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Developing a web based software for the evaluation of architectural designs

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Abstract

When the architectural design is handled based on process and product, we see that many parameters come into play at the point of decision making. Especially as the design problem gets complicated, the value parameters increase so much. Producing solutions to these complex problems only with personal judgments does not yield very productive results in the accuracy of the results. Decision support systems with effective use are needed to select solution suggestions in the design process, at the point of converting personal judgments into real data. For this purpose, a structured decision support method on the fuzzy AHP approach for design evaluation is presented, and a web-based interface is introduced that increases the usability of the method in practice. The interface has been developed based on ASP.Net platform as a web-based evaluation software that allows the participation of many evaluators independent of time and space. The effectiveness and advantages of the developed software are discussed in evaluating the designs obtained in an architectural design studio environment. The software called DDSS (Design Decision Support Software) has shown that it can be applied more effectively in multi-criteria decision-making problems by eliminating the synthesis processes and providing the opportunity to reach faster results. Consequently, when the decision support method presented is used through the developed software, it is seen that more conscious and objective evaluations can be made about the designs in the decision steps in the architectural design process, which has a complex and contradictory structure intertwined with abstract concepts as characters.

Keywords
ASP.Net, Decision making, Fuzzy AHP, Web software.

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1. Introduction

Decision making is one of the most important functions of the human being by nature. In general, after learning about options or alternatives, it can be defined as the process of choosing the most appropriate option for the outcome we want to achieve.

Undoubtedly, people of all ages have to make decisions in the face of situations or events. Decision making, which is an indispensable phenomenon of our lives, is a necessity as well as a requirement. When the decision-making phenomenon is considered as method-oriented in architecture, the fact that design objectives and criteria can change even in the process of design, the uncertainty of the solution path in the development of solution alternatives and subjective decisions increase the importance of decision-making methods in the selection of solution proposals.

At this point, decision support systems, which were firstly used in management sciences and then applied in other engineering disciplines and architecture, emerged with the increasingly complex structure of knowledge, the need for information management, the need for coordination between different types of information, and the search for a system to support the designer. These methods, which are based on artificial intelligence studies, have been widely used in recent years especially in engineering and management areas by combining with many different tools and techniques in the solution of complex, unstructured or multi-criteria problems (Manupati, Ramkumar, and Samanta, 2018).

Considering the design practice, design, which is an intellectual action we encounter in almost every area of our lives; In general terms, it can be described as an interactive problem-solving process consisting of different decision-making steps to reach specific goals.

However, in the literature review, it is understood that the decision support methods that can enable decision steps in the architectural design process with systematically and which can be used in these steps and will be able to make decisions according to the current conditions and problems in the design process has not been handled sufficiently in terms of decision steps in the architectural design process by being limited to the choice of material or location.

In the study, which is performed by Palabiyik and Colakoglu (2012), to carry out the systematic methods of decision making in the design process, a method has been developed to help decision making and the potentials of this method in terms of evaluating the alternatives in the design process and final products have been investigated.

When the advantages, disadvantages and prospective recommendations of the study are evaluated, developed fuzzy multi-criteria decision-making method is seen to provide a rational structure of decision-making, help make more informed and objective decisions about the evaluated designs, make it possible to make collective decisions by including more than one person in the evaluation and provide feedback by revealing the positive and negative aspects related to the designs in the assessments to be made during the design process.

Conversely, the fact that data synthesis activities are carried out through Microsoft Excel program in the assisted decision-making method brings some disadvantages. The fact that this process, especially the data synthesis step involves a large number of repetitive mathematical operations, leads to application difficulties in both formulation and coding and data entry processes. This causes a limited number of users to use the method and compromises data security in the event of a system failure in the computer where the working data is stored.

In this study, a decision support method based on the fuzzy AHP approach to design evaluation and a web-based interface that increases the application potential of this method in the architectural design process is presented. The interface has been developed based on ASP.Net platform as a web-based evaluation software that allows the participation of many evaluators independent of time and space. In the development of the software called DDSS (Design Decision Support Software), the C # programming language in the middle-level language group was preferred, and the effectiveness and advantages of the method presented in the study together with the developed software were discussed in the process of evaluating the designs obtained in an architectural design studio environment.

In this context, the study is organized as follows. Chapter 2 is structured in two stages; In the first stage, the concept of design and decision making in the architectural design process, in the second stage, the decision support method AHP, Fuzzy Logic and Fuzzy AHP theories, and Chang's Order Analysis Method are given with the basic features. In Chapter 3, the use and effectiveness of the method with the developed web-based software are discussed during a case study. In Chapter 4, evaluations are made on the developed DDSS software, and results and forward-looking suggestions are presented over the potentials of use with the method presented.

2. Background and preliminary

2.1. Concept of design

Design, which is handled and evaluated with different aspects in many fields, is research and problem-solving process that generally works within constraints. The goal of this process is to find and offer sustainable and creative solutions that meet the needs specified in the problem description (Giaccardi and Fischer, 2008). Design, a sophisticated cognitive action, begins by generating an abstract idea in architecture and continues with the transformation of this idea into concrete spatial formations. This idea that triggered the start of creative design; Alexander (1964) defines it as "image", Darke (1979) as "primary generator", Rowe (1987) as "organizing principle" and Lawson (1997) as "concept". In this context, architectural design can be defined as the process of creating solutions synthesized in the form of a built environment that starts with a creative idea and meets both practical and impressive requirements according to existing constraints and resources in a utilitarian and aesthetic manner. In the architectural design process, which consists of multiple sub-processes, where different solutions are developed at different times, the creation-evaluation-selection cycles are repeated continuously throughout the entire process to produce design solutions (Roozenburg and Cross, 1991). In this process, which has a hierarchical structure, the relative weight given to each of the quality features of architectural design, such as;

- its suitability for use and adaptability to private/specific activities,
- its durability and permanence,
- and the aesthetic aspect achieved by its form can vary greatly (Ackerman, 2013).

Today, the market that requires specialized design solutions according to customer demands has been diversified and divided into sections. In this environment, architectural designs, whose complexity has increased exponentially due to socio-economic changes, environmental and energy problems, should also increase customer satisfaction by meeting individual needs. For this reason, it is essential to optimize the architectural design process according to many different (sometimes contradictory) requirements and constraints and to choose the solution from the various alternatives produced. At this stage, most designers highlight intuition and experience that may not be sufficient;

- when the desired design solution cannot be found easily,
- when the cost of failure is extremely high,
- when the design task is extremely complex, or
- when multiple stakeholders are involved in the design for the design (Darke, 1979).

At this point, Cross (2000) states that traditional design methods are not suitable for many design projects due to complexity, high probability of error and lack of tools for teamwork.

