ARCHITECTURAL SCIENCES AND THEORY, PRACTICE AND NEW APPROACHES-I

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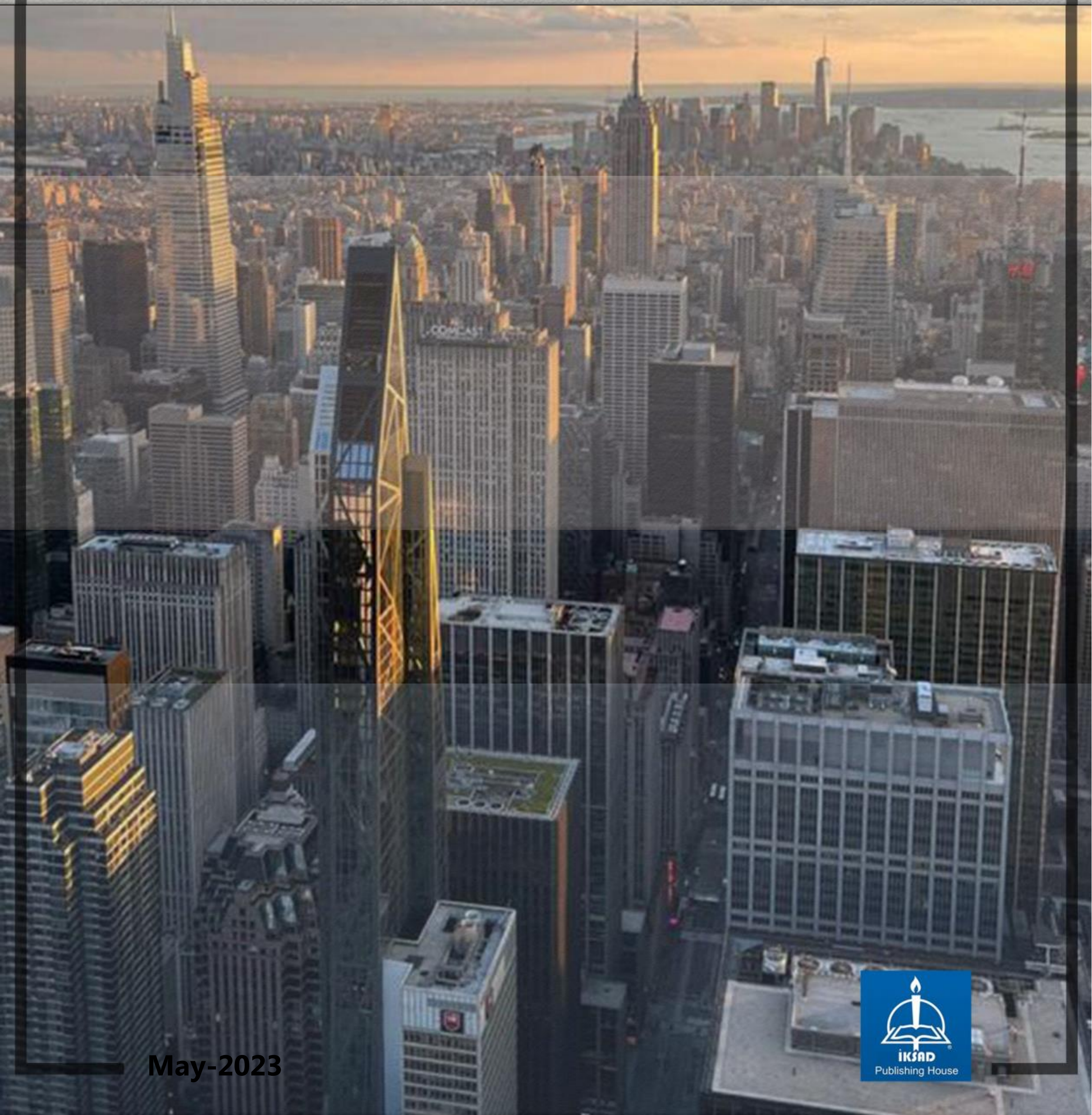

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PREFACE

The editors of this book believe that a more livable world can be created by conducting interdisciplinary studies of spatial planning and design disciplines together under the umbrella of "Architectural Sciences". In this context, the "Journal of Architectural Sciences and Applications (JASA)," which is a pioneer in the collective studies of related disciplines was published for the first time in 2016. Afterward, JASA Editors make significant contributions to the creation of various books containing original works and to bring the latest developments in the field to the reader.

This book named “ARCHITECTURAL SCIENCES and THEORY, PRACTICE and NEW APPROACHES-I” consists of thirteen chapters. In the book, the topics named “Scientific Literature in the Field of Architecture (2018-2022) in Turkiye: R Bibliometrix Biblioshiny Application and Science Mapping”, “Using the Geometric Order in Nature in Architectural Design”, “Analysis of Public Buildings in the First National Architectural Period by Plan and Façade: Example of Afyonkarahisar”, “Inspiration From Nature in Design: Analyzing Biomimicry Approach in Architectural Design”, “Creating Solutions to Climate Change with Wooden Material: A Workshop Experience”, “Characteristics of “Historical Günyurdu Village” Traditional Housing Architecture and Conservation Problems”, “An Evaluation of Stone Material Problems in Historic Masonry Buildings: The Example of the Virgin

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Mary Church in Mardin", "An Observational Research for the Determination of Stone Material Problems in Mardin Kasımiye Madrasa", "The Effect of Material Technology on Architecture", "Utilization of Thermo-Responsive, Shape Changing Smart Materials in Adaptive Facades", "The Use of Autonomous Robots In The Construction Industry", "Analysis of Erasmus+ Eco-Friendly Robotics Project Participants' Awareness Levels in Context of Sustainability, Green Buildings and Recycling", "From Concept to Implementation: A Detailed Study of Landscape Design Process for Uşak OSB Technopark" were discussed in detail. We would like to thank all those who contributed to the completion of the book, the authors, the referees of the chapters, IKSAD Publishing House, and Professor Atila GÜL, who is the General Coordinator of the Architectural Sciences book series.

We hope that our book "ARCHITECTURAL SCIENCES and THEORY, PRACTICE and NEW APPROACHES-I" will be useful to readers.

14.05.2023

EDITORS

Assoc. Prof. Dr. Murat DAL
Dr. Lale KARATAŞ

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Scientific Literature in the Field of Architecture (2018-2022) in Türkiye:

R Bibliometrix Biblioshiny Application and Science Mapping

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1. Introduction

Architecture is the art of constructing functional spaces that meet the economic and technical requirements of individuals' actions, such as sheltering, resting, working, and entertaining, while incorporating aesthetics through creativity. It is also the art and science of designing and constructing structures and the physical environment in appropriate proportions. This research was conducted to map the scientific publications in the field of architecture, synthesize previous research findings, demonstrate the development of a research area, and summarize the extent of scientific activity in the field. However, bibliometric analysis has the potential to provide a systematic, transparent, and repeatable review process. Literature reviews are a crucial means of effectively using the existing knowledge base, especially when the number of academic publications is increasing rapidly, and it is becoming progressively more difficult to keep track of all published material. There are few bibliometric analysis studies in the field of architecture (Sauve et al., 2022; Bem & Krüger, 2022; Zami & Rahaman, 2022; Pramesti et al., 2021).

Bibliometrix is an open-source application that incorporates all of the primary bibliometric analytic methods for quantitative scientometric and bibliometric research. The Bibliometrix package includes algorithms for importing bibliographic data from databases such as Web of Science Core Collection (WoS), Dimensions, Scopus, PubMed, among others. It may also conduct bibliometric analysis and generate data matrices for co-citation, scientific collaboration analysis, and common keyword analysis.

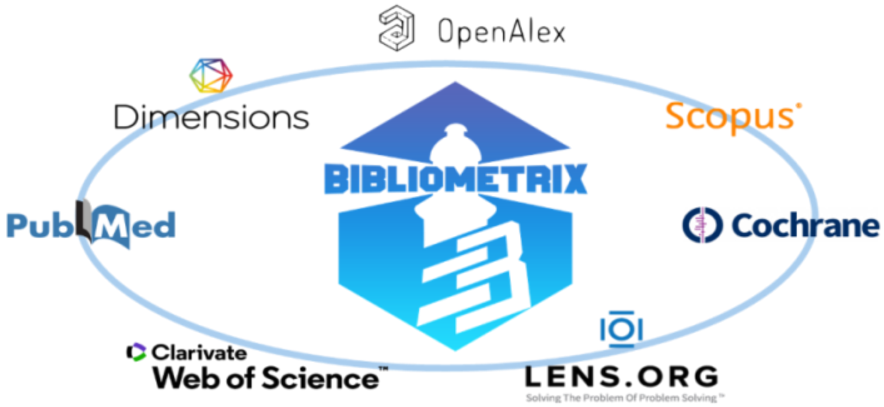

Figure 1. Bibliometrix Package (Bibliometrix, 2023)

Various databases such as Web of Science, Scopus, PubMed, Digital Science Dimensions and Cochrane databases are available for importing bibliographic data, each with unique features and functions (Figure 1). Web of Science is currently the most widely used literature database for almost all disciplines (Popescu et al., 2022).

Bibliometrix is a unique tool developed in the R packages language that provides statistical calculation and graphics according to a logical bibliometric workflow. R packages a highly flexible object-oriented and functional programming language, making it simple to automate studies and build new functions. Being open-source, it is easy to access, install, and use, making Bibliometrix flexible, quickly upgradable, and integrable with other statistical R packages. Biblioshiny is a bright application that provides a web interface for Bibliometrix. The creation of scientific maps with bibliometric analyzes and Biblometrix related publications are increasing rapidly (Ahmi, 2022; Belfiore et al., 2022; Ansari, 2021; Aria et al., 2020; Misra & Muhuri, 2020; Cuccurullo et al., 2015; Cuccurullo et al., 2016).

The original aspect of this research is to present a broad perspective to future researchers by revealing the authors, publications, institutions, sources, the development by years, the effectiveness of the institutions in the publications published in the field of architecture in Turkey, and the most used ones in the titles words and keywords of the publications.

Increasing the visibility of existing publications will be beneficial in terms of making words and focus appear more clearly over the years. In addition, while bibliometric analysis studies are more widely used in other fields of science, there are few studies in the field of architecture. In this respect, the research is original and qualified.

In this study, bibliometric analysis was conducted on article-type publications in the field of architecture from 2018 to 2022 in Türkiye. Publications in the Web of Science Core Collection database were examined for bibliometric analysis. The analyses of these publications were presented in scientific maps using the Bibliometrix-Biblioshiny package software.

This research focuses on publications published in the Web of Science Core Collection (WoS) database in the field of architecture between 2018 and 2022.

The research questions that this research focuses on are;

- What are the most relevant sources in publications in the field of architecture?
- What are the *most locally cited sources* in publications?
- What are *the sources' local impacts by H-index* in publications in the field of architecture?

- What is *the sources' production over time* between 2018 to 2022 years?
- What are *the most relevant affiliations* in publications?
- What is *the affiliations' production over time* in publications?
- What are *the most locally cited authors* in publications in the field of architecture?
- What are *the most frequent words* used authors in publications?

2. Material and Methodology

The aim of this research is to undertake a bibliometric analysis of architectural literature. To accomplish this purpose, bibliometric analysis of published works was performed using a quantitative technique. In this study, bibliometric analysis was performed using Bibliometrix, an RStudio program with a web-based interface, and Biblioshiny. With detailed examination, bibliometric research allows for the formation of a distinct perspective. The R package's bibliometric utility is intended for quantitative scientometrics and informetrics (Shi et al., 2020).

All the processes of the methodology of this research are explained step by step in Figure 2. In this study, articles indexed in the Web of Science Core Collection database were researched as this particular database provides a significant number of articles and richer citation data.

The research was conducted by searching for *"Architecture (Web of Science Categories) AND 2018-01-01/2022-01-01 (Publication Date) AND English (Language) AND Article (Document Type) and TURKİYE (Countries/Regions)"* on the Web of Science Core Collection database. This research was conducted from March, 1, 2023-March, 20, 2023, and the findings were based on these search results.

All bibliographic data was downloaded from the WoS Core Collection database in .txt format. First, the Bibliometrix R package was installed and R Studio was loaded (Ejaz et al., 2022). The Biblioshiny application was launched by entering Biblioshiny the R console. Biblioshiny is a web application that gives non-programmers access to the Bibliometrix R package. Bibliometrix offers a variety of tools that enable academics to undertake in-depth bibliometric study (Aria & Cuccurullo, 2017).

All the processes of the methodology of this research are explained step by step in Figure 2.

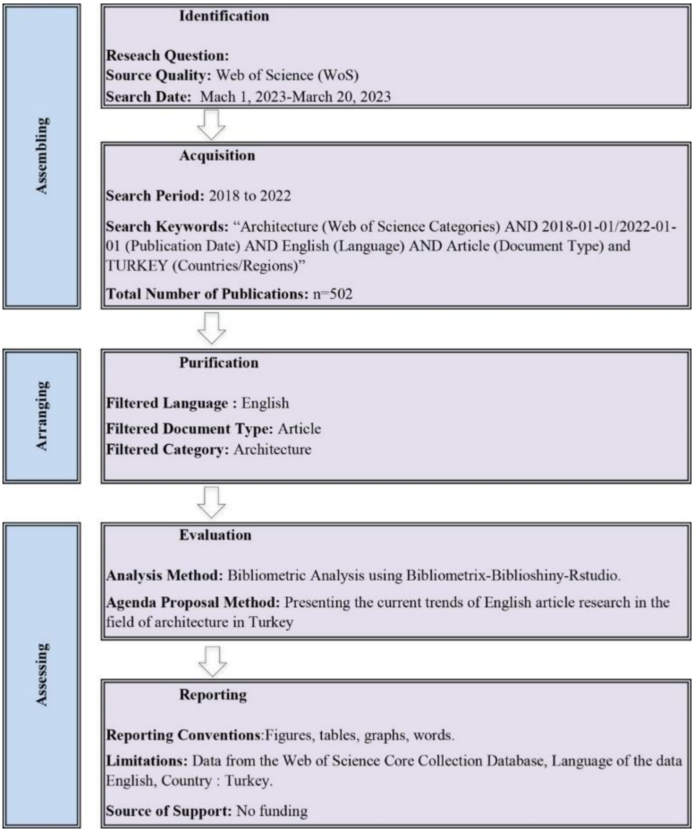

Figure 2. The process of literature search/selection and bibliometric analysis created by Author

3. Results

In this section, the results of the research are explained. The Web of Science Core Collection database was searched for "*Architecture (Web of Science Categories) AND 2018-01-01/2022-01-01 (Publication Date) AND Article (Document Type) AND English (Language) and TURKEY (Countries/Regions) and Architecture (Web of Science Categories)*". According to the results of the process of literature search/selection and bibliometric analysis described in Figure1. A total of 502 publications were accessed from 2018 to 2022 (Figure 3). Table 1 shows the main information bibliometric data about architecture using the Biblioshiny program.

Figure 3. Main Information about Data Creating by Biblioshiny

Table 1. Main Information about Data Creating by Biblioshiny

Main Information About Data	
Description	**Results**
Timespan	From 2018 to 2023
Sources (Journals, Books, etc)	51
Documents	502
Annual Growth Rate %	-54,88
Document Average Age	3,13
Average citations per doc	1,663
References	18313
DOCUMENT CONTENTS	**Results**
Keywords Plus (ID)	664
Author's Keywords (DE)	1865
AUTHORS	**Results**
Authors	833
Authors of single-authored docs	152
AUTHORS COLLABORATION	**Results**
Single-authored docs	174
Co-Authors per Doc	2,01
International co-authorships %	13,94
DOCUMENT TYPES	**Results**
article	483
article; book chapter	13
article; early access	2
article; proceedings paper	4

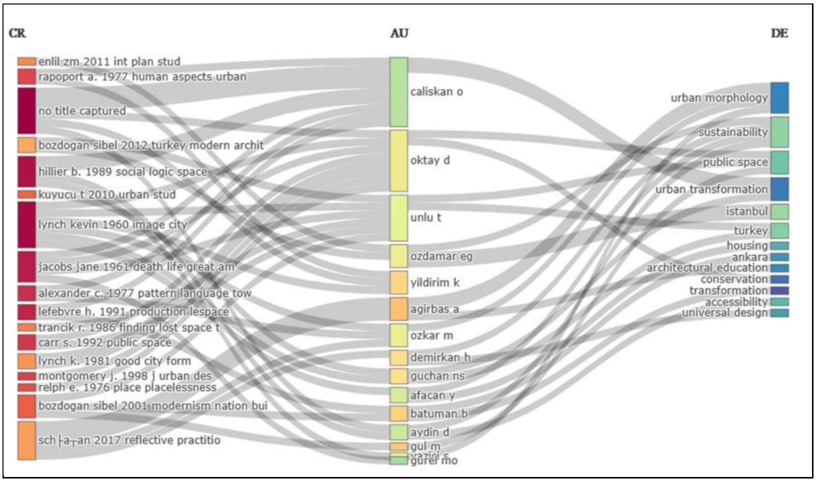

Figure 4. Three Field Plot

Three field-charts are a bibliometric analysis tool that provides a visual representation of the distribution of publication productivity, collaboration patterns, and publication impact in a given field of study or scientific community (Koo, 2021). The three-field plot displayed the connections between the references, authors, and keywords of publications on architectural research in Turkiye (Figure 4). The result in Figure 4 shows that Calıskan's studies has incoming flow count:6 and outcoming flow count:1 is urban transformation (Calıskan & Barut, 2022). Also, Oktay's studies has incoming flow count:7 and outcoming flow count:2 are public space and conservation (Oktay, 2019) and Unlus's studies has incoming flow count:6 and outcoming flow count:2 are public space and Turkiye (Unlu, 2019).

