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Fuzzy Logic as Intelligence Tools in Testing Software Quality

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Abstract:- This study identifies and analyzes critical quality characteristics that should be considered to ensure the successful development and implementation of the E-learning system in High institutes, and the software quality model plays an important role in the success of the information system; it is a critical and essential type of organization's quality that consists of quality criteria which usually capture a model that explains these characteristics and their relationships.

The model has been empirically validated by fitting the model to data collected from 302 students engaged with an e-learning system in one of the Jordan universities through the pairwise comparison technique from all evaluated end users.

Each sub-characteristic of the system has its attributes to determine the evaluation results. The Fuzzy Analytical Hierarchy Process (FAHP) with extent analysis has been applied to the model as an intelligence decision-making tool to execute an empirical study, aiming to verify the model's efficiency.

Keywords*:* *Evaluation of Software, Quality Models, Characterized, Attributes Fuzzy, Analytical Hierarchy Process, Academic Information System, ISO 9126*

1. Introduction

we proposed and built a new quality model in our published paper [1] dedicated to Academic Information Systems (AIS) to support a standard set of software quality characteristics. This study aims to assess the quality of E-learning in Mu'tah University's camps to assist system analysts, developers, and programmers with their eLearning initiatives.

The evaluations conducted in this study will provide recommendations for both the construction and maintenance of the target E-learning system and its long-term consequences.

The same new model has been improved in, [1] by identifying new attributes for the model's sub-characteristics and defining metrics rules to measure the quality of these new attributes.

E-learning system Quality Evaluation is a paper that discusses an evaluation of the software attributes of an E-learning system using our proposed software quality model (ESQE). To determine the quality of web-supported E-learning applications and the universal standard quality in the software industry, some software is available at Jordanian Universities. (ISO/ICE 9126 and ISO/ICE 25010: 2011) These are among the software quality standards commonly used to assess software quality in general [2].

A disadvantage of the current quality standard is that it is more focused on the consumer's point of view, competitiveness, and effectiveness, and it is important to understand the educational side of the view in a scholarly field, not the profit side view [3].

The Analytic Hierarchy Process (AHP) is the best technique to test this new model, separating a complex multi-criteria decision issue into hierarchy levels and rotating measurement levels [4].

A new fuzzy prioritization approach deals with uncertain data and imperious knowledge, so it derived crisp Global Weights priorities from AHP calculations, which were then represented using MATLAB fuzzy tools by Triangle

Fuzzy Number (TFN). Fuzzy-based decision-making, considered an Artificial Intelligence tool (AI), in particular, can help users and developers evaluate the quality of software, making it highly suitable for academic and marketable purposes [5].

2. Objectives

The driving force behind this paper is to inspire researchers to develop fresh software models that can assist system developers in evaluating their systems, including E-Learning systems in universities. This is especially relevant in the wake of the COVID-19 epidemic.

One reason for motivation is the lack of local research and studies on the factors in measuring the quality of educational systems in Jordanian Universities. Additionally, there is no complete model for assessing all attributes and sub-attributes of AIS, throughout the university.

Although web-based applications, such as AIS, are primarily used to support the operational processes of educational institutions, not all AIS are well-managed. As a result, there is a need for an instrument to measure and ensure the quality of AIS.

3. Fuzzy Analytical Hierarchy Process Methodology (FAHP)

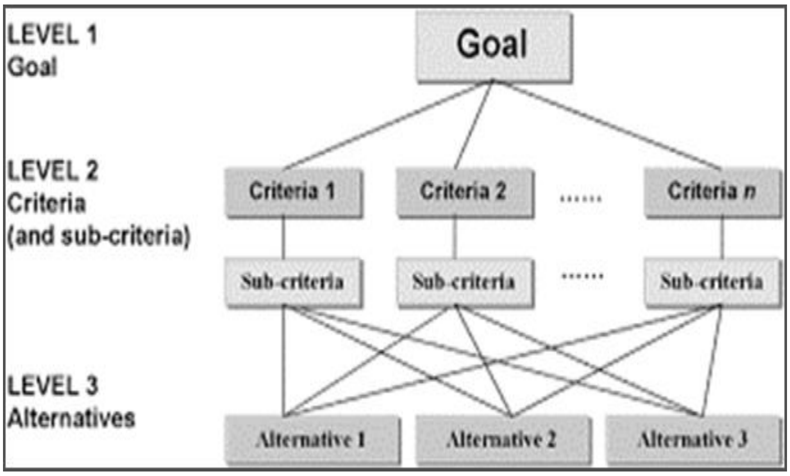
AHP stands for Analytic Hierarchy Process, which is a structured approach to decision-making that helps individuals or groups to make complex decisions by breaking them down into smaller, more manageable pieces. The AHP method is often used when there are multiple criteria and alternatives to consider, and when the decision involves subjective judgments [6].

The following are the steps involved in using AHP for decision-making.

3.1 Define the problem: This involves identifying the decision criteria and the available alternatives.

3.2 Develop a hierarchy: The next step is to create a hierarchy that breaks down the problem into smaller, more manageable sub-problems. The hierarchy typically consists of a goal, a set of criteria, and a set of alternatives; in Figure 1, the lines connecting each alternative to each criterion show how each alternative is evaluated according to each criterion.