Therefore, especially in the conceptual design phase of the architectural design process; More rational and systematic approaches are needed to make decisions that have primary and comprehensive effects on representation, performance and costs (American Institute of Architects, 2007; Cross 2000).

Although several systematic approaches have been proposed in the literature to organize, guide and facilitate the architectural design process (Simon and Hu, 2017), it seems that the applications of the systematic methods developed for decision support are quite limited in architectural practice. This situation may be related to the fact that the methods that help decision making developed in the field of architectural design dominated by individual processes and subjective evaluations are not as successful in evaluating qualitative data as in evaluating quantitative data (Palabiyik and Colakoglu, 2012).

2.2. Decision making in architectural design process

Most studies on the architectural design process show that at this stage, designers often use their knowledge and past experience by using traditional methods to formulate an obvious problem and support an alternative solution based on it (Darke 1979). Gregory (1966) defines architectural design as a process that includes thinking and decision making activities. According to him, the thinking phase that forms the basis of the design; the process in which many criteria are considered separately, and the decision-making phase; It refers to the process in which ideas are compiled, refined and made concrete.

In an architectural design structured according to the traditional understanding, decision making and implementation are learned with a project-based "studio" approach. In this process, where designers explore design alternatives and results with activities related to sketching, modelling and discussion, learning and decision making based on visual analogies is an indispensable tool for designers and architects (Simon and Hu, 2017).

In general, while developing alternative solutions in the architectural design process; decisions are handled at different levels under different scenario types. In this context, high-level decisions are made; Includes scenarios such as team organization, product cost, business breakdown and suppliers. A mid-level decision includes such issues as design requirements, material selection, subsystems and components, and the manufacturing and manufacturing process. At a low level, a designer can determine the design goals, forms, dimensions, etc. of individual components (Zhuang, Hu, and Mousapour, 2017).

Accurately assessing the decision-making process influenced by a range of conditions and contexts that can be controlled (such as the business context) and uncontrollable (such as market, financial requirements, and user preferences) is essential in determining the levels and long-term effects of design decisions. Because decisions with long-term effects are often irreversible after implementation. This situation requires the necessity to consistently justify the decisions taken during the early design phase, especially in the context of architectural design. Otherwise, severe environmental damage may occur. Therefore, it is significant for the decision-maker in the process to seriously analyze the meaning and impact of the alternatives before reaching a decision (Zhuang, Hu, and Mousapour, 2017).

It has been developed in recent years to assist designers in the decision-making process; Various methods such as decision matrix (Shafer, 1976), decision tree (Shamim, Hussein, and Shaikh, 2010), quality function deployment (Akao, Mazur and King, 1990) are widely used. These methods are usually ad hoc structured and comparatively largely subjective judgment or designer intuition. Besides, methods such as utility theory and game theory, which are examined in research on feasibility and feasibility in the fields of management science and economics, are also used to support decision making in design, primarily in engineering and product design (Simon and Hu, 2017).

In this context, although decision-making has been extensively studied in engineering design where scope and risk are well defined, it has not been extensively studied in the architectural design process where more uncertainty and risk are involved (Simon and Hu, 2017). This situation is related to the decision making stages in the architectural design process, besides quantitative values, qualitative values that contain subjective judgments due to human evaluations (Lawson, 1997).

The basic understanding adopted in this study is to examine the architectural design problems as a multi-criteria decision-making problem by considering the qualitative and quantitative criteria in the decision-making process. With this aspect, it is aimed to introduce a practical approach in expressing uncertainties, which allows to work with multiple criteria with different features and to compare alternatives with each other with the decision support method presented within the scope of the study.

In this context, due to its potential in decision making and its effectiveness in expressing subjective judgments in the architectural design process, the decision support method presented within the scope of the study is structured on the fuzzy AHP theory, which is used extensively in the fields of management sciences and engineering, where fuzzy logic and AHP are used together. Technical information about AHP, Fuzzy Logic and Fuzzy AHP is given in the following section.

2.3. AHP method

AHP is a multi-criteria decision-making method developed by Thomas Satty in the 1970s, making it possible to make decisions individually and as a group, while choosing among many alternatives under certainty or uncertainty. The main idea of AHP is to divide a complex and unstructured decision problem into a series of multi-level hierarchically arranged components to minimize complexity (Saaty, 1980). Measuring subjective decisions of decision-makers by assigning corresponding numerical values according to the importance of the factors considered is an essential feature of AHP (Saaty, 1994a). Because it is straightforward to understand and involves simple mathematical calculations, AHP has attracted considerable attention in the analysis of various decisions regarding complex, technological, economic and socio-political problems and has been applied successfully in many areas including marketing, finance, education, public policy, economics, medicine, sports, informatics (Saaty, 1990; 1994a; 1994b).

Saaty (1990) states that perhaps the most creative task in making a decision is to choose the factors that are important for this decision problem. After selecting these factors in the Analytical Hierarchy Process, the process takes place in five main stages: the development of a hierarchy tree, which is a graphical representation of the decision problem, descending from a general target to the criteria, sub-criteria and alternatives consecutively, the development of binary comparison matrices, taking relative priorities, checking consistency and obtaining the general priority of decision alternatives.

Saaty (2001) listed the ten advantages of AHP, which is a decision-making method, as unity, complexity, interdependence, hierarchy structure, measurement, consistency, judgment and consensus, synthesis, imbalances and process repetition. However, the fact that the 9th scale used in binary comparisons in this method is insufficient in explaining the uncertainties can significantly affect the decisions to be made. It is seen that AHP is used in conjunction with Fuzzy Logic to better reflect the way of human thinking by expressing uncertainties and thus creating more appropriate and consistent decisions (Brunelli, 2015).

2.4. Fuzzy logic theory

Lotfi A. Zadeh with his article “Fuzzy Sets” published in 1965, by introducing the concept of fuzzy sets to the world of science; it brought a completely new perspective to systems, logic and reasoning models (Zadeh, 1965; 1968).

Unlike traditional logic systems, fuzzy logic aims to present an approximate model rather than precise reasoning (Bellman and Zadeh, 1977). Fuzzy logic in which the concept of degree is introduced in the verification of a condition and the definition of the condition at an intermediate value between true or false provides precious flexibility for logic. Thus, it is possible to take into account the mistakes and uncertainties, and with fuzzy logic, inference systems closer to human behaviour can be created (Zadeh, 1984).

Fuzzy logic is based on the mathematical theory of fuzzy sets, which is the generalization of classical set theory. The fuzzy set is an object class whose membership degrees are continuous. Such a cluster is characterized by a membership (characteristic) function that assigns a degree of membership ranging from zero to one for each object (Zadeh, 1965).