The Figure 5 shows the top ten most relevant sources for architectural literature. According to the bibliometric study for 2018-2022, *Iconarp-International Journal of Architecture and Planning"* ranks highest in terms of publications (129), followed by "*Megaron*" (72). Then "*METU Journal of the Faculty of Architecture*" (45) and "*Open House International*" *(*37) (Figure 5).

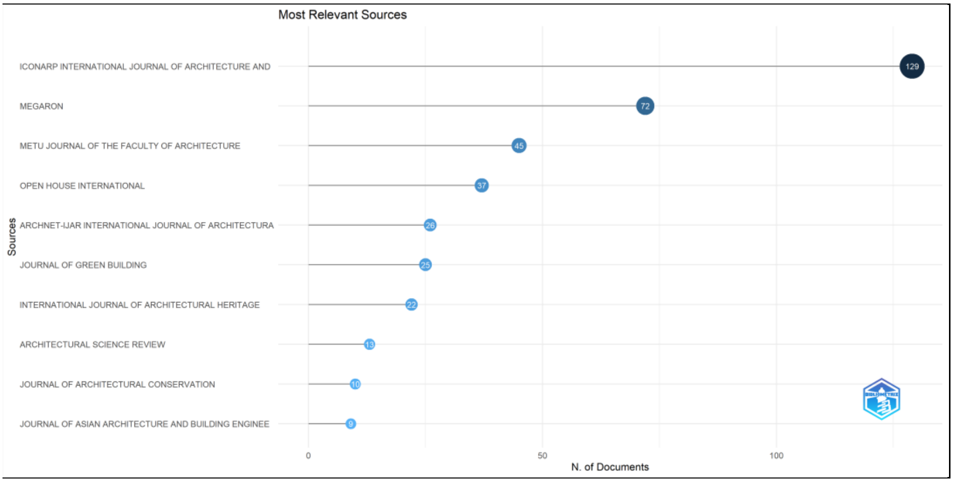

Figure 5. Most Relevant Sources

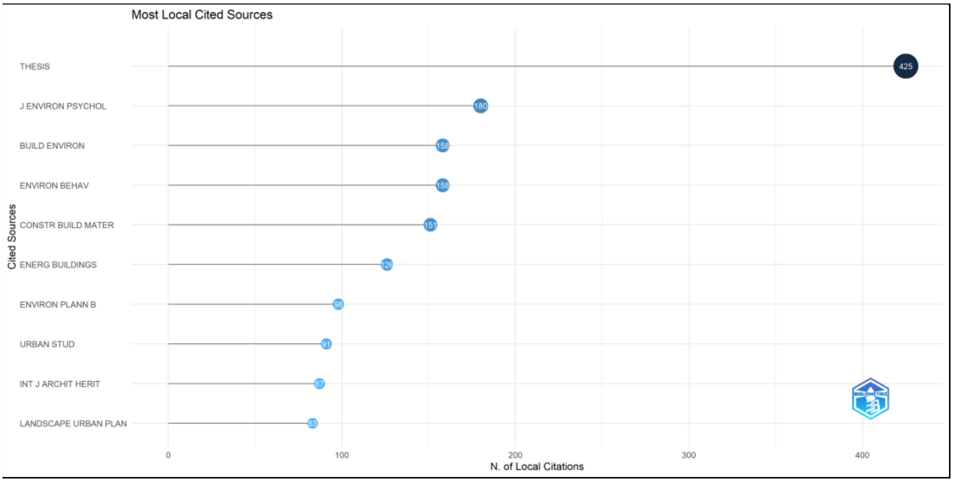

Figure 6. Most Local Cited Sources

Figure 6 shows most local cites sources and Figure 7 shows sources local impact by h-index. "*Archnet-IJAR International Journal of Architectural Research*" (7) and "*International Journal of Architectural Heritage*" (7) equally local impact. Moreover *"Architectural Science Review"* (6), *"Iconarp International Journal of Architecture and Planning"* (5) and "*Journal of Green Building"*(5) equally local impact (Figure 6). Also Figure 7 shows sources' local impact by h-index from 2018 to 2022.

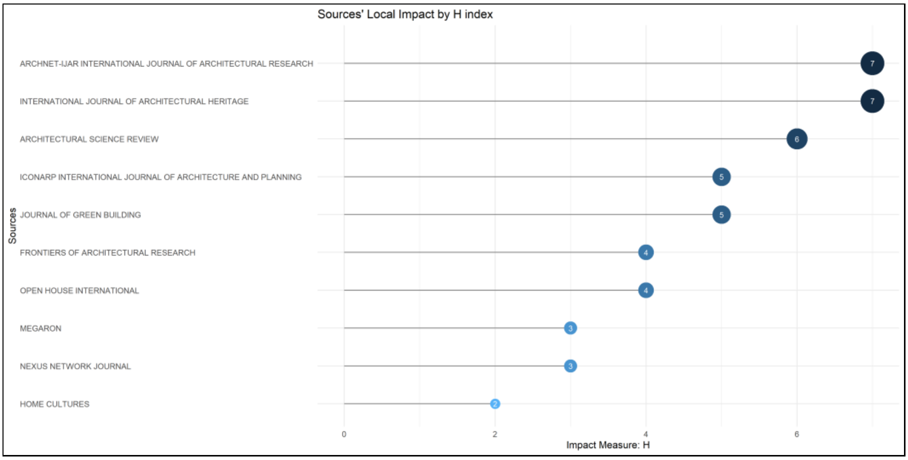

Figure 7. Sources' Local Impact by H Index

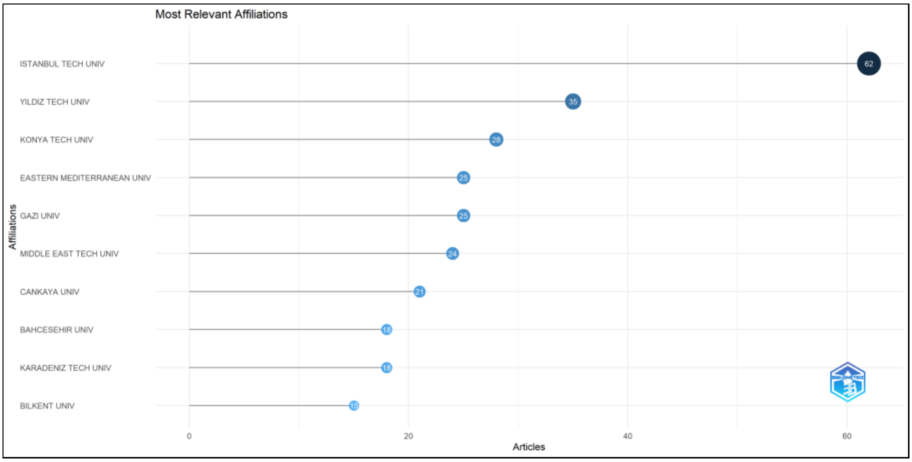

Figure 8. Most Relevant Affiliations

Figure 8 shows the most significant affiliations in architectural research. With 62 papers, *"Istanbul Technical University"* ranked first. Moreover, 35 materials were provided by *“Yıldız Technical University*”, and 28 documents were provided by *“Konya Technical University”* (Figure 8). Figure 9 shows the production of affiliations over time in architectural research. With 62 papers, *“Istanbul Technical University”* ranked first. Moreover, *“Yıldız Technical University”*, *“Eastern Mediterranean University”*, *“Gazi University”*, and *“Konya Technical University”* (Figure 9).

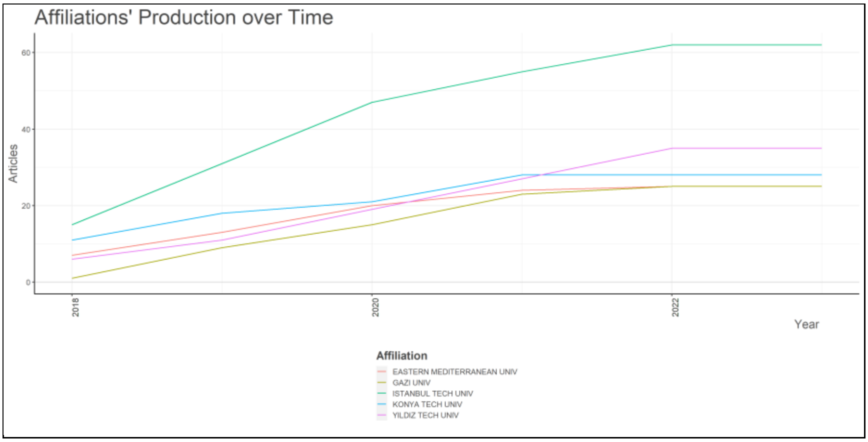

Figure 9. Affiliations' Production over Time

The top most local cited references are shown in Figure 10. According to Figure 10, the first most cited reference is Lynch’s study *“The Image of City”* (Lynch, 1960). Moreover, Hillier and Hanson’s studies title *“The Social Logic of Space”* (Hillier & Hanson, 1984), Jacops’s *“The Death and Life of Great American Cities”* (Jacops, 1965), Lefebvre’s research *“The Production of Space”* (Lefebvre, 1974), Rapoport’s stusy titles “*Human Aspects of Urban Form”* (Rapoport, 1977), Alexander’s study titles *“A Pattern Language: Towns, Buildings, Construction”* (Alexander, 1977) (Figure 10). Also Carr’s study titles *“Public Space”* (Carr et al, 1992), Relph's research title *"Place and Placelessness"* (Relph, 1976) and Whyte's research title *"Social Life of Small Urban Space"* (Whyte, 1980) (Figure 10).

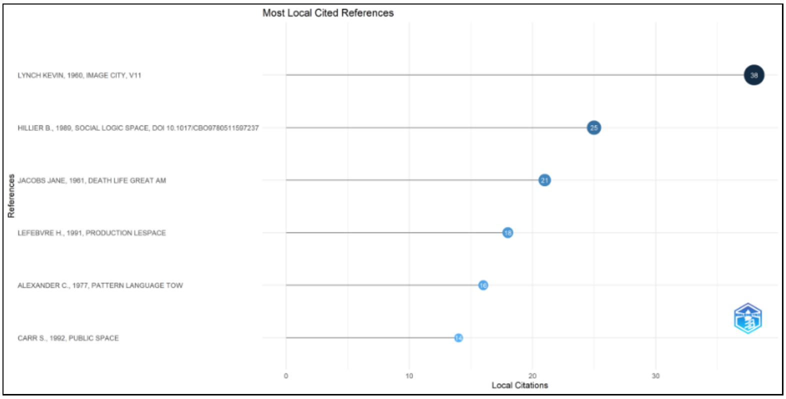

Figure 10. Most Local Cited References

Figure 11 shows most frequent words used architecture studies. These words are *"design"*, *"performance"*, *"city"*, *"behavior"*, *"building"*, *"impact"*, *"environment"*, *"place"*, *"cities"* and *"community"* (Figure 11).

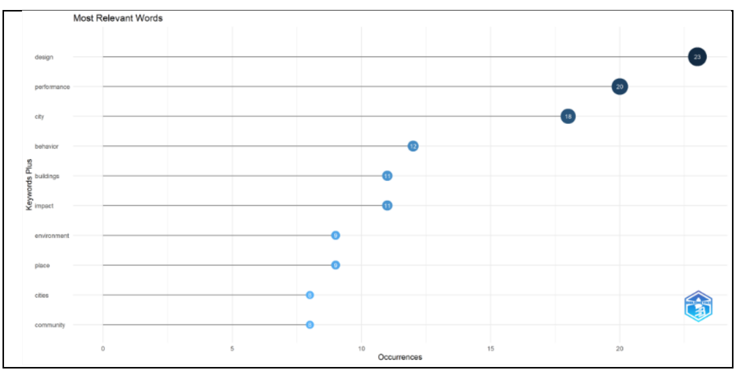

Figure 11. Most Frequent Words used architecture studies

Figure 12. WordCloud

As shown by a word cloud in Figure 12. Figure 13 shows most frequent words used architecture studies TreeMap. These words are “*design” 23 (%9), “performance” 20 (%8), “city” 18 (%7), “behavior” 12 (%5), “building” 11 (%5), “impact”11 (%5), “environment” 9 (%4), “place” 9 (%4)*. Moreover other words are *“cities” 8 (%3), “community” 8 (%3), “education” 8 (%3), “model” 8 (%3), “urban” 8 (%3),* equally are shown in Figure 13.

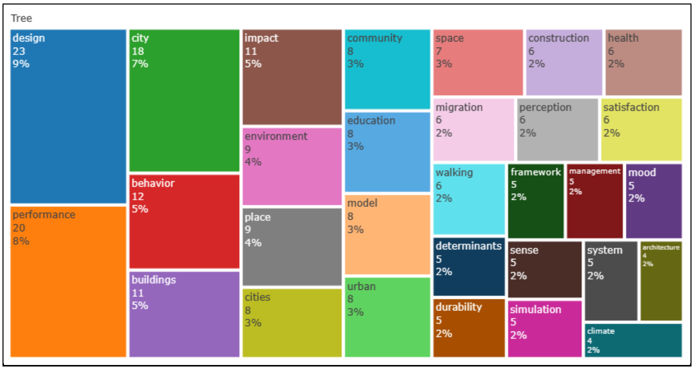

Figure 13 TreeMap

Figure 14 shows trend topics-author's keywords from 2018 to 2022. In 2018 trend topics-author's keyword is *“universal design”*. Between 2018 and 2020, the trend topic words are *“urban transformation”, “energy efficient”,* and *“accessibility”* (Figure 14). In 2020, the trend topic words are *“Istanbul”, “sustainability”* and *“Turkiye”*. Between 2020 and 2022, the trend topic keywords were *“space syntax”, “public space”, and “covid-19”* (Figure 14). In addition, the frequencies of these words according to the years are clearly seen in the Table 2.

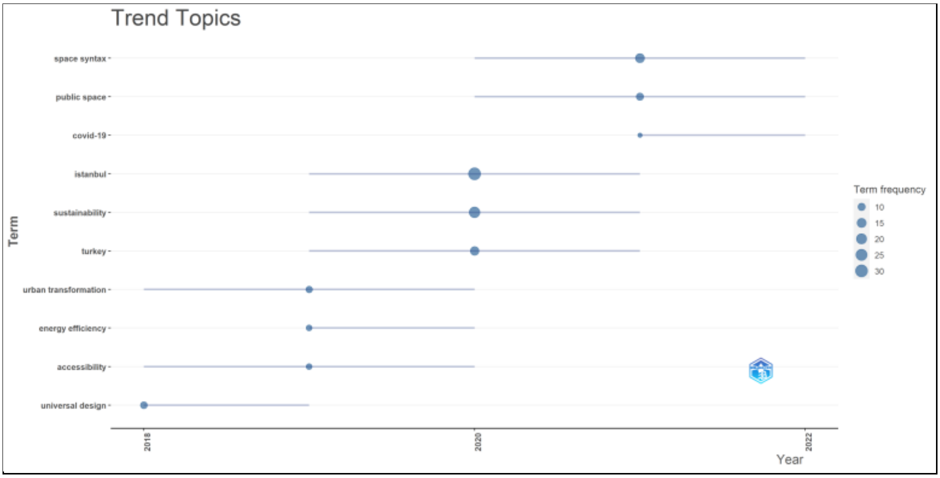

Figure 14. Trend Topics-Author’s Keywords

Table 2. Trend Topics-Author’s Keywords

Item	Frequence	year_q1	year_med	year_q3
Universal design	9	2018	2018	2019
Urban transformation	8	2018	2019	2020
Accessibility	7	2018	2019	2020
Energy efficiency	7	2019	2019	2020
Istanbul	30	2019	2020	2021

Sustainability	22	2019	2020	2021
Turkiye	14	2019	2020	2021
Space syntax	15	2020	2021	2022
Public space	10	2020	2021	2022
Covid-19	6	2021	2021	2022

Figure 15 shows trend topics- keywords plus from 2018 to 2022. In 2018, the trend topics keywords plus were *"cities", "system",* and *"determinants".* Between 2020 and 2022, the trend topics keywords plus were *"urban", "satisfaction", "management".* In 2020 the trend topics keywords plus were *"design", "performance",* and *"city".* Between 2020 and 2202, the trend topics keywords plus were *"behavior", "building", "environment", and "health"* (Figure 15). In addition, the frequencies of these words according to the years are clearly seen in the Table 3 -4.

