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Evaluation of Architectural Design Projects by Fuzzy Logic (Case Study: Residential Complex Design Project in the Islamic Azad University of Mashhad[1])

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ABSTRACT

After two decades, the evaluation system for architectural products has been suspended due to poor quality outputs. This research examines the evaluation structure of architecture students' design projects and aims to introduce a fuzzy system in architectural judgment. the study employs both quantitative and qualitative methods. In the quantitative part, data were analyzed using a fuzzy ranking system. The qualitative part involved content analysis and fuzzy output results to present a proposed arbitration model. A research questionnaire using a standard Likert scale was evaluated by all jury committee members. The sample size was determined by judgmental sampling, with 22 professors participating in the judgment.the top project scored 0.64, closely followed by other options. Proper physical-functional organization and attention to visual, cognitive, and climatic features were identified as crucial factors in scoring. The study revealed the importance of considering students' semester-long performance and attendance in the judgment process. Research highlights the complexity of evaluating architectural projects and proposes a fuzzy evaluation system to enhance assessment accuracy. The study found that top projects scored around 0.64, with proper organization and attention to various features being crucial factors. The implementation of a fuzzy ranking system provided a more nuanced assessment of student work.

Keywords: *Evaluation, Fuzzy, Uncertainty, Architectural Design Project*

1. Introduction

From the early years of 1320th AH, when the first architecture school was established in Iran, the architecture faced a new style influenced by Beaux-Arts and Bauhaus schools. The application of Western models of architecture in combination with a convergent education system led to the gradual forgetting of many valuable qualities and topics of architecture and finally, the production and education turned to be systematic. Today, two decades after the last changes, the evaluation system of architectural production is in a state of suspension as its outputs seem to manifest in frail and multiplied architecture[1]. However, a systematic evaluation organization that respects human rights and material and intellectual values is necessary. Today, the observation of the process between input and output in architecture is investigated by different viewpoints, and sometimes they differ sharply so that they result in a lack of identity in contemporary productions. A comprehensive outlook in education and evaluation is the solution to get out of this contemporary crisis. A holistic outlook can revive the architectural production which is unbelievable[2]. By studying the systematic evaluation in different sciences and comparing them in architecture, it is realized that there is a great need for the application of new methods of the evaluation of architectural works. Thus, the necessity of the present study is justified in the following ways:

[1] This research is the result of 15 years of teaching and experience in the design course of biological complexes in the field of architecture, which the author was able to evaluate the output of students' projects with fuzzy science.

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1. The knowledge of technical methods of interdisciplinary sciences and their appropriate connection with architectural problems
2. Lack of absolute trust in sensual cognition and other intervening variables while choosing the most efficient and best designs
3. Complete knowledge of the complex nature of the new age and striving for creative innovations resulted from existing requirements under uncertainty.

Today, intelligent calculators can evaluate complex models in vague and uncertain conditions. The fuzzy method is one of these techniques. It has proved its ability in recent years. With a creative outlook in the present study, a limited statistical sample was created and first, the evaluation criteria were extracted from the topics of residential complex design courses. Then, the questionnaire was created, distributed, and the required output was received. In the second stage of the fuzzy logic matrix, the items were evaluated and the ideal sample was introduced. current research first examines the evaluation structure of architecture students' design projects with the help of citation studies. In the next step, the fuzzy system is introduced in architectural judgment. Subsequently, the main research question is as follows:

How the fuzzy system can judge students' projects knowing the architectural evaluation criteria?

The sub-question of the research is:

What is the qualitative model resulting from content analysis and evaluation of fuzzy output?

According to the research questions, the objective is divided into two parts. In the quantitative part, the data were analyzed in the fuzzy rating system and the output of the findings was analyzed with the opinion of experts. In the second part, with content analysis and fuzzy output results, evaluation model with fuzzy approach was presented.

2.Literature Review

The instructional methods used in the architecture design studio have inherited the historical tradition of the Ecole des Beaux-Arts and its atelier model. Moore argues that instructors in architectural studios have followed ingrained conventions through generations without seriously examining the underlying pedagogy[3]. While practicing architects no doubt bring a great deal of experience to the studio, their teaching methods are often based only on their own learning experiences or on intuition[4]. They often cannot articulate what instructional method they are using, or is appropriate, for a specific condition. Three architectural education programs at Tehran's Shahid Beheshti University were assessed using the Delphi method and content analysis in terms of cultural markers [2]. In architectural design studios, they created an educational evaluation model that employed the AHP approach to assess and judge the design criteria. Naturally, it is important to remember the indisputable influence of human variables on judgements. [4]in an article entitled "Examination of the role of evaluation in architecture education" found the intervening factors by content analysis method and in They were divided into five groups. These groups include the role of instructor-grade-subject-management and the composition of the jury and the duration of training. In the book "Students' Motivation and Their Achievements", Alton introduced the approach in the evaluation of art and design courses as completely diverse. and considers it dependent on the way of interactions and social relations between professor and student [5]. in an article titled "Presenting an evaluation model for architectural design courses using the AHP method" concluded that continuous evaluation during the semester has the greatest effect on the qualitative progress of architectural design. In addition, form, idea, and performance were introduced as the most effective criteria in architectural evaluation. In Tyler's model, the goal is only to achieve the educational goals. And if there is a big difference between the goal and the student's performance, the model will not be responsive [6]. The primary objective is to satisfy the requirements of the design challenge, and the assessment specifies the first criterion [7]. Webster approaches the evaluation issue from another point of view. He believes that put your initiative in the educational path, the learning will be deep. And here the role of the student is determined as the most important factor in the evaluation. In confirmation of this statement, Webster considers the effect of verbal and graphic explanations of students in judgments to be very important[5]. In an article titled "A Review of Critical Training in Architectural

