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EVALUATION OF THE EFFICIENCY OF UNIVERSITY CLASSROOMS WITH THE FUZZY LOGIC

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Abstract. *In this paper, a fuzzy logic algorithm was created in order to grade and classify the design efficiencies of classrooms selected from Süleyman Demirel University. The existing classrooms were examined on site and the orientation of the classrooms, the number of people, the classroom area and the window area of the classroom were calculated. As the input variables, the orientation of the classrooms, the number of people, the area per-capita and the ratio of window area to the classroom area were modelled. The design efficiencies of the classrooms as the output variables were obtained by the rules formed among the input variables. In the model, fuzzy model as the Mamdani type and "weighted average" method as the clarification method were used. For fuzzy logic model, 180 fuzzy rules have been formed in the type of IF, which are associated with the facade of the classroom, the number of people, the area per capita and the ratio of the window area of the classrooms to the design efficiency of the classroom. Design efficiency of the classrooms were created; the design efficiency classes and the average design efficiencies of classrooms in faculties were compared and concluded according to faculties. The efficiency of the classrooms, which is the main place of the educational buildings, depends on the decisions taken during the design phase. With the model created in this paper, more efficient designs will be provided by having knowledge about the design efficiency through making use of the decision-making process of the classrooms during the design process.*

Key words: *Fuzzy logic, Decision making, Classroom, Design efficiency.*

1. INTRODUCTİON

Education is an important instrument of social and economic development. Education is a process that begins with the birth of the individual and continues throughout his life. Most of this process takes place in educational structures. Educational structures are the places that will form the basis of the social structure, and thus that should be specially

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designed for the individuals who will give direction to the future of the country (Bal and Ekinci, 2012). In addition to increasing the quality of education and educators in order to be among the modern and information societies, it is very important to organize educational environments, which is to have educational structures with the right architectural features (Katırcı, 2016).

According to the educators, learning may occur in a suitable environment in terms of physical, social and psychological aspects. For effective education, this environment needs to be organized in a way that is appropriate to the teaching and learning activities. This necessitates organizing and directing the various interaction dimensions between the environment and the individual according to the educational objectives (Küçükoğlu and Özerbaş, 2004).

Lack of safe educational spaces suitable for learning and education can adversely affect students' achievement, motivation, learning performance and attendance to school. Therefore, the spatial quality of school buildings is an important issue to be emphasized to determine the impact of the physical conditions of the school on student achievement and school attendance (Şensoy 2018).

Education structures are the structures where the physical, mental and spiritual development of individuals occurs. When education structures provide suitable environments, an appropriate development takes place. The spaces in the educational structures enable individuals to learn, think, question, research, produce, explore and socialize. These opportunities affect education positively and contribute to social and economic development.

The education program and the philosophy of education are related to the educational environment. Therefore, architectural design is very important in educational buildings. For effective training, the design of the classrooms where education is taking place should be designed appropriately. Variations in classrooms affect education positively or negatively. A good classroom environment increases the learning rate by motivating individuals. A poor classroom area where lighting and ventilation are insufficient affects the individuals negatively.

As a result, many recent studies show that the physical quality of the building is correlated with student achievement, learning performance and motivation (Al, 2014).

The education and training process is usually carried out in classrooms, which are important components of educational structures. The realization of the educational philosophy and training program is directly related to the design of the classrooms. Designing the classrooms in accordance with the right architectural properties plays an important role in the success of individuals in the process of learning and teaching.

In this paper, classrooms in Süleyman Demirel University were examined and the design efficiencies were evaluated with fuzzy logic method.

2. Fuzzy Sets Theory And Fuzzy Logİc

In classical logic, there are “right” and “wrong” or “1” and “0”. In other words, an element is either a member of a set or not, there are no partial truths. But in real life it is not possible to define the propositions as completely true or completely wrong. In these cases, classical logic remain insufficient. Where classical logic is not sufficient, there is a need for fuzzy logic. Fuzzy logic, unlike classical logic, mimics human logic, and can perform operations in approximate and uncertain situations. Contrary to classical logic, in fuzzy logic, an element can be the element of more than one set.

2.1. Fuzzy Set Theory

Fuzzy sets are sets of inadequately defined objects without sufficient criteria for membership. Such communities have undefined boundaries. Such that, it is impossible to define whether these objects in the community belong to the community (Öz, 2007).

The Fuzzy Set Theory has been developed to express and solve problems that do not have clear boundaries. The most important feature of the fuzzy set theory is to process ambiguities by mimicking human logic. The fuzzy set theory aims to make the right decision with incomplete and indefinite information.