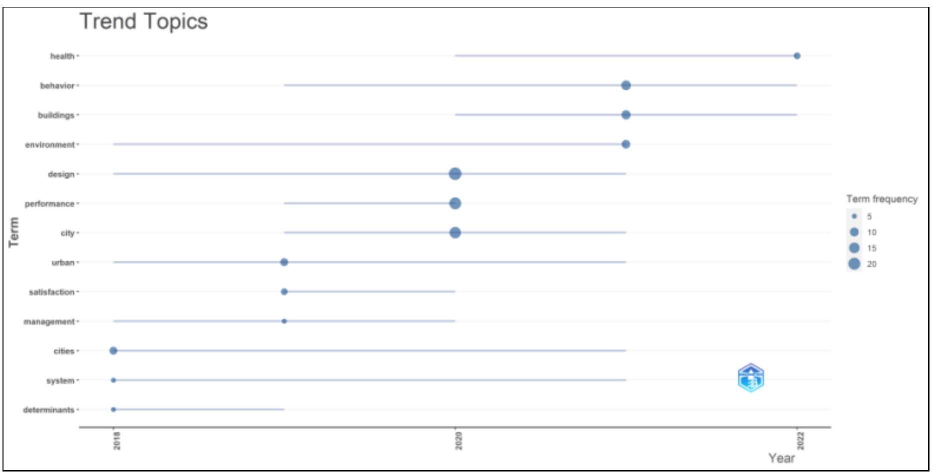

Figure 15. Trend Topics-Keywords Plus

Table 3. Trend Topics-Keywords Plus

Item	Frequence	year_q1	year_med	year_q3
Cities	8	2018	2018	2021
Determinants	5	2018	2018	2019
System	5	2018	2018	2021
Urban	8	2018	2019	2021
Satisfaction	6	2019	2019	2020
Management	5	2018	2019	2020
Design	23	2018	2020	2021
Performance	20	2019	2020	2020
City	18	2019	2020	2021
Behavior	12	2019	2021	2022
Buildings	11	2020	2021	2022
Environment	9	2018	2021	2021
Health	6	2020	2022	2022

Table 4. Factorial Analysis-Words by Cluster

Word	Dim.1	Dim.2	Cluster
Istanbul	-0,61	-0,18	1
Sustainability	-0,05	-0,47	1
Space syntax	-0,68	0,01	1
Turkiye	-0,47	-0,06	1
Architectural design	0,16	0,27	1
Architecture	1,28	-2,08	1
Architectural education	1,53	0,47	1

Public space	-0,1	-0,39	1
Urban morphology	-0,94	-0,06	1
Housing	0,83	0,61	1
Universal design	-0,44	2,62	1
Conservation	-0,35	-0,38	1
Cultural heritage	0,02	-1,03	1
Urban transformation	-0,47	-0,2	1
Accessibility	-0,49	2,72	1
Energy efficiency	-0,41	-0,13	1
Ankara	-0,32	-0,05	1
Covid 19	3,68	2,08	1
Restoration	-0,27	-0,07	1
Vernacular architecture	-0,54	-0,03	1
Computational design	-0,21	0,01	1
Design education	0,79	2,79	1
Design studio	4,08	0,19	1
Flexibility	1,34	-0,15	1
Parametric design	-0,21	0,01	1

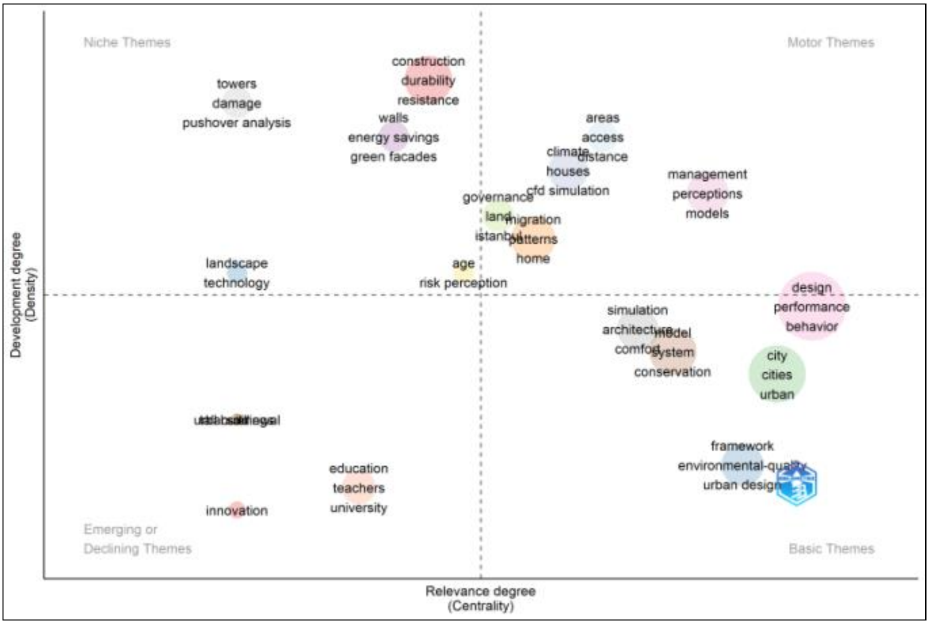

Figure 16. Thematic Map (Development Degree/Relevance Degree)

Themes are keyword clusters that may be organized into a single circle and mapped as a two-dimensional picture using density and centrality. Figure 17 shows a thematic map that categorizes topics according on the quadrant in which they are located. The upper-right quadrant contains motor themes, whereas the lower-right quadrant contains fundamental concepts. The lower-left quadrant is about emerging or vanishing themes, while the upper-left quadrant is about exceedingly specialized issues.

Correspondence analysis is a graphical approach used to determine the relationship between variables in a contingency table. It provides an approach for summarizing and visualizing data sets using two-dimensional graphs (Dungey, 2018). Figure 17 shows author's keywords factorial analysis. Also, Table 4 shows factorial analysis-words by Cluster.

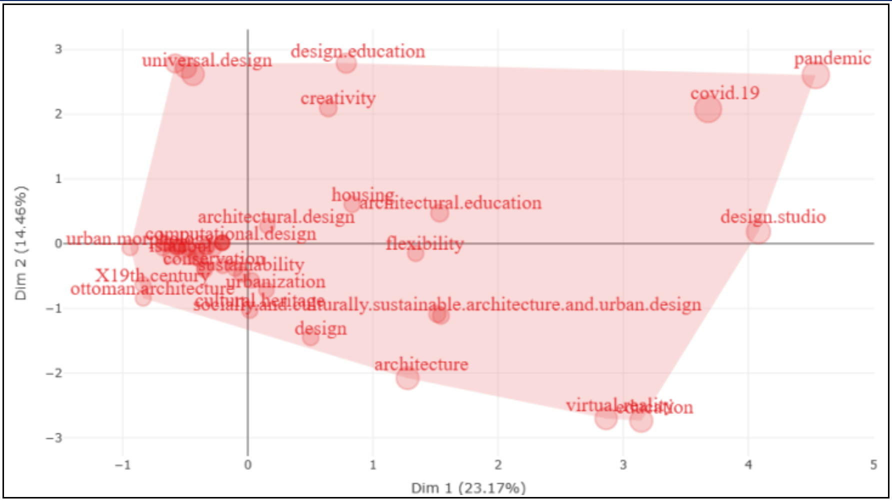

Figure 17. Factorial Analysis- Author's Keywords-Word Map

Finally, to summarize, the top ten authors in order of the number of citations of all these reviewed publications are as follows; (Erkan, 2018), (Ceylan et al., 2021), (Akdag & Maqsood, 2020), (Turkoglu et al., 2019), (Ozkan & Yılmaz, 2019), (Gucyeter, 2018), (Yılmaz & Oral, 2018), (Aydın & Sayar, 2021), (Demiroglu et al., 2020) and (Yıldızlar et al., 2020). It is possible to access the publications other than these publications from the Web of Science database with the same keywords.

Table 5 The Top Ten Authors in Order of The Number of Citations (Title, Authors, Source, Citatitons and Average (WoS, 2023)

	Title	Authors	Source Title	Total Citations	Av. per Year
1	“Examining wayfinding behaviours in architectural spaces using brain imaging with electroencephalography (EEG)”	(Erkan, 2018),	Architectural Science Review	27	4,5
2	“An evaluation of online architectural design studios during COVID-19 outbreak”	(Ceylan et al.,2021)	Archnet- IJAR International Journal Of Architectural Research	18	6

3	"A roadmap for BIM adoption and implementation in developing countries: the Pakistan case"	(Akdag & Maqsood, 2020),	Archnet- IJAR International Journal Of Architectural Research	18	4,5
4	"Residential satisfaction in formal and informal neighborhoods: the case of Istanbul, Turkey"	(Turkoglu et al, 2019)	Archnet- IJAR International Journal Of Architectural Research	18	3,6
5	"The effects of physical and social attributes of place-on-place attachment A case study on Trabzon urban squares"	(Ozkan & Yılmaz, 2019)	Archnet- IJAR International Journal Of Architectural Research	17	3,4
6	"Evaluating diverse patterns of occupant behavior regarding control-based activities in energy performance simulation"	(Gucyeter, 2018)	Frontiers Of Architectural Research	16	2,67
7	"An approach for an educational building stock energy retrofit through life-cycle cost optimization"	(Yılmaz & Oral, 2018)	Architectural Science Review	16	2,67
8	"Questioning the use of the balcony in apartments during the COVID-19 pandemic process"	(Aydin & Sayar, 2021)	Archnet-IJAR International Journal Of Architectural Research	14	3,5
9	"In-Plane Seismic Response Analyses of a Historical Brick Masonry Building Using Equivalent Frame and 3D FEM Modeling Approaches"	(Demirlioglu, et al., 2020)	International Journal Of Architectural Heritage	14	3,5
10	"A Case Study on the Restoration of A Historical Masonry Building Based on Field Studies and Laboratory Analyses"	(Yildizlar et al., 2020)	International Journal Of Architectural Heritage	14	2,8

4. Conclusion and Suggestions

This study sought to examine English articles in the field of architecture published from between 2018 to 2022. The bibliometric analysis methodology, one of the quantitative research methods, was used in this study. The research was conducted by searching for *"Architecture (Web of Science Categories) AND 2018-01-01/2022-01-01 (Publication Date)*

AND English (Language) AND Article (Document Type) and TURKİYE (Countries/Regions)" in the Web of Science Core Collection database. This study was conducted between March 1, 2023 and March 20, 2023. Bibliometrix and Biblioshiny software programs were used for the statistical analysis of publications. This study emphasizes advancements and trends in scientific collaboration in the field of architecture. It also serves as a model to show global trends related to the topics covered in architectural publications. This study may help to better understand the current state of architectural research.

According to the search results, 502 publications were accessed in the Web of Science Core Collection database. Bibliometric analysis determined the most productive sources, and *"Iconarp-International Journal of Architecture and Planning"* was at the top of the list with 129 publications in the field of architecture. The most locally cited sources were *"Thesis"*, followed by *"Journal of Environmental Psychology"*. According to the research findings, *"Archnet-IJAR International Journal of Architectural Research" and "International Journal of Architectural Heritage"* had an equal number of publications (7) in the analysis of Sources' Local Impact by H Index. The most relevant affiliation with 62 publications was *"Istanbul Technical University"*. The most locally cited references were Lynch's study title *"The Image of City"* (Lynch, 1960) with 23 publications and Hillier and Hanson's study title *"The Social Logic of Space"* (Hillier and Hanson, 1984) with 16 publications.

The most relevant words were *"design" (23), "performance" (20), "city" (18), "behavior" (12), "impact" (11), "environment" (9),* and *"place" (9).* Between 2018 and 2020, the trend topic keywords in authors' keywords were *"urban transformation"*, *"energy efficient"*, *"accessibility"*, and *"universal design"*. In 2020, the trend topic keywords were *"Istanbul"*, *"sustainability"*, and *"Turkiye"*. Between 2020 and 2022, the trend topic keywords were *"space syntax"*, *"public space"*, and *"covid-19"*.

In summary, this study provides a general overview of the current state and trends in research in the field of architecture (2018-2022). Scientific maps use knowledge frameworks to identify the structural and dynamic elements of a research field. Conceptual frameworks were employed in this study to present a thorough summary of major trends and results in architectural research, identifying main themes, subjects, and intellectual structures that influence a writer's work. The aim is to better grasp the development of concepts or situations over time. This approach offers researchers with a list of the most significant articles for each topic set, which may be used to narrow down research on a certain theme. The clustered thematic map can give information on the relevance of themes based on their centrality and density.

Future study should look at a wide range of novel and advanced machine learning-based bibliometric analysis tools, such as forecasting subject dominance based on rankings. Other databases that might be used include Dimensions, Web of Science, Cochrane Library, and PubMed, this study focused on the WoS database. Another possible route of future research would be to design and develop from the beginning a visualization tool that covers more dimensions and gives more data.

Finally, to summarize, this study provided an important literature contribution for future research in the field of architecture. As a suggestion, researchers can examine their research over a wider range of time periods. A bibliometric analysis of its relationship with architecture can be done by focusing on a specific subject, or it can be focused on the same subject with different analysis programs and compared the findings.

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Using the Geometric Order in Nature in Architectural Design

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1. Introduction

Today, there are various design approaches/tendencies in the formation and interpretation of architectural design. When these approaches are examined, we encounter the concept of biomimicry, which has been on the agenda of architecture recently, and which is based on inspiration/reference from nature in the solution of problems. Today's architecture conducts research on the methods of transferring inferences from nature to architectural designs, and nature's working principles, forms, living and inanimate structures, geometries constitute the source of many innovative designs.

Today, with the renewed and developing digital and information technologies, designers' being inspired by the formation processes in nature and the beings in nature has been systematized with certain studies. With that in mind, in this study, the ways of being inspired by nature as a model, criterion, mentor and order were examined and how the geometric order in nature was transferred to the designs by the designers using mathematical concepts such as Fibonacci sequence, Golden ratio, Fractal geometry and Voronoi diagram was examined through examples.

The most comprehensive and broad living space of living things is called "nature". In the TDK Dictionary, it is defined as “*all living and non-living things, which are constantly evolving and changing within the framework of their own rules*”. *The environment, which has not undergone major changes by human hands and preserves its natural structure*, is also described as nature.

The nature and human beings are in a balanced and integrated relationship. In the architectural design process, designers have always seen nature as a guide and a source of inspiration. Architecture has been affected by different changes and developments until today and has started to produce approaches from different perspectives to the problems that exist in the design process. One of these approaches is biomimicry. Imitating the formations that occur in nature over time in the building design process creates the understanding of biomimicric design in architecture (Çetiner, 2023).

Although human beings have built many structures inspired by nature from the past to the present, the term 'bionic' for the first time in 1960 was started to be mentioned with the names of biomimetic in 1969 (Gruber, 2011).

Biomimicry is to bring solutions to problems with designs produced by being inspired by the beings found in nature, learning from nature, and imitating nature. Biomimicry deals with the functions of the structural forms of the entities rather than the formation process.

Biomimicry is a term commonly used by people who work in engineering, medicine, artificial intelligence, military hardware, computer and software technologies, industrial products, architecture and transportation Technologies (DTI, 2007).

With the discovery and explanation of the structures and formations in nature with the biomimicry approach, the way of examining nature has changed greatly. In this change, new design approaches and thought systems emerged with the recognition and examination of the measure, proportion, rhythm and balance in nature. With the change in our perspective on nature in the biomimicry approach, the data we have obtained by experiencing nature has become usable. In the design process, new designs were realized by imitating nature in line with the data obtained from nature.

2. Material and Method

The conceptual information obtained from the literature review on the concept of biomimicry, which is a current topic, constitutes the basic data and material of the study.

The aim of the study is to examine the methods of using the geometric order in nature in architectural design under the concept of biomimicry.

In this context, firstly, biomimicry studies from the past to the present were examined based on the literature review, and then examples of how the geometric order in nature was used in architectural design were evaluated.

3. Findings and Discussion

3.1. Ways To Be Inspired By Nature

Biomimicry approach; examines the ways of being inspired by nature under four different headings (Benyus, 2002). They are divided into nature as a model, nature as a criterion, nature as a mentor, and nature as an order. In this way, ways of being inspired were created by considering different aspects of nature.

3.1.1. Nature as a Model

The nature-as-model approach seeks solutions to human problems by examining the models of beings found in nature, being inspired by them and imitating their life processes, and uses the solution produced by nature against the problem in its own design. This inspiration and imitation brings out the analogical approach. Analogy is a concept based on establishing similarities between two different things. It is to produce new functions and forms based on an exemplary entity. Although nature is a direct source of inspiration for many designers from the historical process to the present, it is more common to be inspired by analogical approaches in architectural forms and structural design (Figure 1-2).

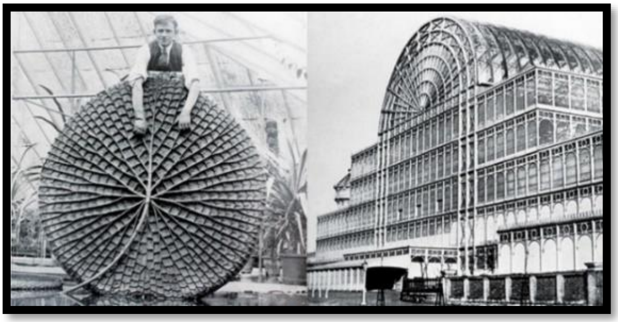

Figure 1. Lotus Flower- Crystal Palace Form Analogy (URL-2)

Figure 2. La Sagrada Familia- Forest Structure Analogy (URL-3)

3.1.2. Nature as a Criterion

Biomimicry uses an ecological standard to determine the accuracy of our designs. These standards are the standards taken to reduce the damage caused by the developing and globalizing humanity on issues such as energy efficiency, sustainability and waste management. Thanks to these standards, productions that harm nature have been replaced by productions that clean and protect nature (Figure 3).

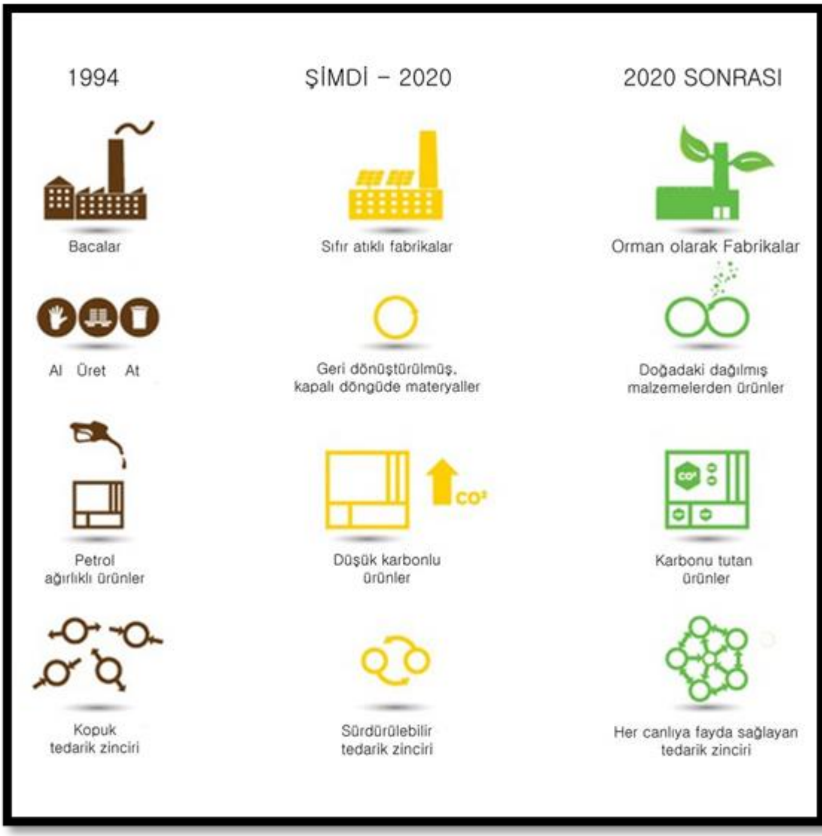

Figure 3. Change of Ecosystems of Industrial Structures (URL-4)

3.1.3. Nature as a Mentor

Nature as a mentor; It is a way of observing and experiencing nature in a different way from other people. Its purpose is not to exploit nature, but what we can learn from nature and living things in nature, how we will interpret and use what we have learned. In this process, it is important to understand the formation and functioning of systems in nature instead of struggling against nature.

