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A proposal for a method to calculate the adaptive reuse potentials of structures by using artificial neural networks

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Abstract
Adaptive reuse involves repurposing existing structures that have outlived their original purpose, preserving cultural heritage while addressing contemporary needs. This approach offers numerous benefits, including economic advantages, environmental sustainability and the protection of cultural heritage. Recycled buildings enhance the character and aesthetics of cities, fostering social vibrancy. However, successful adaptive reuse requires a careful assessment of a structure's potential. Artificial neural networks, with their data mining capabilities and potential for learning from data, can effectively evaluate complex reuse potential scenarios. This study employs artificial neural networks to calculate adaptive reuse potential, regardless of a structure's original function, promoting sustainable building practices.

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Keywords
Adaptive reuse, Adaptive reuse potential, Artificial neural networks, Cultural heritage.

1. Introduction

The concept of adaptive reuse addresses the sustainability problems that arise when old historical buildings with cultural importance lose their original functions. This concept is mainly based on the need to protect these qualified structures as well as to transform them in ways that will adapt to new needs and changing conditions. In this context, adaptive reuse not only expresses the process of giving a new life to existing structures but also aims at preserving the original structural features and historical texture of the structures. Especially when historical structures become dysfunctional, this approach redefines and updates the functions of these structures based on certain principles. In this way, it is ensured that the cultural heritage is protected and transmitted to future generations.

In the architecture, restoration and building information fields, the subject of adaptive reuse is considered from many different perspectives. The use of structures that have been dysfunctional for any reason by adapting them to a new function is of great importance for various reasons. At the beginning of these, economic factors come first. The use of existing buildings instead of constructing a new one usually provides resource savings (Eray et al., 2019). In addition, reuse plays a critical role in reducing carbon emissions and combating global warming, and it creates values on behalf of society in resource efficiency by promoting it (Conejos et al., 2013). In addition to factors such as affordability and sustainability, adaptive reuse is also an extremely effective method in terms of historical and cultural preservation. Adaptive reuse of structures that bear the traces of the past and have taken place in social memory strengthens the belonging to the place by ensuring the preservation of memory and continuity of transmission along with the protection of the old structure (Günçe & Mısırlısoy, 2019). In addition, reused buildings can also increase the character and aesthetic value of cities. They can give a more attractive appearance to the existing texture and contribute to the social life of the region with this aesthetic touch (Günçe & Mısırlısoy, 2019). As a result, adaptive reuse is often a preferred method in terms of its advantages such as ensuring sustainability, protecting cultural heritage, and promoting resource efficiency. However, in order for this method to provide the expected benefits, it is necessary to carefully assess the adaptive reuse potentials of the structures before the application and to consider them depending on their suitability for the reuse criteria of existing buildings.

Although it has many advantages, the adaptive reuse approach, which is preferred for the sustainability of structures, may not be the right solution for every structure. In this case, it is important to observe a balance between the adaptive reuse potential of constructions and the burden that this process will bring. The processes that an existing structure must undergo in order for adaptive reuse are described as burden (cost), and as a result of this burden, the targeted gains, as mentioned above, are characterized as benefits. The fact that a structure can maintain its long-term utility value depends on the fact that it can comply with these change demands easily and without burden; that is, the potential and the burden should be in balance. In summary, when the ratio of the benefit obtained to the burden remains at an efficient level, or when the feasibility of adaptive reuse of the existing structure in accordance with changing conditions is appropriate, it will be meaningful to reuse it. However, in order for this assessment to be performed correctly, it is necessary to use systematic and rational methods at the assessment stage rather than intuitive and experience-based inferences.

When the literature is reviewed, it is seen that researchers have produced various models in order to realize the assessment processes in a structural and logical way and to calculate the adaptive reuse potentials of structures. These developed models usually take into account parameters such as the expected physical life of buildings, their current age, and the aging effects caused by physical, economic, functional, technological, social and legal factors (Hong & Chen, 2017; Langston, 2012; Tan et al., 2014). These systems in question usually aim to produce decisions for a specific region by weighting criteria and using methods such as focus group interviews, analytical hierarchy process (AHP) and Delphi technique. Such approaches are appropriate for situations where expert opinions are determinative and subjective factors are important. However, when studying with more complex estimations and different types of data in different areas, it may be more appropriate to use models based on artificial intelligence and with the ability to learn from data. There are no examples of the use of this type of model in the literature. The choice of this method both ensures that the potential assessment can be made using a rational method and provides an opportunity to test the effectiveness of artificial intelligence, which has been used increasingly in recent years, in such decision-making processes. For this purpose, in this study, an artificial neural network-based decision support system that can produce fast and accurate results was designed in order to calculate the reuse potentials of existing structures independently of function.