Figure 1. AHP Hierarchy



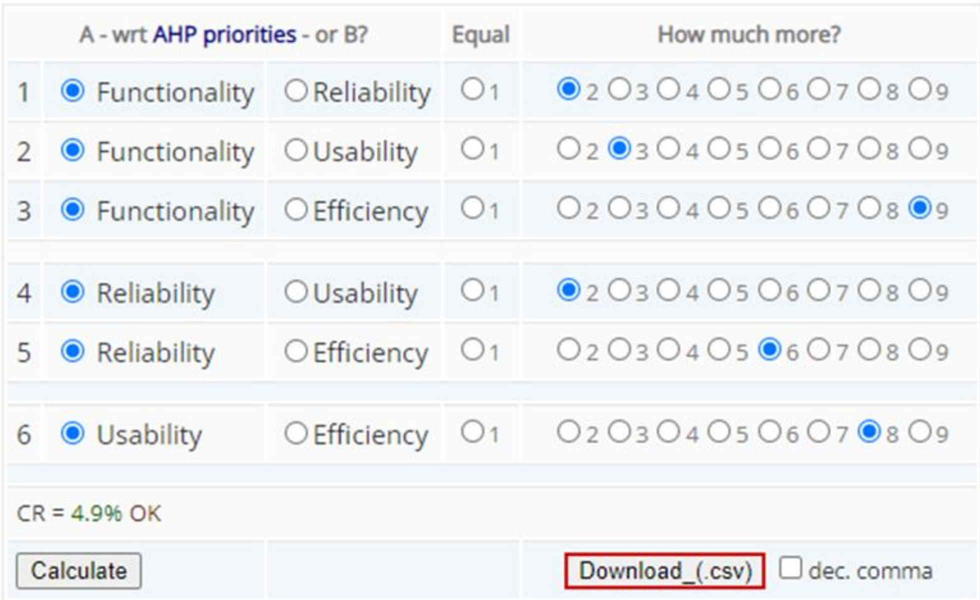
3.3 Pairwise Comparison. This involves comparing each element to every other element at the same level and assigning a score to indicate the relative importance or preference

Figure 2. Decision Matrix and Pair Comparison Matrix

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & & & \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & & & \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix}$$

3.4 Calculate priority weights: Based on the pairwise comparison results, priority weights are calculated for each element in the hierarchy. These weights are used to determine the overall priority of each alternative.

Figure 3. AHP priority calculator



The local priority is calculated using the following equation:

$$LP_i = \frac{\sum_{j=1}^{N} (RW\,ij)}{\sum_{i=1}^{N} \sum_{j=1}^{N} (RW\,ij)} \qquad (1)$$

Where LPi is a local priority criterion of I, RWij is the relative weight of criterion I over criterion j, and N is the number of criteria (Schwartz, 2013).

An M×N matrix is constructed from the local priorities for criteria and alternatives, where M is the number of alternatives considered, and N is the number of criteria. The following equation calculates the global priority or global weight [7].

$$GP_k = \sum_{j=1}^{N} (LPA_{kj}) \times (LP_j) \qquad (2)$$

Where GPk is the Global Priority for alternative k, N is the number of criteria, LPA Ki is a Local Priority of alternative k where ($l \le k \le M$) and criterion j, and LPi is the local priority of criterion j, Using the global priority, the decision-maker determines which alternative should be selected; the alternative to the highest global priority is the best [7]. The eigenvalues of this matrix must be calculated, giving the relative weights of the criteria. The relative weights obtained in the fourth step should satisfy the formula:

$$\lambda_{max} = A * W \qquad (3)$$

Where A represents the Pairwise comparison matrix, W represents the weight and λmax represents the highest eigenvalues [4]. The importance of weight is evaluated in terms of the criterion's importance in reaching the goal. Criteria with an enormous impact on achieving the goal should receive higher importance weights than those with less of an impact. A scale frequently used is the nine-point scale, shown in Table 1.

Table 1. The scale of Relative Importance

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	This is very strong importance.
9	Extreme of Importance.
2,4,6,8	For a compromise between the above values.

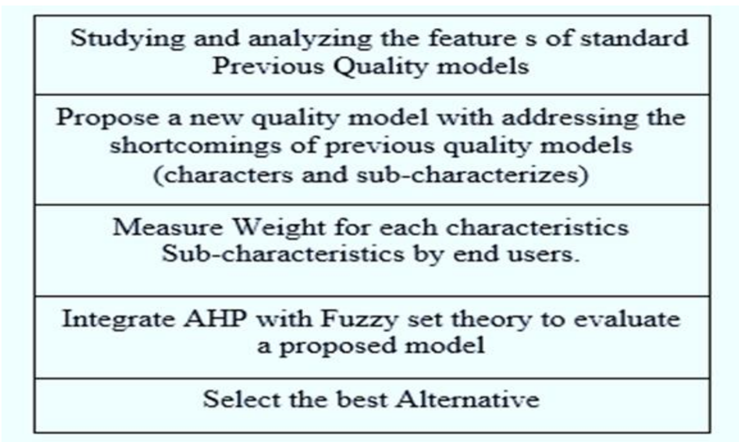
After the pairwise comparisons have been conducted for the criteria, the weights provided in the comparisons have been structured as a matrix.

3.4 Evaluate Consistency Ratio: It is important to ensure that the pairwise comparisons are consistent and not contradictory. This is done by evaluating the consistency ratio, which is a measure of the consistency of the decision maker's judgments. The C.R was calculated as follows [8].

$$C.I = \lambda_{max} - \frac{n}{n-1} \qquad \textbf{(4)}$$
$$C.R = \frac{C.I}{R.I}$$

Where λ max stands for the highest eigenvalues (explained in step 6 below), and N stands for several criteria. The consistency ratio should be lower than or equal to 0.10 to accept the AHP results as consistent. If not the case, the decision-maker should go back to Step 3 and 4 and redo the comparisons and assessments [8]

Figure 4. Schema of work



4. Data Analysis Technique

our selection would be the integrated analytical hierarchy process with fuzzy set theory (FAHP) with extending the analysis to evaluate a proposed model as business intelligence tools. The comparison of two elements at the same level of the decision hierarchy can be compared using MATLAB fuzzy tools branch of AI and the resulting data can be represented by a Triangle Fuzzy Number (TFN). After obtaining the TFN, the Fuzzy Extend Analysis (FEA) procedure can be employed to calculate and derive the final results [9].

By following these steps, the AHP method helps decision-makers to make well-informed decisions that are consistent with their values and preferences. During the process of pairwise comparison, which is described in previous steps, the evaluation takes place. The number of comparisons required to determine priorities for a matrix containing N elements is (N^2 - N)/2. As the number of alternatives increases, the number of comparisons required also increases quadratically [8].