3.1.4. Nature as an Order

Nature and living things in nature have a certain order. This order is explained by numbers, proportions, and formal (geometric) interactions. The order and chaos in nature, where life is intertwined, attracted the attention of some scientists over time and led them to work in this field. As a result of these studies, aesthetic harmony in nature is explained with certain numerical and geometric concepts (Benyus, 2002).

3.2. Nature, Geometry And Archıtecture

The forms of beings found in nature affect our aesthetic understanding. Over time, these forms have been associated with mathematical formulas and geometric shapes. In the past, designers did not establish a relationship between geometry and aesthetic forms, but today they have started to establish a relationship between geometry and aesthetic forms with the concepts of rhythm, hierarchy, proportion, emphasis, color, harmony, space, pattern, balance by using geometry to create aesthetic forms. As a result, designers have accepted that aesthetic forms found in nature are directly related to mathematics and geometry. They have created algorithms by doing various studies to imitate nature in new designs.

In the historical process, scientists have tried to explain the beauty and aesthetic appearance of the forms in nature with numerical and geometric concepts with their independent and different studies. As a result of these studies, the concepts of Fibonacci Sequence, Golden Ratio, Fractals, Voronoi Diagram have emerged. Architectural designers have benefited from these concepts in order to reflect the forms, aesthetics and proportions in nature to their designs.

3.2.1. Fibonacci Sequence

The Fibonacci sequence is a set of numbers ordered by the sum of two consecutive numbers that come before it. Its beginning is 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987…. When a number selected from the number sequence is divided by the number preceding it, a fixed ratio defined as the golden ratio, 1.618 is reached. The Fibonacci sequence of numbers provides the mathematical explanation of some sequential forms in nature. The golden ratio in the Fibonacci number sequence appears in the forms of living and non-living beings in nature. For example, the human body is symmetrical and the skeletal system has the golden ratio. The formations in natüre and planetary movements can be explained by the geometric spiral formed by the Fibonacci number sequence. Discovering this order in nature, designers inspired by the geometry of nature and imitated nature in their art.

Order and geometry in nature can be described by the Fibonacci sequence of numbers and observed on examples. As an example, the number of sunflower seeds, the pedigree drawing to determine the sex of the bees, the reproduction of the branches of archillea ptarmica/sneezewort plant can be given (Cengiz et al., 2020) (Figure 4).

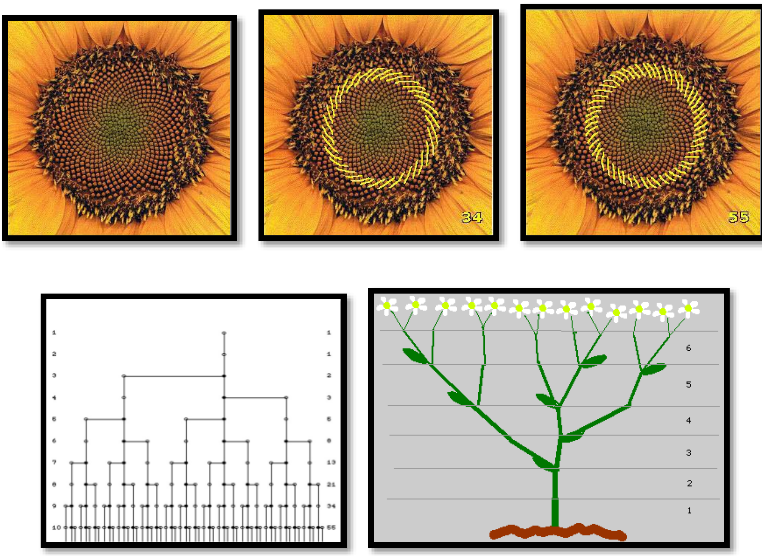

Figure 4. Number of Sunflower Seeds, Pedigree Drawing for Determining the Sex of Bees, Reproduction of Branches of Archillea Ptarmica Plant (URL-5)

3.2.2. Golden Ratio (Φ)

Throughout history and today, people continue to seek the most beautiful and the best. In this process, they discovered that the order and disorder found in nature actually have the golden ratio. They agreed that forms with the golden ratio look beautiful and aesthetic to the eye.

While the disproportion of the elements that make up the form is perceived as ugly by people, the proportionality of the relationship between the elements was perceived as beautiful. For this reason, designers gave importance to concepts such as proportion, symmetry and balance in their compositions.

According to written sources, the golden ratio was first used in the 3rd century BC, and it was called the "extreme and average ratio". However, in some sources it is stated that the golden ratio was discovered by Pythagoras in 3000 BC (Bergil, 1993; Kara, 2000).

Geometrically, the definition of the Golden Ratio (Φ) is the ratio of a line part cut into two pieces of different lengths such that the ratio of the whole part to that of the longer part is equal to the ratio of the longer part to the shorter part. This ratio is approximately equal to 1.618(Figure 5).

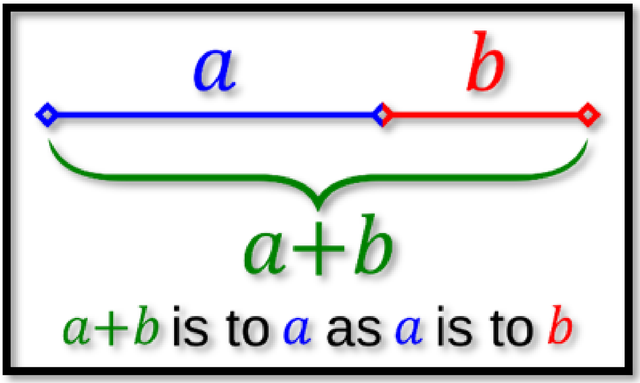

Figure 5. Golden Section of Line Segment (Değirmenci, 2009)

Architects and artists dealing with plastic arts such as sculpture and painting have used the golden ratio effectively while creating their compositions. Many parts of the human body have a golden ratio in themselves. When the human anatomy is examined, the golden ratio is seen even in the arrangement of the internal organs.

Many artists and architects such as Leonardo da Vinci, Albrecht Dürer and Le Corbusier have studied the golden ratio in the human body. With the drawings they made, they transferred the human body to paper using the golden ratio (Çağlarca, 1997). Leonardo Da Vinci and Albrecht Dürer, one of the leading artists of the Renaissance, used the proportionality rules revealed by Vitruvius. The two artists gained extensive knowledge as a result of their studies on the proportions of the human body(Figure 6).

Leonardo Da Vinci created the illustrations for a mathematics book, "De Divinia Proportione (Holy Proportion)", written by Luca Pacioli around 1490 and published in 1509. He defined ideal body proportions. Albrecht Dürer published his drawings of the golden ratio in the human body in his work, "Four Books on Human Proportion" in 1528. When the drawings of the ratio systems in the human body of the artists are examined, it is seen that they comply with Vitruvius' ratio system and the ratios are approximately the same (Figure 7).

Architect Le Corbusier is one of the designers who accept that the human body has the golden ratio. Le Corbusier created an alternative to the metric system by scaling the human body with the golden ratio in his book published in 2 volumes in 1950 and 1955. He used this ratio system in his works to bring human ergonomics to the forefront in his designs. Le Corbusier considers the human on which he is based as 183 cm (Figure 8).

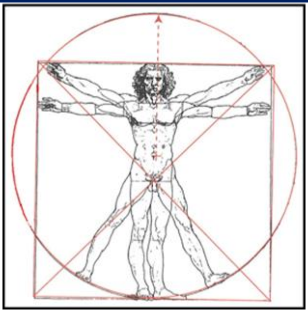

Figure 6. Leonardo Da Vinci Ratio System Vitruvian man (URL6)

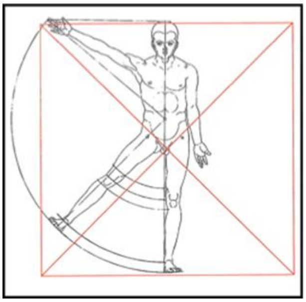

Figure 7. Albrecht Dürer Ratio System (URL6)

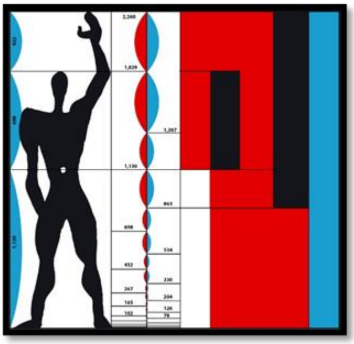

Figure 8. Le Corbusier Ratio System, Modular (URL-7)

Developing themselves with what they learned from nature, human beings are produced architectural works by using the proportion and geometry in nature. According to Marcus Frings, one of the most important issues in architecture is proportion. When the structures built during the ancient Egyptian and Greek civilizations were examined, it was seen that the building elements were built in proportion to each other. When these ratios in the building are examined, it is understood that they have the same value as the ratios in nature. Among the geometric ratios used in these structures, the most used ratio is the golden ratio (Frings, 2007).

It is known that the concept of the golden ratio in architecture started with Vitruvius' work called Ten Books on Architecture, took place in architectural designs in different periods and reached its peak with Le Corbusier's Modular. In this process, the structures built using the golden ratio are divided into architectural periods and examined in the table below (Fletcher,2001; Olsen, 2006) (Figure 9).

Figure 9. Golden Ratio Architecture (Selçuk et al., 2009)

3.2.3. Fractals

The word fractal, which comes from the Latin root "fractus", means fragmented or broken. Fractals have three basic properties. These are that they occur as a result of repetitions, have self-similarity and a fractional (fractal) dimension (Alik, 2015).

Nature is made up of many systems that work in conjunction with each other. These systems are chaotic and complex. Although the water cycle in the atmosphere, the blood flow in the circulatory system, the shapes of trees and mountains are perceived as irregular, they have an order that can be explained by mathematics. The functioning of these complex systems that we see in nature and in our bodies cannot be explained by linear systems in mathematics. These systems with fractional dimensions can be explained by fractals.

Mathematicians such as Giuseppe Peano, Georg Cantor, David Hilbert, Waclaw Sierpinski, Niels Fabian by Helge Von Koch have worked on the concept of fractal. The Cantor set theory, invented by Georg Cantor, forms the basis of early work on fractals. The Cantor set is created by dividing a line segment into 3 equal parts and subtracting the middle segment. The process continues indefinitely by applying the same process to the remaining 2 pieces (Figure 10).

Figure 10. Cantor Cluster Formation Stages (Tepe, 2014)

Found by the Swedish mathematician Niels Fabian Helge Von Koch, the Koch snowflake is formed by stacking an equilateral triangle in the form of a symmetrical snowflake (Figure 11).

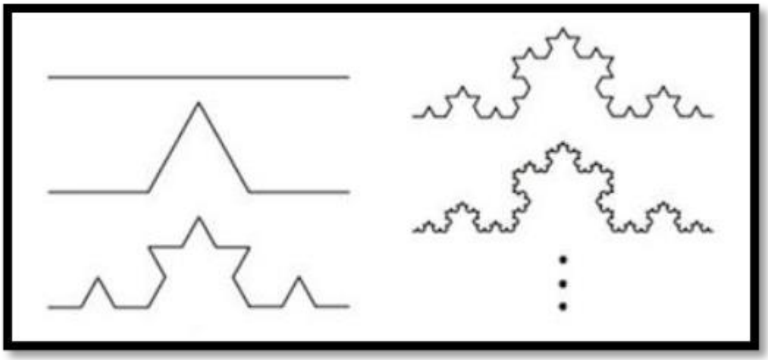

Figure 11. Koch Snowflake Formation Stages (URL-8)

The Sierpinski triangle, found in 1916 by the mathematician Waclaw Sierpinski, is formed by 3 different methods. These are the triangle subtraction method, the reduction method, and the duplication method. The same shapes are formed when these methods are used(Figure 12-13).

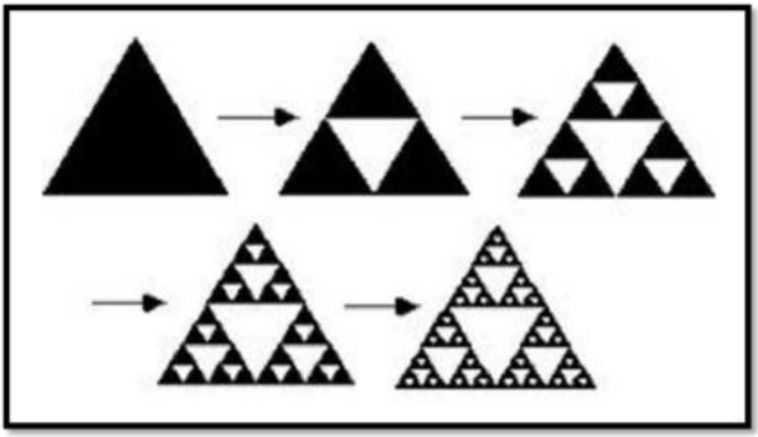

Figure 12. Sierpinski Triangle Formation Stages (Yılmaz,2013)

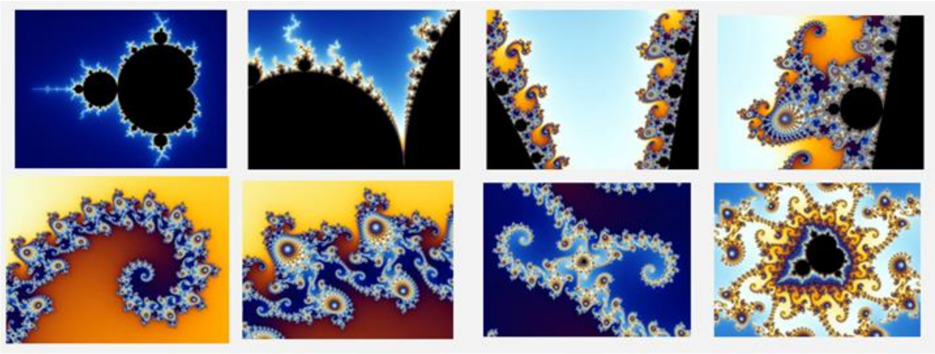

Figure 13. Mandelbrot Cluster Formation Stages (URL-9)

Formations in nature are complex and irregular. Shapes in nature do not consist of perfect circles and perfect squares. It is necessary to explain that irregular formations have a certain order with fractals instead of explaining them with basic mathematics. Examples of these natural formations are tafoni, cave stalactites, geological formations and the bifurcation of the dragon tree(Figure 14).

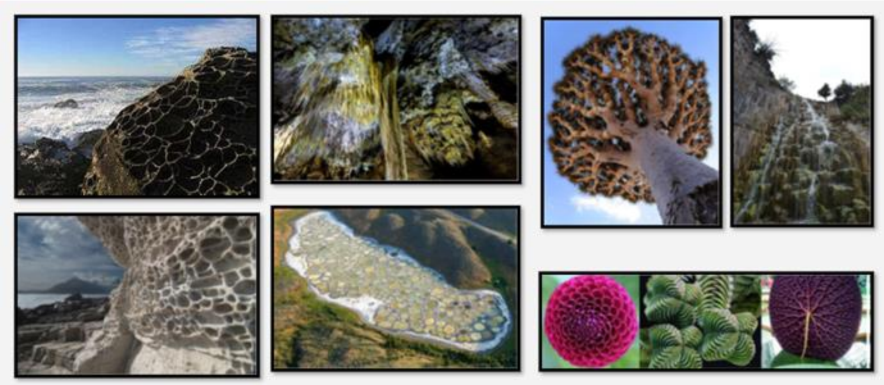

Figure 14. Fractal Structures in Nature(Genç, 2019)

Fractal geometry can be used as a tool to be inspired by the forms found in nature in an architectural design. For example, when the form of a tree is used through fractals in architectural design, the resulting design will not be a tree-like structure. However, this structure will be in a structure that shows the same level of development throughout the continuity in details as in the objects in nature. For this reason, it may be useful to use fractal geometry in the design process (Ediz, 2003).

If self-similarity is desired from small scale (details in the structure) to large scale (building form) in architectural design, fractal structures can be used in the design. In this design process, a common design language is created thanks to fractals (Bavill, 1996).

When the examples of structures in which people use fractal geometry consciously or unconsciously from past to present are examined, it is seen that similar forms are used.

People in Africa have arranged their habitats in complex clusters. These clusters came together to form fractals. An example is the residential area of Ba-ila in Southern Zambia. Houses of families in this region are in the form of rings. Annular structures grow proportionally and become residential(Figure 15).