The beginning of the system design is the determination of assessment criteria and the assignment of values related to these criteria. Then, a data set is created about the structures with these criteria and values by using the data obtained through literature review and focus group studies. The created data sets are processed by a program to be able to produce decisions for different scenarios using models capable of learning from data, such as artificial neural networks. This program provides an effective solution for situations that require complex forecasts and helps decision-makers determine the potential for adaptive reuse of structures. This method aims to create an effective decision support system for the adaptive reuse of structures by reflecting a data-oriented approach.

Within the scope of the study, a decision support system created using artificial neural networks to determine the adaptive reuse potentials of structures was introduced. Literature review, determination of criteria, data collection, model training and analysis steps was performed to evaluate how existing structures can be transformed in a sustainable and economically viable way. It is believed that the obtained results will guide decision-makers in the planning and implementation phase of adaptive reuse projects.

2. Assessment of the adaptive reuse potential

The life cycle of structures is defined in five different stages: birth, development, use, pause, and demolition (Douglas, 2006). In addition, this life cycle concept also refers to the period of use of a structure. This period is determined by the sustainability of functional and economic benefit value, primarily durability. It is inevitable that buildings, especially those with long periods of use, will face spatial change demands due to the differentiation of vital and economic requirements during the life span. These types of structures that cannot keep up with the emerging demands are either demolished or abandoned to their fate.

It may be necessary to transfer some structures that are dysfunctional and inert by being abandoned to their fate to future generations with the cultural heritage qualities they carry. In this case, one of the maintenance, repair and intervention types that can be examined under six main groups, such as integration, renovation, adaptive reuse, reconstruction, cleaning and transportation, can be applied to these structures (Kocabıyık, 2014).

The concept of "adaptive reuse", which is among these intervention types, can be summarized as making cultural heritage structures that serve as a link between the past and the future available for today's needs. In this application, it is aimed that the structure will continue to live while its historical value is preserved and undergo a transformation that will meet today's needs. In addition to ensuring the sustainability of cultural heritage, the adaptive reuse method can also provide many different benefits from an environmental and economic point of view by promoting resource efficiency.

It has been found that as the intervention measure applied to the structure for adaptive reuse increases, the probability of adaptation to a new usage increases, while the cost, duration, and energy savings decrease. Here, when making an adaptive reuse decision, it is expected that the relationship between the interventions to be made to the structure for transformation and the benefits to be obtained as a result of this process will be at an optimal level (Sarıcı, 1990) (Figure 1).

The decision to adaptive reuse is made based on whether this optimal level can be achieved by considering the qualities possessed by the existing structure. However, in conditions where various stakeholders are involved and each party has different opinions, it can be extremely difficult to make a rational and systematic decision (Douglas, 2006; Wilkinson et al., 2009; Alauddin, 2014).

For example, in the decision-making process regarding the adaptive reuse of a structure, building owners, who are stakeholders, focus on the financial resources necessary for transformation, while investors are interested in potential future returns. Marketers, on the other hand, take into account the latest market demands. Professional teams, such as architects, engineers and designers, focus on architectural, structural, functional and space-related factors that will affect decisions about the reuse of the building. Another factor that increases the complexity of the stakeholders involved in this decision-making process is that each of them has different levels of influence (Alauddin & London, 2011). In addition, the future users of a building are also an important factor in the decision-making process since the decisions can affect the activities or functioning of the building. All these components complicate the decision-making process for the adaptive reuse of a structure and make it necessary to take into account more concrete factors related to the structure.

The measurement of the functioning (reuse) feasibility of the existing structure depends on the implementation of change requests easy and burdenless. In other words, the measurement of the reusability potential is based on the analysis of the findings obtained from the comparison of the burden values and the benefit values of the change demands. At this point, it is usually expected that the demands for change have been put forward. However, within the process, it may also be necessary to decide about the cases where the preliminary design of the new function is not included. This usually applies to situations where it is important to take quick action regarding protection. In such cases, regardless of the space requirements of the new function, it becomes even more important to determine the assessment criteria related to the intrinsic value and structural characteristics of the structure.