Fuzzy inference systems are systems formed by fuzzy If rules. The fuzzy inference system consists of the priori and posteriori parts. The priori part contains the input variables and the logical relations between them, and the posteriori part contains the result variables that arise depending on these input variables. In general, fuzzy rules are created as follows:

Rule 1: If x = a1 and y = b1 and z = c1, then t=m1

Rule 2: If x = a2 and y = b2 and z = c2, then t=m2

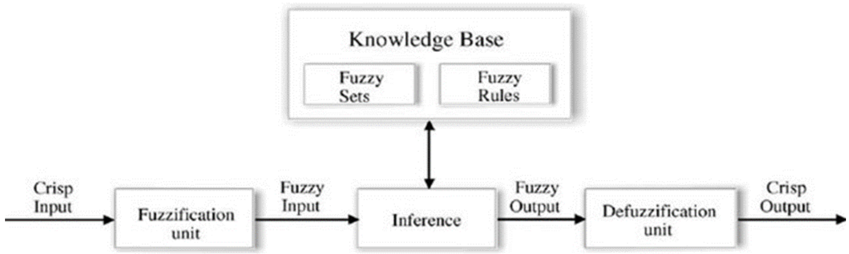


Fig. 1 The structure of a typical fuzzy logic system (Konstandinidoua et al., 2006).

Fuzzification. It is the process of decomposing a system input variables into one or more fuzzy sets, thus producing a number of fuzzy perceptions of the input.

Fuzzy Inference. After the inputs have been decomposed into fuzzy sets, a set of fuzzy if-then-else rules is used to process the inputs and produce a fuzzy output. Each rule consists of a condition and an action where the condition is interpreted from the input fuzzy set and the output is determined on the output fuzzy set. In other words fuzzy inference is a method that interprets the values in the input vector and, based on some set of rules, assigns values to the output vector.

Defuzzification. It is the process of weighting and averaging the outputs from all the individual fuzzy rules into one single output decision or signal. The output signal eventually exiting the system is a precise, defuzzified, crisp value (Konstandinidoua et al., 2006).

2.1.1. *Membership Function*

In fuzzy logic, the probability that an element belongs to the corresponding set takes values from 0 to 1. These values are expressed with a continuous membership function. The value that an element gets from the membership function is called membership degree. The membership functions determine the degree to which an element belongs to a set.

Three ways can be followed to create the membership function. These are:

1. To discuss with the people who have knowledge about the concept and to make the necessary arrangements later,
2. To utilize the data,
3. To determine with the help of the feedback from the system performance (Mayuk, 2015).

2.2. Fuzzy Logic

Fuzzy Logic was first introduced in 1965 by L.A. Zadeh. Zadeh has shown that many concepts can be better determined verbally than traditional mathematics, and that fuzzy logic and its expressions in fuzzy sets constitute a better model of real life.

On the basis of fuzzy logic, there is uncertainty. In other words, in fuzzy logic, a thinking is used that includes partial values, as well as definite values. In fuzzy logic, everything is indicated by a certain degree in the range of [0,1]. In fuzzy logic, information is in the form of verbal expressions such as very large, large, medium, small and very small. Fuzzy inference is made by the rules formed between verbal expressions. Fuzzy logic solves problems by using verbal expressions that people use in their daily life. The use of verbal expressions is a characteristic of fuzzy logic that distinguishes it from other methods.

Fuzzy Logic is one of the methods that find the most industrial application area among artificial intelligence methods and it has been used in many different fields. Some areas of application can be listed as follows: electrical appliances, auto electronics, brake systems, electronic control systems, fault monitoring, decision making, process planning, traffic signal optimization (at junction and main arteries), database inquiry, robotics, image processing and genetics algorithms.

2.3. Fuzzy Decision Making

Decision making is the process of choosing the most appropriate of all available alternatives. This process can involve very complex situations, and this situation becomes fuzzy because it cannot be expressed mathematically clearly.

In the first study on fuzzy decision making; Bellman and Zadeh (1970) proposed a fuzzy model that expresses appropriate objectives and constraints relative to fuzzy sets and determines the decision by an appropriate combination of these fuzzy sets (Özdemir Dağ, 2011).

The main objective of fuzzy logic decision-making methods can be explained as designing mechanisms that will help decision makers to make correct decisions in line with incomplete and inaccurate information (Türkbey, 2003).

It is often difficult for a decision-maker to assign a precise performance rating to an alternative for the attributes under consideration. The merit of using a fuzzy approach is to assign the relative importance of attributes using fuzzy numbers instead of precise numbers. (Yang ve Hung, 2007).

Many decision-making and problem-solving tasks are too complex to be understood quantitatively, however, people succeed by using knowledge that is imprecise rather than precise. Fuzzy set theory resembles human reasoning in its use of approximate information and uncertainty to generate decisions (Kahraman et al, 2003a)

The proposed adaptive fuzzy system with learning ability has been shown to mimic the decision-making of transport support managers and show a level of expertise comparable to their level of expertise (Pamučar et al., 2018).

Since decisions are made by man and human thought approaches more accurately with precise logic than with clear logic, Vilela et al (2019) research study has developed a methodology that integrates human logic into VoI assessment, specifically for problems in the oil and gas industry; Integration of uncertain thinking and terminology into VoI is done using FIS.