Design"Alizadeh states that the quality of diagrams, maps, volume replicas and students' drawing plans plays a big role in the final judgment and its influence cannot be taken into account[6].In the book titled “Architecture, Problems, and Purposes”, John William Wade states that there are two methods of judging students' final design. The first method of judging only evaluates the student's final product, and in the second method, the design process is combined with the final judgment. Second method, learning and evaluation are simultaneous and can be more productive[7].Engineers commence the process of conceptualizing when a necessity arises to enhance the operations of preexisting entities or to fabricate an artifact endowed with innovative functionalities. The most concise and accurate definition of the engineering design pastime has been given by means of Dym and Levitt (1991)[7], who state: design is the systematic, wise technology and assessment of specifications for artefacts whose form and characteristic attain said targets and fulfill specified constraints[8].Design should begin with a goal, constrains inside which the intention have to be finished and standards with the aid of which the solution might be recognized. The design requirements pertain to the characterization of perceived demands surrounding the context of the artefact. [8] The objectives are aligned with these perceived needs. Goals must be characterized into one or more statements in order to be used realistically. An aim is any characterized statement regarding a goal. An objective that the design must achieve is known as a design requirement [7]. The objective is the most crucial element in academic architectural projects. Considering an effective evaluation strategy is necessary to reach the correct objective[9]. There is a significant impact and good qualitative and quantitative outcome from continuous measuring throughout the design process. the optimum assessment of an architectural design at its conclusion. It is influenced by a variety of elements and is not solely connected to the final product's evaluation [8].

Researchers note several goals for a final review. For example, Dinham (1986) suggests three purposes:

(1)The jury can directly teach individual students by discussing and evaluating their designs.

(2)The final review is a tool for teaching all students in the studio together. As the jury comments on an individual student's work, they often broaden the scope of discussion from an issue found in one student's work to a common issue leading other students to learn from their classmates' work.

(3)A jury composed of professional architects who continually engage in professional dialog provides students the opportunity to hear challenging and inspiring conversation, observe professional skills, and perhaps acquire some of their expertise. Students can learn the prevailing culture of architectural practice and professional experience. They can practice analyzing and evaluating the presented projects while referencing their expertise or experiences and observe how to conduct a professional presentation.

Assessment ought to encourage learning in a system of education where teaching and learning are the main priorities [16]. There is, however, a significant lack of alignment between the goals pursued by different learning techniques and the classroom tactics selected by teachers to measure these lessons, and some assessment procedures frequently work against the emergence of learning.

Every design curriculum is fundamentally emergent and constructivist. Conditions and settings affect not just what we do as designers but also how we do things. In the studio, teachers are particularly conscious of the fact that neither the design process nor the final product are ever predetermined. Anything that functions well in one situation might not work in another, because every class is unique.

To provide a more accurate assessment of learning [17] can be categorised into functions based on the evaluation's time and purpose. The authors categorized the evaluation into three roles based on several studies: a "diagnostic evaluation" for learning issues prevention, a "formative assessment" for learning regulation, and a "summative evaluation" for social recognition or certificates. In fact, learning challenges are addressed right away, either by altering the course to match the speed at which students are learning or by modifying the educational environment through formative evaluation [18]. Because the assessment can easily result in mistakes in judgement, the outcomes can be either favourable or negative. It might result in both bad and good decisions. This is the reason that each of the fundamental components should be carefully examined.

Researchers list a number of objectives for the final review[10] , for instance, proposes three goals: (1) Through discussion and assessment of each student's design, the jury can provide one-on-one instruction. (2) The final review serves as a teaching tool for all of the studio's students. When the jury provides feedback on a single student's work, they frequently expand the conversation from a problem raised by that student to a problem that affects all students, allowing other students to benefit from the effort of other students.(3) A jury made up of practicing architects who frequently participate in professional dialogue gives students the chance to hear thought-provoking and motivating discussions, see professional techniques in action, and possibly even pick up some of their knowledge. The prevalent culture of architectural practice and professional experience can be taught to students. They can watch how to conduct a professional presentation and practice analysing and assessing the projects that are presented while drawing on their knowledge or experiences. One of the most popular procedures for evaluating design projects is the jury format, particularly in the field of architectural design education. It serves as the main conduit for information between reviewers and students [19, 20]. This approach involves conducting evaluation and instruction at the same time in the most reputable performative stage of design education [19]. Four different modes of evaluation can be distinguished in addition to the jury format. These consist of the anonymous review, the online evaluation, the peer review, and the one-on-one critique. In the one-on-one critiques, a teacher gives each student comments and an assessment depending on how they performed. Students assess one other's work throughout the peer assessment process, which offers insightful formative and summative feedback [21]. Another type of evaluation is the online evaluation, in which the evaluated and the evaluators communicate virtually in a synchronized or asynchronous manner while not meeting in person [18]. Usually employed in contests, the anonymous assessment is carried out in secret by the designers to choose potential concepts based on predetermined standards [22,23] states that four stages or levels of appraisal can be distinguished. These were eventually combined to form a model that was initially published in the Journal of in 1959 as a series of papers. American Association of Training Directors. Kirkpatrick referred to these stages as "steps" in an assessment methodology. The evaluation's phases or levels are: • Step1 : Response This stage shows the learners' opinions and how much they like the process of learning. Step 2: Acquiring Knowledge This stage demonstrates the degree to which students pick up new information and abilities. • Step 3: Behavior: This stage focuses on the ability to apply the recently acquired skills and the adjustments made to job performance. Step 4: Outcomes This stage concentrates on the observable outcomes of the learning process, such as higher production and efficiency, lower costs, and better quality. Kirkpatrick's model/technique, which prioritizes behavior and results, was eventually turned on its head to create a more effective model [22]. As a result, the levels of the updated evaluation model were: 1. Result: The influence, outcome, and result that may be utilized to enhance the educational system are the main topics of this level. 2. Performance In order to produce the intended outputs and results, this level places a strong emphasis on the performance of instructors and students. 3. Education This level is concerned with the resources, information, and abilities that a student requires to succeed. 4. Motivation: This stage focuses on the perceptions that students must have in order to achieve the intended results.

