)$$

While α is fixed, the following matrix can be obtained by setting the index of optimism, , in order to estimate the degree of satisfaction.

$$\breve{A} = \begin{bmatrix} 1 & \breve{a}_{12} & .. & .. & .. & .. & .. & \breve{a}_{1n} \\ \breve{a}_{21} & & & 1 & & & & \breve{a}_{2n} \\ \breve{a}_{n1} & & & \breve{a}_{n2} & & & & 1 \end{bmatrix}$$

***Step 4.Normalization of the matrices:*** Normalization of both the matrix of paired comparisons and calculation of priority weights (approx. criteria weights) and the matrices and priority weights for alternatives on each criterion are also done before calculating $\lambda_{max}$. In order to control the result of the method, the consistency ratio for each of the matrices and overall inconsistency for the hierarchy calculated. The deviations from consistency are expressed by the following equation consistency index and the measure of inconsistency is called the consistency index (CI); max;

$$CI = \frac{\lambda_{max} - n}{n-1} \text{ ----------} \rightarrow (4)$$

The consistency ratio (CR) is used to estimate the consistency of pairwise comparisons directly. The CR is computed by dividing the CI by a value obtained from a table of Random Consistency Index (RI);

$$CR = \frac{CI}{RI} \text{ ----------} \rightarrow (5)$$

If the CR less than 10%, the comparisons are acceptable. Otherwise, they should be repeated until reached to the CR, less than 10%. RI is the average index for randomly generated weights (Saaty, 1981).

***Step 5.Calculation of priority weights for each alternative:*** The priority weight of each alternative can be obtained by multiplying the matrix of evaluation ratings by the vector of criterion weights and summing over all criteria. Expresses in conventional mathematical notation

*Weighted evaluation for alternative K* = $\sum_{i=1}^{t}(Criterion\ weight_{\ i} * \ evaluation\ rating_{\ t})$ -----→ (6)
for *i=1,2,..,t* ( *t :* total number of criteria )

After calculating the weight for each alternative, the overall consistency index is also calculated that it should be less than 10% for consistency on all judgments

## 3. DATA ANALYSIS AND INTERPRETATION

Data gathered via a questionnaire survey. The questionnaire contains proposed CSF indicators and their criteria. The questionnaires were distributed among sample library professionals and asked them for comparing the importance of each CSF indicator to another one and compare the importance of each criterion under each indicator to the other one at the same indicator. The scale used in this questionnaire is presented in Table 2. Surveys were sent to 235 library professionals in different universities offering library facilities via email which 200 of them were received back. So the respond rate is approximately 85%. To calculate the final score of each indicator and criterion, the arithmetic operations between triangular fuzzy numbers is used. Then answers are analyzed by FAHP method. To simplify calculations in FAHP program which is developed by the authors is applied.

The performance indexing system comprises six (06) dimensions and having four (04) sub-criteria in each dimension.

**Table 1. Lists of Criteria for Performance Indexing**

| Criteria | Code |
|---|---|
| Library Efficiency | $X_1$ |
| Library Core People Process | $X_2$ |
| Library Environment | $X_3$ |
| Library Users' Satisfaction | $X_4$ |
| Library Adaptability | $X_5$ |
| Library Capacity | $X_6$ |

Table 1 exhibits major criteria's of performance evaluation of library service

**Table 2. Fuzzy Evaluation Scale**

| Assessment variables | Triangular Fuzzy Scale |
|---|---|
| Equally Important | (1,1,1) |
| Weakly Important | (1,3,5) |
| Essentially Important | (3,5,7) |
| Very Strong Important | (5,7,9) |
| Absolutely Important | (7,9,9) |

Table 2 exhibits Triangular Fuzzy AHP for evaluation of performance evaluating criteria in performance indexing system.

**Table 3. Pairwise Comparison of Fuzzy Evaluation**

| | $X_1$ | | | $X_2$ | | | $X_3$ | | | $X_4$ | | | $X_5$ | | | $X_6$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 1.00 | 1.00 | 1.00 | 5.28 | 7.4 | 0.69 | 2.92 | 5.28 | 7.40 | 0.69 | 1.19 | 2.92 | 0.69 | 6.08 | 7.61 | 1.91 | 4.33 | 6.08 |
| $X_2$ | 0.59 | 1.44 | 2.92 | 1.00 | 1.00 | 1.00 | 0.59 | 0.84 | 1.44 | 0.13 | 0.16 | 0.25 | 4.33 | 3.98 | 6.08 | 7.61 | 1.91 | 4.33 |
| $X_3$ | 0,84 | 1.44 | 0.13 | 0.14 | 1.79 | 2.26 | 1.00 | 1.00 | 1.00 | 0.79 | 1.45 | 1.55 | 2.50 | 0.55 | 7.40 | 0.69 | 2.92 | 0.59 |
| $X_4$ | 0.13 | 0.69 | 0.84 | 0.08 | 0.14 | 0.08 | 0.11 | 0.05 | 0.05 | 1.00 | 1.00 | 1.00 | 1.71 | 0.14 | 0.19 | 0.34 | 0.23 | 0.25 |
| $X_5$ | 0.13 | 0.19 | 0.34 | 0.23 | 0.14 | 0.19 | 0.26 | 1.89 | 0.84 | 0.11 | 0.12 | 0.19 | 1.00 | 1.00 | 1.00 | 1.71 | 0.19 | 0.26 |
| $X_6$ | 0.12 | 0.11 | 0.09 | 0.14 | 0.16 | 1.44 | 0.30 | 0.59 | 0.34 | 0.11 | 0.12 | 0.11 | 0.25 | 1.44 | 2.92 | 1.00 | 1.00 | 1.00 |

*Source: Author calculation*

Table 3 exhibits Fuzzy evaluating scale for the study, the consistency of pairwise comparison matrices expresses in Assessing variables are evaluated via using (Kwong & Bai, 2003) approach. The number of triangular fuzzy (4m + s + u) / 6 subjected to defuzzification by the formula is converted to some not blurred, and a consistency check is performed. Consistency control with Nonfuzzy numbers is done in the same way as Classical AHP. In this study, all created on the criteria and alternatives in matrix consistency rate is <0.10 and All matrices were consistent. The main criteria based on pairwise comparison of fuzzy evaluation matrix is the same as in Table 2.