3. Studies related to the assessment of the adaptive reuse potential and the selection of criteria

In the literature, there are many studies adopting various approaches and covering different frameworks to assess the potential for adaptive reuse. In these studies, factors such as aging, economic applicability, social aspects, functional appropriateness, physical condition, technological feasibility and legal considerations have been usually taken into account. The aim is to assess the adaptability and potential of existing buildings for reuse, taking into account sustainability, cultural heritage protection and urban development considerations. By using different methodologies such as performance-based frameworks, multi-criteria analysis and decision-making models, researchers have aimed to create comprehensive assessments and guidelines to measure the adaptive reuse potential (Bottero et

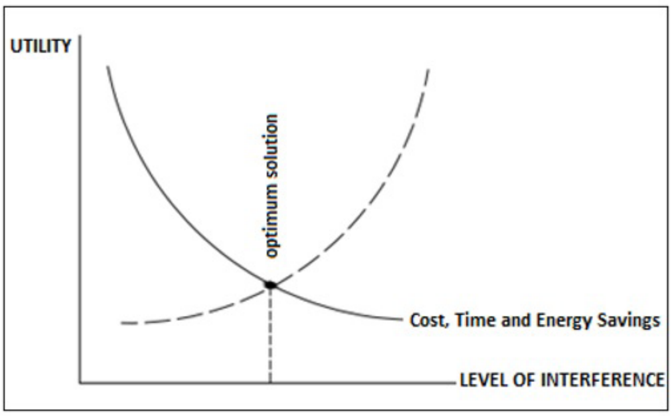

Figure 1. *In reuse, the relationship between the measure of intervention and benefit (Sarıcı, 1990).*

al., 2019; Hamida & Hassanain, 2021; Conejos et al., 2015; Tan et al., 2018; Aigwi et al.,2019). In all these studies in the literature, assessment of the potential is considered as a decision-making process and often they focus on economic analyses, environmental, historical and cultural assessments, risk assessments, functionality and usability analyses and social and social impact analyses. In addition, there are also studies that aim to create decision support systems and use mathematical models to assess the potential of adaptive reuse. While some of these studies involve the Analytical Hierarchy Process (AHP) as a mathematical decision-making tool (Hong & Chen, 2017), in some others, Adaptive Reuse Potential (ARP) model validation by using iconCUR software was preferred as the method (Langston, 2012). In some studies, on the other hand, it is seen that fuzzy logic, a mathematical model that deals with uncertainty, is used to assess the adaptive reuse potential of specific structures (Tan et al., 2014). It can be said that the models produced in all these studies aim to provide a systematic and quantitative approach to assess and sort the adaptive reuse potential by taking into account various factors and criteria.

As can be seen in the literature, the process of creating a model for analyzing the adaptive reuse potential of historical structures begins with defining the goals of the project, and then criteria appropriate to these goals are determined. Following this, these criteria are prioritized, and each of them is weighted. Data collection methods and resources are planned, analyses are carried out and the appropriateness of the project is evaluated. The results are shared with stakeholders and they are asked to contribute to the direction of the project. By constantly reviewing this process and updating it to meet the needs of the project, the success of the project and increasing sustainability can be ensured. It should not be forgotten that the selection of criteria in this process is the most critical step affecting the success of the project.

The correct selection of criteria is of vital importance for the success and sustainability of adaptive reuse projects. Correctly, selected criteria ensure the appropriateness of the project to its objectives, support the efficient use of resources, improve decision-making processes, increase stakeholder participation, ensure the measurability of results and increase the long-term sustainability of the project. Incorrectly, selected or incomplete criteria can jeopardize the success of the project and cause unintended consequences. Therefore, the selection of criteria is a critical step for the effective management of adaptive reuse projects; it must be carefully planned, and it should be in accordance with the specific requirements of the project.

When the literature is examined, the evaluation criteria used in calculating the adaptive reuse potential can be grouped as follows although their importance and ranking can change depending on the original conditions and goals of the project:

- Historical and Cultural Value: The historical and cultural significance of a building is a critical factor in determining the potential for adaptive reuse. The history, architecture, and cultural context of the building are important in evaluating this criterion.
- Physical Condition and Durability: The physical condition of the existing structure affects how useful it is and its adaptive reusability. Within the scope of this criterion, the durability, integrity of the structure, and whether potential repairs are required are assessed.
- Environmental Effects: This criterion refers to the effects of the structure on the environment. This may include energy efficiency, waste management, and the environmental impacts of the construction process.
- Economic Factors: Adaptive reuse costs and turnaround time constitute a part of the economic evaluation criteria. The cost for the adaptive reuse of a structure must be in balance with the economic benefits to be provided in the future.
- Usage Potential: The new function of the structure should be in accordance with local market demands and needs. The usage potential in-

cludes evaluation of the suitability of the function and the demand.