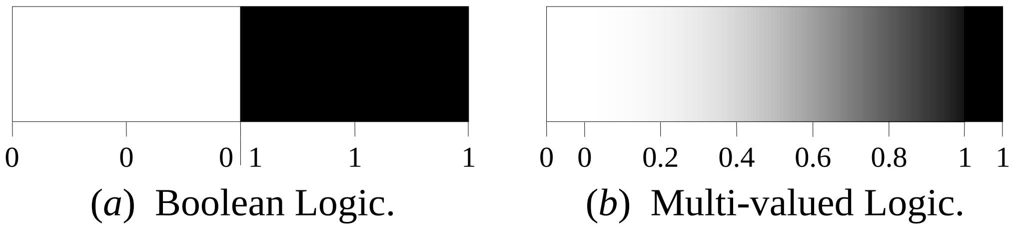
4.1 The Fuzzy Set Theory

The concept of a set is fundamental to mathematics; the basic idea of the fuzzy set theory is an element belonging to a fuzzy set with a certain membership. This degree is usually taken as a real number in the interval [0, 1].

$$f_A(x): X \rightarrow \{0, 1\}, \text{ where } F_A(x) = \begin{cases} 1, \; if \; x \in A \\ 0, \; if \; x \notin A \end{cases}$$

- Let X be the universe of discourse and its elements be denoted as x.
- In the classical set theory, crisp set A of X is defined as function fA(x) called the characteristic function of A This set maps universe X to a set of two elements.
- For any element x of universe X, characteristic function fA(x) is equal to 1 if x is an element of set A, and is equal to 0 if x is not an element of A.
- Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic.

Figure 5. Fuzzy Logic



4.2 Integration between Fuzzy Set Theory and AHP.

The disadvantage of AHP when applied to handle the inherent uncertainty and impression of a decision maker's perception to get the exact actual value [1] and [2, 2].

Therefore, the natural way to cope with uncertainty conditions is to pass the comparison ratios as fuzzy sets. Figure 4.8 Present how integration between the AHP method and fuzzy set theory to extract FAHP.

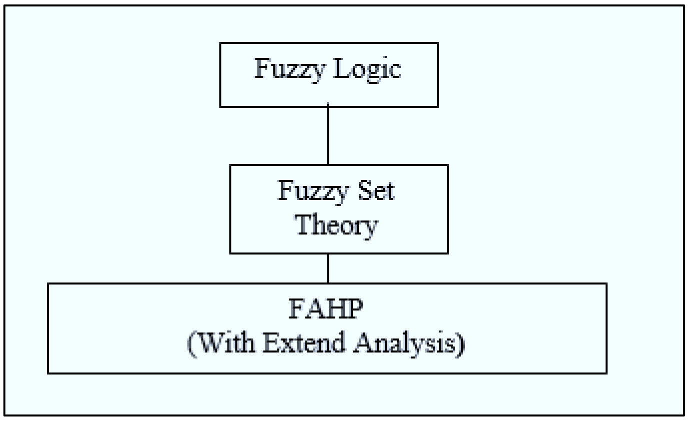


Figure 6: Diagram of FAHP

The priority weight extraction from the AHP method is an input in fuzzy set theory evaluative judgment resulting from the comparison of any two elements , [1].

The TFN required to form the decision matrix in the fuzzy AHP procedure may be determined by deriving numbers from questionnaires, in which users are prompted to evaluate the selected criteria of relative importance, which can be converted to fuzzy numbers using a suitable conversion scale.

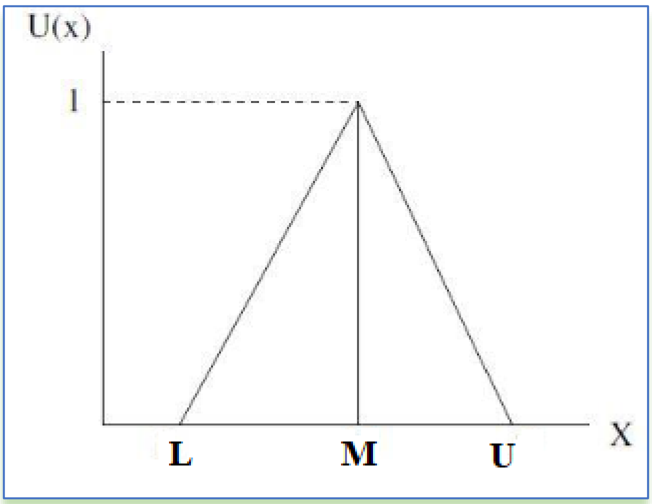
Questionnaires may determine Procedure by identifying and evaluating attributes on which the Information System functions depend on, but in our study, we will get TFN from the Global Weights (GW) in AHP, then assigns to each GW a membership grade between zero and one. Evaluating alternative models and rank, then after the given criteria .[10].

4.3 Obtaining Triangular Fuzzy Numbers (TFN)

Triangular Fuzzy Numbers (TFN) are a special type of fuzzy number. They are capable of combining subjective opinions from end users, TFN is described by a triplet (L, M,U) where M is the middle value (Geomean), L is a minimum value, and U is the maximum value, when L, M and U are equals then fuzzy numbers become crisp numbers. TFN is used to represent stakeholder opinions for quality goals in quality [11].

Such a set is characterized by a membership function, which assigns to each object a membership grade between zero and one. Figure 4.6 depicts a triangular fuzzy number (Karaa, Cherif, & Lamouchib, 2016).

Figure 7: Triangular Fuzzy Numbers



4.4 The Membership Function

A fuzzy set is one that assigns grades of membership between 0 and 1 to objects using a particular membership function µA(x), will be discussed later In chapter 6.

The membership functions can be of different types, including triangular membership functions and trapezoid membership function, depending upon the experience of the decision-maker/project manager [11].

TFNs can be represented graphically as triangles with their points defined by the low, medium, and high values. These triangles can be used as membership functions in fuzzy logic systems to model the uncertainty and imprecision inherent in many real-world systems [10].