**Table 4. Normalization Score of Criteria under FAHP**

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|
| $X_1$ | 0.485 | 0.661 | 0.159 | 0.2901 | 0.257 | 0.107 |
| $X_2$ | 0.161 | 0.220 | 0.718 | 0.348 | 0.585 | 0.25 |
| $X_3$ | 0.069 | 0.031 | 0.079 | 0.290 | 0.178 | 0.178 |
| $X_4$ | 0.060 | 0.027 | 0.009 | 0.058 | 0.071 | 0.107 |
| $X_5$ | 0.060 | 0.027 | 0.015 | 0.006 | 0.035 | 0.321 |
| $X_6$ | 0.161 | 0.031 | 0.016 | 0.006 | 0.009 | 0.035 |

*Source: Author calculation*

Table 4 exhibits normalization score for main criteria of performance indexing in library services which is calculated by applying developed Fussy-AHP model.

**Table 5. Weights under Criteria of *Library Efficiency***

| Alternatives | Weight |
|---|---|
| With Minimum Time | 0.401 |
| Update Books Catalogues | 0.196 |
| New Information | 0.273 |
| Respond Of Users Valid Demand | 0.130 |

*Source: Author calculation*

**Table 6. Weight under Criteria of *Library Core People***

| Alternatives | Weight |
|---|---|
| Entertain All The Queries | 0.256 |
| Proper Knowledge | 0.257 |
| Users Feedback | 0.406 |
| Relations Between Users And Staff | 0.082 |

*Source: Author calculation*

**Table 7. Weight under Criteria of *Library Environment***

| Alternatives | Weight |
|---|---|
| Healthy And Hygienic Environment | 0.265 |
| Cleansing Technology | 0.156 |
| Homely Environment | 0.500 |
| Additional Support | 0.079 |

*Source: Author calculation*

**Table 8. Weight under Criteria of Users' Satisfaction**

| Alternatives | Weight |
|---|---|
| Enough Facilities For Users | 0.317 |
| Library Net Facilitates | 0.155 |
| Reserve Book Through Online | 0.272 |
| Subscriber To Other Library | 0.256 |

*Source: Author calculation*

**Table 9. Weight of Alternatives under Criteria of *Adaptability***

| Alternatives | Weight |
|---|---|
| Book Logging System | 0.384 |
| E-Corner For Online Study | 0.309 |
| High-Speed Net Facility | 0.149 |
| No Of Subscribers | 0.159 |

*Source: Author calculation*

**Table 10. Weights under Criteria of *Library Capacity***

| Alternatives | weight |
|---|---|
| Availability Of Books | 0.487 |
| Increasing Books | 0.205 |
| Capacity Building Activates | 0.211 |
| Separate Section | 0.095 |

*Source: Author calculation*

**Table 11. Weights of six (06) Major Criteria in Performance Evaluation in Library Service**

| Criteria | Priorities | Weight |
|---|---|---|
| Library Efficiency | 1 | 0.279 |
| Library Core People Process | 3 | 0.152 |
| Library Environment | 4 | 0.125 |
| Library Users' Satisfaction | 2 | 0.249 |
| Library Adaptability | 5 | 0.113 |
| Library Capacity | 6 | 0.080 |

*Source: Author calculation*

From tables 5 to 10; exhibit respective weight of each alternative under main criteria calculated by apply Fuzzy-AHP extended model which is developed by the author. Moreover, Table 11 exhibits critical factors weight while measuring library perforce in six different aspects.

## 4.CONCLUSION AND FINDINGS

By regarding dynamic and changing environment, successful educational organizations and institutes are those who manage and integrate learning systems continuously to gain learning objects and superior performance. Continuous evaluation of performance is the prime way of improving performance for service oriented organizations. Every university has its library towards proving service to students, researchers and so one. Measurement of library service is a critical issue nowadays to improve performance and create ultimate satisfaction to users. This paper proposes an approach based on the FAHP for evaluating the performance of university library. The analytic hierarchy is structured by the seven major CSFs including *Library Efficiency, Library Core People Process, Library Environment, Library Users' Satisfaction, Library Adaptability, Library Capacity* followed by subcategories of CSFs.

The results show that library performance is significantly attributed towards users' satisfaction with the currently available service as well as the level of efficiency in providing service to users' in the library. While among the subcritical factors, it is found that users are concerned about (1) time required to desired services, (2) address users' feedback regarding expected level of services, (3) congenial environment, (4) online book logging facility, (5) available required no of books, and (6) enough facilities.

Considering the critical factors and sub-critical factors, library management should try to improve their library service and ensure periodic evaluation of performance by proposed model having critical factors weight derived from FAHP. This approach for evaluation provides an opportunity for educational institutes and universities to concentrate on key issues, and it can also offer beneficial information in strategic planning of enhancing library performance initiatives.

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