- Legal and Regulatory Factors: Adaptive reuse projects may be subject to local, national, or international regulations. These factors may affect whether the project complies with legal requirements.
- Social Factors: Adaptive reuse projects should take into account the needs and expectations of society. Within the scope of this criterion, how the structure can make a social contribution is evaluated.
- Functionality: The new function of the structure is evaluated in terms of usability and functionality. The new function of the structure should be in accordance with the needs and expectations of users.
- Technical and Spatial Facilities: The technical capacity of the structure and its compliance with spatial arrangements are the criteria that affect the adaptive reuse potential.
- Value Increase and Profit Potential: The increase in the value of the structure and profit potential as a result of adaptive reuse potentially indicates the profitability of the investment.

The criteria proposed in the literature usually include a detailed examination and a detailed process that especially requires the design of a new function. However, rapid intervention may be required, especially in cases where some structures are in danger of extinction. For this reason, it is necessary to develop a critical preliminary assessment stage in order to make quick decisions for such emergency situations. This assessment is based on the current state of the structure, its qualities and vital factors before the new function is determined. In order to determine the adaptive reuse potential of the structure, at this stage, a calculation method based on criteria such as the soundness status of the structure, building efficiency and historical, cultural and architectural values is used. This pre-evaluation process can guide decision makers and experts to make quick and informed decisions about the future of the structure.

In this context, based on references, five main criteria were identified in order to make conservation decisions quickly and to assess the adaptive reuse potential by using a model method, regardless of the function predicted for the structure. These criteria focus on basic factors such as structural robustness, functionality, architectural significance, historical value, and cultural significance. For these five main criteria, an assessment scale using scores from 1 (the lowest score representing a poor situation) to 4 (the highest score representing a good situation) was used. Descriptions and status assessments related to the criteria to be used in the model are presented in the following table (Table 1).

As can be seen in the table, the stability status of the existing structure and the data on the functionality of the systems related to the structure are related to the physical body of the structure, and they are important determinants of whether an adaptive reuse decision should be made. Since the adaptive reuse decision of buildings should be considered not only from the perspective of physical soundness but also from the perspective of preserving and emphasizing heritage values, the architectural, historical, and cultural values attributed to the structure have also been identified as other important criteria. Essentially, the location, dimensions and design flexibility of a structure are closely related to its adaptability capacity. However, it is obvious that the weight values of these determinants will differ depending on the type of function. Therefore, in this study, where structural features independent of function were taken into account in order to make quick decisions about protection, these criteria were excluded.

After determining the criteria, the implementation phase of the method is started in order to calculate the adaptive reuse potentials of the structures. In this study, artificial neural networks (ANNs), which are one of the artificial intelligence models designed by taking inspiration from biological nervous systems, were used for the calculation in question. These models are used to process complex data, learn its properties, and perform various tasks. Although it is used in a wide range of

Table 1. *Criteria and assessment levels.*

Criteria	Description		Levels			
			Poor (1)	Weak (2)	Medium (3)	Good (4)
Static Condition	Structural Integrity	Status	Most of the walls are not present, the roof is missing, and there is no surviving woodwork.	Widespread deterioration in the structure and building components, it is dysfunctional or about to be.	Wear and tear at the element level, neglected, about to lose structural performance.	It can be reused with a simple renovation. There is no major destruction. Many of the user needs can be met.
Structure Efficiency	Condition of the building's mechanical systems (heating, cooling, ventilation, electricity, water) and its current insulation and energy efficiency		None of the mechanical systems are present, the building is in ruins	The mechanical systems are damaged, water and airtightness are problematic at the component level	The mechanical systems are damaged but water and airtightness are maintained	The mechanical systems are present but may require updating and repairs, insulation is present
Architectural Value	The building's aesthetic value and its compatibility with the environment		The building has largely lost its original texture and aesthetic value. It is incompatible with the environment.	The building's architectural value has been damaged, but can still be read in some places.	The building's architectural value has been damaged, but can still be followed throughout the building. It is compatible with the environment.	The building's architectural value has been preserved but worn down. The building adds value to the texture.
Historical Value	The building's history, past, protection status, and legal status		Unregistered building with no historical past	Historical building, detection has not been made for conservation, a legal decision has not been made	Structure that has a historical past, whose detection work has been completed, but a legal status has not been determined	Registered structure that has a historical past and should be protected
Cultural Value	Symbolic and administrative value, social and human value		Structure with no any symbolic value	A structure that makes sense for a limited human community.	A structure that has a symbolic value for a certain segment of society.	Structure, which is the place of an important historical event, has taken place in the memory of the society and has symbolic importance

areas in the field of architecture, from building design and optimization to energy efficiency improvement and security systems, there are no studies in the literature aimed at using these models to determine the potential of adaptive reuse. However, considering that they are also effective in complex tasks such as evaluating the adaptive reuse potential of existing buildings and then determining the most appropriate use cases, they were preferred in this study in order to create data-oriented decision support systems. Thus, it is believed that using ANNs will contribute to sustainable and efficient transformation.