Saaty's prioritization of the design criteria is one of the evaluation methods used in design research. There are two steps involved in this approach. The first focuses on eliciting traits that are stated vocally. The second's primary goal is to numerically scale the qualities that were formulated in the first. In order to give weights for a set of non-numerical criteria based on their subjective value, prioritization is a normative ranking technique that is increasingly employed in the evaluation of intangible traits [24]. In evaluation, rating systems come in a wide variety [3,5] .evaluated architectural designs using a hierarchical framework. This approach is typical. The fuzzy logic system is another appropriate way in addition to this one. In order to perform fuzzy logic in the ranking of architectural designs, the following explanations are necessary.

Fuzzy logic is a form of many-valued logic that deals with the approximate argument and was first proposed by Zadeh in 1965 under the title fuzzy sets[11]. Today, fuzzy logic is applied in various fields (Table1) like the theory of artificial intelligence and decision-making. Fuzzy logic was employed in the present article. The architectural endeavors undertaken by students were assessed and scrutinized through the utilization of the fuzzy decision making.

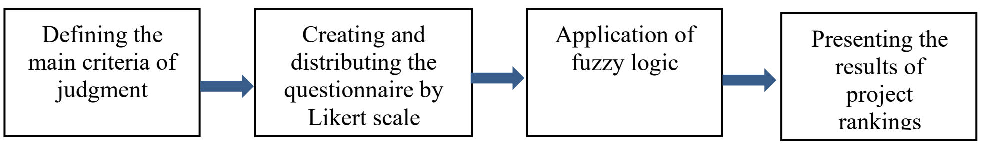
Table1. Timeline of changes in fuzzy application (Source: Author)

Theorist	indicators
1970 • Lotfizadeh	Founder of fuzzy decision-making
1971 • Lotfizadeh	Solution for optimized choice processes
1975 • Mamdani and Asilian	optimized control of a steam engine
1983 • Sugeno	optimized decision of smart robot
1987 • Yamakawa	The best condition of inverted pendulum
2001 • Chen	System analysis
2001 • Alharbi	The best contractor
2002 • Butkiewicz	Choosing the tourism agency staff
2004 • Huang	Choosing the manager
2005 • Shafighian and Hejazi	Finding the best teacher
2006 • Zing and Di	Evaluation of project managers
2008 • Canos and Liern	Finding and choosing the best staff
2009 • Celik and Kandaglu	Personnel employment

3.Methodology

In terms of goal, this is applied research, and essentially, it uses a combined qualitative and quantitative method. The data is collected by descriptive exploratory research. The main goal is to choose the best student's design under uncertainty. The quantitative stages could be modeled as follows:

Diagram 1. Stages model (Source: Author)



In order to find the evaluation criteria, the topics of the residential complex design course were studied and it was approved by experts. The judgment criteria were set in five sections as presented in Table **2**.

Since this study was conducted in the Azad Islamic University of Mashhad, a class was chosen randomly, and five projects were proposed in a stratified sampling for fuzzy evaluation by the judgment committee. To properly scrutinize the fuzzy output, the committee members were chosen from the teachers who were more knowledgeable than others according to at least two or three of the five above criteria.

Table2: Main criteria of design evaluation (Source: Author)

No.	Criterion	Interpretation
C1	residential pattern	Defining the main and minor patterns so that they are variable based on requirements
C2	organization	How does the complex meet the main requirements in the group, linear, and radial sets?
C3	space classification	How is the collective space designed in the form of semi-private, semi-public, and public zones?
C4	complex appearance	How much does the primary elevation concept accord with the environment and physical hierarchical regulations?
C5	visual, cognitive, and climatic qualities	Variety, proportions, scale, balance, identity aspects, conditioning, light, and other climatic factors

Architecture teachers were selected as judges. Because the decision-making method is used in the research, judgmental sampling was used. With the consultation of faculty experts, 22 people were selected and they were divided into three groups. The first group were teachers who had more than 20 years of experience and were experts in architecture. The second group was the architecture teachers of the subject to be evaluated, and the third group was the regular teachers. The target population of the questionnaire was the participating professors to evaluate students' projects.

3.1. Reliability and validity of the questionnaire: Reliability is one of the technical characteristics of measuring instruments. The mentioned concept is related to the fact that the measurement tool gives similar results when compared to the same one. The range of the reliability coefficient is between zero and one, and the more this coefficient tends to one, the more reliable it is, and the values above 0.7 of these coefficients indicate the reliability of the questionnaire. (Table 3)

Table 3. reliability of the questionnaire

Composite Reliability Coefficient (CR)	Cronbach's alpha	riable
0.873	0.820	c1
0.871	0.915	c2
0.847	0.794	c3
0.852	0.794	c4
0.829	0.747	c5

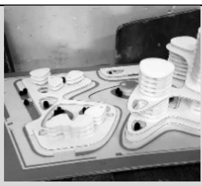
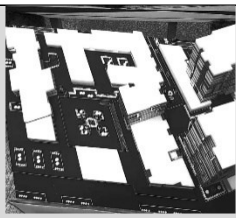
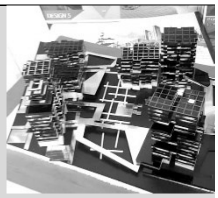
Considering that Cronbach's alpha and composite reliability coefficient are more than 0.7 in all variables of the questionnaire, it can be said that the questionnaire has good reliability (Table 3). Face validity is checked by ensuring the compatibility of the measurement indicators with the existing literature. The validity of this questionnaire was obtained by surveying professors. And in this research, it was approved by experts. In order to reduce and considered suitable for further analysis. In this research, the indices were all higher than 1.5.and approved for analysis.