In this paper, the researcher will use Fuzzy Logic Toolbox software with MATLAB® technical computing software as a tool for solving problems with fuzzy logic [12].

Figure 8: Triangular Membership Function

$$\mu_A(x) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a < x \le b \\ 1, & x = b \\ \frac{c-x}{c-b}, & b < x \le c \\ 0, & x \ge c. \end{cases}$$

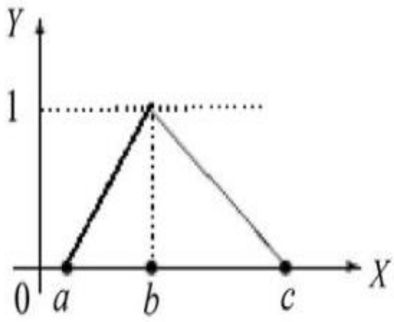
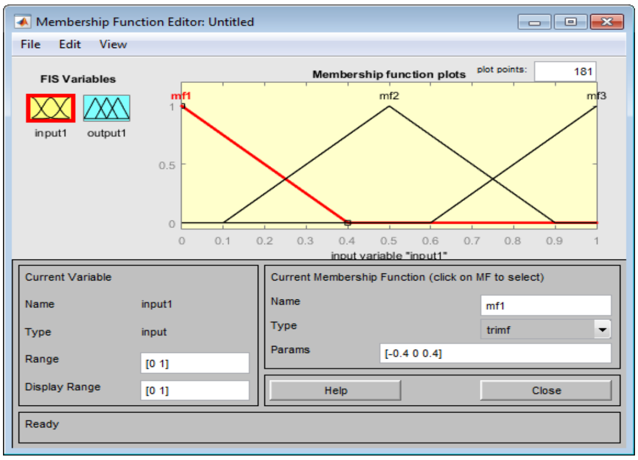


Figure 9. Membership Function in Matlab



4.5 Extended Fuzzy Logic

Extended fuzzy refers to an extension of the traditional fuzzy logic framework that allows for more complex and flexible representations of uncertainty and imprecision in reasoning and decision-making.

In traditional fuzzy logic, membership functions are used to represent the degree of truth or falsity of a statement. These membership functions are defined over a fixed domain, and their values range between 0 and 1 [13].

Extended fuzzy logic extends this framework by allowing for more general forms of membership functions that can be defined over a more flexible domain, such as a continuous range of values or a set of intervals. This allows for more fine-grained representations of uncertainty and imprecision in reasoning and decision-making, which can be useful in a variety of applications, such as control systems, pattern recognition, and decision support systems [14].

Some examples of extended fuzzy logic frameworks include type-2 fuzzy logic, which allows for more complex membership functions that include uncertainty about the membership values themselves, and fuzzy rough sets, which combine fuzzy logic with rough set theory to deal with incomplete and uncertain data.

5. Weights Values Matrix for Mu'tah University

Since its launch in 1993, the Computer Center has been considered the electronic portal of the University of Mu'tah, which would support all electronic services for students and workers at the university.

The Department of Publishing and E-Learning was established in 2008 to oversee the E-Learning website in terms of working on managing computerized exams, monitoring their progress and publishing electronic content related to materials for students and providing protection and security for E-Learning data and recently.

Later the University launched Moodle App services with these application features:

- Easily access course content even when offline.
- Connect with course participants.
- Keep up to date - receive instant notifications of messages and other events, such as assignment submissions.
- Submit assignments from your mobile device.
- Track student's progress - View the grades, check completion progress in courses and browse the learning plans.
- Complete activities anywhere, anytime - attempt quizzes, post in forums.

Here the pairwise comparison judgments for all E-Learning software attributes that have been evaluated by end-users.

Matrix 1: Weight values for the Characteristics According to Goal

GOAL	Functional	Reliability	Usability	Efficiency	Maintability	System Content
Functional	1.000	3.000	1.000	2.000	8.000	1.000
Reliability	0.333	1.000	0.500	2.000	2.000	0.250
Usability	1.000	2.000	1.000	4.000	3.000	0.500
Efficiency	0.500	0.500	0.250	1.000	1.000	0.250
Maintainability	0.125	0.500	0.333	1.000	1.000	0.167
System Content	1.000	4.000	2.000	4.000	6.000	1.000
Sum	3.958	11.000	5.083	14.000	21.000	3.167

Matrix 2: Pairwise Comparisons Judgment for the Characteristics According to Goal

GOAL	Functional	Reliability	Usability	Efficiency	Maintainability	System Content	Priority Weights
Functional	0.253	0.273	0.197	0.143	0.381	0.316	0.260
Reliability	0.084	0.091	0.098	0.143	0.095	0.079	0.098
Usability	0.253	0.182	0.197	0.286	0.143	0.158	0.203
Efficiency	0.126	0.045	0.049	0.071	0.048	0.079	0.070
Maintainability	0.032	0.045	0.066	0.071	0.048	0.053	0.052
System content	0.253	0.364	0.393	0.286	0.286	0.316	0.316
C.R=.033						∑Priority Weights=1	

Matrix 3: Pairwise Comparisons Judgment for the Sub Characteristics According to Functionality

Functionality	Interopratability	Suitability	Compliance	Security	Priority Weights
Interopratability	0.200	0.214	0.167	0.200	0.195
Suitability	0.400	0.429	0.500	0.400	0.432
Compliance	0.200	0.143	0.167	0.200	0.177
Security	0.200	0.214	0.167	0.200	0.195
C.R=.08					∑Priority Weights=1

Matrix 4: Pairwise Comparisons Judgment for the Attributes According to Interoperability.

Interoperability	Data Compatibility	Platform Compatibility	Priority Weights
Data Compatibility	0.875	0.875	0.875
Platform Compatibility	0.125	0.125	0.125
C.R=0%			∑Priority Weights=1

Matrix 5: Pairwise Comparisons Judgment for the Attributes According to Suitability.

Suitability	Application Domain	Function Specification	Priority Weights
Application Domain	0.833	0.833	0.833
Function Specification	0.167	0.167	0.167
C.R=0%			∑Priority Weights =1

Matrix 6: Pairwise Comparisons Judgment for the Attributes According to Security.