In classical set theory, the elements of the universe are defined in two groups, those that belong to an M set and those that do not. The elements belonging to the cluster are assigned "1", and those who do not belong to "0" are assigned to explain whether they are members of the M cluster or not. In the fuzzy set approach, there is no precise classification as members or non-members, and the elements of the set are defined by membership functions. These functions assign real values to the elements in the interval [0,1]. These real values show how suitable the elements are to the concept represented by the fuzzy set M (Palabiyik and Colakoglu, 2012).

Fuzzy logic systems structured on fuzzy logic and fuzzy sets theory are rule-based systems used to solve different types of problems in economics, linguistics, law, artificial intelligence and other human-centred application areas (Herrera, 2005; Zadeh, 1965). The processing of input and output data in the fuzzy logic system is performed in three stages, as shown in figure 1: These stages are as follows:

1. Fuzzification: In the fuzzification stage, membership functions are defined for both input and output variables to transform the data input received from the user into meaningful linguistic data with fuzzy components in varying degrees.
2. Fuzzy Inference: At this stage, fuzzy control rules are applied with a series of IF-THEN conditions to organize meaningful input-output relationships and obtain linguistic outputs.
3. Defuzzification: In the defuzzification phase, linguistic outputs are converted into numerical outputs by specific calculation methods (Naz and Nadin, 2018).

Fuzzy logic came to the fore in explaining the relationship between real life and logic and has been able to produce more realistic solutions to many problems.

2.5. Fuzzy AHP method

Fuzzy AHP, which results from the combination of fuzzy logic and AHP method, is based on fuzzy set theory, which uses fuzzy numbers in the inputs of binary comparison matrices put forward by Zadeh (1965) (Table 1).

The first study on fuzzy AHP was conducted by Laarhoven and Pedrytcz (1983), which compared fuzzy rates expressed with fuzzy triangular numbers. In 1985, Buckley developed a new model by identifying fuzzy priorities of binary comparisons through trapezoidal membership functions. Later in 1996, Chang introduced a new approach using fuzzy triangular numbers for the binary comparison scale of fuzzy AHP and using the extent analysis method for the synthetic grade values of these binary comparisons. In this study, Chang's "Extent Analysis Method", which is similar to the classical AHP method and easier to apply than other methods, is used.

It is seen that the fuzzy AHP method is used in many different areas of decision making. Bozbura, Beskese, and Kahraman (2007) proposed the fuzzy

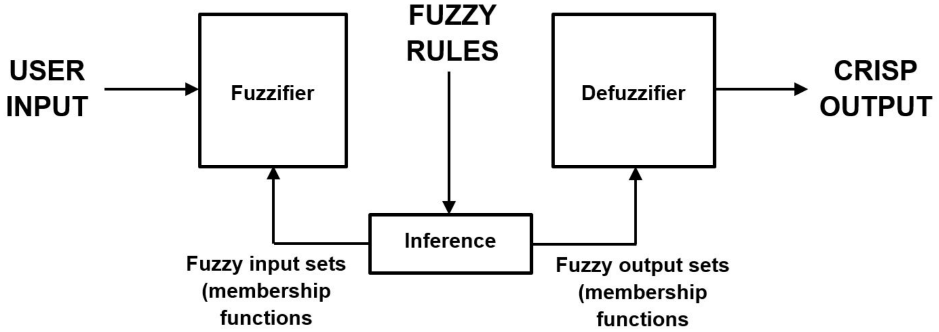


Figure 1. Conceptual scheme of a fuzzy logic system.

Table 1. Triangular fuzzy transformation scale.

Linguistic Variables	Triangular Fuzzy Values	Triangular Fuzzy Corresponding Values
Equally important	(1, 1, 1)	(1, 1, 1)
Intermediate value	(1, 2, 4)	(1/4, 1/2, 1/1)
Moderately important	(1, 3, 5)	(1/5, 1/3, 1/1)
Intermediate value	(2, 4, 6)	(1/6, 1/4, 1/2)
Strongly important	(3, 5, 7)	(1/7, 1/5, 1/3)
Intermediate value	(4, 6, 8)	(1/8, 1/6, 1/4)
Extremely important	(5, 7, 9)	(1/9, 1/7, 1/5)
Intermediate value	(6, 8, 10)	(1/10, 1/8, 1/6)
Definitely more important	(7, 9, 11)	(1/11, 1/9, 1/7)

AHP method to improve the quality of the “human capital” measurement indicators in priority. Pan (2008) used the Fuzzy AHP method to select the appropriate bridge construction method. Sun (2010) developed a performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. Taylan et al. (2014) conducted a study on the comments about “selection of construction projects and risk assessment with Fuzzy AHP and Fuzzy TOPSIS methodologies”. Chen, Hsieh and Do (2015) performed a study on evaluating fuzzy AHP-based teaching performance and a comprehensive assessment approach. Toklu, Erdem, and Taskin (2016) proposed a fuzzy model for strategic planning in production companies. Li et al. (2017) proposed a mixed approach based on fuzzy AHP and fuzzy linguistic method for the evaluation of in-flight service quality. Awasthi, Govindan and Gold (2018) used a fuzzy AHP-VIKOR-based approach to multilayer sustainable global supplier selection. Harputlugil et al. (2014) conducted a study that focused on conveying the preferences of stakeholders to the design team in the architectural design stages in order to increase the architectural design quality. However, there are a limited number of studies in the literature that try to combine the fuzzy AHP method with computer systems. The study developed by Cakir and Canbolat (2008) developed a web-based decision support system for multi-criteria inventory classification using fuzzy AHP methodology and the survey by Armillotta (2008) uses adaptive AHP decision model for the selection of layered production techniques can be given as examples of the few studies conducted in this field.

In this study; With the fuzzy AHP-based decision support software developed, it is aimed to contribute to the development of alternative designs by making the evaluations in the decision steps based on product and process in a more effective and faster manner in architectural design. In this direction, the mathematical process related to fuzzy AHP method, which is the Chang’s Extent Analysis Method, which forms the infrastructure of the software, is given in the continuation of the section.

2.6. Chang’s fuzzy AHP method (Extent Analysis Method)

The Extent Analysis Method developed by Chang (1996) aims to achieve the significance of the criteria and the performance of the alternatives according to each criterion by solving blurred reciprocal binary comparison matrices as the main idea. This approach can be addressed in 4 stages. The application of the method, together with these steps, is described below.

Stage 1: Fuzzy synthetic value analysis. The primary purpose of this analysis is to determine the significance of the criteria and alternative performances by solving blurred binary comparison matrices.