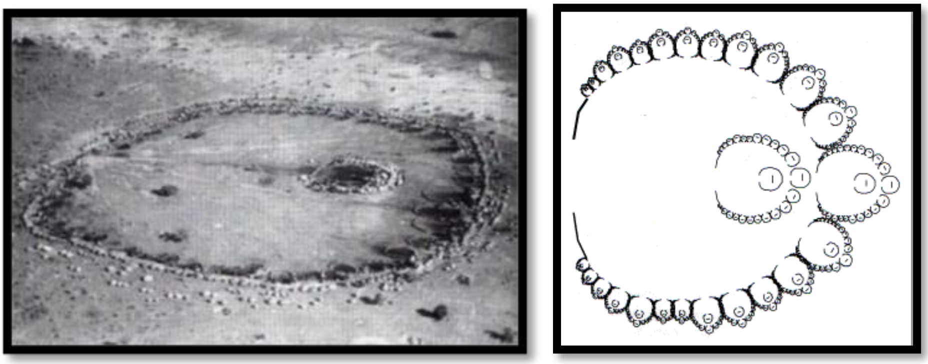

Figure 15. Ba-ila Settlement, Southern Zambia (URL-10)

In India and its surrounding structures, fractal geometry was used in the structural system of the building. The carrier system element is designed similar to the form of the structure (Figure 16).

Figure 16. Hindu Temples (URL-11)

In European architecture, fractal geometry is seen in repetitive details. It is seen that the motifs and column capitals on the facades of cathedrals and churches built with Gothic and Baroque architecture have a form similar to the form of the building. The same setup is observed in the small motifs that make up the large motifs on the façade and the smaller detail motifs that make up the small motifs. These structures, which are frequently encountered in the history of architecture and consist of similar elements, are examples of fractal geometry (Figure 17).

Figure 17. Gothic cathedrals and early early column headings (URL-12)

Since the construction of structures with fractal geometry is costly today, we cannot see fractal structures that have become mass-produced. Designers interested in this subject have done theoretical studies on the relations between fractal geometry and architecture, and some of them have had the chance to apply these studies.

Today, with the development of construction techniques, building materials and technology, fractal geometry has begun to be seen more prominently in buildings. There are examples where we can see fractal geometry in the whole structure rather than a building element.

One such example is the Habitat 67 residential complex built by Moshe Safdie in Montreal, Canada, in 1967. The designer working on the Three-Dimensional Modular Building System during his master's thesis designed the Habitat 67 project, inspired by the movements of metabolism and Brutalism.

There are 146 residences in the Habitat 67 complex, which reached its general lines with the placement of 354 prefabricated reinforced concrete modules. Although the reinforced concrete modules seem to be placed irregularly, they are placed in a certain fractal order (Figure 18).

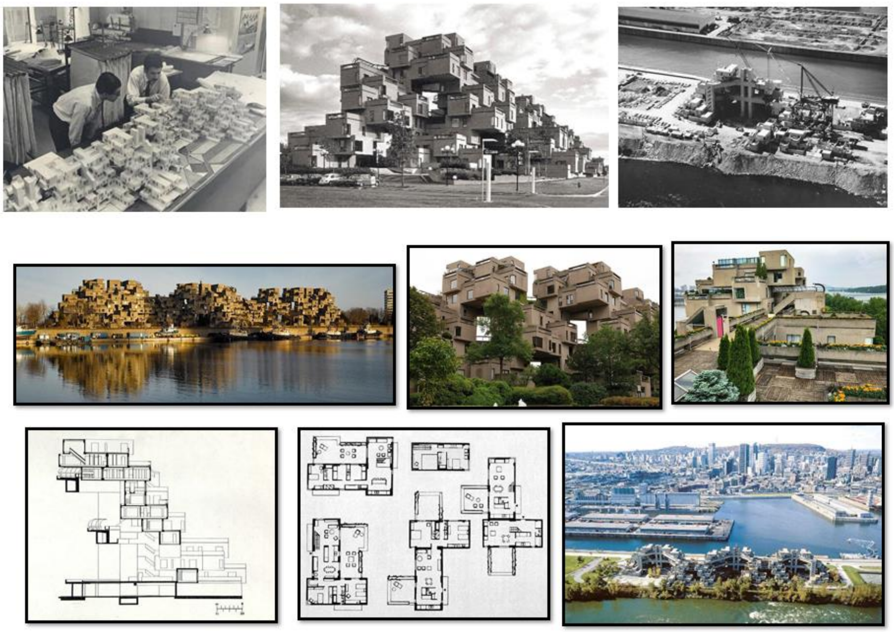

Figure 18. HABITAT 67 (URL-13)

21st century architecture has been influenced by the concepts of "fractal" and "self-similarity". When the examples of contemporary architecture are examined, it is seen that various structural forms that have not been seen before and unfamiliar have emerged, and that there are architectural approaches based on very different phenomena in the conceptual sense.

The Arab World Institute was built in 1987 by Jean Nouvel in Paris, France. The façade design of the project was inspired by the repetitions of Arabic decorative art. Facade elements created by using the working principle of the camera diaphragm provide light control by opening and closing. In this way, a repeating fractal pattern was formed on the façade. The designer has created a synthesis by using technology and Arabic arts together in his facade design. The façade system has photosensitive diaphragms that regulate the amount of light allowed to enter the building. The diaphragm creates different geometric patterns at various stages. Square, circle and octagonal shapes are produced on the facade with the diaphragm moving in the direction of the incoming light. Thus, both light and openings are displayed on the facade(Figure 19).

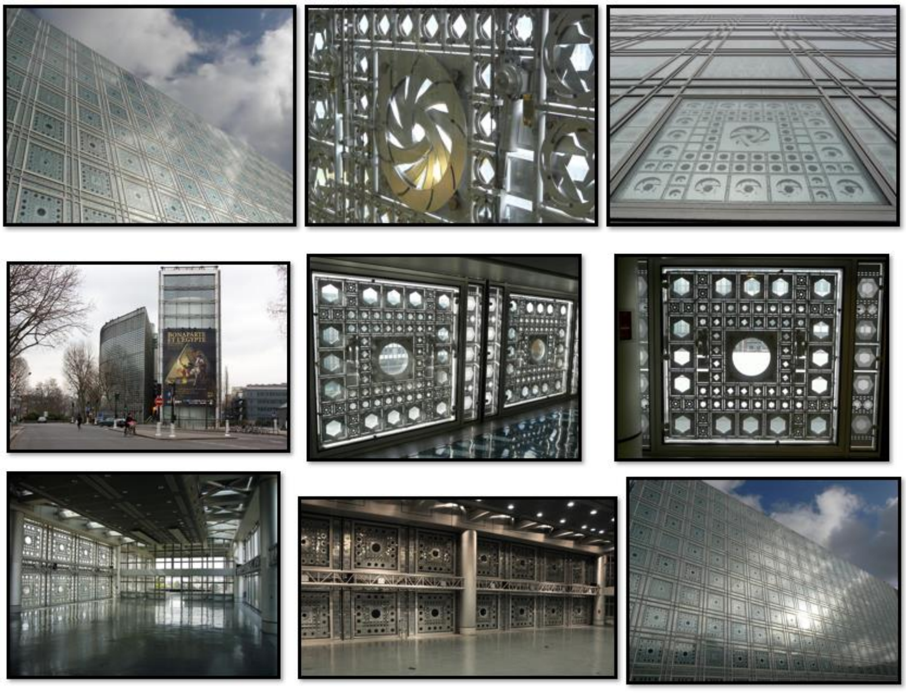

Figure 19. Le Arab World Institute (URL-14)

In Federation Square and surrounding structures designed by LAB Architecture Studio in Melbourne, Australia in 2002, fractal geometry is seen to be used in façade system part design and interior structure design (Figure 20).

Figure 20. Federation Square and Surrounding Buildings (URL-15)

Louvre Abu Dhabi Museum roof cover and roof carrier structure designed by Jean Nouvel in Abu Dhabi in 2017 were inspired by fractal geometry (Figure 21).

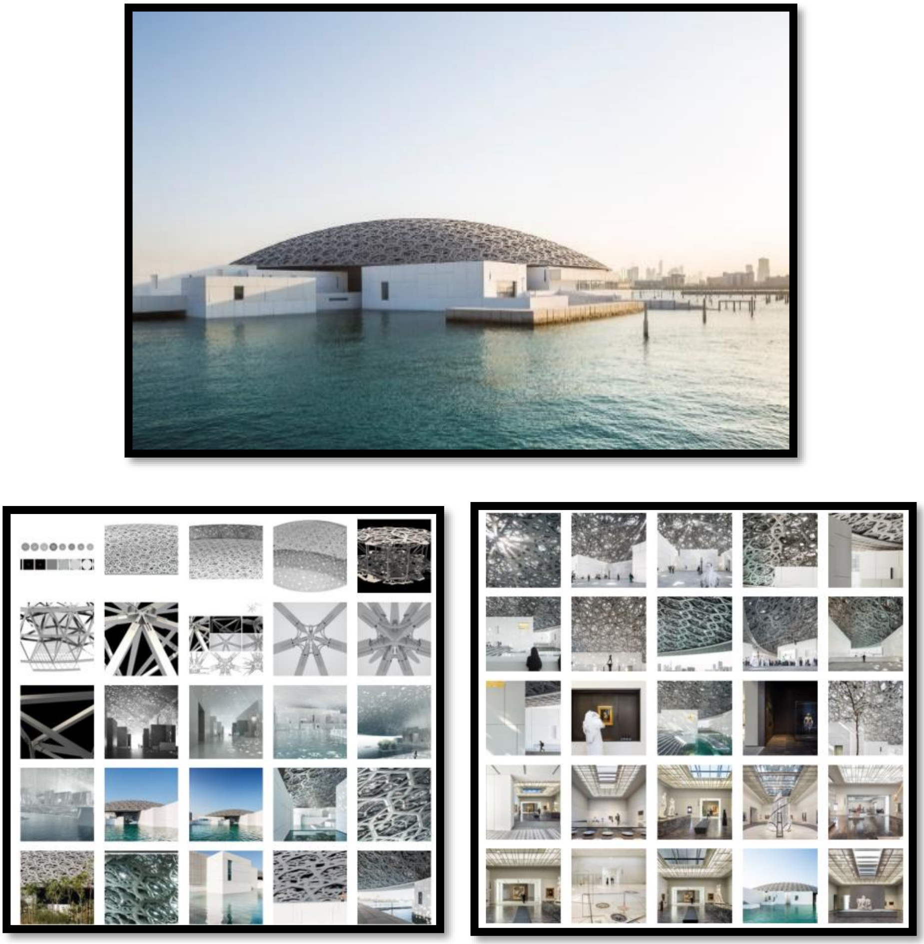

Figure 21. Louvre Abu Dhabi Museum (URL-16)

3.2.4. Voronoi Diagram

The Voronoi diagram is named after the mathematician Georgy Voronoy. The first idea of applying spatial division in this way was the method of explaining the distribution of matter in the universe mentioned by Descartes in 1644. (Pokojski et al., 2018)

Then, this method was presented by Drichlet in 1850 and it was named Dirichlet tessellation (Okabe et al., 2009).

In 1908, Russian mathematician GEORGY developed an algorithm using Voronoy diagram. In the field of mathematics, a voronoi diagram is a way of solving or separating a 2-dimensional space or surface into areas based on the initial set (Shadmand, 2015).

With the determination of the points defined as nuclei in the shapes observed as mixed in nature, the order they have can be revealed in a simple way with the voronoi diagram. Examples include dragonfly wing, giraffe skin, tortoise shell (Shadmand, 2015) (Figure 22)

Figure 22. Examples of Voronoi diagrams in Animal Bodies (Yavuz & Çam, 2022)

Voronoi diagram is created in 3 stages. In step 1, an area is determined and core points called regions are placed. In the second stage, the nuclei are combined with lines. In the 3rd step, the cell borders are drawn at equal distances from the 2 nuclei and the voronoi diagram is created. The nuclei of the resulting cells are equidistant from neighboring cells(Figure 23).

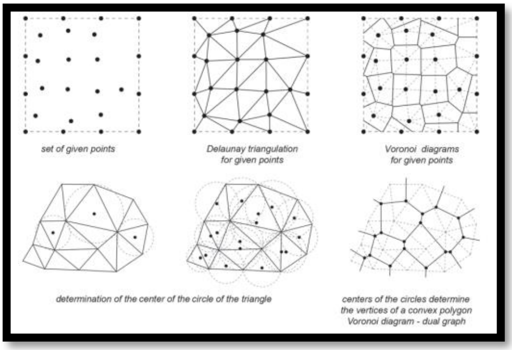

Figure 23. Voronoi Diagram Formation Stages (Rokicki & Gawell, 2016).

Voronoi diagrams consist of 2 elements as region and cell. These cells and regions always maintain their basic properties geometrically (Figure 24).

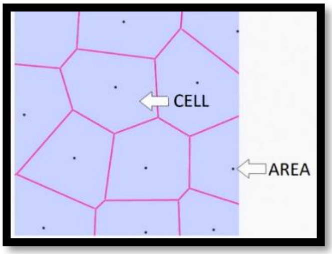

Figure 24. Voronoi Diagram Region and Cell Elements (URL-17)

Each cell boundary is always the same distance from the 2 closest regions (Figure 25).

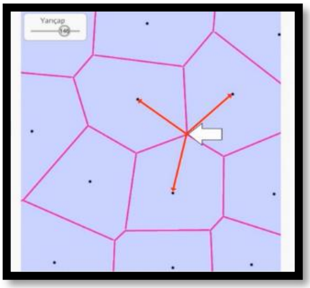

Figure 25. Voronoi Diyagramı Bölge ve Hücre Elemanları (URL-17)

The point where the 3 cell borders intersect is equidistant from the 3 nearest regions (Figure 26).

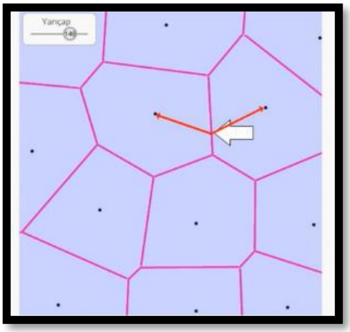

Figure 26. Voronoi Diyagramı Bölge ve Hücre Elemanları (URL-17)

Thanks to the developing technology and science, architectural designers have come up with different projects they created with the voronoi diagram. In the examined design examples, the voronoi diagram was used to create the form, structure and facade composition of the building.

The Hourglass Corral project, designed by DECA Architecture in Milos, Greece in 2012, is shaped by natural topography conditions. In the project, a connection was established between nature and the building by using a green roof, and the project, which was cooled by sea breezes and heated by sunlight, was designed by preferring passive air conditioning systems. In addition to the project design, the name of the house is inspired by the Voronoi diagram. With the Voronoi formula, the interior furnishings are placed in such a way that they have the most space compared to the neighboring areas. Thus, space efficiency is increased indoors (Kutlu, 2021) (Figure 27).

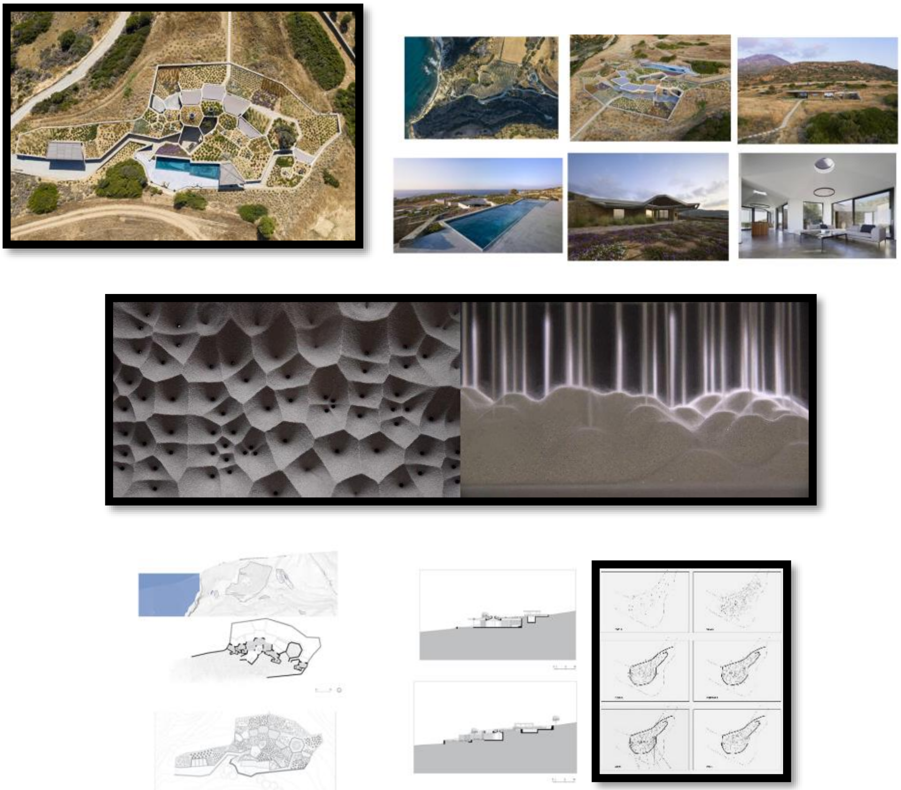

Figure 27. Hourglass Corral (URL-18)

Another example is the ITKE Research Pavilion designed by ITKE Stuttgart University in Stuttgart, Germany in 2011. In the project, the biological principles of the plate skeleton morphology of the sea urchin were transferred to the architectural design. The project was supported by new computer-based design and simulation methods as well as computer-controlled production methods for building application. Thin plywood (6.5mm) was used as the material.

The plates and finger joints of each cell were produced with the university's robotic manufacturing system. Then the plywood panels were brought together to form cells(Figure 28).