4.Research Findings

eliminate inappropriate items and to determine the importance of each item, the quantitative method of item impact will be used. In this method, the numbers 3, 2, 1,... are assigned to each of the item options in the questionnaire according to their number. And we calculate the frequency of each one and use the following relationship. Option number * (%) frequency = index.If this index is more than 1.5, the item is

In this stage, a quantitative analysis was conducted. The project site was considered to be located in Haft-Tir district of Mashhad covering an area of 38000 m^2 with a high density. The lot coverage was supposed not to exceed 35 percent, and the higher terms of municipality must be met, considered as the main variables. A common site for design could minimize the effect of intervening variables. These projects were supervised by the course teacher and a design assistant. Teaching was also based on the five above criteria. The students covered an age range from 24 to 29. Some groups were of different sexes. To reduce the error in decision-making, according to the following figures, the architectural models were investigated without details. Also, the students were supposed to present a phase 1 study notebook in A1 dimensions without coloring, in black and white prints in addition to technical sheets. The judgment was started step by step by analyzing the ideas and then, examining the forms and plans. The projects were created in different stages. In other words, the first scores were recorded based on the first criteria, then, the other criteria were analyzed based on the committee agreement. Each criterion contained a set of questions responded to by the Likert scale. During the examination, the judgment committee held no group consultation. Each question was to take two minutes. By the time the evaluation finished, the questionnaires were collected and transferred to the fuzzy analysis stage. Table 4 shows the status of the presented documents.

Table 4. The documents presented by students to the judgment committee (Source: Author)

	 A3					 A5					 A1					 A4					 A2				
	plans	SECTIONS	elevation	form	ideogram	plans	SECTIONS	elevation	form	ideogram	plans	SECTIONS	elevation	form	ideogram	plans	SECTIONS	elevation	form	ideogram	plans	SECTIONS	elevation	form	ideogram
Lack of documents	1-5	1-5	6-10	6-10	---	10–6	MORE	6-10	1-5	---	---	---	1-5	1-5	----	1-5	6-10	---	1-5	11-15	1-5	--	---	6-10	11-15
Gendr	**F**		**M**			**F**		**M**			**F**		**M**			**F**		**M**			**F**		**M**		
	2		**1**			**--**		**4**			**3**		**---**			**3**		**1**			**---**		**3**		
Age	**22-24**					**23-28**					**24-26**					**23-29**					**25-27**				

The ideal fuzzy method is nowadays applied in many evaluation systems because in many cases human thoughts are mixed with uncertainty, and this will affect the evaluation output to a great extent. In this method, the decision-making matrix elements or criteria weights or both of them are evaluated by the linguistic variables presented by fuzzy numbers. Being among the most credited scholars of the fuzzy method, Chen & Yuan have presented the evaluation steps based on Table 5. This is applied in the present study.

Table 5. hierarchical process steps of the projects' fuzzy matrix (Source: Author)

fuzzy matrix			
Step 1: formation of fuzzy decision	Step 2: Determination of criteria weight matrix	Step 3: Unscaling the fuzzy matrix	Step 4: Determining the fuzzy weight matrix

Step 5: Finding the ideal and anti-ideal solution	Step 6: Calculating the distance from the ideal	Step 7: Calculating the similarity index	Step 8: Gradation of items

As it was said, five samples were chosen from the works of students for ranking and evaluation. The decision-making group was divided into three parts. Five evaluation criteria were introduced based on the common consultation of the architectural group, and they were based on course topics. According to these, the ideal fuzzy evaluation stages were passed through as follows:

The judgment committee members shared their thoughts based on the following table and linguistic variables.

Table 6. Conversion of qualitative variables into quantitative fuzzy (Source: Author)

Importance	Fuzzy Number	Importance	Fuzzy Number
Very poor	(0.0, 0.1, 0.2)	Poor	(0.1, 0.2, 0.2, 0.3)
Medium-poor	(0.2, 0.3, 0.4, 0.5)	Medium	(0.4, 0.5, 0.5, 0.6)
Medium-Good	(0.5, 0.6, 0.7, 0.8)	Good	(0.7, 0.8, 0.8, 0.9)
Very Good	(0.9, 0.9, 1, 1)		

According to Table 6, the viewpoints of decision-makers are made quantitative based on the fuzzy model as follows:

Table 7. Conversation Of Linguistic Variables Into Numerical Patterns (Source: Author)

Criterion	First judge	Second Judge	Third Judge
C1	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)
C2	(1.1, 0.9, 0.9)	(1.1, 0.9, 0.9)	(1.1, 0.9, 0.9)
C3	(1.1, 0.9, 0.9)	(1.1, 0.9, 0.9)	(0.9, 0.8, 0.8, 0.7)
C4	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)
C5	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)

Table 8. Fuzzy quantitative agreements (Source: Author)

Fuzzy Number	Importance	
(2, 1, 0, 0)	VP	Very Poor
(3, 2, 2, 1)	P	Poor
(5, 4, 3, 2)	MP	Medium-Poor
(6, 5, 5, 4)	F	Medium
(8, 7, 6, 5)	MG	Medium-Good
(9, 8, 8, 7)	G	Good
(10, 10, 9, 8)	VG	Very Good

According to Table 8, the linguistic variables proposed by professors were made quantitative. Table 9 shows the output of the viewpoints of the judgment committee based on fuzzy numbers.