If $A = \{a_1, a_2, \ldots\ldots\ldots, a_n\}$ is the object set and $U = \{u_1, u_2, \ldots\ldots\ldots, u_m\}$ is accepted as the objective set, each object is taken, and synthetic performance analysis is performed for each purpose. Thus, m synthetic (expansion) analysis values for each object are obtained as follows (Palabiyik and Colakoglu, 2012; Paksoy, Yapıcı Pehlivan and Özceylan, 2013).

$$M_{gi}^{1}, M_{gi}^{2}, \ldots M_{gi}^{m}, \quad i=1, 2, 3, \ldots n \quad (1)$$

Here, Mgij, (j=1, 2, 3, … m) are each fuzzy triangular numbers and the fuzzy synthetic magnitude value for i object is found by the following equation.

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \odot \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad \textbf{(2)}$$

The M_{gi}^{j} specified indicates the performance of the a_i object for the ui purpose.

Stage 2: Comparison of fuzzy synthetic values. If a fuzzy binary comparison matrix is determined, the principle of comparing fuzzy numbers for the weigheq2t vector values under each criterion is needed.

The probability of $M_1 \geq M_2$ can be defined as follows.

$$V(SM_1 \geq SM_2) = \sup_{x \geq y}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \quad \textbf{(3)}$$

If a pair (x,y) is given, if $y \geq x$ and $\mu_{M1}(x) = \mu_{M2}(y) = 1$;

since the fuzzy numbers $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are convex, $V(M_1 \geq M_2) = 1$.

$$V(M_1 \geq M_2) = 1 \quad \text{if } m1 \geq m2, \quad \textbf{(4)}$$

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M1}(d)$$

In the above equation, d is the ordinate of D the highest intersection between μ_{M1} and μ_{M2}.

If $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, the ordinate of D can be obtained from the following equation.

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2)$$

$$= \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \quad \textbf{(5)}$$

To compare M_1 and M_2, $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ values are required (Figure 2) (Chang, 1996).

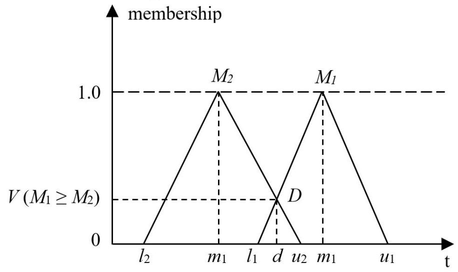


Figure 2. *Comparison of synthetic values.*

Stage 3: Calculation of weight performances. The probability that a convex fuzzy number is greater than *k* the convex fuzzy number M_i (i=1,2,…,k) can be defined as follows:

$$V(M \geq M_1, M_2, \ldots, M_k) \quad \textbf{(6)}$$

$$= V[(M \geq M_1)\ ve\ (M \geq M_2)\ \text{ve} \ldots \text{ve}\ (M \geq M_k$$

$$= \min\ V(M \geq M_i), i = 1, 2, \ldots, k \quad \textbf{(7)}$$

$$\text{If, } d'(A_i) = \min V(S_i \geq S_k)$$

$k = 1,2,\ldots,n$; $k \neq i$ is assumed, the non-normalized weight vector can be specified as in Equation 2.19.

$$W' = (d'(A_1).d'(A_2) \ldots d'(A_n))^T \quad \textbf{(8)}$$

In this equation, A_i (i = 1,2,…,n) refers to n elements.

Stage 4: Normalization. Weight vectors (W) obtained by normalization can be expressed as follows.

The W value in this equation is a non-fuzzy number (Chang, 1996).

$$W = (d(A_1).d(A_2) \ldots d(A_n))^T \quad \textbf{(9)}$$

Manually editing and controlling the mathematical operations given above causes application difficulties in terms of fast and efficient use of the method. With the DDSS web-based evaluation software developed within the scope of the study, it is aimed to use the method more efficiently by ensuring that the data synthesis activities involving all these mathematical operations are carried out automatically by hiding from the user (Figure 3). In the following section, the general features of the developed software and the application of the decision support method over the software are discussed with the process of evaluating the designs obtained in an architectural design studio environment.

3. General editing of decision support method

The application of the method through the developed DDSS software is discussed in two main stages as analysis and synthesis. The first analysis phase takes place in 4 steps:

Step 1: Establishing the hierarchical organization by defining evaluation criteria,