Sremac et al (2018) have developed an expert model for determining the economic order quantity. The model was developed using hybrid method-ANFIS of artificial intelligence adaptive neuro-fuzzy inference systems. The validity analysis of the model results was performed on the basis of the mean relative error and showed that the model imitated the expert work in the observed company with great accuracy.

Stojčić et al (2019) have created a model based on the principles of fuzzy logic and artificial neural networks that will fulfill the task of predicting the maximum energy of photovoltaic modules as accurately as possible. The model represents a simple solution that requires the value of the teoutput variable for the given values of the energy of the solar radiation and the average temperature of the module. Model training was performed based on the data obtained by the simulation, so as to determine whether the values obtained by estimation were compared with the actual measured values.

3. CREATİON OF THE MODEL AND RESULTS

The physical space quality of educational structures depends on the decisions taken during the design phase. In this paper, the design efficiency of the classrooms at Süleyman Demirel University was evaluated. Classrooms were examined on site and data were collected. The existing classrooms were examined on site and the orientation of the classrooms, the number of people, the classroom area and the window area of the classroom were calculated. As the input variables, the orientation of the classrooms, the number of people, the area per-capita and the ratio of window area to the classroom area were modelled. The design efficiencies of the classrooms as the output variables were obtained by the rules formed among the input variables. In the model, fuzzy model as the Mamdani type and "weighted average" method as the clarification method were used. For the fuzzy logic model, 180 fuzzy rules have been formed in the type of IF, which are associated with the facade of the classroom, the number of people, the area per capita and the ratio of the window area of the classrooms to the design efficiency of the classroom.

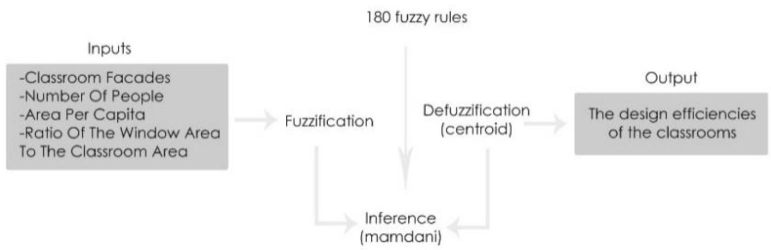


Fig. 2 The structure of fuzzy logic system

3.1.Inputs Selected In Fuzzy Logic Model

In order to evaluate the design efficiency of classrooms in Süleyman Demirel University in MATLAB2017a SDU-student- version, a mamdani-type fuzzy inference systems was used. Four inputs (parameters) were selected for this application:

3.1.1. *Classroom Facades*

The orientation of the building depends on the properties of the land it is located on. Orientation of the building according to factors such as climatic conditions, sun rays, dominant wind direction, slope, elevation, road condition and landscape provides the maximum level of performance from the building as well as the comfort of the users.

The main aim in the direction of the building is to increase the energy efficiency through optimizing climate effects in providing comfort conditions. Therefore, periodically, it is necessary:

- To protect from the heating effect of solar radiation (shading) and at the same time to benefit from the cooling effect of the wind during the hottest season (summer: during which no heating is wanted),
- To benefit from the heating effect of solar radiation and to protect from the cooling effect of the wind (wind breaker) during the least hot season (winter: during which heating is wanted) (Kısa, 2009).

When orienting the classrooms, it is useful to provide the students with a comfortable and health-friendly environment and to use the existing factors in a way to support this aim. Space design can affect students directly or indirectly in classroom and school level (Zorlu and İsmailoğlu, 2018).

It is important that the spaces in the educational structures are correctly oriented for the comfort of the users. The classrooms in which the education and training takes place in the educational buildings should be designed in the appropriate orientation according to the climate zone. According to the Educational Structures Minimum Design Standards Guide (2015), for the classrooms:

- The best advantageous orientation is the south, southeast and southwest directions.
- Middle advantageous orientation is east and west directions.
- The least advantageous orientation is north, northeast and northwest directions.

Four membership functions were created for the orientation of the classrooms. In evaluating the orientation of the classrooms; the south, southeast and southwest directions were most advantageous, the east and west directions were middle advantageous, and the north, northeast and northwest directions were considered to be the least advantageous. The orientation of the classrooms is respectively graded as 4, 3 and 2 while the dark classes without orientation are graded as 1.

Subsets (MFs) for orientation of classrooms: “dark” trimf [0 1 2], “north-northEast-northWest” trimf [1 2 3], “west-east” trimf [2 3 4] and “south-southEast-southWest” trimf [3 4 5] are given in Figure 3. The situation between this input and the output is as follows: '1' is the least advantageous, '2' is less advantageous, '3' is the middle advantage, while '4' shows the most advantageous direction.