4. Material and method

The research material of the study consisted of structures that had historical and cultural significance but had lost their original functions and had the potential for adaptive reuse.

In this study, an artificial neural network (ANN) model was used to evaluate the adaptive reuse potential. At the first stage of model creation, original adaptive reuse criteria and evaluation levels were defined in light of information obtained from literature review and in accordance with the purpose of the model. Then, in addition to the literature study, a series of "focus group studies" were organized, and experts assessed the adaptive reusability of structures based on these criteria. As a result of these assessments, data sets were created that included the appropriateness of the structures for adaptive reuse and their failure to be evaluated. Following the creation of the data sets, an ANN model was developed. The ANN was fed with data sets containing assessments of structures based on different criteria. As a result of this feeding, it was ensured that the ANN model could calculate the adaptive reuse potential for different situations as well.

4.1. Data collection and preparation

After the determination of the criteria, datasets, which included the decisions to reassessment or exclude the structures rated according to these criteria, were created through literature review and focus group studies. When designing the datasets, column headings containing the determined criteria (static state of the structure, building efficiency, architectural value, historical value, cultural value) and the result were created first. The scale (from score 1 (poor state) to score 4 (good state)) used to assess these criteria was composed of rows. The last column indicates whether the structure being examined is suitable for reassessment; a value of "1" indicates that the structure has a possibility of adaptive reuse, while a value of "0" indicates that adaptable reuse is not possible. While the rows were being created, as in the determination of criteria, it was determined whether structures with various levels had been reused based on the criteria determined in accordance with the perspectives offered by studies focusing on case studies and user experiences in particular (Günce & Mısırlısoy, 2019; Bullen & Love, 2011; Hussein, 2021; Uğursal, 2011; Uçar, 2013; Selçuk, 2006; Pekon, 2010). In addition, the inferences obtained from these data were processed into the table. Here, not only the adaptive reuse practices specific to the Turkish context

Table 2. *Example of a dataset.*

Static Condition of the Structure (1-4)	*Structure Efficiency (1-4)*	*Architectural Value (1-4)*	*Historical Value (1-4)*	*Cultural Value (1-4)*	*Result (1-0)*
1	1	1	1	1	0
1	1	1	1	2	0
1	1	1	2	1	0
1	2	1	1	3	0
1	2	3	3	3	1
1	2	3	3	4	1
2	2	3	3	4	1
2	3	3	3	4	1
2	3	3	3	4	1
3	3	3	3	4	1
3	4	3	3	4	1
1	1	1	1	4	1
1	1	1	4	1	1
2	1	4	1	1	1
1	2	1	1	4	1
1	2	1	4	1	1
2	2	4	1	1	1
2	1	1	1	1	0
2	2	2	1	1	0
2	2	1	2	1	0
2	2	2	1	2	0
2	2	2	2	4	1
3	1	1	1	1	0
3	1	1	1	2	0
3	1	1	2	1	0
3	1	2	1	1	0
3	1	3	1	1	1
3	1	1	3	1	1
3	3	2	2	3	1
3	3	2	3	2	1
3	3	3	2	2	1
4	2	1	1	1	0
4	2	2	1	1	1
4	2	1	2	1	1
4	2	1	1	2	1
4	3	1	1	1	1
4	3	2	1	1	1
4	3	1	3	1	1
4	3	3	1	1	1
4	3	3	3	3	1

were considered, but also the values were tried to be reached in accordance with the criteria determined for such structures worldwide. Moreover, not only the reused structures but also the structures that had not been transformed were added to the dataset (Table 2).

Using the data obtained from literature, field, and focus group studies, a total of 111 rows, examples of which are seen in the table above were created, and the data set was completed.

4.2. Artificial neural networks

Artificial Neural Networks (ANNs) are multi-layered structures designed getting inspired by the abilities of human biological neurons, such as learning and remembering.

In 1943, McCulloch and Pitts made the first mathematical description of the neuron by imitating the functionality of biological neurons (McCulloch & Pitts, 1943). Then, in 1957, inspired by McCulloch and Pitts, Rosenblatt designed neurons, which are the ancestor of today's models and have weights, and single-layer perceptrons that can learn from data (Rosenblatt, 1958). In this way, the neurons that enable a person to think, comprehend events, establish relationships between these events and make decisions have been used and remodeled by computer systems. These studies represent a major advance in transferring the basic logic of human thought processes and learning abilities to computer systems.