Table 9. Fuzzy analysis of all data (Source: Author)

Criterion	Item	First Judge D1	Second Judge D2	Third Judge D3
	A1	(8, 7, 6, 5)	(8, 7, 6, 5)	(8, 7, 6, 5)
	A2	(9, 8, 8, 7)	(9, 8, 8, 7)	(9, 8, 8, 7)
C1	A3	(10, 10, 9, 8)	(10, 10, 9, 8)	(9, 8, 8, 7)
	A4	(9, 8, 8, 7)	(9, 8, 8, 7)	(9, 8, 8, 7)
	A5	(8, 7, 6, 5)	(8, 7, 6, 5)	(8, 7, 6, 5)
	A1	(8, 7, 6, 5)	(8, 7, 6, 5)	(10, 10, 9, 8)
	A2	(10, 10, 9, 8)	(10, 10, 9, 8)	(10, 10, 9, 8)
C2	A3	(10, 10, 9, 8)	(9, 8, 8, 7)	(9, 8, 8, 7)
	A4	(9, 8, 8, 7)	(9, 8, 8, 7)	(8, 7, 6, 5)
	A5	(8, 7, 6, 5)	(9, 8, 8,7)	(9, 8, 8,7)
	A1	(9, 8, 8, 7)	(9, 8, 8, 7)	(9, 8, 8, 7)
	A2	(10, 10, 9, 8)	(10, 10, 9, 8)	(10, 10, 9, 8)
C3	A3	(10, 10, 9, 8)	(10, 10, 9, 8)	(10, 10, 9, 8)
	A4	(8, 7, 6, 5)	(8, 7, 6, 5)	(9, 8, 8,7)
	A5	(8, 7, 6, 5)	(8, 7, 6, 5)	(8, 7, 6, 5)
	A1	(8, 7, 6, 5)	(8, 7, 6, 5)	(8, 7, 6, 5)
	A2	(9, 8, 8, 7)	(10, 10, 9, 8)	(10, 10, 9, 8)
C4	A3	(10, 10, 9, 8)	(10, 10, 9, 8)	(10, 10, 9, 8)
	A4	(9, 8, 8, 7)	(9, 8, 8, 7)	(9, 8, 8, 7)
	A5	(8, 7, 6, 5)	(8, 7, 6, 5)	(9, 8, 8, 7)
	A1	(9, 8, 8, 7)	(9, 8, 8, 7)	(9, 8, 8, 7)
	A2	(10, 10, 9, 8)	(10, 10, 9, 8)	(10, 10, 9, 8)
C5	A3	(9, 8, 8, 7)	(10, 10, 9, 8)	(9, 8, 8, 7)
	A4	(9, 8, 8, 7)	(9, 8, 8, 7)	(10, 10, 9, 8)
	A5	(8, 7, 6, 5)	(8, 7, 6, 5)	(8, 7, 6, 5)

After converting the linguistic variables of the decision matrix and weight vector into trapezoidal fuzzy numbers, the fuzzy decision matrix and weight matrix should be created. For example, the first item of the second criterion is presented in Table 10 by evaluation members.

Table 10. An example of a fuzzy weight matrix calculation method (Source: Author)

Decision Maker	Qualitative Point	Fuzzy Number
D1	Medium-Good	(8, 7, 6, 5)
D2	Medium-Good	(8, 7, 6, 5)
D3	Very Good	(10, 10, 9, 8)

According to professors, the components of the fuzzy number regarding the first item of the second criterion are as follows:

a12 = Min {5,5,8} = 5 b12 = (6+6+9) /3 =7

c12 = (7+7+10) /3 =8 d12 =Max {8,8,10} = 10

Therefore, the first item of the second criterion is evaluated as the fuzzy numb (5, 7, 8, 10) After calculating other data, Table 11 will be proposed.

Table 11. Completed weight matrix (Source: Author)

Weight	C1	C2	C3	C4	C5
	(0.9, 0.8, 0.8, 0.7)	(1, 1, 0.9, 0.8)	(1, 0.93, 0.87, 0.7)	(0.9, 0.8,0.8, 0.7)	(0.9, 0.8,0.8, 0.7)
A1	(8, 7, 6, 5)	(10, 8, 7, 5)	(9, 8, 8, 7)	(9, 8, 8, 7)	(9, 8, 8, 7)
A2	(9, 8, 8, 7)	(10, 10, 9, 8)	(10, 10, 9, 8)	(10, 9.33, 8.67, 7)	(10, 10, 9, 8)
A3	(10, 9.3, 8.7, 7)	(10, 8.67, 8.33, 7)	(10, 9.33, 8.67, 7)	(10, 10, 9, 8)	(10, 8.67, 8.33, 7)
A4	(9, 8, 8, 7)	(9.7, 76.7, 7.33, 5)	(99.7, 33.6, 67.5)	(9, 8, 8, 7)	(10, 8.67, 8.33, 7)
A5	(8, 7, 6, 5)	(9.7, 76.7, 7.33, 5)	(8, 7, 6, 5)	(99.7, 33.6, 67.5)	(8, 7, 6, 5)

All the criteria are positive, therefore, the following expression is used to unnscale them:

$$rij = \left[\frac{aij}{dj^*}, \frac{bij}{dj^*}, \frac{cij}{dj^*}, \frac{dij}{dj^*}\right]$$

For example, in the case of the first item of the first criterion:

$$r_{11} = \left[\frac{5}{10}, \frac{6}{10}, \frac{7}{10}, \frac{8}{10}\right] = (0.5, 0.6, 0.7, 0.8)$$

Other elements of the unscaled decision matrix are calculated in the same way the results of which are presented in Table 12.