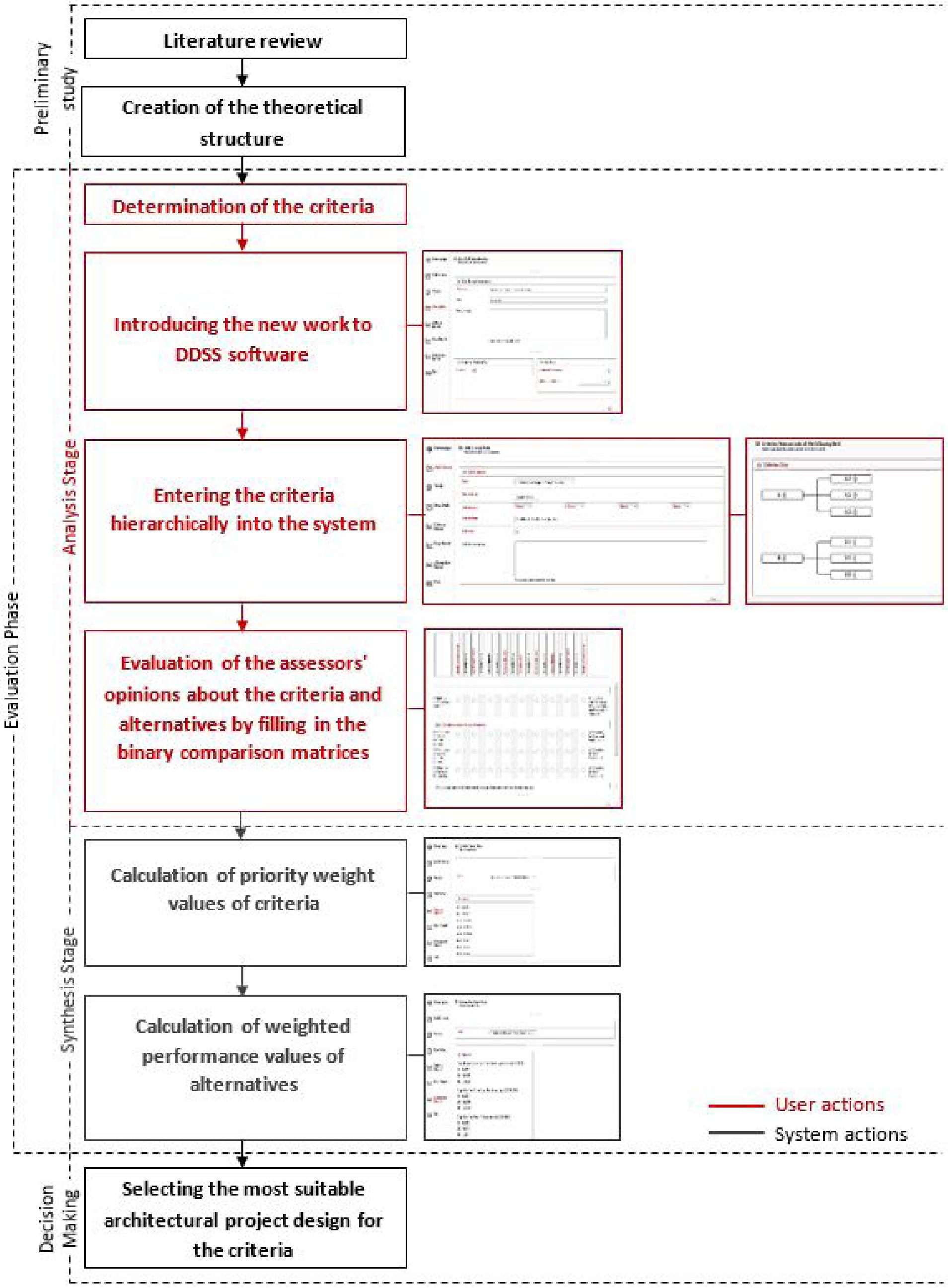


Figure 3. *Stages of the methodology used.*

Step 2: Introduce the new study to the system via DDSS software,

Step 3, entering the evaluation criteria of the new study into the system,

Step 4: The evaluators enter data into the system through DDSS software, which expresses their thoughts and values about the evaluation criteria and alternative designs that are evaluated.

The synthesis stage, which is the second stage, is carried out in 2 steps consisting of determining the weight vectors expressing the relative importance of each evaluation criteria, calculation of weighted performance values of each alternative according to determined criteria by creating the result performance matrix. The three steps mentioned at this stage are carried out by the developed software without any action. Following these processes in the background of the software, the last step is that the administrator can view and evaluate the result data of the evaluation criteria and alternative designs.

The general process algorithm related to the steps performed with DDSS software, which is envisaged to be used more effectively by the process, especially in the synthesis stage, is given in Figure 4.

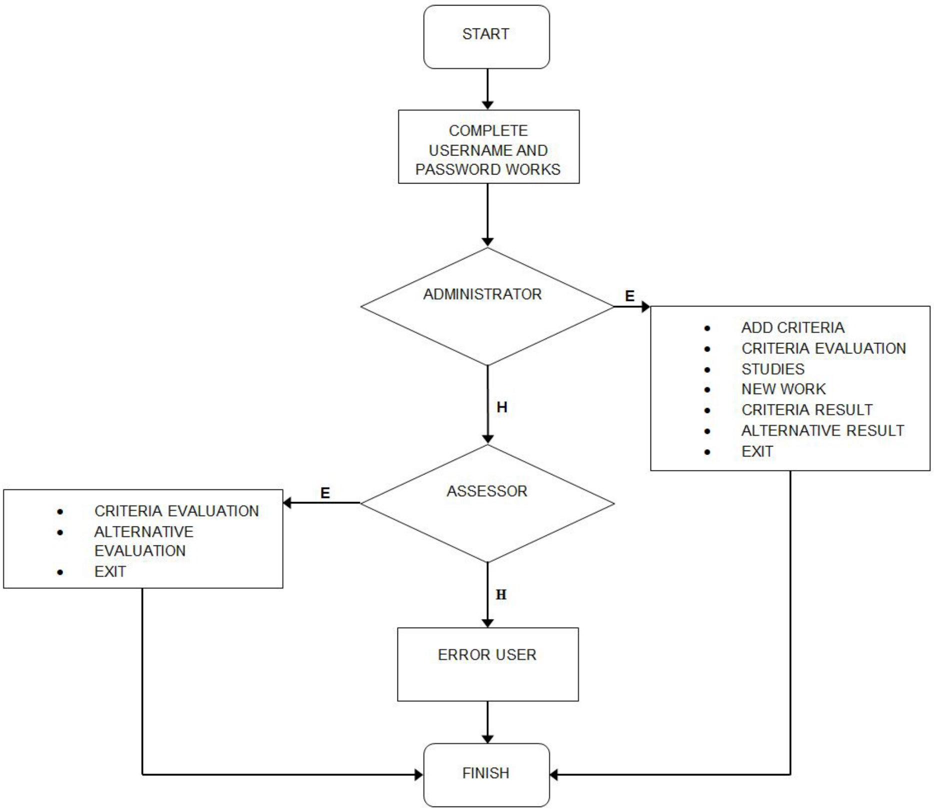


***Figure 4**. Introduction to the system and process algorithm.*

The general infrastructure of the software and the processes that must be done on the software are discussed in detail in the rest of the section during the evaluation of the designs obtained in an architectural design studio environment.

3.1. Theoretical background of DDSS software

The developed software is web-based due to the advantages of being accessible by different people at different places and times. In the first stage of the design of web-based software, the web interface made with Adobe Photoshop program was converted to HTML (Hypertext Sign Language) with Adobe Dreamviewer program, and necessary CSS coding was done. The generated HTML files were programmed with Microsoft Visual Studio software, and .aspx pages were created. Asp.Net infrastructure has been used to create these dynamic web pages due to its advantages, such as ease of use and management. The programming language is C #, which works in compliance with Asp.Net platform, offers ease of use and works according to object-oriented programming principles. MsSQL database management system was used to store the data to be used in the study, and "SQL Server Management Studio" program, which enables access, configuration, management and development of all components, was used to manage MsSQL. In the last stage, the files are prepared to be published by providing the necessary domain and hosting services to work on the web.

3.2. Effectiveness of the method with DDSS software: Field study

The functionality of the developed DDSS software is still considered in design studies of different content and scales, both in the process and in the context of evaluating the architectural design alternatives obtained as final products.