The structure of biological nerve cells is similar to a network in which dendrites collect signals from the environment in a complex way, these signals are processed in a central region called the soma, information is transmitted through axons, and communication is established by synapses (connections between neurons). This process constitutes the basis of basic cognitive abilities such as information processing, learning, remembering, and decision-making.

On the other hand in artificial neural networks, by depending on these biological elements, neurons are converted into components such as input, sum function, activation function, and output.

Conventional Artificial Neural Networks are basically divided into two as single-layer and multi-layer perceptrons. The structures that produce output by passing the input parameters through the activation function are known as single-layer perceptrons. Structures that feed input parameters into hidden layers, transfer hidden layers to each other, and then generate output values are known as multilayer perceptrons (Öztemel, 2003).

Multi-layer perceptrons are artificial neural networks which were introduced in the 1960s and consist of two parts (feedforward and backpropagation).

- The feedforward method is currently used by single-layer perceptrons. The outputs of the cells in one layer are given as inputs to the next layer via weights. The input layer transmits the information, it receives from external environments (if any), to the neurons in the hidden layer. The result is produced by processing information in hidden and output layers.
- The backpropagation method became popular with an article published by Rumelhart, Hinton, and Williams in 1989 as a result of studies conducted to solve the XOR problem. It works based on the strategy of supervised learning (during the training of the network, both the inputs and the outputs expected to be generated in response to those inputs are shown). In the backpropagation method, the difference between the output value obtained as a result of the feedforward calculation and the target output value is taken, and the weights of the neurons are updated depending on the situation. If the error rate is close to zero, the error rate is low. If the number of epoch is below a certain threshold value, the training is terminated without the need to update the weight. However, if the difference between the target and the expected value is large, this error rate is proportionally propagated backward and the weights are updated, and training is continued. This process continues until the specified epoch number or error threshold value is reached.

4.3. Hyperparameters

The variables that define the learning style of artificial intelligence models are called hyperparameters. Some of these hyperparameters are as follows:

- 1. Activation Function: By limiting the output value of the neuron, it brings a processed value to a certain range. It also adapts nonlinear real-world data to the form that the model can understand. The tanh function was used within the scope of the study.
- 2. Optimization Function: This is the function used to ensure that the model uses weights at the most appropriate value for problems that cannot be linear. The adam function was used within the scope of the study.
- 3. Loss Function: This function calculates the error rate between the target value and the estimated value. The Mean Squared Error (MSE) function was used within the scope of the study.
- 4. Learning coefficient: It is a hyperparameter that determines how quickly a network learns its parameters. A low learning rate causes a slow learning process, while a high learning rate can prevent the convergence of the network. In this case, the optimal value should be determined intuitively based on the model.
- 5. Momentum: It allows to determine the direction of the next step by using the knowledge of previous steps during learning.
- 6. Epoch: It determines how many times all training data will be shown to the network.
- 7. Batch size: It determines the number of subsamples given to the network. It determines how many network samples will be seen during an epoch.

4.4. Designed Model

Within the scope of the study, a multilayer artificial neural network model was designed. As shown in Figure 3, the model consists of 1 input layer, 2 hidden layers, and 1 output layer. The input layer consists of 5 neurons, and the hidden layers consist of 10 and 8 neurons, respectively.