Table 12. Fuzzy unscaled matrix (Source: Author)

	c1	c2	c3	c4	c5
A1	(0.8, 0.7, 0.6, 0.5)	(1, 0.8, 0.7, 0.5)	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.8, 0.8, 0.7)
A2	(0.9, 0.8, 0.8, 0.7)	(1, 1, 0.9, 0.8)	(1, 1, 0.9, 0.8)	(1, 0.93, 0.87, 0.7)	(1, 1, 0.9, 0.8)
A3	(1, 0.93, 0.87, 0.7)	(1, 0.87, 0.83, 0.7)	(1, 0.93, 0.87, 0.7)	(1, 1, 0.9, 0.8)	(1, 0.87, 0.83, 0.7)
A4	(0.9, 0.8, 0.8, 0.7)	(0.9, 0.77, 0.73, 0.5)	(0.9, 0.73, 0.67, 0.5)	(0.9, 0.8, 0.8, 0.7)	(1, 0.87, 0.83, 0.7)
A5	(0.8, 0.7, 0.6, 0.5)	(0.9, 0.77, 0.73, 0.5)	(0.8, 0.7, 0.6, 0.5)	(0.9, 0.73, 0.67, 0.5)	(0.8, 0.7, 0.6, 0.5)

In order to calculate the elements of the weighted unscaled fuzzy decision, the corresponding elements should be multiplied by the unscaled fuzzy decision in the corresponding importance coefficient. For example, in the case of the first item of the third criterion:

V 13 = (1, 0.93, 0.87, 0.7) * (0.9, 0.75, 0.69, 0.49) = (0.9,0.8,0.8,07)

Other elements of the weighted unscaled decision matrix are calculated in the same way the results of which are presented in Table 13:

Table 13. Weighted unscaled fuzzy decision matrix (Source: Author)

	C1	C2	C3	C4	C5
A1	(0.72, 0.56,0.48, 0.35)	(1, 0.80, 0.63, 0.4)	(0.9, 0.75, 0.96, 0.49)	(0.81, 0.64, 0.64, 0.49)	(0.81, 0.64, 0.64, 0.49)

A2	(0.81, 0.64, 0.64, 0.49)	(1, 1, 0.81, 0.64)	(1, 0.93, 0.78, 0.56)	(0.9, 0.75, 0.69, 0.49)	(0.9, 0.8, 0.72, 0.56)
A3	(0.9, 0.75, 0.69, 0.49)	(1, 0.87, 0.75, 0.56)	(1, 0.87, 0.75, 0.49)	(0.9, 0.8, 0.72, 0.56)	(0.9, 0.69, 0.67, 0.49)
A4	(0.81, 0.64, 0.64, 0.49)	(0.9, 0.77, 0.66, 0.4)	(0.9, 0.68, 0.58, 0.35)	(0.81, 0.64, 0.64, 0.49)	(0.9, 0.69, 0.67, 0.49)
A5	(0.72, 0.56, 0.48, 0.35)	(0.90, 0.77, 0.66, 0.4)	(0.8, 0.65, 0.52, 0.35)	(0.81, 0.59, 0.53, 0.35)	(0.72, 0.56, 0.48, 0.35)

Ideal and anti-ideal fuzzy solutions for the first criterion are calculated:

V_1^* = (max (0.72,0.81,0.9,0.81,0.72) max (0.72,0.81,0.9,0.81,0.72) max (0.72,0.81,0.9,0.81,0.72) max (0.72,0.81,0.9,0.81,0.72)) = (0.9,0.9,0.9,0.9)

V_1^- = (min (0.35,0.49,0.49,0.49,0.35) min (0.35,0.49,0.49,0.49,0.35) min (0.35,0.49,0.49,0.49,0.35) min (0.35,0.49,0.49,0.49,0.35)) = (0.35,0.35,0.35,0.35)

In the same way, for other criteria, the ideal and anti-ideal solutions are determined the results of which are as follows:

$A^* = [(0.9,0.9,0.9,0.9), (1,1,1,1), (1,1,1,1), (0.9,0.9,0.9,0.9), (0.9,0.9,0.9,0.9)]$

$A^- = [(0.35,0.35,0.35,0.35), (0.4,0.4,0.4,0.4), (0.35,0.35,0.35,0.35), (0.35,0.35,0.35,0.35,), (0.35,0.35,0.35,0.35)]$

The distance between the first item and the ideal fuzzy solution of each criterion is calculated as follows:

$$s_{11}^* = \sqrt{\frac{1}{4}((0.35-0.9)^2+(0.48-0.9)^2+(0.56-0.9)^2+(0.72-0.9)^2)} = 0.4$$

$s_{12}^* = 0.37$, $s_{13}^* = 0.33$, $s_{14}^* = 0.28$, $s_{15}^* = 0.28$

Therefore, the distance from the first item of the fuzzy ideal solution is:

$s_1^* = 0.4+0.37+0.33+0.28+0.28=1.65$

The distance of the first item from the fuzzy anti-ideal solution of each criterion is calculated as follows:

$$s_{11}^- = \sqrt{\frac{1}{4}\ [(0.35-0.35)^2+(0.48-0.35)^2+(0.56-0.35)^2+(0.72-0.35)^2]}$$

$s_{12}^- = 0.38$, $s_{13}^- = 0.39$, $s_{14}^- = 0.32$, $s_{15}^- = 0.32$

Therefore, the distance of the first item from the anti-ideal fuzzy solutions is:

$s_1^- = 0.32+0.32+0.39+0.38+0.22=1.62$

$$cc_1 = \frac{1,62}{1,62+1,62} = 0.5$$

Similar calculations were applied for other items, the calculation results of the difference between each item and the ideal solution for each criterion, the difference between each item and the anti-ideal solution for each criterion, the difference between each item from the ideal solution, the difference between each item and the anti-ideal solution and the similarity index for each item is presented in Tables 14, 15, and 16.