In this study, to test the application of the method via DDSS software; in the first year of the architectural design studio, where the students met with the form, space and the principles that guide them in the urban built environment, it was aimed to design the houses where the functional requirements of the housing phenomenon were solved with the physical environ-

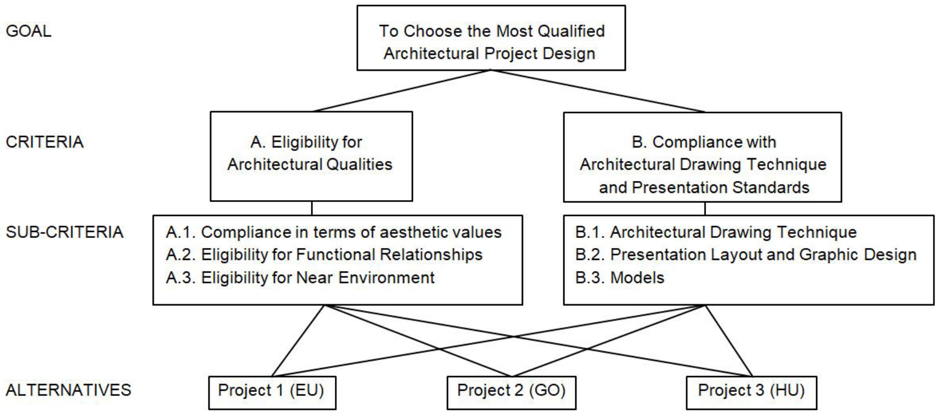


***Figure 5**. Hierarchy of criteria used in selection of architectural project design.*

ment data and the correct applications to the structural problems. Among the residential designs obtained at the end of the process, three designs that were considered to be more qualified than the others were selected by the project executives within the scope of the field study to investigate the effectiveness of the developed software.

3.2.1. Analysis phase of decision support method

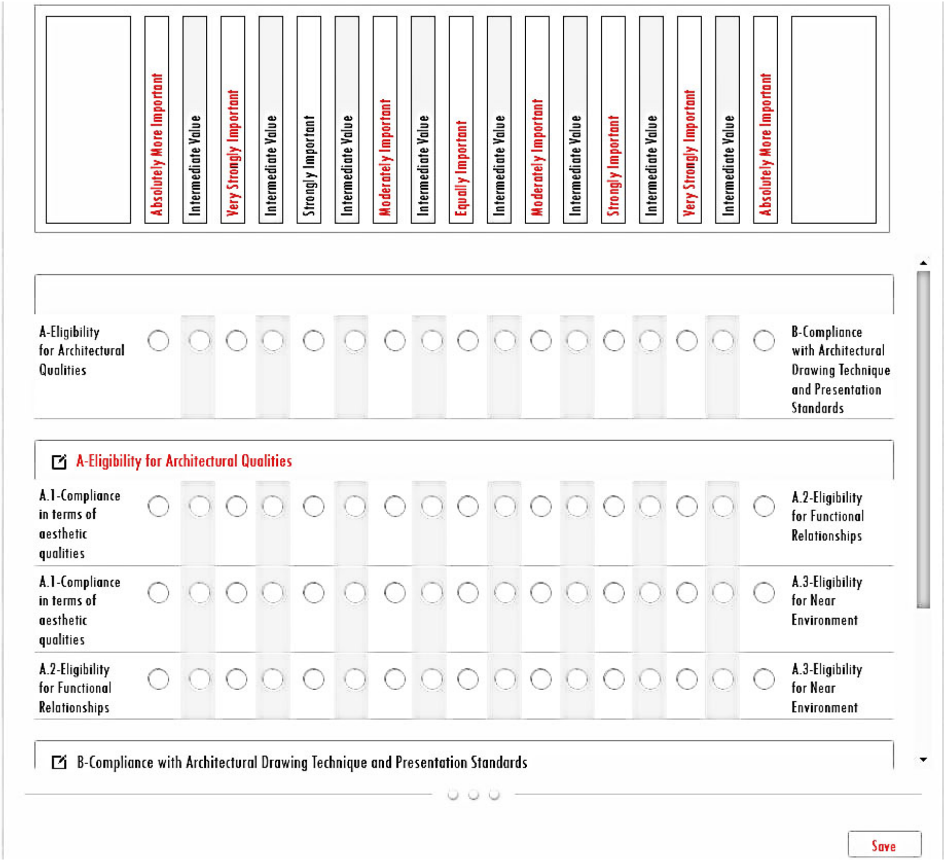
The evaluations of the selected designs made by the project executives using DDSS software are stated below in 4 steps performed during the analysis stage of the decision support method.

Step 1_ Determining the evaluation criteria and forming a hierarchical organization: The process starts with the determination of the evaluation criteria related to the intended design subject. Next, a hierarchical organization chart showing the relationships between the evaluation criteria determined is formed. The criteria determined within the scope of the field study and the hierarchical decision tree created are indicated in Figure 5.

Step 2_ Introducing the new study to the system via DDSS software: After defining the criteria, the main page of the software is accessed via the web. In the login screen that appears on the main page, the verification process is performed according to the user name and password. The login screen offers two different options for administrators and users to log in to. By entering the user name and password correctly in the administrator login field, you are logged in with full access to the administrator's homepage. Via the homepage, new studies can be created, criteria can be added to the studies, values entered by the evaluators can be controlled, criteria and alternative results and data from previous studies can be accessed.

During the introduction of the new study, the required information is entered into the system via the "new study" page. Within the scope of the field study, Architectural Design I - Project Evaluation " was introduced in the study name field, and the number of alternatives and evaluators was entered as 3. When the evaluator and alternative numbers of the study are written, the areas in which the name and password are registered in the specified numbers are formed. The evaluators can enter the system with the evaluator password entered in these fields. If the "publish" box is checked, the evaluators can log in and see the work they will be evaluating.

Step 3_ Entering the evaluation criteria of the new study into the system: After the new study is created, the process to be performed is to enter the determined criteria into the system in hierarchical order. The specified criteria are entered into the system from the "add criteria" page. If criteria are added without selecting anything in the criteria group field, the main criteria (first step) are formed (such as A, B, C). If one of the main criteria is selected from the first box of the criteria group field, the entered criteria will be a sub-criterion of the main criteria (second step). For example, if A is selected as the first criterion group, the criterion whose information is entered will be A.1. Similarly, if the main criterion and a sub-criterion are chosen from the first



	Absolutely More Important	Intermediate Value	Very Strongly Important	Intermediate Value	Strongly Important	Intermediate Value	Moderately Important	Intermediate Value	Equally Important	Intermediate Value	Moderately Important	Intermediate Value	Strongly Important	Intermediate Value	Very Strongly Important	Intermediate Value	Absolutely More Important	
A-Eligibility for Architectural Qualities	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	B-Compliance with Architectural Drawing Technique and Presentation Standards
☑ A-Eligibility for Architectural Qualities																		
A.1-Compliance in terms of aesthetic qualities	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	A.2-Eligibility for Functional Relationships
A.1-Compliance in terms of aesthetic qualities	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	A.3-Eligibility for Near Environment
A.2-Eligibility for Functional Relationships	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	A.3-Eligibility for Near Environment
☑ B-Compliance with Architectural Drawing Technique and Presentation Standards																		

Figure 6. *Binary comparison chart of criteria.*

and second boxes, the resulting criterion will be the third step. When the name, code (such as A, A.1, A.1.1) and description of the criterion are entered and saved, a hierarchical decision tree of the criteria is formed at the bottom. Within the scope of the field study, the criteria were entered into the system according to the hierarchy in figure 5. The hierarchical organization chart can be controlled to prevent errors in cascading criteria. When the criterion input is completed, the comparison charts that the evaluators will evaluate are created by the system.