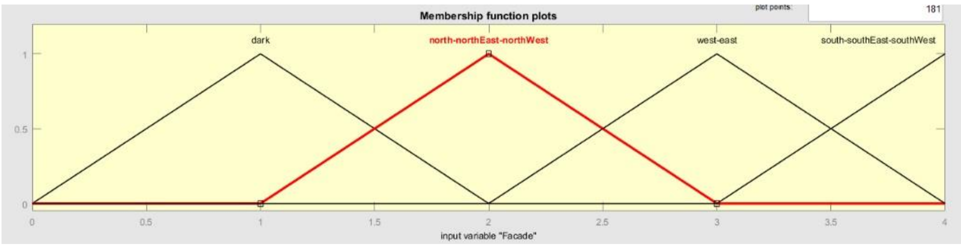


Fig. 3 Subsets and membership functions defined in the model for the orientation of classrooms.

3.1.2. *Number of People*

Educators stated that the maximum number of students acceptable in a classroom would be 36; the normal number can be 30, but the best is the acceptance of 24 students per classroom. Currently, according to the standards of the Ministry of National Education, considering the conditions of our country, 40 students per class as an optimum (Çetinkaya, 2016).

In this paper, the number of people in the classroom was calculated according to the table and chair in the classroom. Five membership functions were created for the number of people in the classrooms. The number of people in the classrooms was considered to be very low, low, middle, high and very high.

Sub-sets (MFs) for the number of people in the classrooms: "veryLow" trimf [0 24 30], "low" trimf [24 30 36], "middle" trimf [30 36 40], "high" trimf [36 40 60] and "veryHigh" trimf [40 60 200], are given in Figure 4. The situation between this input and output is as follows: the increase in the number of people has been evaluated as a disadvantage.

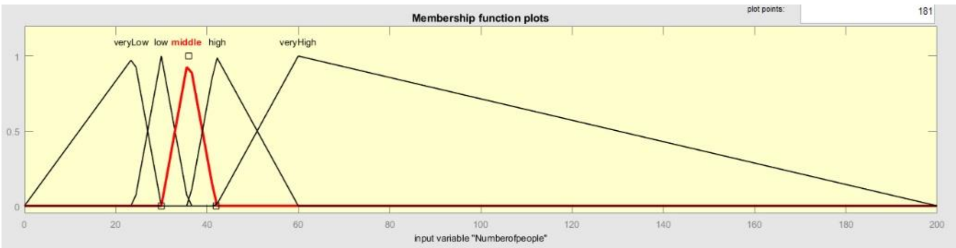


Fig. 4 The subsets and membership functions defined in the model for the number of people in the classrooms.

3.1.3. *Area per Capita*

It is thought that knowing the area per capita in the buildings is proportional to the capacity information of that structure (Erkan et al., 2017). World standards indicate that the classroom space per pupil is minimum, 1.5 m² for a student, normally 2 m², and 2.5 m² for best (Çetinkaya, 2016). Three membership functions were created for the area per capita in classrooms. The area per capita in the classrooms was evaluated as low, medium and high.

Sub-sets (MFs) for area per capita of classrooms: "low" trimf [0 1.5 2], "middle" trimf [1.5 2 2.5] and "high" trimf [2 2.5 6] is given in Figure 5. The situation between this input and the output is as follows: the closer is the area per capita to the best, the more advantageous it is.

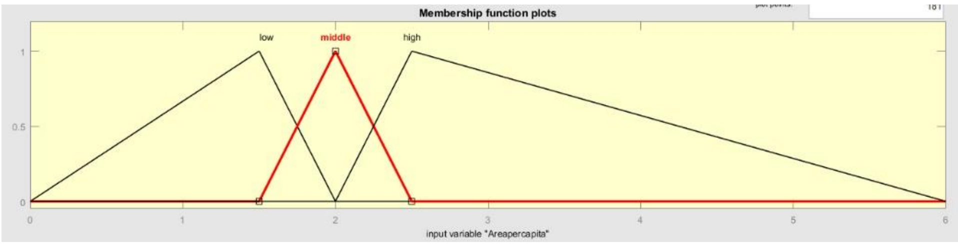


Fig. 5 Sub-sets and membership functions defined in the model for area per capita of classrooms.

3.1.4. *Ratio of the Window Area to the Classroom Area*

Windows are designed to visually link the buildings with the environment and to ventilate and illuminate the spaces. The daylight, which will be taken from the windows during the day, is important for both the physical and mental health of the users of the educational structures. Therefore, optimal illumination levels for classrooms should be determined. Due to the high share of heat loss in windows, their design and size should be well designed.

According to the Educational Structures Minimum Design Standards Guide (2015), the ratio of classroom windows to the floor area should be at least 25%. This ratio can be increased up to 50% depending on the characteristics of the climate zone. Three membership functions were created for the ratio of the window area in the classrooms to the classroom area. The area per capita in the classrooms was evaluated as low, medium and high.

The sub-sets (MF's) for the Ratio of Window Area of Classrooms to the Classroom Area: “low” trimf [0 0 25], “middle” trimf [0 25 50] and “high” trimf [25 50 50] is given in Figure 6. The situation between this input and the output is as follows: the closer is the area per capita to the best, the more advantageous it is.