Table 14. The difference between each item and the ideal solution for each criterion (Source: Author)

	C1	C2	C3	C4	C5
d(A_1,A^*)	0.4	0.37	0.33	0.28	0.28
d(A_2,A^*)	0.28	0.2	0.25	0.24	0.2
d(A_3,A^*)	0.24	0.26	0.29	0.2	0.26
d(A_4,A^*)	0.28	0.37	0.42	0.28	0.26
d(A_5,A^*)	0.4	0.37	0.45	0.37	0.4

Table 15: The difference between each item and the ideal solution (Source: Author)

	C1	C2	C3	C4	C5
d(A_1,A^-)	0.22	0.38	0.39	0.32	0.32

d(A_2,A^-)	0.32	0.49	0.5	0.39	0.41
d(A_3,A^-)	0.39	0.43	0.47	0.41	0.37
d(A_4,A^-)	0.32	0.34	0.34	0.32	0.37
d(A_5,A^-)	0.22	0.34	0.28	0.27	0.22

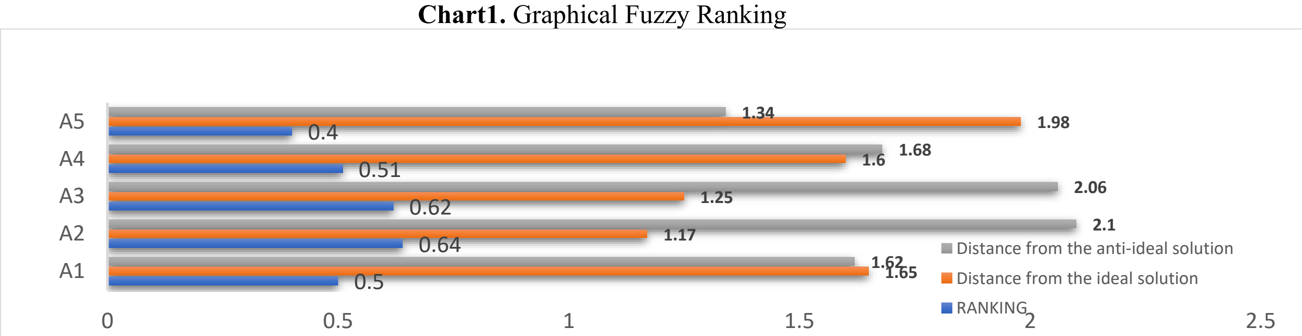
Table 16. The distance from the ideal and anti-ideal solution and the similarity index (Source: Author)

	A1	A2	A3	A4	A5
Distance from the ideal solution	1.65	1.17	1.25	1.60	1.98
Distance from the anti-ideal solution	1.62	2.10	2.06	1.68	1.34
Similarity index	0.50	0.64	0.62	0.51	0.40

According to the calculations, the design proposals are ranked as follows:

$$\boldsymbol{A_2 > A_3 > A_4 > A_1 > A_5}$$

Chart1. Graphical Fuzzy Ranking



5.Discussion and Conclusion

By analyzing the fuzzy output, the following could be counted as personal judgment traps:

1. Project A2 was ranked first, although it is the most incomplete in the case of ideogram documents. In the personal judgment stage, this incompleteness could hide other good values of the project, so that the judging approach could deviate, but the fuzzy input showed that the criterion weight is not influenced by cognitive errors.

2. The rank of project A3 shows that the difference in sex and lower age (which is understood as low experience) does not influence the output considerably. This result is also deduced from the project A2. This group includes three men. In the personal judgment, there was the possibility of the intervening mental image of the indexes of age and sex.

3. In project A5, it is deduced that although there were four members and they were of the same sex, they were ranked the last. However, many professors consider the groups with more members to be medium or good (the intervening mental image error), and the fuzzy analysis shows the opposite.

In order to perform a detailed analysis for the fuzzy output (according to experts note), it was decided that the design teacher report on each project at the same time. which is as follows:

4. - The result of the A2 assessment with a score of 0.64 indicated that the students changed several design scenarios in order to reach the solution. Paying attention to proper physical-functional organization and visual, cognitive and climatic features

is one of the most important factors and has increased the score. The focus on geometry [18] and the emphasis on neighborhood scale [19] are the two main features of the project. And it gave meaning to it. In addition, drawing appropriate and complete plans has influenced the evaluation. Table 7 shows that in project A2, criteria C2, C3, C5 were more favorable than C1, C4.

5. A1 examination showed that despite the complete plans, a score of 0.5 was recorded. In Table 13, C1and C2 criterion received the lowest score. High absenteeism at the beginning of the semester caused the students of A1 group to not get proper training in theoretical content. Table 4 shows that the lack of attention to details of the view [20] and form [21] have caused the rating to decrease.

6. The A5 project has been evaluated with a score of 0.4, and it was placed in the lowest grade. The C2 criterion has the highest score for A5, and the other criteria were average. This project did not have the proper volume and section details, and it caused an inappropriate understanding. The lesson says that in the middle of the semester, group A5 had a lot of absenteeism in classes and did not have the necessary information about aesthetics [22] and climate. For this reason, the plans did not reach the desired conditions. In addition, the volume and sections were not suitable.

7. - Project A4 has been evaluated with a score of 0.51. Table 12 shows that the evaluation of all criteria was average and good. Table 4 shows that the volume and facade were of good quality, but the number of plans was small, even though they were of good quality. The project had many defects in the ideogram. In the initial evaluation, this project is the worst, (Table 4) but the professor is not dissatisfied with the A4 group. This group had four main factors: 1- There were no absences in class. 2- He had learned the studies. 3- He had a moderate academic progress. 4- He behaved well with the professor and students. These four factors caused the fuzzy analysis to give it an average score. Despite the defects of the A4 documents, it had an average and acceptable design process.