Security	Privacy	Authentication	Priority Weights
Privacy	0.833	0.833	0.833

Authentication	0.167	0.167	0.167
C.R=0%			∑Priority Weights =1

5.1 Constructing the Weights Values Matrix for Reliability

Matrix 7: Pairwise Comparisons Judgment for the Sub-Characteristics According to Reliability and Consistency Ratio.

Reliability	Recoverability	Availability	Maturity	priority
Recoverability	0.735	0.750	0.692	0.726
Availability	0.184	0.188	0.231	0.201
Maturity	0.082	0.063	0.077	0.074
C.R=0.01				∑Priority Weights=1

Matrix 8: Pairwise Comparisons Judgment for the Attributes According to Recoverability and Consistency Ratio.

Recoverability	Time To Recover	Error Reporting	Priority Weights
Time To Recover	0.833	0.833	0.833
Error reporting	0.167	0.167	0.167
C.R=0%			∑Priority Weights=1

Matrix 9: Pairwise Comparisons Judgment for the Attributes According to Maturity.

Maturity	**Fault Tolerance**	**Evolvability**	**Priority Weights**
Fault Tolerance	0.822	0.822	0.822
Evolvability	0.178	0.178	0.178
C.R=0%			∑Priority Weights=1

5.2 Constructing the Weight Values Matrix of Usability

Matrix 10: Pairwise Comparisons Judgment for the Sub Characteristics According to Usability

Usability	Opreatability	Understandability	Learnability	User Interface	Priority Weight
Opreatability	0.387	0.533	0.375	0.333	0.407
Understandability	0.097	0.133	0.250	0.167	0.162
Learnability	0.129	0.067	0.125	0.167	0.122
User Interface	0.387	0.267	0.250	0.333	0.309
C.R=0.048					∑Priority Weights=1

Matrix 11: Pairwise Comparisons Judgment for the Attributes According to Operability.

Operability	Effort To Operate	Administrability	Priority Weights
Effort To Operate	0.200	0.200	0.200
Administrability	0.800	0.800	0.800
C.R=0			∑Priority Weights=1

Matrix 12: Pairwise Comparisons Judgment for the Attributes According to Understandability.

Understandability	Training	User Support	Documentation	Priority Weight
Training	0.692	0.692	0.692	0.692
User Support	0.231	0.231	0.231	0.231
Documentation	0.077	0.077	0.077	0.077
C.R=0				∑Priority Weights=1

Matrix 13: Pairwise Comparisons Judgment for the Attributes According to Learnability.

Learnability	Time to use	Time to Configure	Priority
Time to use	0.870	0.870	0.870
Time to Configure	0.130	0.130	0.130
C.R=0%			∑Priority Weights=1

Matrix 14: Pairwise Comparisons Judgment for the Attributes According to User Interface.

User Interface	Consistency	Simplicity	User Control	Priority Weights
Consistency	0.735	0.776	0.544	0.685
Simplicity	0.184	0.194	0.396	0.258
User control	0.082	0.030	0.060	0.057
C.R=0.02				∑ Priority Weights=1

5.3 Constructing the Weight Values Matrix of Efficiency

Matrix 15: Pairwise Comparisons Judgment for the According to Efficiency (Normalize matrix).

Efficiency	Time Behavior	Resource Behavior	Priority Weights
Time Behavior	0.800	0.800	0.800
Resource Behavior	0.200	0.200	0.200
C.R=0%			∑ Priority Weights=1

Matrix 16: Pairwise Comparisons Judgment for the Attributes According to Time Behavior

Time Behavior	Response Time	Scalability	Priority Weights
Response Time	0.857	0.750	0.804
Scalability	0.143	0.250	0.196
C.R=0%			∑Priority Weights=1

Matrix 17: Pairwise Comparisons Judgment for the Attributes According to Resource Behavior

Resource Behavior	Memory Utilization	Disk Utilization	Priority Weight
Memory Utilization	0.500	0.500	0.500
Disk Utilization	0.500	0.500	0.500
C.R=0%			∑Priority Weights=1

5.4 Constructing Weight Values Matrix for Maintainability

Matrix 18: Pairwise Comparisons Judgment for the Sub-Characteristics According to Maintainability.

Maintainability	Changeability	Testability	Upgrading	Priority Weights
Changeability	0.125	0.143	0.122	0.130
Testability	0.125	0.143	0.146	0.138
Upgrading	0.750	0.714	0.732	0.732
C.R=0.004				∑Priority Weights=1

Matrix 19: Pairwise Comparisons Judgment for the Attributes According to Changeability.

Changeability	**Customize**	**Portability**	**Priority Weights**
Customize	**0.800**	**0.800**	**0.800**
Portability	**0.200**	**0.200**	**0.200**
C.R=0%			**∑Priority Weights=1**

Matrix 20: Pairwise Comparisons Judgment for the Attributes According to Testability.

Testability	Self_Test	Test Suite	Priority Weight
Self_Test	0.800	0.800	0.800
Test Suite	0.200	0.200	0.200
C.R=0%			∑Priority Weights=1

5.5 Constructing the Weight Values Matrix for System Content Quality

Matrix 21: Pairwise Comparisons Judgment for the Sub-Characteristics According to System Content's Quality.

System Content's Quality	Student Oriented Domain	Online Services	Content Quality	Priority Weights
Student Oriented Domain	0.692	0.714	0.643	0.683
Online Services	0.231	0.238	0.286	0.252
Content Quality	0.077	0.048	0.071	0.062
C.R= 0.01				∑Priority Weights =1

Matrix 22 : Pairwise Comparisons Judgment for the Attributes According to Student Oriented Domain.