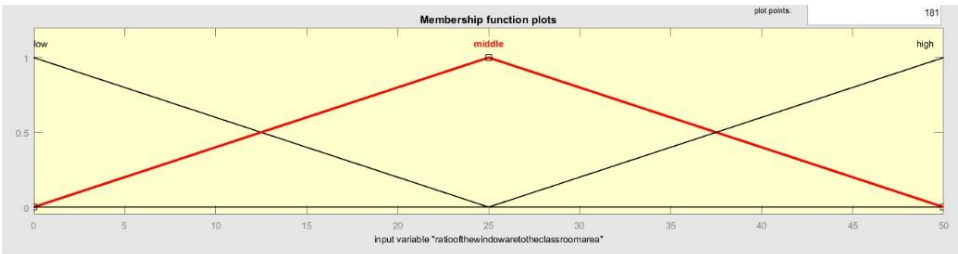


Fig. 6 The sub-sets and membership functions defined in the model for the ratio of the Window Area of Classrooms to the Classroom Area.

3.2. Output Created in the Fuzzy Logic Model

In Mamdani type Fis, five membership functions were created for efficiency values. The number of people in classrooms was evaluated as very low, low, middle, high and very high.

Sub-sets (MFs) for the design efficiency of the classrooms: "veryLow" trimf [0 0 0.25], "low" trimf [0 0.25 0.5], "middle" trimf [0.25 0.5 0.75], "high" trimf [0.5 0.75 1] and "veryHigh" trimf [0.75 1 1] is given in Figure 7.

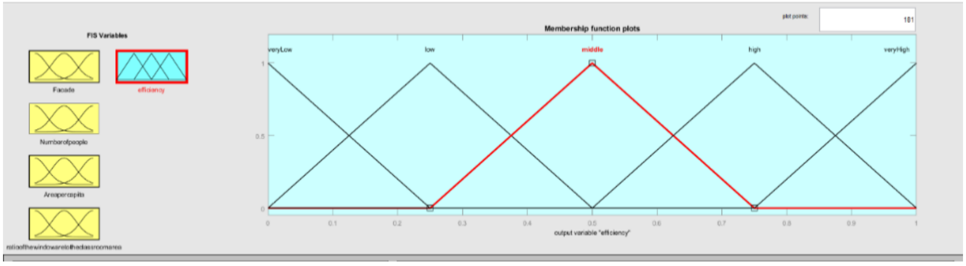


Fig. 7 Subsets and membership functions defined in the model for design efficiency of classrooms.

The fuzzy rule base includes the IF, THEN type rules written between logical input and output variables (Şen, 1999; Tayfur, 2003; Kazanasmaz, 2010). In this paper, 180 fuzzy rules have been created, which are related to the efficiency of the classroom, the number of people, the area per capita, and the ratio of the window area of the classroom to the classroom area. 20 of these Rules are shown in Figure 8.

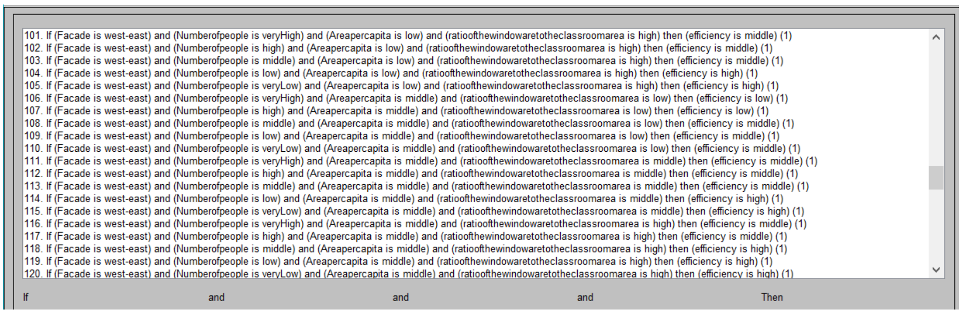


Fig. 8 Rules created in the model for the design efficiency of classrooms

The part that starts with (if) and goes until (then) is based on the direction of the classroom, the number of people, the area per capita, and the ratio of the window area of the classroom to the classroom area. The part after (then) forms a situation on the efficiency value.

The fuzzy inference engine generates fuzzy output from a given input set, taking all the rules in the fuzzy rule base into account. Clarification converts the fuzzy outputs generated by the fuzzy inference engine into a single number (Şen, 1999; Tayfur, 2003; Kazanasmaz, 2010). There are clarification methods such as Centroid, bisector, mom, lom, som etc. In this paper, centroid was used as the clarification method.

The fuzzy logic algorithm was applied in order to grade and classify the design efficiencies of the selected classrooms.

The efficiency values obtained by calculating the direction, number of people, the area per capita, and the ratio of the window area of classrooms to the classroom area of 93 classrooms selected from the Süleyman Demirel University were shown in Table 1,2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13.

Although the number of classrooms at the Faculty of Sport Sciences is normal, the classrooms are in a low efficiency class due to the darkness of the classrooms and the low ratio of the window area to the classrooms.