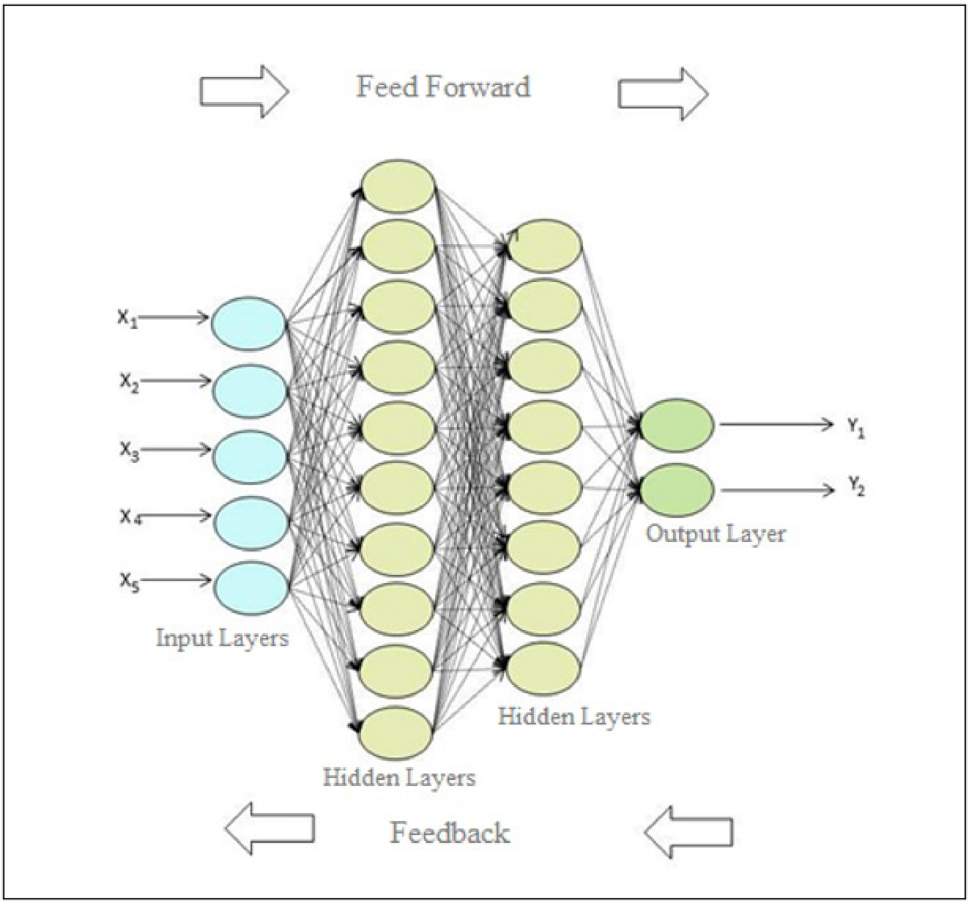

Figure 2. *Architecture of the model.*

The training of the model was carried out on the open-source google colab platform. During the training, tanh was used as the activation function, adam was used as the optimization function, and mse was used as the loss function. Moreover, other hyperparameter information used during the training of the model is shown in Table 3.

4.5. Assessment Metrics

In order to assess the performance of the model, accuracy, recall, precision, and f1 score metrics were used. These metrics are based on the complexity matrix. The elements of the complexity matrix (True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN), False Positive (FP) and False Negative (FN)) and their abbreviations are shown in Table 4.

5. Findings and discussion

94 pieces of data were used in the training of the model designed within the scope of this study. 70% of this dataset was used for training and 30% for validation. For the test process, on the other hand, a dataset consisting of 16 pieces of data that had not been processed before during the training of the model was created. In order to measure the performance of the training and test results, classification metrics accepted in the literature were used. Table 6 shows the validation results and Table 7 shows the outputs of the test results.

Table 3. *Hyperparameters.*

Hyperparameters	Value
Epoch	200
Batch-size	16
Number of learning	0.01
Momentum	0.7

Table 4. *Complexity matrix.*

	PREDICTED POSITIVE	PREDICTED NEGATIVE
ACTUAL POSITIVE	TP	FN
ACTUAL NEGATIVE	FP	TN

Table 5. *Assessment metrics.*

Assessment Metrics	Description	Formulas
Accuracy - ACC	It measures the accuracy success of the data in the classification	$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$
Precision	It is the success of the model in predicting the positive class labels in the dataset.	$Precision = \frac{TP}{TP + FP}$
Recall	It measures the positive prediction value through dividing the correctly predicted positive class labels of the model by total positive class labels as shown below.	$Recall = \frac{TP}{TP + FN}$
F1-Score – F-SC	It calculates the ratio of the actual positive values to the positive values predicted by the classifier.	$F1 - skor = \frac{2\ x\ recall\ x\ precision}{recall\ x + precision}$