Student Oriented Domain	Content Relevancy	Student's Services	Priority Weights
Content Relevancy	0.667	0.667	0.667
Student's Services	0.333	0.333	0.333
C.R=0%			∑Priority Weights =1

Matrix 23: Pairwise Comparisons Judgment for the Attributes According to Online Services

Online Services	Online assessment	FTP service	Connectivity	Priority Weights
Online Assessment	0.600	0.265	0.600	0.488
FTP Service	0.200	0.088	0.200	0.163
Connectivity	0.200	0.647	0.200	0.349
C.R=0				∑Priority Weights=1

Matrix 24: Pairwise Comparisons Judgment for the Attributes According to Content Quality

Content Quality	Up to date	Content design	Accessibility	Priority Weights
Up to date	0.400	0.333	0.429	0.387
Content design	0.200	0.167	0.143	0.170

Accessibility	0.400	0.500	0.429	0.443
C.R=0.019				∑Priority Weights=1

Table 2. Triangular Fuzzy Number to Mu'tah University

Characteristics (Level-1)	**Sub Characteristics (Level-2)**	**Attributes (Level-3)**	**Global Weight**	**Triangular Fuzzy Numbers (TFN)**
Functionality	Interoperability	Data Compatibility Platform Compatibility	0.0445 0.0063	(0.742,0,0) (0.105,0,0)
	Suitability	Application Domain. Function Specification.	0.0935 0.0187	(0.442,0.558,0) (0.312,0,0)
	Compliance	Standardization.	0.0460	(0.766,0,0)
	Security	Privacy. Authentication.	0.0422 0.0084	(0.703,0,0) (0.140,0,0)
Reliability	Recoverability	Time to Recover. Error Reporting.	0.0593 0.0119	(0.988,0,0) (0.198,0,0)
	Availability	Planned Down Time.	0.0197	(0.328,0,0)
	Maturity	Fault Tolerance. Evolvability.	0.0059 0.0012	(0.098,0,0) (0.020,0,0)

Usability	Operability	Effort to Operate Administrability	0.0165 0.0660	(0.0275,0,0) (0.900,0.100,0)
	Understandability	Documentation. Training. User Support	0.0025 0.0227 0.0075	(0.042,0,0) (0.378,0,0) (0.125,0,0)
	Learnability	Time to Use Time-to Configure	0.0216 0.0030	(0.360,0,0) (0.050,0,0)
	User Interface	Consistency Simplicity User Control	0.0430 0.0161 0.0035	(0.716,0,0) (0.268,0,0) (0.058,0,0)
Efficiency	Time Behavior	Response Time Scalability.	0.0450 0.0109	(0.750,0,0) (0.182,0,0)
	Resource Behavior	Memory- Utilization. Disk Utilization.	0.0070 0.0070	(0.116,0,0) (0.116,0,0)

Maintainability	Changeability	Customizability. Portability.	0.0055 0.0013	(0.092,0,0) (0.022,0,0)
	Testability	Self-Test. Test Suite.	0.0058 0.0014	(0.096,0,0) (0.023,0,0)
	Upgrading	Easy to Upgrade	0.0387	(0.645,0,0)
System's Content Quality	Student Oriented Domain	Content Relevancy Student Service Information.	0.1587 0.0792	(0,0.355,0.645) (0.68,0.32,0)
	On-Line Services	On-Line Assessment. FTP Service. Connectivity	0.0143 0.0047 0.0102	(0.238,0,0) (0.078,0,0) (0.170,0,0)
	Content Quality	Up to Date Content. Content design. Accessibility.	0.0630 0.0442 0.0892	(0.950,0.050,0) (0.736,0,0) (0.513,0.486,0)

Table 3: Fuzzy Aggregate Pairwise Matrix to Mu'tah University.

Functionality	**Reliability**	**Usability**	**Efficiency**	**Maintability**	**System's Content Quality**
(0,0.241,0.758)	(0,0.572,0.428)	(0.787,0.213,0)	(0.862,0.138,0)	(0.808,0,0)	(0.227,0,0)
(0.747,0,0)	(0.607,0,0)	(0.303,0,0)	(0.277,0,0)	(0.135,0,0)	(0.045,0,0)
(0.112,0.888,0)	(0.860,0,0)	(0.055,0,0)	(0.237,0,0)	(0.312,0,0)	(0.088,0,0)
(0.472,0,0)	(0.503,0,0)	(0.453,0,0)	(0.056,0,0)	(0.103,0,0)	(0.018,0,0)
(0.732,0,0)	(0.083,0,0)	(0.093,0,0)		(0.108,0,0)	0.01,0,0)
(0.15,0,0)		(0.190,0,0)			(0.012,0,0)
(0.03,0,0)		(0.037,0,0)			(0.006,0,0)
		(0.106,0,0)			(0.006,0,0)
		(0.037,0,0)			

		(0.012,0,0)			

We need to calculate crisp relative importance for software criteria; the Fuzzy Extent Analysis (FEA) was applied next to calculate crisp relative importance weights for software criteria of the three universities in our study.

Table 4: Fuzzy Pairwise Comparison of software criteria in Mu'tah University

	Functionality	**Reliability**	**Usability**	**Efficiency**	**Maintability**	**System's Content Quality**
Mu'tah University	(3.21,0.558,0)	(1.632,0,0)	(2.924,0.1,0)	(1.64,0,0)	(0.787,0,0)	(3.365,1.211,0.645)

6. Fuzzy Extended Analysis for Mu'tah University

For each dimension M, dimension analysis was obtained. Here, all described Mj

and gi variables as l, m and u are triangular fuzzy numbers.

$M^1{}_{gi}$, $M^2{}_{gi}$, $M^3{}_{gi}$, ……..$M^m{}_{gi}$ *i=1,2,3,……n .*

In the original Extent Analysis method, provided we have S= {S_1, S2, S3….Sn} as an object set and $G = \{g1, g2, \cdots, Gn\}$ as a goal set, then for each object, extent analysis for each goal {gi}is implemented in our research are the attributes of software quality for three universities, The value of fuzzy synthetic extent for the ith.