At the point of adding criteria in the developed DDSS software, it is possible to use the criteria of previous studies in a new study by calling from the database. Since the criteria of the studies are kept by the system, a criterion library is formed, and the criterion base can be created in similar studies thanks to the feature of transferring criteria from previous studies. If the criteria will remain precisely the same, and their weights can be used, the criterion data of the previous study can be used directly by copying the study instead of adding the criteria.

Step 4_ Evaluators enter data into the system via DDSS software, which expresses their opinions and judgments about the evaluation criteria and alternative designs that are evaluated: After the new work is created by the administrator and the criteria are entered into the system, users can access the user interface by logging in to the system with the user name and password defined to them from the user login page. Through this interface, users can only make evaluations using the paired comparison scales of the criterion evaluation and alternative evaluation processes, respectively.

In the calculation of the priority weight values of the criterion determined according to the expectations about the intended architectural design, the evaluator first makes the paired comparisons of all criteria on the paired comparison tables according to their own knowledge, experience and value judgments (Figure 6). These scales are formed by using the 9-comparison table (Table 1) bidirectionally and using the verbal judgments used in daily life and reflecting a certain degree of superiority (certainly more important, very strongly important, strongly important, moderately important, equally important). All evaluations are completed by ticking the boxes corresponding to the severity of the criteria on the right and left sides of the comparison chart. In the comparison chart, if a period exceeds the criteria, short descriptions entered by the administrator of that criterion can be displayed. In case of incomplete comparison charts, the system notifies the user and does not allow the data to be saved until complete. After the evaluation of all criteria, the evaluator presses the “save” button, and the verbal data is converted to digital form and saved in the database. Within the scope of the field study, all three evaluators made evaluations on different computers and at different times over the web.

3.2.2. Synthesis phase of decision support method

Step 1_ Calculation of priority weight values of the evaluation criteria: After all, evaluators have completed the data entry, in the synthesis stage of the decision support method, the system creates the priority weight values for each criterion by making the necessary calculations for the steps such as conversion, blur, syntheticization, and normalization by fuzzy AHP method in the background.

Step 2_ Calculation of weighted performance values of alternatives: This process is very similar to the process where the priority weight values of each criterion are found. The most significant difference in the process of calculating the weighted performance values of the alternatives is the dual comparisons of alternatives according to each criterion. In this process, after the evaluations are completed, the necessary calculations are made, and in the last stage, the importance of the alternatives is multiplied by the weight of the criteria they are compared and weighted according to the importance of the criteria. After determining the weights of the individual alternatives for all criteria, the overall weight of the alternatives is calculated, and the evaluation process is completed.

The software algorithm that shows how the processes in the synthesis stage are performed in the background of the system is given in Figure 7.

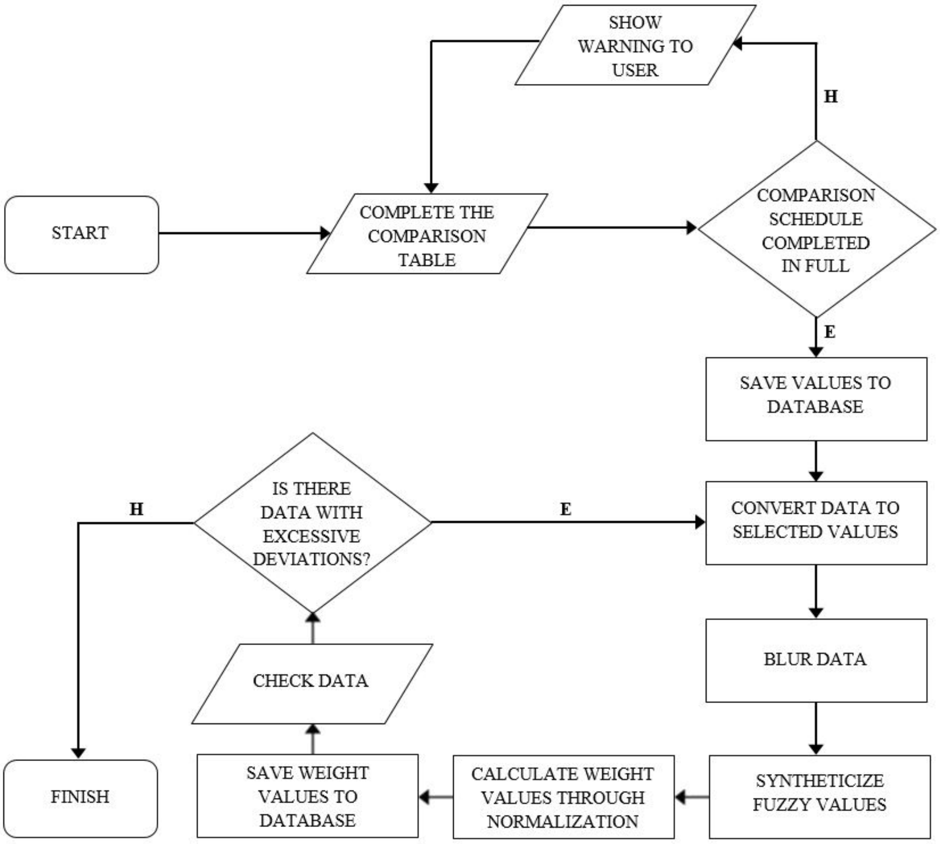
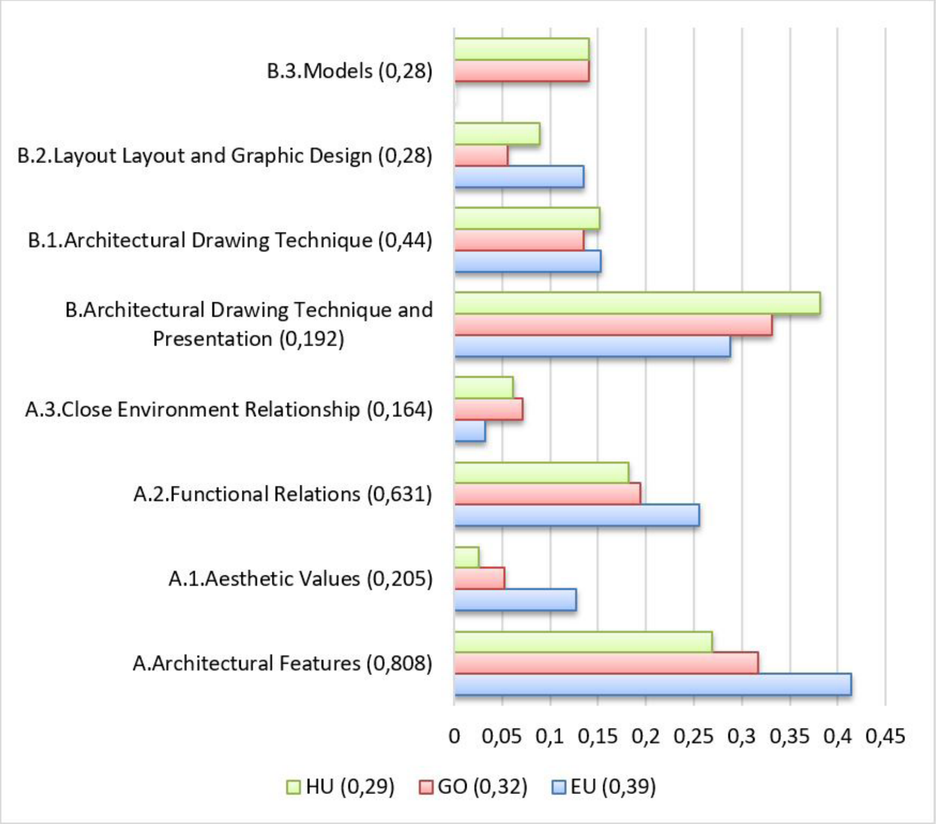