Table 6. *Training validation results.*

Accuracy	Recall	Precision	F1-score
0.88	0.90	0.88	0.87

Table 7. *Test results.*

Accuracy	Recall	Precision	F1-score
0.94	0.95	0.93	0.94

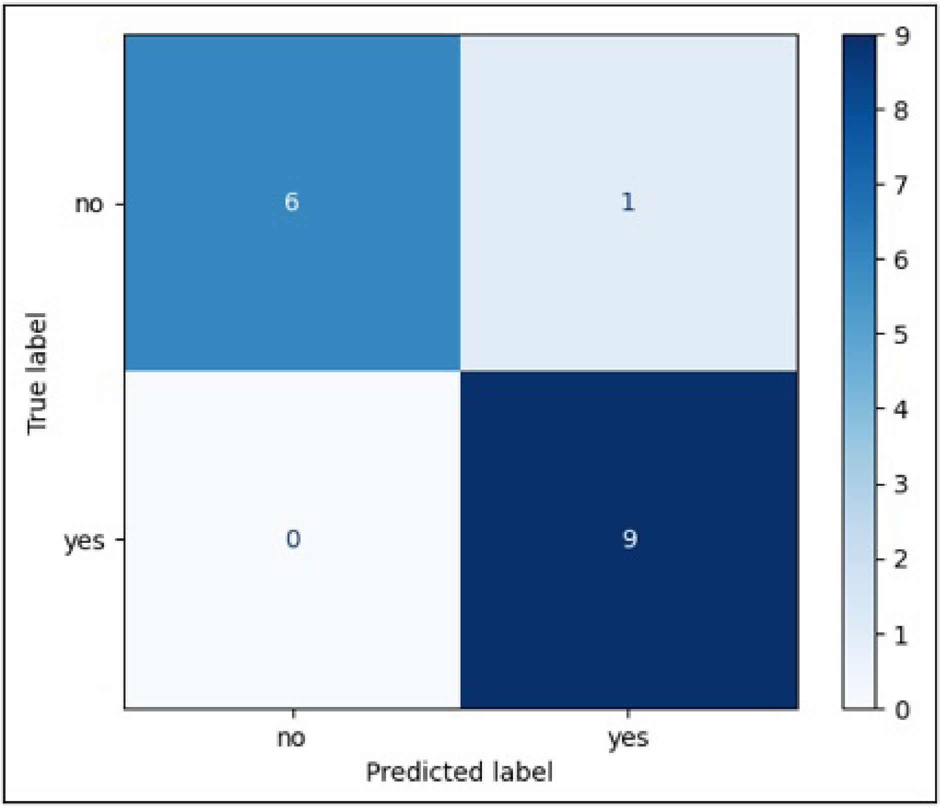

Figure 3. *The complexity matrix of the test results.*

Since any artificial neural network models used on this topic were not encountered when the literature was reviewed, an objective performance comparison could not be performed. However, from an expert point of view, it can be said that the fact that the results produced by both training and test data are close to each other is evidence that the model does not memorize and performs good learning. Moreover, as can be seen in the complexity matrix in Figure 5, the presence of an FN value indicates that the model makes a successful distinction between its classes, that is, its classification success is high. In the context of the study, it was shown that the designed model was successfully operated in the field of architecture. In addition, a dataset that is not included in the literature and is considered that its contribution will be high has been prepared. It is thought that this data set will be able to be used in different models to create a standard for performance comparisons.

6. Conclusion

Because of the inability to meet the expectations due to changing needs over time, many structures become unusable. The reuse of these structures with different functions cannot only contribute to structural sustainability but also create positive effects from an economic, social and environmental point of view. In this sense, it is important to know whether many idle structures have the potential for adaptive reuse with innovative sustainable designs. These structures can be converted into different areas, such as residential, hotels, offices, retail stores and sports centers. Or, if their potential is not found sufficient, they can be demolished and new buildings can be built instead. However, to be able to make such a decision, first of all, the existing structures must undergo a preliminary assessment, and the transformation potential they have must be revealed. This assessment is a complex stage that requires many details to be taken into account, has a large number of stakeholders and its success affects the entire process.

For this purpose, in this study, an artificial neural network-based model was developed in order to calculate the adaptive reuse potentials of old structures. The developed model is presented as a tool that can help decision makers in the field of architecture to determine the adaptive reuse potential of a structure in a rational manner, especially in situations requiring quick decisions. When the main findings of the study were evaluated, it was seen that the developed artificial neural network model achieved successful results in determining the adaptive reuse potentials of idle buildings. The results obtained on the training and test data showed that the model had an adequate learning capacity and was sensitive to excessive compliance. The dataset used to assess the reuse potential is unique in the literature; therefore, it may be an important resource for future studies. This dataset can be a reference point for comparing the results of similar studies.

Despite the successful results, the limitations of this study should also be considered. Firstly, no similar studies have been found in the literature for performance comparison; therefore, more research needs to be done in order for the model to be compared with other similar studies. Also, the dataset is limited to a certain number of samples, and it may be necessary to use larger and more diverse datasets in the future.

As a result, it is foreseen that this model based on an artificial neural network created to calculate the adaptive reuse potentials of idle buildings may be a valuable tool for architects, city planners, and decision-makers. It is also believed that this model can contribute to the protection of historical and cultural heritage, economic sustainability and reducing environmental impacts. Moreover, it is thought that in future studies, testing the model with more data and in different geographical regions will allow the performance of the model to be assessed in a broader context.

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