Table 1 Efficiency Values Estimated by Fuzzy Model for Faculty of Sport Sciences

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
Z-201	1	20	1,47	5,31	0.25
Z-202	1	22	1,30	5,44	0.25
B-11	1	40	2,21	14,38	0.34
B-12	1	37	1,88	15,22	0.24
B-13	1	42	2,12	12,10	0.30

The classrooms at the Faculty of Technology and the Faculty of Technical Education are in a low efficiency class due to the low advantage of the facade, the high number of people and the low per capita area.

Table 2 Efficiency Values Estimated by Fuzzy Model for Faculty of Technology

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
E14-Z-12	2	90	1,01	18,01	0.24
E14-Z-13	2	77	1,18	18,15	0.24
E14-Z-14	2	62	1,46	18,18	0.24

Table 3 Efficiency Values Estimated by Fuzzy Model for Faculty of Technical Education

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
E12-Z-10	2	41	1,65	18,22	0.29
E12-Z-11	2	48	1,41	18,20	0.24
E12-Z-12	2	62	1,46	17,98	0.24
E12-Z-14	2	81	1,12	17,97	0.24

Although the classrooms in the Faculty of Law are most suitable as facades, they are in a low efficiency class due to the high number of people, the low per capita area and the low ratio of the window area to the classroom area.

Table 4 Efficiency Values Estimated by Fuzzy Model for Faculty of Law

Classrooms	Orientation	Number of People	Area per capita	Ratio of window area to classroom area	Efficiency
Z-11	4	150	0,99	11,56	0.25
Z-12	4	80	0,79	12,42	0.25

Classrooms at the Faculty of Architecture are in the middle efficiency class due to the fact that the area per person is suitable, the facades are less advantageous and the number of people is high.

Table 5 Efficiency Values Estimated by Fuzzy Model for Faculty of Architecture

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
Z-10	2	66	2,07	17,79	0.30
Z-11	2	55	2,49	18,02	0.42
Z-12	2	53	2,58	18,23	0.42
K-10	2	43	2,71	17,79	0.42
K-11	2	40	2,87	17,38	0.41
K-12	2	54	2,16	17,77	0.34
K-13	2	38	1,81	17,90	0.39

Although some of the classrooms at the Faculty of Education and Faculty of Religious Studies and Faculty of Pharmacy are most suitable as facades, the number of people is high, the per capita area is low and the window area is in low efficiency class due to the low ratio of the classroom area.

Table 6 Efficiency Values Estimated by Fuzzy Model for Faculty of Education

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
Z-5	2	88	0,86	9,48	0.20
Z-6	2	80	0,96	9,32	0.20
Z-12	4	80	0,95	9,38	0.25
Z-13	4	90	0,84	9,42	0.25
Z-14	4	81	0,93	9,52	0.25

Table 7 Efficiency Values Estimated by Fuzzy Model for Faculty of Religious Studies and Faculty of Pharmacy

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
Z-38	2	64	1,18	10,47	0.21
Z-39	2	61	1,24	10,48	0.21
Z-40	2	64	1,22	10,14	0.20
Z-41	2	64	1,12	10,97	0.21
Z-42	2	72	1,09	10,05	0.20
Z-48	4	64	1,18	10,44	0.25
Z-49	4	72	1,17	9,40	0.25

Although some of the classrooms at the Faculty of Engineering and the Faculty of Economics and Administrative Sciences are most suitable as facades, they are in a low efficiency class due to the high number of people and the low per capita area.

Table 8 Efficiency Values Estimated by Fuzzy Model for Faculty of Economics and Administrative Sciences

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
A/K2-47	4	70	1,20	14,12	0.25
A/K2-51	4	100	1,18	9,99	0.25
A/K2-62	2	100	1,15	10,32	0.21
A/K2-64	2	70	1,20	14,24	0.23
A/K2-65	2	70	1,23	13,79	0.22
A/K2-69	2	90	1,28	10,21	0.20
A/K2-76	4	120	1,22	15,89	0.25
A/K2-77	4	60	1,19	16,53	0.25
A/K2-74	4	60	1,26	15,78	0.25
A/K2-84	2	60	1,28	15,33	0.23
A/K2-89	2	30	1,19	16,55	0.41