Figure 28. ITKE Research Pavilion (URL-19)

At a conceptual level, the decision to place Voronoi cells along concrete pathways and main stage walls in the Hota Outdoor Stage designed by ARM Architecture in Australia in 2018 makes the model read much more convincingly as a form of growth emerging from the space. The Voronoi Diagram is a unique design motif that defines the shapes on the walls, canopies, pathways and garden beds of the outdoor scene (URL-20)

Rather than succumbing to Voronoi's viral-like features or registering as a powerful overlay on existing terrain, the resulting structure looks more like a bulge. In this context, the project also does a remarkable job of concealing (or at least downplaying) key pieces of infrastructure and technology that allow it to house up to 5,000 spectators, a black box theater and fully equipped function room (URL-21) (Figure 29).

Figure 29. Hota Outdoor Stage (URL-21)

4. Conclusion and Suggestions

Mankind has learned to imitate nature by experiencing it in the process of living in nature. Humanity has become one with nature over time and has seen itself as a part of nature. Man, who sees nature as a source of inspiration and thus develops himself with what he learns from nature, has left traces of nature and his own life in every design he has created.

The aesthetic concern in design and the desire to reach the best affected the designer during composition creation. Designers used the defined and known geometric proportions unconsciously at first. Later, thanks to the concepts of Fibonacci sequence, Golden Ratio, Fractal Geometry and Voronoi Diagram, which were revealed as a result of researches especially in the field of mathematics, they began to consciously use them in their designs by explaining the aesthetics in nature with numerical and geometric data.

Designers, who examine and analyze the geometry of nature, continue to be inspired by nature in their designs and with the contributions of computer programs renewed from the past to the present, they have begun to include the geometric order in nature effectively in the form, structure and facade compositions of the building.

Thus, in the process to date, thanks to trial and error period in building design, scientific research knowledge about the use of order and aesthetics in nature in buildings, awareness of imitating nature and technology have developed into its final form.

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Ethics Committee approval was not required for the study.

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Analysis of Public Buildings in the First National Architectural Period by Plan and Façade: Example of Afyonkarahisar

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1. Introduction

Throughout the history of the world, many important events such as war, technology, revolution, epidemic have significantly affected the change and development of countries in the social, political, political, economic and cultural context. The most important events affecting the changes and developments in the countries; It can be listed as the Industrial Revolution, the French Revolution and the two world wars. The changes and developments of the countries have shown themselves in the field of architecture as well as in many different fields. Especially after the Industrial Revolution, the advancement of technology, the emergence of new materials, the use of machines played a very important role in the change and development of architecture. With the proclamation of the Republic, the regime that changed in the country, political, social, cultural and of course; reflected its influence in the field of architecture.

Sözen & Tanyeli (2007) stated that the nationalism that emerged with the proclamation of the Second Constitutional Monarchy in 1908 was reflected in architecture, and in this period between 1910-1930, which is known as the 1st National Period Architecture; He emphasizes that the forms of Turkish architecture are reinterpreted in building plans and especially on their façades. The Committee of Union and Progress, especially in the society after the Second Constitutional Monarchy; in addition to bringing innovations in the political, economic, cultural and artistic fields, it was also influential in a new architectural approach. In particular, the architectural understanding formed within the framework of Ziya Gökalp's ideas of "Turkism" appears as "national architecture", "national Renaissance" and "Neo-classical style" (Sözen, 1984). In this period, which is also known as the First National Architecture Style, which lasted until 1930, the efforts of Architect Vedat, Architect Kemalettin Bey, Muzaffer Bey, Julia Mongeri and Arif Hikmet Koyunoğlu (Kızıldere & Sözen, 2005) to create a national style (Sözen, 1984) architects came to the fore with their works reflecting the characteristics of the period. It is possible to find the Western influence in the lines of these architects who were trained by foreign architects in the West, but the aim of the architects of the 1st National Architecture Period was to design with the understanding of the Turkish movement and to refer to Ottoman architecture (Yavuz, 2009).

While the architectural examples of this movement were first seen in big cities such as Ankara, Istanbul and Izmir, later this movement affected small cities as well. In this period, new structures were built in order to reveal the national identity of the country (Aslanoğlu, 2001). Ural (1994) states that the works that started with the effort to create a new nation were first built as public buildings (such as banks, hospitals, palaces, schools), and then apartments and office buildings were built. The architectural education given in Sanayi-i Nefise and Engineering School, two important educational institutions in this period, laid the groundwork for the national architectural understanding (Çubukçu, 2021). In the cities that were devastated after the War of Independence, many buildings were needed that could serve different functions. Due to the limited financial resources, the need for a new building had to be met quickly. For this reason, the reproduced buildings were designed within the framework of the adopted style (Sözen, 1984). The most important feature of the buildings of the First National Architecture Period was the combination of the building elements and decorations that make up the Ottoman architecture, and the design principles and construction techniques of the West (Bozdoğan, 2015). Its history started with the First National Architecture Period, which adopted the approach of emulating Ottoman architecture, and then the Modern Architecture Period under the name of New Architecture became effective.

In the process called the First National Architecture Period, it was seen that especially public buildings were needed and public buildings were built due to the changing regime and state order. To shed light on the past and roots of modern architecture, there are studies in the literature in this field (Berber, 2010; Durukan, 2006, Arslan & Alagöz (2015a), Arslan & Alagöz (2015b); Alpagut, 2005; Çubukçu, 2021). By same motivation in this study, the architectural features of the public buildings from the city of Afyonkarahisar, bearing the characteristics of the First National Architecture Period were analyzed in this study. The plan schemes and façades of the Zafer Museum and Rıza Çerçel Cultural Center public buildings, which are located in Afyonkarahisar and whose construction years coincide with the First National Architecture Period, were made and compared with the architectural features of the period.

2. Architectural Characteristics of Public Buildings of the First National Architectural Period

The trend, which started to be adopted in 1910, did not lose its influence immediately after the establishment of the Republic. On the contrary, its use in the architectural context has increased considerably in the newly established country and the nation environment that is being tried to be established. In addition, in the country, which could not keep up with the external developments due to the economic difficulties experienced, it was possible to create a national consciousness in terms of architecture with this movement (Sözen, 1984). According to Alsaç (1976), "national architecture" approaches in the Early Republican Period are examined in two periods. The first of these periods is the “1. National Architectural Movement”, and the second one, “2. National Architecture Movement. The movement called "national style", which defended the Ottoman and Seljuk approaches until the 1930s, was influential.

The First National Architecture Period, which started with the proclamation of the Second Constitutional Monarchy in 1908 and continued until the 1930’s, developed with the influence of the "Turkism" movement, which showed its influence in the fields of language, religion, politics, philosophy and law adopted by Ziya Gökalp (Sözen, 1984). This architectural understanding, pioneered by Architect Kemaleddin and Architect Vedat Bey, includes an eclectic attitude that references the building elements and decorations that make up the Ottoman and Seljuk buildings. In this period, Ottoman architectural elements (dome, arch, portico, portal, etc.) ornament motifs were used, especially by emphasizing the exterior façades. Although the identity of architectural approaches in this eclectic attitude is called “national style”, “national architecture” (Sıkıçakar, 1991). It is seen that it contains the features of the Neo-Baroque and Art Nouveau movement, and the architectural elements of classical

Ottoman buildings (Ertuğrul, 2007) are reflected in the buildings of this period. In summary, it is aimed to design a new Turkish National Style that will be formed by the interpretation and evolution of the works of Classical Turkish Architecture. This movement, which was formed with the claim of revealing the Turkish identity, tried to create new architecture by feeding on elements such as wide eaves, domes, arches, overhangs inspired by old religious buildings. Aslanoğlu (1984) states that the 1st National Architectural Style is dominant in the public buildings that existed in the 1920s and 30s. The monumental features in the Neo-Classical style, in which the entrance area defined by two columns and three spaces and defined by stairs, is especially exaggerated, became the characteristics that define the formation of the public buildings of the period (Aslanoğlu, 1984). Stating that among the features requested in the projects in the competition specifications of this period, criteria such as 'emphasizing the young Republic, representing the reforms, robustness, functionality, local materials and Turkish character' were at the forefront (Meltem, 2013). stated that it was founded on the reflection of the Turkish character and power.

Since the architecture of the public buildings of the period was formed by adapting the Neo-classical architectural features to the Turkish style; Turkish Neo-classical appearance is also exhibited in the buildings (Alpagut, 2005; Alsaç, 1976). According to Aslanoğlu (2010), the use of Ottoman building elements and decorations, especially on the exterior façades, kept national and national feelings alive. In this context, the style of the First National Architecture period has been a style mostly used in the architectural shaping of large, public buildings in order to increase the nationalist effect on the Turkish people.

2.1. Plan Features of Public Buildings of the First National Architectural Period

Public buildings of the First National Architectural Period; It was built in line with the needs of the state, such as banks, educational buildings, directorate buildings, parliament, organizational buildings, courthouse, museum and PTT buildings. It is possible to mention that the public buildings of the period were generally located in the city centers, and that there were also public buildings located in the corner plots, although rarely. The common feature of the buildings built in this period (Yaldız & Parlak, 2018) is that the rectangular plan scheme is used regardless of their functions, wide eaves, arches are used in the windows, and the symmetrical planning approach is dominant. According to Yavuz (1973), the dominance of a symmetrical order both in the planning and the façade, the façades arranged in three different styles in accordance with the Renaissance architecture, and the division into three parts are the common features of the architecture of the period. Although the interior spaces of public buildings are simply arranged to respond only to the function, it is seen that the façade arrangements are exaggerated and natural lighting is given importance. In the public buildings of the period, there are generally symmetrical and axial mass arrangements and plans, and the schemes used, the measures and proportions in the masses and spaces, and the composition rules are similar to European Neoclassicism. (Eldem, 1973). When the plan features of the buildings of the First National Architecture period are analyzed, it is possible to see that most of them were designed with a single architectural language. In addition, the architects of the period, while emphasizing the Turkish identity, emphasized the formal elements, but did not adopt the idea that the form should overlap with the functions of the buildings. The characteristic plan features of public buildings built during the National Architecture period are given in the table (Table 1).

Table 1. Plan Characteristics of the Buildings of the First National Architectural Period

• Has a single architectural language
• Function is not important
• Rectangular plan scheme
• Symmetrical plan type
• Natural lighting is important
• Hall or gallery space in the middle
• Axial mass arrangement

2.2. Façade Features of Public Buildings of the First National Architectural Period

In the public buildings of the First National Architectural Movement period, the building elements and decorations in the architecture of the Seljuk and Ottoman periods were applied in new orders on the façades. The striking element of the façades is the importance of the entrance area, its diversification with marble columns, tile panels and decorations. There is a gradation on the façades of the buildings, both horizontally and vertically. (Yaldız & Parlak, 2018) Façade elements such as pointed arches and domes in Ottoman and Seljuk architecture, (Yavuz, 1973), column capitals with lozenges and muqarnas, moldings tiled panels decorated with geometric reliefs, wide eaves with ornamented lower surfaces, corner towers, false domes The effect of monumentality is increased by using. Building entrances are generally designed as central and grand entrances. The entrances occupy a unique place on the moving façades and marble columns, tile panels and metal decorations define the entrances. Most of the entrances are elevated by a few steps and are accentuated by small balconies that open to the outside just above them.The characteristic façade features of public buildings built during the First National Architecture period are given in the table (Table 2).

Table 2. Façade Characteristics of the Buildings of the First National Architectural Period

• Monumentality with traditional Seljuk and Ottoman architectural forms
• Marble columns, tile panels
• Column headings with muqarnas
• Moldings decorated with geometric reliefs
• A gradation both horizontally and vertically
• Pointed arch and dome
• Wide eaves with decorated lower surfaces
• Corner towers
• Elevated entrance with few steps
• Small balconies opening to the outside above the entrance

3. Material and Method

In the study, it is aimed to analyze the public buildings of the First National Architecture Period in Afyonkarahisar in line with the architectural features of the period. Within the scope of the study, a model as created (Figure 1). According to the model, firstly, the architectural features of the First National Architecture Period were investigated, and the plan and façade features were revealed. Secondly, public buildings built in the First National Architectural Period (1908-1930) in Afyonkarahisar were investigated, and the criteria for the selection of the buildings were determined as their existence today. In this direction, Zafer Museum and Rıza Çerçel Cultural Center were included in the study. Then, the buildings were analyzed by making plan diagrams and façade readings and analysis tables were created (Table 3, Table 4).

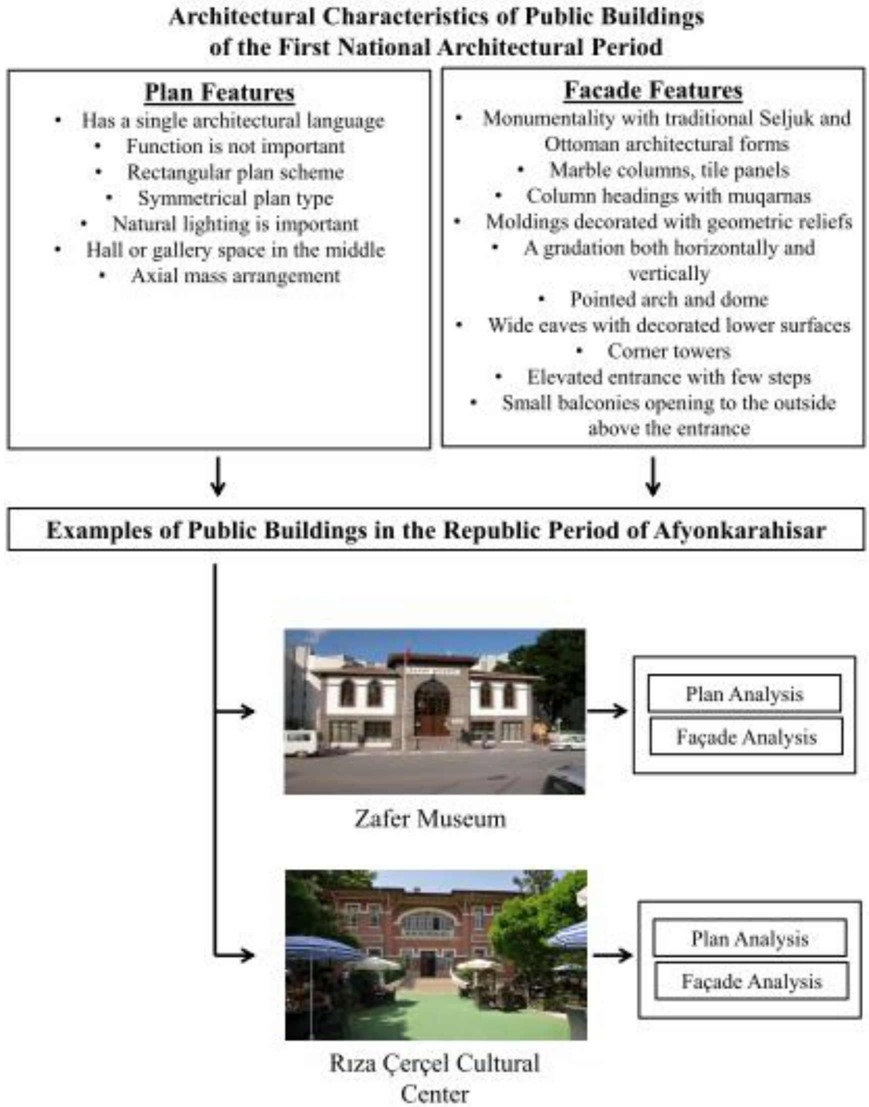


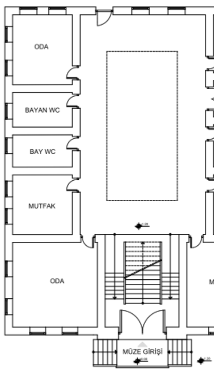
Figure 1. Model of the study

3.1. Zafer Museum

The building has the characteristic of being the first specially built municipality building. Although there is not enough information about the architect of the building, which was built in 1919-1920, it is stated that it was built by an Armenian architect (Yüksel, 2005; Üyümez, 1995). The building was registered as a cultural property to be protected by the High Council of Monuments on 11.07.1980 (Abi, 2020a).

Figure 2. Zafer Museum (İnce, 2011)

The building, located in the city square in the center of the city, was built as a two-storey masonry. The building has a rectangular plan and there are rooms lined up on both sides of the rectangular sofa in the middle. When you enter the building, the first floor is reached by the stairs located opposite the entrance and the ground floor is reached by the stairs located on the sides. There are ten rooms on the ground floor (Figure 3), and nine rooms and a meeting room on the first floor (Figure 4) (Uyan, 2004).



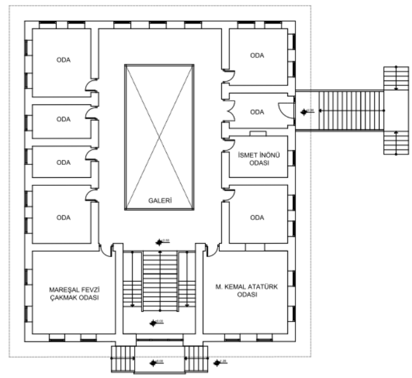


Figure 3. Ground floor plan **Figure 4.** First floor plan (Created by authors)

The main entrance is provided by the pointed arched structure facing the city square, and there are also entrances on the back and side façades of the building. On the side façade, there is a door accessed by a staircase at the corner of the first floor, and on the rear façade, there is an entrance obtained by transforming the window opening to the hall into a door. With horizontal moldings on both sides of the main door, between floors are indicated on all façades (İnce, 2011). The main and intermediate walls of the building are made of stone, the ceiling tiles and roof are made of wood. On the exterior of the building, the perimeter and corners of the entrance door located in the front are covered with andesite stone, the arched windows of the building, the windowsills and perimeter of the arched windows and the keystone on the top are covered with finely carved stone (Figure 5). The entrance eaves of the building are high and decorative ornamented woods are nailed to the eaves. The roof of the building is covered with Turkish style tiles (Abi, 2020a).