The criterion for *M* goals is defined as [3].

$$F_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \qquad \textbf{(5)}$$

the fuzzy addition operation is performed of *m* extent analysis values for a particular matrix such as:

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j \right) \qquad \textbf{(6)}$$

First step: Following a similar calculation, the fuzzy synthetic degree values of other software attributes according to Mu'tah University are obtained as shown below**, (6)**

$$M_{g_i}^1, M_{g_i}^2, M_{g_i}^2, \ldots, M_{g_i}^m, \qquad i = 1,2,3, \ldots n.$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j = (3.21, 0.558, 0) + (1.632, 0, 0) + (2.924, 0.1, 0) + (1.164, 0, 0) + (0.878, 0, 0) + (3.365, 1.211, 0.645)$$

$$= (13.173,\ 1.869,\ 0.645\ )$$

The group fuzzy number of the pairwise comparison between the three universities for the software criteria is shown in Table ؛4 The Extent Analysis Method (EAM) was applied next to calculate crisp relative importance weights for software criteria of three universities in our study.

Second Step : According to Equation (8), the results were:

= (1.550, 0.535, 0.076)

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (5)$$

The value of the fuzzy synthetic extent is obtained by applying the Equation (5).

Third Step: The fuzzy synthetic degree values of software characterize for Mu'tah University

Functionary, Reliability, Usability, Efficiency, Maintability, and System's Contents can be calculated as indicated in Equation (5), as follows:

F1= (4.975, 0.298, 0)

F2= (2.529, 0, 0)

F3= (4.532, 0.053, 0)

F4= (1.804, 0, 0)

F5= (1.361, 0, 0)

F6= (5.215, 0.647, 0.049)

Fourth Step:

In this approach, a pairwise comparison is carried out for every fuzzy weight with other fuzzy weights for software attributes, and the corresponding degree of possibility of being greater than other fuzzy weights is determined [2] . The minimum of these possibilities was use as the overall score for each criterion *i.* the degree of probability is obtained for each pairwise comparison as follows:

$V\,(F \geq F1, F2, F3, \ldots. FK) = \min V(F \geq Fi), \quad i = 1,2,3 \ldots, k.$

$$d\,(Fi) = min\,V(Fi \geq Fk) = w'i \qquad k = 1,2,3 \ldots., n \text{ and } k \neq i \quad \textbf{(9)}$$

We define the degree of possibility V (M1 >= M2) = 1, Otherwise, we can calculate the highest intersection point (Chang, 1996), (see appendix H).

$$\mu\,(d) = (m^{-}_{1} - m^{+}_{2}) / ((m^{-}_{1} - m_{1}) - (m^{+}_{2} - m_{2})) \quad \textbf{(10)}$$

Based on the above calculations, we can obtain the weights of criteria W'_i:

$$W' = \left(w'1, w'2, \ldots, w'n\right)^{T} \quad \textbf{(11)}$$

After normalization, the final priority weights are:

$$W = (w1, w2 \ldots wn)\,T. \quad \textbf{(12)}$$

The group fuzzy number of the pairwise comparison for the attributes of software characters is:

V (F1 ≥ F2) = 1, V (F1 ≥ F3) =1, V (F1 ≥ F4) = 1, V (F1 ≥ F5) = 1, V (F1 ≥ F6) =0.933

V (F2 ≥ F1) = 0.894, V (F2 ≥ F3) = 0.979, V (F2 ≥ F4) =1, V (F2 ≥ F5) =1, V (F2 ≥ F6) = 0.793

V (F3 ≥ F1) =0.948, V (F3 ≥ F2) =1, V (F3 ≥ F4) =1, V (F3 ≥ F5) = 1, V (F3 ≥ F6) =0.883

V (F4 ≥ F1) = 0.858, V (F4 ≥ 342) =1, V (F4 ≥ F3) = 0.971, V (F4 ≥ F5) = 1, V (F4 ≥ F6) = 0.730

V (F5≥ F1) =0.298, V (F5≥ F2) =1, V (F5≥ F3) =0.962, V (F5≥ F4) =1, V (F5≥ F6) =0.669

V (F6≥ F1) = 1, V (F6≥ F2) = 1, V (F6≥ F3) = 1, V (F6≥ F4) =1, V (F6≥ F5) =1

Fifth Step: The priority weights were calculating by using the fuzzy rules as follows:

$$\mu_{A\cap B}(x) = \min [\mu_A(x), \mu_B(x)] \quad (13)$$

$d(f1) = min\, V(f1 \geq f2, f3, f4, f5, f6)$ =0.933

$d(f2) = min\, V(f2 \geq f1, f3, f4, f5, f6) = 0.793$

$d(f3) = min\, V(f3 \geq f1, f2, f4, f5, f6) = 0.883$

$d(f4) = min\, V(f4 \geq f1, f2, f3, f5, f6) = 0.730$

$d(f5) = min\, V(f5 \geq f1, f2, f3, f4, f6) = 0.298$

$d(f6) = min\, V(f6 \geq f1, f2, f3, f4, f5) = 1$

By applying Equation (11) then Equation (12), After normalization, the final priority weights are:

= $(0.933, 0.793, 0.883, 0.730, 0.298, 1)^T$

7 .Results Evaluation

The normalized weights vector of software criteria for the three university the field of study, which are obtain from pairwise comparison between the software criteria for

The normalized weights vector of software criteria for Mu'tah University are:

= (($0.933, 0.793, 0.883, 0.730, 0.298, 1)^T$

Table 7.5 Presents all the final calculations for normalized weights vector of software characterizes here we will discuss the results:

1. System Content Quality.

The obtained results revealed that Mu'tah University achieved the optimum value for **System Content's Quality** in their E-learning system (1.00) in compare with other criteria.

Mu'tah University ranked first in end-user satisfied of their E -learning system, such as the student-oriented domain, on-line services and content's quality with their associated attributes, for instance, content relevancy, Student service information, Accessibility, On-line assessment, FTP service, Connectivity, Content design, Up to date contents and Accessibility.

2. Functionality.

In second place was the characterize of functionality, Mu'tah University high ratio in **Functionality its (0.933)**

compare with other criteria Which means the capability of the software to provide functions and implied needs

when the software is used under specified conditions, with protecting privacy and Authentication for staff,

students and developers. Therefore, from students and academician's perspectives the functionality features of the E-learning system is the most important characterize in their Learning Management Systems (LMS) while staying at home, not in their campus.