Table 9 Efficiency Values Estimated by Fuzzy Model for Faculty of Engineering

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
E1-Z-13	2	90	1,01	18,34	0.24
E1-K1-11	2	62	1,12	18,06	0.24
E1-K1-13	2	81	1,15	17,90	0.24
E1-K1-14	2	90	1,03	17,98	0.24
E4-K1-10	2	100	0,91	18,03	0.24
E4-K1-11	2	90	1,03	17,89	0.24
E6-Z-15	2	64	1,01	10,94	0.21
E7-K1-13	2	70	1,33	18,16	0.24
E8-Z-5	4	66	1,48	16,80	0.25
E8-Z-6	4	90	1,10	16,31	0.25
E8-Z-7	4	88	1,12	16,67	0.25
E9-Z-10	2	60	1,13	18,18	0.24
E9-Z-11	2	70	0,97	18,25	0.24
E9-Z-12	2	80	1,14	18,05	0.24
E9-Z-14	2	90	1,01	18,21	0.24
E9-K1-11	2	56	1,24	18,01	0.24
E9-K1-12	2	76	0,90	18,05	0.24
E9-K1-13	2	90	1,03	17,73	0.24
E10-K1-13/A	4	35	1,21	11,33	0.37
E10-K1-13/B	4	38	1,21	10,45	0.36
E10-K1-8	2	74	1,34	7,18	0.18
E11-Z-1/3	4	78	1,26	11,24	0.25
E11-Z-1/4	4	78	1,27	11,27	0.25
E13-Z-7	2	63	0,91	13,00	0.22
E13-Z-8	2	49	1,18	12,90	0.22

Half of the classrooms at the Faculty of Medicine and Faculty of Health Sciences are in a low efficiency class due to the fact that they are dark, the number of people is high and the area per person is low.

Table 10 Efficiency Values Estimated by Fuzzy Model for Faculty of Medicine and Faculty of Health Sciences

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
A-B23	2	32	1,39	18,79	0.41
A-B24	2	110	0,87	17,60	0.24
A-B25	3	132	0,88	16,96	0.23
A-B01	3	74	1,29	17,46	0.24
A-B19	1	25	1,70	0,0	0.25
A-B20	1	65	1,70	2,0	0.13
B-119	1	182	0,92	0,0	0.11
B-120	1	182	0,91	0,0	0.11

Although the classrooms of the Faculty of Fine Arts and the Faculty of Communication show different differences, they are on average in the medium productivity class.

Table 11 Efficiency values Estimated by fuzzy model for Faculty of Fine Arts and Faculty of Communication

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
Z-30	3	13	5,63	12,25	0.75
Z-38	3	14	4,35	11,42	0.75
Z-24	1	17	2,92	3,28	0.54
Z-25	1	12	4,15	3,27	0.55
Z-16	4	16	4,53	11,56	0.78
Blue Class	2	72	1,03	13,23	0.22
Z-29	2	70	1,03	20,35	0.24

The classrooms in the Faculty of Dentistry are in a low efficiency class due to the darkness of the classrooms, the high number of people, the low per capita area and the low ratio of the window area to the classroom area.

Table 12 Efficiency Values Estimated by Fuzzy Model for Faculty of Dentistry

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
B-ZO2	1	100	1,78	0	0.09
B-ZO6	1	100	1,78	0	0.09

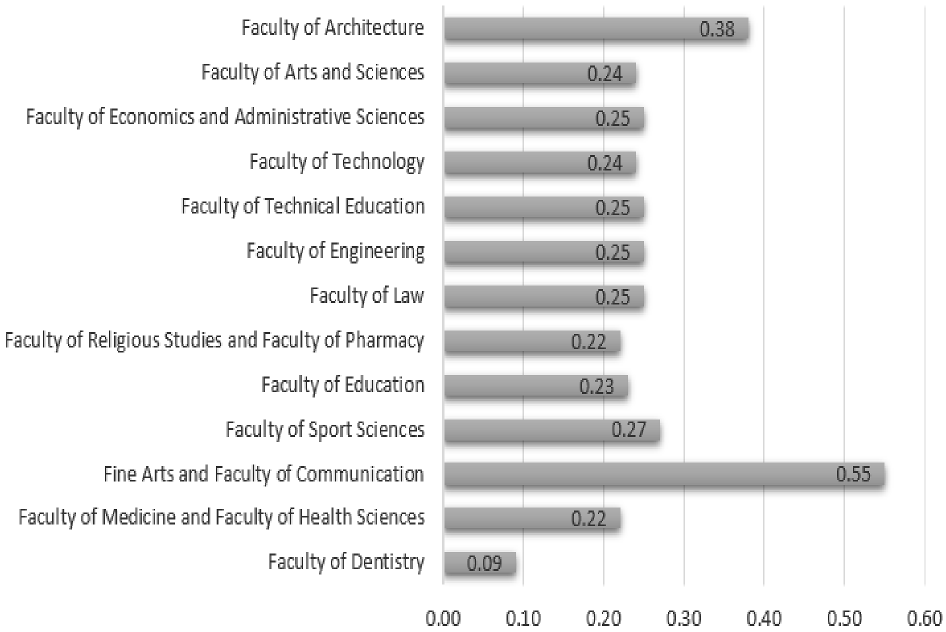
Some of the classrooms at the Faculty of Arts and Sciences are in the lower efficiency class due to the fact that some of them are on the middle and some have less advantageous fronts, the number of people is high and the area per person is low.