Figure 5. Zafer Museum entrance façade (Created by authors)

The building hosted the Afyonkarahisar Congress in 1920, was used as the Greek headquarters until 25 August 1922, and as the command center of the Turkish army after the enemy occupation of Afyonkarahisar on 27 August 1922. The main decisions of the Dumlupınar Pitched Battle were made in this building. The building has a historical significance in this respect. Between 1922-1940, the municipality building was used as the police department between 1963-1985, and on 26 August 1995 it started to be used as the Zafer Museum (Abi, 2020a).

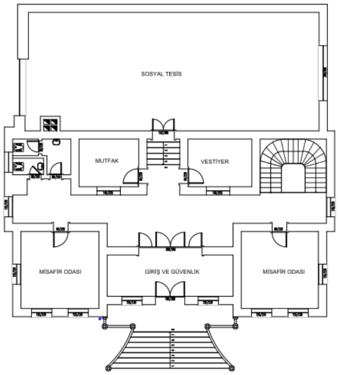
3.2. Rıza Çerçel Cultural Center

The building, which was designed as the Turkish Hearth building, started in 1930, to be used as the branch of the Community Centers in Afyon on 19 February 1932. The projects of the building were prepared by Architect

Arif Hikmet Koyunoğlu, the project designer of the Ankara Türk Ocakları service building (Ilgar, 2001; Interview with Mahmut Ülküer Abi).

Figure 6. Rıza Çerçel Cultural Center (Url 1)

The building, located on Ordu Boulevard in the center of the city, is a two-storey masonry building. The entrance of the building, where the main entrance is on the façade facing Ordu Boulevard, is provided by a nine-step staircase with a marble railing. The entrance hall is reached when you enter through the two-winged wooden entrance door. On the ground floor there are four rooms, wet areas and a staircase to reach the upper floor (Figure 7). When you go up the stairs to the first floor, the corridor connecting the exhibition halls is reached, on this floor there are nine exhibition halls of different sizes and a terrace. Located on the front, the room has a balcony, the front of which is covered with glass and iron joinery (Figure 8).



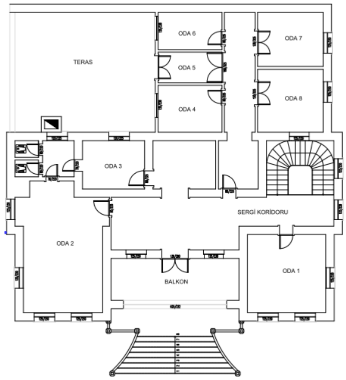


Figure 7. Ground floor plan **Figure 8.** First floor plan

(Afyon Kocatepe University Department of Construction Archive)

The roof of the building is hipped roof and covered with Marseille tiles. The wide eaves of the building are decorated with laths by creating geometric patterns (Uyan, 2004).

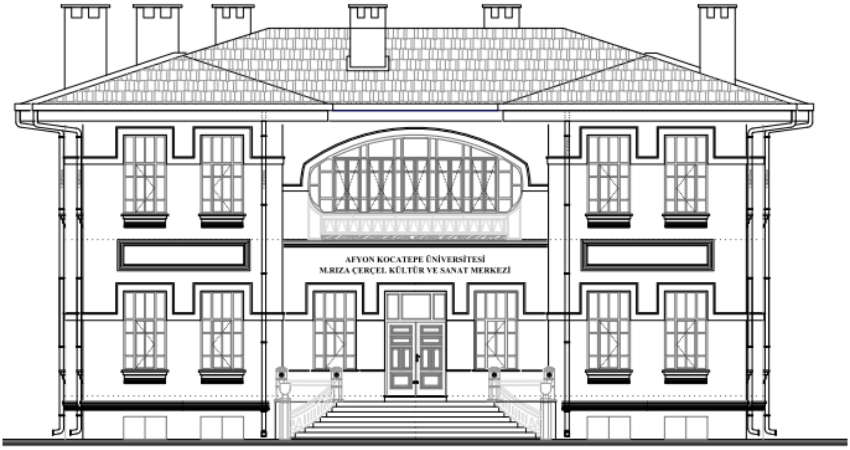


Figure 9. Rıza Çerçel Cultural Center entrance façade

(Afyon Kocatepe University Department of Construction Archive)

It is stated that Atatürk visited this building during his visit to Afyon on 2 March 1931 and wanted the building to be converted into a Community Center, whereupon the building used as a Turkish Hearth was converted into a Community Center (Ilgar, 2001; Abi, 2020b). The building was transferred to the Ministry of Finance upon the closure of the Community Centers and was used as the Revenue Office until 1992 (Uyan, 2004). With the establishment of Afyon Kocatepe University, it started to be used as the Rectorate building, and today it has been used as a cultural center affiliated to Afyon Kocatepe University (Özpınar, 2014).

4. Findings and Discussion

The analyzes made with the plan schemes and façade characteristics of the public buildings in Afyonkarahisar, which have the characteristics of the First National Architectural Period, are shown in Table 3 and Table 4.

Table 3. Zafer Museum plan and façade analysis

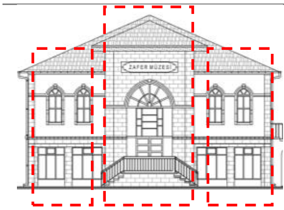
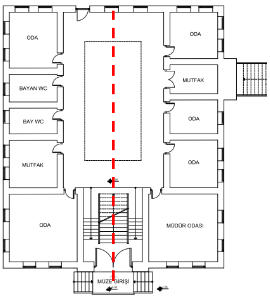
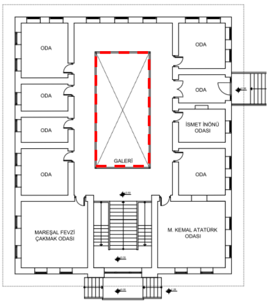
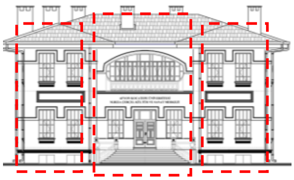
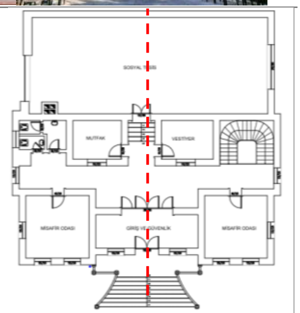
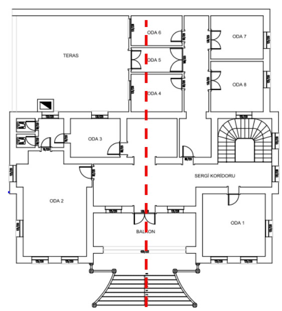
Zafer Museum		
Figures (Url 2, Url 3, Url 4)		
		
	Plan analysis; • symmetrical and rectangular plan, • gallery space in the middle, • axial mass arrangement Façade analysis; • horizontal and vertical gradations, • use of pointed arches in windows, • wide eaves use, • reading floor traces from the front with floor moldings, • elevated entrance with steps, • the façade consists of three parts, •differentiation of the window layout located on the entrance facade above the entrance door from the other window layout	 
Entrance Façade	**Analysis**	**Floor plans**

Table 4. Rıza Çerçel Cultural Center plan and façade analysis

	Rıza Çerçel Cultural Center	
	Figures (Url5, Url 6, Arşiv)	
		
	Plan analysis; • symmetrical and rectangular plan, • the hall in the middle, • axial mass regulation Façade analysis; • horizontal and vertical gradations, • the use of wide and decorated eaves on the lower surfaces, • reading floor traces from the front with floor moldings, • balcony located above the entrance, • elevated entrance with steps, • the façade consists of three parts, •differentiation of the window layout located on the entrance facade above the entrance door from the other window layout	 
Entrance Façade	**Analysis**	**Floor plans**

5. Conclusion and Suggestions

Architectural analysis of the public buildings of the First National Architectural Period in Afyonkarahisar was made on the plan and facade plane. From the data obtained as a result of the plan and facade analyzes of the Zafer Museum and Rıza Çerçel Cultural Center buildings selected within the scope of the study;

• the plan schemes of the buildings and accordingly their facades show symmetrical features,

• entrances to the buildings are provided through an axis of symmetry and a raised entrance with a few steps,

• entrance stairs raised with steps in buildings have decorated balustrades,

• the window arrangement above the entrance door on the entrance facades of the buildings is different from the other window arrangement,

• floor moldings and floor traces are evident from the facade,

• the facades of the buildings consist of three parts,

• wide eaved hipped roofs are used in buildings detected.

In addition, the architectural features of the First National Architectural Period; Features such as the presence of a gallery space in the middle, the use of pointed arched windows, the use of cut stone in the corners and around the entrance door can be seen in the Zafer Museum. The features such as the use of arches in the window above the entrance door, the decoration of the wide eaves with geometric ornaments, and the balcony covered with a glass surface above the entrance can be seen in the Rıza Çerçel Cultural Center. The architectural features of the First National Architectural Period; the use of column capitals with muqarnas, the use of tiles on the façade, the use of structural elements such as domes and corner towers were not encountered in either building.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article contributed. There is no conflict of interest Ş. Ebru Okuyucu or Gamze Çoban.

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Inspiration from Nature in Design: Analyzing Biomimicry Approach in Architectural Design

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1. Introduction

The destruction caused to the planet by human beings is becoming a bigger problem with each passing day. Uncontrolled resource and energy use and environmental pollution are among the most important issues discussed in this context. These problems faced by the world cannot be reduced to a simple one, and they are related to many areas in which human beings are in contact. One of these fields is architecture. Different design ideas have emerged in architecture, and there has been a tendency towards nature-oriented designs. One of these design ideas is the biomimicry approach that emerged by transferring knowledge and methods between the science of biology and the discipline of architecture. In this context, it is seen that innovative production methods are tried and the use of new generation materials and environmental conditions sensitive building envelope or similar tectonics are investigated (Mutlu Avinç & Arslan Selçuk, 2019). Architecture seeks the solution of the damage done to nature by humans in nature, and this search is supported by the use of biomimicry approach and technology.

It is common to think that the biomimicry approach is just an act of copying nature. However, the biomimicry approach is a succinct and creative process in which the original is reconstructed. The biomimicry approach is a solution to the design problem, resulting in an original design. Transferring the logic of the approach will provide a correct understanding of the concept. The aim of the study is to explain the basis of the biomimicry approach, to examine the use of the natural environment in the production and design areas in the past and today, to analyze the purpose of using the process of inspiration from nature in architectural designs and at what levels.The study consists of 3 main parts. In the first part, the historical development of the biomimicry approach will be explained. In the second part, the use of the approach in architectural designs from past to present will be examined. In the third part, the usage forms and purposes of the concept of biomimicry in architectural design will be reinforced with examples of biomimetic design from today.

2. Material and Method

The study was created by the literature review method. The study methodology is divided into three parts: description, analysis of biomimetic approaches and levels, and exemplify. In the first part, the definition of the term of biomimicry and the definition of the use of biomimicry in architecture are discussed. The second part is the subtitle of the second step of the first part and includes the biomimetic approaches and levels. In this part, the biomimetic approaches and levels are explained in detail and expressed with diagrams. The third part includes the headings of sample analysis and drawing conclusions from the samples, together with the data obtained in the second part. In this part, sample structures are analyzed in the context of biomimicry approaches and levels, and the integration of the approach into structures is discussed. In the last step, a general conclusion was drawn from the samples examined(Figure 1).

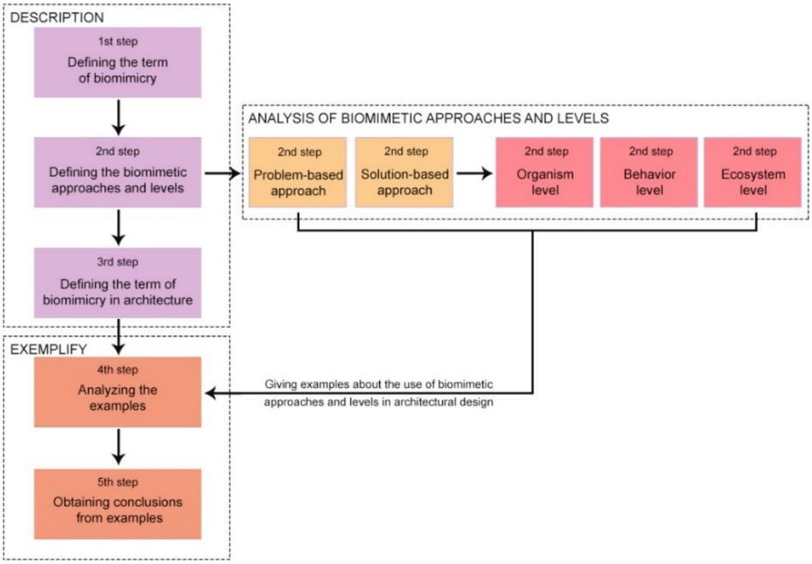


Figure 1. Methodology of the study (by the authors)

3. The Term of Biomimicry and Evolution of Biomimicry

There is a great similarity between organisms in the ecosystem cycle and architectural designs in terms of being functional and responding to conflicting needs. Since nature is a source of inspiration that includes the most appropriate solutions and performance criteria, mankind has obtained solutions by imitating and/or interpreting nature throughout history. With the industrial revolution, human beings started to use the possibilities offered by new technologies to observe and understand nature, which he saw as a source of inspiration. By the 50's, a new branch of science emerged beyond imitating nature, which could be described as learning/adaptation/application from its best ideas. Biomimicry has entered the literature with a general approach such as "emulating strategies", which is seen as the basis of design in biology, and has evolved into a field of science that offers solutions for humanity's design problems by learning how natural forms and processes work in order to create more sustainable designs (Zari, 2007) (Figure 2).

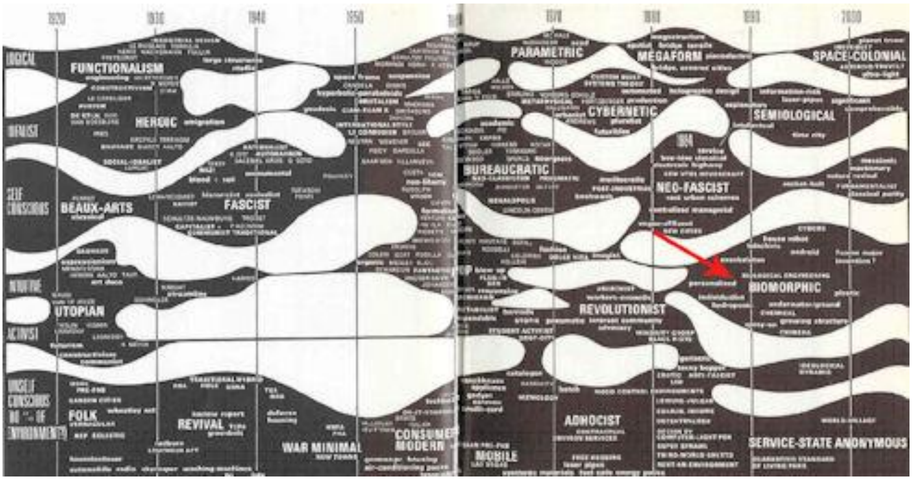


Figure 2. Table of concepts that will affect 20th century architecture envisioned by Jencks in 1971 (Keskin, 2008)

The term "biomimicry" was introduced by Otto Schmitt in 1982 and rediscovered by Janine Benyus in 1997 (Othmani, et al., 2022). The concept transferred as biomimetic in the literature is the adjective form of the name biomimesis or biomimicry and the biomimesis design method describes the applied concepts. Although biomimicry and biomimesis are considered synonymous by some sources, they are separated with slight differences by others. Benyus (1998), defined the concept of biomimicry as "a new discipline that studies nature's best ideas to solve human problems, and consequently imitates their designs and methods". On the other hand, Gruber (2011), for biomimicry, said “It is the study of the disciplines of biology and architecture with innovative potential for architectural problems." When these definitions are examined, it can be concluded that biomimicry is the process of mimicking nature in design (Fedakar & Yamaçlı, 2022). While talking about biomimicry, the definitions of mimicry or mimesis should also be examined. Although these two terms are natural phenomena, they should be distinguished from imitation, copy and pastiche. Mimicry is an exploratory and creative process and is based on creating something new from an original model, recreating the original. Copy is the reproduction of the existing. Mimicry is about substance and form, while copy is only concerned with appearance. Pastiche, on the other hand, is a partial and incomplete copy. The order of nature constitutes the archetype and the ideal. Nature is at the core and beginning of mimicry. Human perception of nature causes him to imitate it in different dimensions (Yürekli & Yürekli, 2004). However, biomimicry is not just an environmental and sustainable design approach in which an existing object or system in nature is imitated and produced in the same way. This discipline is the close examination of a living thing or ecosystem and then the adaptation of this information in a logical and scientific way by integrating it with design principles (Abbaslı, 2019).

The biomimetic design approach is used in many design disciplines. For example, in the bionic vehicle concept developed by Daimler's R&D team, the ostracion cubicus fish was examined and solutions were produced so that the car could move with minimum energy (Figure 2). Another important example is the discovery of the self-cleaning paint technique on building facades, inspired by the morphological structure of the lotus leaf (Abbaslı, 2019) (Figure 3).

Figure 2. Daihmler's bionic vehicle concept (Abbaslı, 2019)

Figure 3. Self-cleaning paint produced by mimicking the lotus flower (Abbaslı, 2019)

3.1. Different Biomimetic Approaches

In the biomimesis approach, researches are carried out from biological analogies, appropriate principles are determined from the examined samples, abstraction is made from biological samples with suitable principles, the determined method is tested and analyzed, and thus the product of biomimetic design is reached (Yazıcıoğlu & Selçuk, 2019). In the literature, there are basically two different approaches in the field of biomimetic design. The first of these is the solution-based approach (biology to design) (Figure 4). In this approach, a biological solution is started and a principle is derived from this solution. Then, it is determined how this principle will be adapted to which problem (Avinç & Selçuk, 2019).