Figure 7. *System evaluation algorithm.*

Table 2. *Weighted performance values of alternatives according to each criterion.*



After users finish entering data, the administrator can log back in and view the results of the work. When the criterion results and alternative results pages are introduced, and the related study is selected, the results of that study can be displayed. If the administrator checks the evaluator data from this page and detects an incorrect evaluation, he or she can delete the evaluation data from this database. If there is a change in the number of evaluators, when the result page is re-displayed, the results are updated according to the existing evaluators.

In Table 2, the priority weight values of each evaluation criteria determined within the scope of the field study are presented graphically. According to the results of the evaluation carried out by three project executives, criteria A (conformity in terms of architectural characteristics: 0,808) are considered to be more critical in terms of evaluating the intended designs according to criteria B (compliance to architectural drawing technique and presentation standards: 0,192). A similar assessment can be made between the A2 criterion (suitability in terms of functional relationships: 0.631) and the A1 (conformity to aesthetic values: 0.205) and A3 criteria (close environment relationship: 0.164). On the other hand, although there is not a big difference between the weight values of the B1, B2, and B3 criteria, the B1 criteria (architectural drawing technique; 0.44) are compared to B2 (layout and graphic presentation: 0.28) and B3 criteria (model: 0.28). According to the evaluation of the designs considered to come to the fore.

EU, GO and HU design alternatives (Figure 8) were evaluated according to each decision criterion within the scope of decision support method and evaluation results (EU = 0,39, GO = 0,32, HU = 0,29) were obtained. According to these results, EU design which was developed under accepted conditions, was found to be 39% more successful than the other designs GO and HU in the evaluation made by the group executives. In other words, the design with GO nickname is 32%, and the design with HU nickname is 29% successful compared to other alternatives. In this case, it is determined that the most appropriate design alterna-

Figure 8. *Design alternatives EU, GO, HU.*

tive is EU nicknamed design. Table 2 shows the criteria that the three alternative designs evaluated were found to be more successful.

4. Results and discussion

Today, with the developing technological, social, economic, political and environmental factors, the design problem has become increasingly complex. In particular, increasing material diversity, production methods, production systems, scientific and technological advances force the designer to make decisions with many economic, social and environmental impacts that he cannot predict in the design process. In this process, only a certain number of data can be consciously evaluated by a decision-making method that is not systematic and is based entirely on the knowledge and experience of the evaluators. At this point, it is essential to carry out decision-making in the design process by systematic methods and to develop decision support methods that enable decision making according to the conditions and time in the design problem.

In this study, a fuzzy multi-criteria decision support method which enables a better organization of the design process with an analytical approach to the design problems encountered and subjective evaluations within architecture as well as objective assessments to be made in decision steps is presented. To use this method effectively, a web-based computer software called DDSS has been developed. The effectiveness of the developed software was discussed in the process of evaluating the designs obtained in an architectural design studio environment.

The developed DDSS software generally increases the usability of the method by the designers by hiding the matrix operations needed for determining the synthetic values required by the decision support method presented. The advantages it provides are detailed below;

- In each new study, the reorganization of the model is prevented, and the necessary steps to achieve the results are reduced.
- By entering the evaluation data directly into the system by the evaluators on the web, a secondary data entry process is eliminated. Thus, it enables the desired number of evaluators to input data directly to the model at the same time wherever it has internet access.
- While the system can work on a single computer in applications made through Microsoft Excel program, all users can enter data from different computers at the same time with the software running on the web and thus loss of time is prevented.
- Since the system operates with the same codes in each run, the margin of error is reduced to a minimum. This situation is seen as an essential advantage for achieving more accurate results in evaluations.
- The software works like a standard web site, providing users with an easy to use without requiring expertise.

In addition to the advantages provided by the DDSS software, the identified disadvantages that need to be developed are as follows:

- Since no evaluator pool is created in the system, a new evaluator is added in each run, and the system fails if the passwords are the same. Therefore, if the same evaluator participates in different studies, a different password must be defined.
- Since it is assumed that there is only one user as an administrator, all work data can be accessed if other people use the software, and this creates a security vulnerability.

In addition, in the implementation of the decision support method through the developed DDSS software, criteria and alternative numbers are issues that need to be taken into consideration. As both the criteria and the number of alternatives increase in design evaluations, binary comparisons for evaluators are exhausting, and the method is no longer convenient.

As a result, with the developed software, primarily by eliminating the synthesis processes and providing faster results, it has been shown that the method can be applied more effectively in multi-criteria decision-making problems encountered in the architectural design process. Thus, it has been seen that with the use of the decision support method, evaluations can be placed in a rational structure in the decision steps in the architectural design process and more conscious and objective assessments can be made about the designs.

In future studies, if it is possible to independently evaluate a single alternative to the decision support method supported by the DDSS software developed; It is foreseen that it can be integrated into systems such as LEED, CASBEE, BREEAM, IISBE, Greenstar where green buildings are evaluated and certified, and even a national-based green building evaluation system which is integrated with the decision support method can be proposed. It is also thought that assessing a single alternative will increase the potential of the method to be used in architectural design competitions.

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