Table 13 Efficiency Values Estimated by Fuzzy Model for Faculty of Arts and Sciences

Classrooms	Orientation	Number of people	Area per capita	Ratio of window area to classroom area	Efficiency
Z-20	2	62	0,98	23,83	0.25
Z-44	2	40	1,05	24,99	0.25
Z-63	3	48	0,90	19,74	0.24
Z-65	3	48	0,93	19,14	0.24
Z-108	3	64	0,93	19,01	0.24
Z-109	3	85	0,90	18,52	0.24

The efficiency values obtained as a result of the model were collected in 5 main groups. Those with an efficiency value less than 0.125 forms a very low efficiency class, those between 0,125 and 0,375 forms low efficiency class, those between 0,375 and 0,625 forms middle efficiency class, those between 0,625 and 0,875 forms high efficiency class and those above 0,875 forms a very high efficiency class. The design efficiency of the classrooms is between 0,375 and 0,625.

Of the 92 samples, 4 are in the very low-efficiency class, 76 in the low-efficiency class, 9 in the middle-efficiency class and 3 in the high-efficiency class. There are no examples in the very high efficiency class.



Graphic 1 Distribution of average efficiency of classrooms in faculties.

(a) (b) (c) (d)

Fig. 9 Photos of the classrooms (a) Photos of the B-Z02 classroom of the Faculty of Dentistry. Efficiency value= 0.09 (b) Photos of the Z-16 classroom of the Fine Arts and Faculty of Communication. Efficiency value= 0.78 (c) Photos of the A/K2-51 classroom of the Faculty of Economics and Administrative Sciences. Efficiency value= 0.25 (d) Photos of the K-10 classroom of the Faculty of Architecture. Efficiency value= 0.42

When the average efficiency of the classrooms in the faculties is examined, the best efficiency is in the Fine Arts and Faculty of Communication. The worst efficiency is in the Faculty of Dentistry. The presence of dark classrooms at the Faculty of Sport Sciences, Faculty of Health Sciences led to low efficiency values. The high number of people in the classrooms and the low per capita area caused the efficiency values of the classrooms to be low.

4. Discussion and Conclusions

In this paper, a fuzzy logic algorithm was formed in order to grade and classify the design efficiencies of the classrooms which are the main spaces of the educational buildings. The model was constructed by using the parameters of the orientation of the classrooms, the number of people, the area per capita and the ratio of the window area of classrooms to the classroom area. As a result of evaluations and comparisons of existing classrooms, a design efficiency was established.

Education is an important tool in the progress and economic development of a society. The design of the educational structures can affect the users positively and negatively. Therefore, classrooms, which are the main spaces of educational buildings, should be well designed. This model enables more efficient designs to be created by using classrooms in the decision-making process during the design process and by learning about the design efficiency.

The model is open to the addition of new parameters and rules, and constitutes an analytical infrastructure for making decisions in the design process of educational structures. In addition, the development of the model allows it to be used not only in educational structures but in similar approaches for all building groups.

The paper can be used in the decision-making stage of the design of educational structures. Feedback can be obtained as a result of evaluations and comparisons of existing classrooms. This leads to the development of better designs and generations of solutions. For example, it may decide to improve the renovation, improvement of classrooms, and generate ideas about how the existing classrooms should adapt to the most current standards in terms of technological developments and change of educational curricula.

The paper was conducted with 4 input variables. However, it is open to the addition of new parameters and rules according to the course type and geographical characteristics of the classroom.

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PROCENA EFIKASNOSTI UNIVERZITETSKIH UČIONICA KORIŠĆENJEM FAZI LOGIKE

U ovom radu, stvoren je algoritam fazi logike da bi se ocenila i klasifikovala efikasnost projektovanja odabranih učionica sa Univerziteta Sulejman Demirel. Postojeće učionice ispitane su na licu mesta i izračunata je orijentacija učionica, broj ljudi, površina učionice i površina prozora učionice. Kao ulazne varijable modelirane su orijentacija učionica, broj ljudi, površina po osobi i odnos površine prozora i površine učionice. Efikasnost dizajna učionica u vidu izlaznih varijabli dobijena je pravilima formiranim među ulaznim varijablama. U modelu su korišćeni fazi model kao Mamdanijev tip i metoda "ponderisanog proseka" kao metoda razjašnjenja. Za model fazi logike formirano je 180 fazi pravila IF tipa, koja su u vezi s fasadom učionice, brojem ljudi, površinom po osobi i odnosom površine prozora učionica i efikasnosšću projektovanja učionice. Kreirane su efikasnost dizajna učionica; klase efikasnosti dizajna i prosečne efikasnosti projektovanja učionica na fakultetima su upoređene i izvedeni su zaključci prema fakultetima. Efikasnost učionica, koje su glavno mesto obrazovnih zgrada, zavisi od odluka donesenih u fazi projektovanja. Sa modelom stvorenim u ovom radu, obezbediće se efikasniji dizajn poznavanjem efikasnosti dizajna i korišćenjem procesa odlučivanja o učionicama tokom procesa projektovanja.

Ključne reči: *Fazi logika, donošenje odluka, učionica, efikasnost dizajna*.