The student is required to engage in lectures from any location using their own device through the Mobile Learning feature. The features of functionalities like Asynchronous Learning, Gamification, Video Conferencing, and Social Learning significantly amplifies the importance of these features in our study, as learners worldwide seek them out. After normalization, the final priority weights are:

$(SC\ 1, F\ 0.933, U\ 0.883, R\ 0.793, E\ 0.730, M\ 0.298)^T$

***3*. Usability**

Aaccording to Table 7, the score reached for Mu'tah University (0.883) in the Usability of the E-learning system) with a sufficiently learnable, easy-to-operate, easy-to-understand, and very comfortable user interface.

4. Reliability.

The forth characterize is the Reliability with weight 0.793, it means the capability of the software to be modified which may include corrections, improvements or adaptations, in Another way, It’s a measure of how long it takes for a system to fail, this characterize assessment by developers as end users.

System developers must prioritize enhancing the reliability, maturity, recoverability, and availability of the e-learning system to cater to instructors and students, particularly during electronic assessments. This can be achieved through effective fault tolerance measures, continuous preventive and corrective maintenance, and rigorous quality control procedures throughout the academic processes, utilizing high-quality software components.

5. Efficiency.

In five place was the Efficiency (0.730) they must be utilizing available resources such as software, hardware, networks, the time needed to carry out operations, and Scalability to support the incremental growth of data volumes from a user as well to modify and expand system capabilities.

6. Maintability.

The sixth characterize in this study for evaluating is Maintability with value (0.298). This may be due to the availability of software and hardware infrastructure; according to developers, the computer center boasts an application server housing essential software, alongside computer labs for every college, equipped with both wired and wireless networks. For systems developers in all educational institutes, such evaluation technique could help in the prediction the quality of software attributes. Prediction helps to gain insight and provide strategies to improve the quality of software for all Academic Information systems (AIS) and enhances system acceptance by the end-user.

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References

[1] A. J. Al_Nawaiseh, Y. Helmy, and E. Khalil, “A New Software Quality Model For Academic Information Systems" Case Study E-Learning System,” *Int. J. Sci. Technol. Res.*, vol. 9, no. 01, pp. 271–282, 2020.

[2] U. L. Yuhana, I. Saptarini, and S. Rochimah, “Portability characteristic evaluation Academic information System assessment module using AIS Quality Instrument,” in *2015 2nd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE)*, IEEE, 2015, pp. 133–137.

[3] E. F. Franco, K. Hirama, and M. M. Carvalho, “Applying system dynamics approach in software and information system projects: A mapping study,” *Inf. Softw. Technol.*, vol. 93, pp. 58–73, 2018.

[4] A. J. Al Nawaiseh, A. Albtoush, R. Al-Msiedeen, and S. J. Al Nawaiseh, “Evaluate Database Management System Quality By Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW) Methodology,” *Mendel*, vol. 28, no. 2, pp. 67–75, 2022, doi: 10.13164/mendel.2022.2.067.

[5] M. Kaczorek and M. Jacyna, “Fuzzy Logic As a Decision-Making Support Tool in Planning Transport Development,” *Arch. Transp.*, vol. 61, no. 1, pp. 51–70, 2022, doi: 10.5604/01.3001.0015.8154.

[6] M. Mostafa, N. Hatami, K. Espahbodi, and F. Asadi, “Fuzzy Analytic Hierarchy Process (FAHP) applied to evaluating the forest management approaches,” *J. For. Sci.*, vol. 68, no. 7, pp. 263–276, 2022, doi: 10.17221/27/2022-JFS.

[7] J. Aguarón, M. T. Escobar, J. M. Moreno-Jiménez, and A. Turón, "AHP-group decision making based on consistency. Mathematics, 7 (3), 242." 2019.

[8] W. Yang, H. Kang, G. Ri, and J. Kim, "Consistency Improvement Method of Pairwise Matrix Based on Consistency Ratio Decreasing Rate and Attribute Weighting Method Considered Decision Makers ' Levels in Analytic Hierarchy Process : Application to Hip Joint Prosthesis Material Selection," vol. 2022, 2022.

[9] F. Ahmed and K. Kilic, "Fuzzy Analytic Hierarchy Process: A performance analysis of various algorithms," *Fuzzy Sets Syst.*, vol. 362, pp. 110–128, 2019, doi: https://doi.org/10.1016/j.fss.2018.08.009.

[10] Z. Mao, S. Shi, H. Li, J. Zhong, and J. Sun, *Landslide susceptibility assessment using triangular fuzzy number-analytic hierarchy processing (TFN-AHP), contributing weight (CW) and random forest weighted frequency ratio (RF weighted FR) at the Pengyang county, Northwest China*, vol. 81, no. 3. Springer Berlin Heidelberg, 2022. doi: 10.1007/s12665-022-10193-3.

[11] R. Díaz *et al.*, "Averaging functions on triangular fuzzy numbers," 2023, [Online]. Available: http://arxiv.org/abs/2301.02290

[12] A. Guidara and A. Guidara, "Artificial Intelligence and Fuzzy Logic," *Policy Decis. Model. with Fuzzy Log. Theor. Comput. Asp.*, pp. 47–67, 2021.

[13] M. Akram, A. Khan, and U. Ahmad, "Extended MULTIMOORA method based on 2-tuple linguistic Pythagorean fuzzy sets for multi-attribute group decision-making," *Granul. Comput.*, vol. 8, no. 2, pp. 311–332, 2023, doi: 10.1007/s41066-022-00330-5.

[14] C. Chen, T. R. Razak, and J. M. Garibaldi, "FuzzyR: An extended fuzzy logic toolbox for the R programming language," *IEEE Int. Conf. Fuzzy Syst.*, vol. 2020-July, no. June 2021, 2020, doi: 10.1109/FUZZ48607.2020.9177780.