8. Project A3 was evaluated with a score of 0.62. According to Table 4, it has the least defects in the document. It had a beautiful shape, but it paid moderate attention to the principles of studying and designing the neighborhood and feeling of belonging [23]. The open space did not have a proper hierarchy and changed the original concept of neighborhood scale. Table 13 shows that two criteria C2 and C3 were better than other criteria. The functional characteristics of the design were evaluated as average. Appropriate studies in the middle of the semester did not have a high impact at the end of the semester. In the initial judgement, this project is ranked highest, but fuzzy analysis puts it in second place.

This research was done with the aim of introducing fuzzy logic in the ranking of architectural design projects. Therefore, tables and matrices show the process of implementing fuzzy logic. The fuzzy ranking showed that the output analysis is not possible without the presence of the design professor and the presentation of the report between the semester and the final product can provide a correct interpretation of the findings. By examining the background of the research in terms of content, this research discovered two main limitations. First, the quantitative methods commonly used in the evaluation of architectural projects are rudimentary and cannot provide a complete understanding of the correct evaluation. Second, fuzzy knowledge in the field of architectural evaluation needs to be developed. and the spread of. The introduction of this method can provide an interpretation close to the correct evaluation in the environment of uncertainty.

In the analysis of research findings, it was found that many hidden layers affect the evaluation of architectural design. And necessarily, the evaluation models reviewed in the articles cannot be efficient in the conditions of every architectural problem. According to what was said, the following model (Figure 1) has been proposed, which was formed by focusing on the following points:

1- The three areas of form, function and meaning are the main dimensions and are included in the evaluation in combination with five criteria. The five main evaluation criteria are shown as C1, C2, C3, C4, C5. These criteria are extracted from the course title.

2- It seems (Table 17) that the evaluation of the class during the semester is completely dependent on the result at the end of the semester. And the student's absence has a high contribution to the final evaluation. and is the control variable of the model.

3- The results of the architectural projects showed that the exact answer to the design problem requires continuous attendance in class and studies. The appropriate answer to the problem of design is with the continuous supervision of the professor.[24]

4- The progress of the student depends on the complete understanding of basic studies and the three fields of knowledge of form, function and meaning and studies related to site analysis.

5- The students' lack of mastery of executive and technical knowledge of architecture is a general weakness, which is mostly related to past semesters and intervention variables.[4]

This study introduces the fuzzy ranking method in architectural design. It must be said that correct evaluation is not limited to tools and is a very complex category. This requires full knowledge of the student's ability and academic performance during the semester. Another point, awareness and discovery of measurement criteria and according to the conditions of the architectural design problem. Examining these categories requires in-depth investigation and further studies.

Figure 1 . The image of the research result

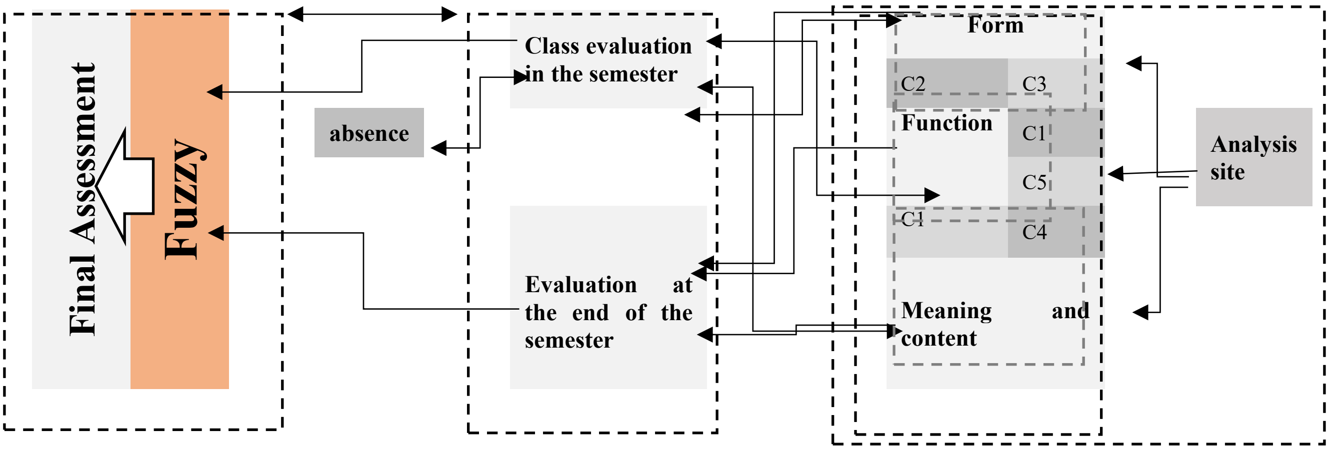


Table 17. Conclusion of Interpretation

No.	Criterion	Interpretation
C1	residential pattern	Defining the main and minor patterns so that they are variable based on requirements
C2	organization	How does the complex meet the main requirements in the group, linear, and radial sets?
C3	space classification	How is the collective space designed in the form of semi-private, semi-public, and public zones?
C4	complex appearance	How much does the primary elevation concept accord with the environment and physical hierarchical regulations?

C5	visual, cognitive, and climatic qualities	Variety, proportions, scale, balance, identity aspects, conditioning, light, and other climatic factors

6.research limitations:

So far, many articles have been written on the subject of evaluating architectural design projects, but most of these articles have been analyzed with the help of common hierarchical and statistical methods. It has been done, but it is Not enough in the evaluation of architecture education. And this caused the process of conducting the research to have many problems. The term and the final delivery were fuzzified and compared and analyzed with the opinions of the professors, but only the analysis was done by three referees because, firstly, the calculations were very heavy, and secondly, the main goal of the research was to introduce the method of doing fuzzy in the measurement, so that it can be a model for the researchers' future research. be placed.

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