Figure 4. Solution-based approach steps (By the authors)

In the solution-oriented approach, the solutions first determined in a biological system are adapted to the technology. The principle or principles are formed from the adapted solutions. Then problems in any design discipline are investigated and defined. In the last step, principles based on biological systems are applied to the design problem.

The second approach is the problem-based approach (Figure 5). This approach is referred in the literature by different terms that mean the same thing as biology-facing design, top-down approach, and problem-focused biological-inspired design. In this approach, the process begins with the definition of the problem. After the problem is defined, the solutions that exist in nature are researched and defined; The solution and the problem are analyzed together, and the principles are determined and applied in the design. It has been argued that it is only possible to reach biomimetic solutions without interdisciplinary work with biologists or ecologists and without an in-depth scientific intuition. However, in this approach, the technical analysis of biological information is limited due to the superficial scientific understanding.

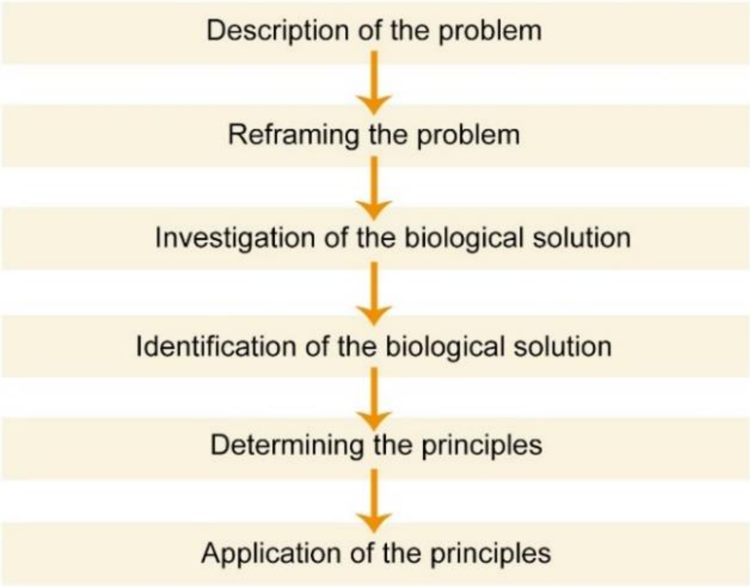


Figure 5. Problem-based approach steps (By the authors)

3.2. Biomimetic Design Levels

In the solution-based and problem-based biomimetic approach, which was expressed in the previous section, there are three biomimetic levels that can be applied to the design problem: organism, behavior and ecosystem (Figure 6).

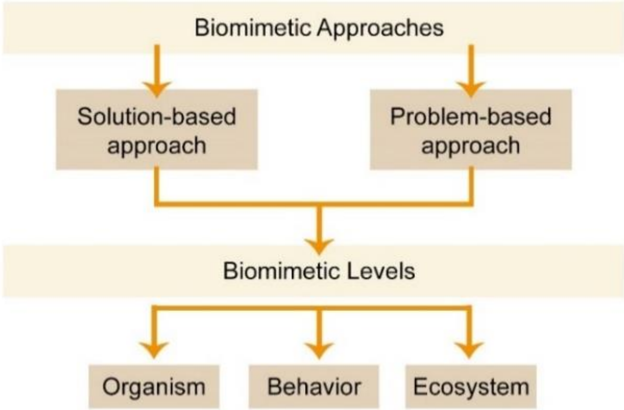


Figure 6. Biomimetic levels (By the authors)

The organism level may refer to a whole organism such as a plant or animal, or it is used to mimic a certain part or all of the organism. When a design is inspired at the organism level by any entity belonging to the natural environment, the form of the design reflects the physical characteristics of the inspired organism. For example, when inspired by a snail at the organismal level, the form of the design resembles a snail. The second level expresses the behavior and includes the transfer of holistic behavior of the organism in a specific/limited or broader context. When the design is inspired at the behavioral level, the design mimics the behavior of the inspired organism. For example, the façade of a building whose design was inspired by the sunflower at the behavioral level may have kinetic parts that move with the sunlight. The third level means mimicking the entire ecosystem and this includes transferring its general principles.

Regardless of the level of inspiration from nature, all of the levels are inspired by nature through five different extents: material, form, function, process and construction technique (Figure 7). In the form extent, the shapes of the entities in nature, the materials used in the formations in nature at the material extent, the methods followed in the formation of the constructions in the nature at the construction technique extent, the tasks exhibited by the living creatures in the nature in the function extent, and the formation phases of the constructions in nature at the process extent, these features are mimicked (Zari, 2007).

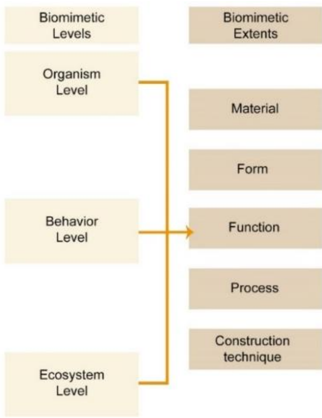


Figure 7. Biomimetic extents (By the authors)

Organism, behavior and ecosystem levels; material, function, form, process and construction technique extents were examined in Zari's (2007) study according to the biological characteristics of termites, the characteristics of the ecosystem they live in, their nests and their techniques of building their nests. In this way, it has been shown how a building that can be built with a biomimicry approach is inspired by which biomimetic level and size and how it can be examined in the context of biomimicry.

Table 1. Application of biomimicry in design-termite example (Adapted from Zari, 2007).

Level of Biomimicry	Extent	Sample Building Mimics the Termite
Organism	Form	The building looks like a termite.
	Material	The building is made from the same material as the termite's skin.
	Construction	The building is made the same way as a termite.
	Process	It works the same way as a termite; produces hydrogen through meta-genomics.
	Function	The building recycles cellulose waste and creates soil like a termite.
Behavior	Form	The building looks like a termite termite mound.
	Material	The building is made from the same materials used by a termite in a building.
	Construction	It is built in the same way a termite would build its nest.
	Process	It works the same way as a termite mound or mimics how termites work together.
	Function	The building functions similarly to termite or termite mounds.
Ecosystem	Form	It looks like an ecosystem a termite would live in.
	Material	It is made from the same materials that a termite's ecosystem is made from.
	Construction	It is assembled in the same way as a termite's ecosystem.
	Process	It works the same way as a termite's ecosystem; it captures and converts energy from the sun and stores water.
	Function	It works in the same way as a termite's ecosystem and be a part of a complex system.

4. Biomimicry In Architectural Design

Design approaches have changed many times from past to present in parallel with the conditions of the time, people's needs and perspectives. However, being inspired by nature has never been a new and forgotten activity for human beings, and has included nature in its life since its existence. From the first human, the need for shelter is one of the most basic needs of human beings. Mankind, who uses caves and tree hollows for their protection and shelter needs, started to establish shelters by examining natural forms and structures, feeling the need for shelter. By this way, mankind, who imitates nature, has developed construction techniques.

Architects have been searching for answers from nature to their complex questions about different kinds of structures. Because of this, they have mimicked a lot of forms from nature to find answers to their questions, create better and more efficient structures for different architectural purposes (Pathak, 2019). The use of forms in nature in architectural formations in the period A.C. started with the use of human form at the level of building elements and decoration in Ancient Greek architecture. The proportions in forming in ancient Greece were similar to the human proportion. In 1436, Filippo Brunelleschi designed the dome of the cathedral in Florence by examining eggshells. In the early 19th century, naval architect George Cayley studied the skins of dolphins to streamline the navigation of ships on the water surface. After the biomimicry movement, which became more evident with Gaudi in the 19th century, many architects were inspired by nature in a simple and formal sense

(Figure 8). Because the perfect ratio that the human eye seeks is already hidden in nature.

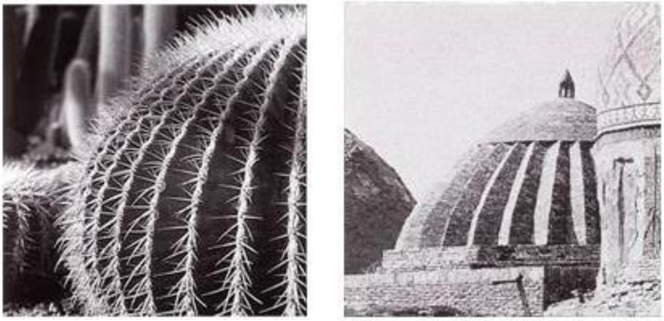


Figure 8. A dome inspired by a cactus (Keskin, 2008)

In 1851, the Crystal Palace building was inspired by giant water lilies, and James Paxton designed the structural system of the building. The design of the Eiffel Tower, built in the 19th century, was inspired by the femur bone at the organismal level (Figure 9). The outward projections of the tower resemble the femur bone (Radwan & Osama, 2016). The reason for its inspiration is to provide resistance against bending and shear effects due to wind.

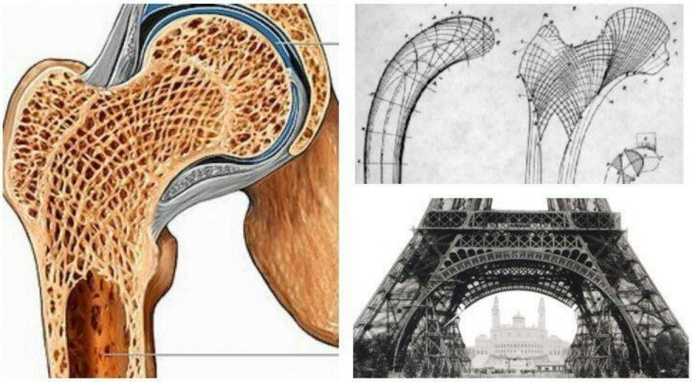


Figure 9. Eiffel Tower inspired by femur bone (Molinari, 2020)

During the same century; many designers such as Le Corbusier and Frank Lloyd Wright were inspired by nature. Frank Lloyd Wright incorporated organic architecture into his designs, while Le Corbusier affirmed as biology to be "the great new word in architecture and planning" (Radwan & Osama, 2016). In the 20th century, the Sydney Opera House was inspired by seashells and aimed to provide lightness of construction and structural durability. In the same century, the design of the Guggenheim New York Museum was inspired by living things in nature at the organism level and an organic structure form was created (Sayed et al., 2020).

5. Biomimetic Architectural Design Examples

Inspiration from nature, which has become a design method and tool in the field of architecture, directly or indirectly, in line with the process flow diagrams developing from biology to architecture and from architecture to biology, is expressed by different names in different periods, today it is called "biomimicry in architecture" (Yorulmazel, 2020). Today, unlike its purpose in the past, biomimicry is used in architecture to find solutions to the threats faced by the world due to excessive resource use, which has become a major problem with the industrial revolution. The use of the approach in architecture is seen in the context of kinetic designs, parametric designs and organic architecture.

5.1 Eastgate Office Building

Eastgate office building was built in 1996 in Harare, Zimbabwe (Figure 10). The architect of the building is Mick Pearce (Fıstıkçı & Gündüz, 2021). Eastgate office building has several differences from conventional office buildings. In the design process, a problem was determined first, and a solution was found to this problem by being inspired by nature. The inspiration for the design of the building is the nests of termites.

Figure 10. The facade of the Eastgate Office Building (Lynch, 2020)

Termites are creatures that build their nests according to the climatic characteristics of the region they live in. In termite nests, it is important that the nest is ventilated, the ambient temperature is constant and the humidity level is 89-99% since they must live in a humid environment. Some termites living in rainy areas build mushroom-like nests with a protruding roof that prevents damage to the walls of the nest in heavy rains In termite nest species seen in northern Namibia, it was observed that the tower mounds sloped to the north and had this inclination of 19 degrees. This angle is equal to the mean zenith angle of the sun for Namibia (Tekin & Kurugöl, 2011). On the other hand, Termites living in Australia make their nests flat in order to ensure that the east-facing part of their nests is warmed by the sun rays when the sun rises. When the sun goes down, the nest receives the sun's rays from the other side. There are also termite nests ventilated with a chimney system. In these nests, life is under the ground, and the part above the ground consists of chimneys. The humid and CO2-

rich air in the environment rises and is evacuated from the chimney; With the air flow formed, the cold air under the ground rises under the slot (Gould & Gould, 2007) (Figure 11).

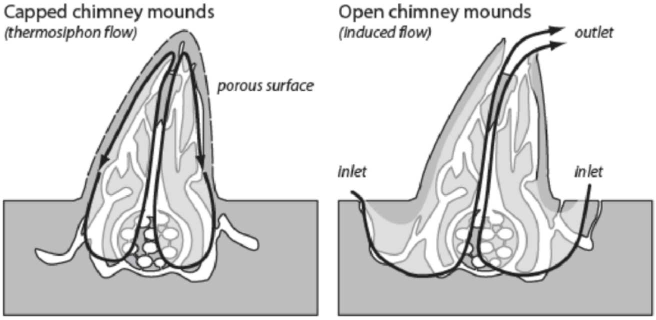


Figure 11. Termite nests ventilated with chimney system (Turner, 2008)

The problem-based biomimetic approach was used in the design of the Eastgate office building. In the design process of the building, a problem was first identified. The identified problem is excessive energy use. For this reason, in order to provide indoor thermal comfort in the building by consuming less energy, biomimetic design was used and inspired by termite nests. The principle of termite nests ventilated with a chimney system was applied in the building, no mechanical ventilation system was used, and the building became the first building with a natural cooling system in the world (Yılmaz, 2021).

The building and the storage in the basement absorb the heat caused by the environment and human activities during the day, and at night, the cold air descends to the basement floor and initiates the convective flow by removing the hot air absorbed during the day from the roof vents. In addition, this cold air is stored and distributed to the offices the next day through perforated floors and skirting ventilators (McKeag, 2008) (Figure 12).

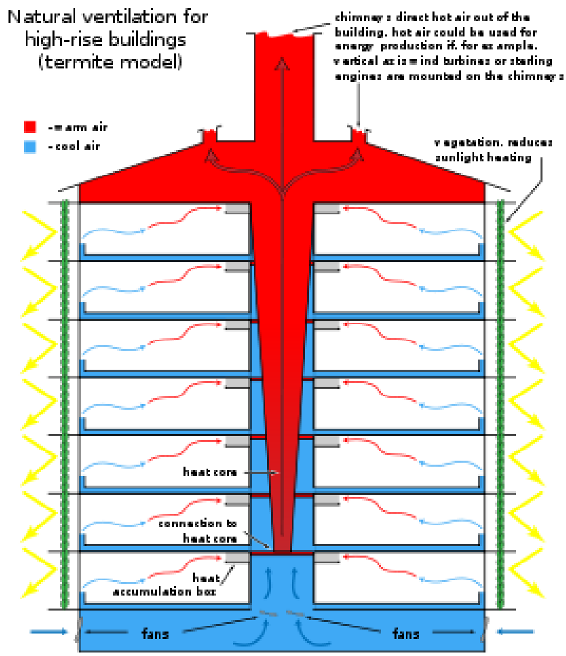


Figure 12. Ventilation principle in the building (Wikipedia)

5.2 BIQ (Bio Intelligent Quotient) Building

Designed by the architecture office Splitterwerk and engineered by Arup, the BIQ house was built in Hamburg in 2013 as part of the International Building Exhibition (Tokuç et al., 2019). Emphasis was placed on the efficient use of energy and reducing CO2 emissions in the building, and for this purpose, algae were used on the facade of the building and biomimesis was utilized.

Algae can be found as single or multicellular in the ecosystem. These creatures constitute one third of the biomass in the world and realize about

50% of the oxygen production (Chapman, 2013). As a result of burning algae as a biomass source, it has a high potential to obtain energy and to use it for the production of biofuels such as bioethanol, biodiesel, methane and hydrogen. Thanks to the fact that they can be produced locally and in almost any environment, they are seen as the fuel of the future in many studies (Ulukardeşler & Ulusoy, 2012).

Photobioreactor façade, a system in which algae reproduce within the façade elements, was used in the building. With this feature, the BIQ house became the first pilot project in the world to have a photobioreactor façade. In this context, it can be said that the design of the building was inspired by biomimesis at the behavioral level. The photobioreactor façade was installed as a second façade to the building that moves on rails (Architonic, n.d.) (Figure 13). The façade collects energy by absorbing light which is not used by the algae and generating heat, which is then used directly for hot water or heating. It also provides shading.

Figure 13. Photobioreactor sample (Kükdamar, 2017)

Different photobioreactor applications were investigated in various trials during the design process. As a result of the research, it was observed that the algal biomass in the flat-panel photobioreactor converted the sunlight with 10% efficiency (Figure 14). Flat panel photobioreactors were not only more efficient than tubular photobioreactors, but also required less maintenance and repair (Kükdamar, 2017).

Figure 14. Facade of the building and flat-panel photobioreactors (Kükdamar, 2017)

As a precaution against damaging the algae by overheating the system, this temperature is converted to hot water with heat exchangers or the heat is stored in geothermal wells. In this way, the facade system contributes to both thermal energy and biomass energy. On-site measurements were made for one year in the project, which has a net surface area of 200 m2 with 129 photobioreactor elements. According to the measurement results, in the year the measurement was made, 30 kWh/m² of biomass and 150 kWh/m² of heat energy were produced in the building, thanks to the photobioreactor facades, and 6 tons of CO_2 emissions were reduced (Tokuç et al., 2019).

5.3 Esplanade Theatre

Esplanade Theater in Singapore was designed by DP Architects and Michael Wilford (Yeler & Yeler, 2017). The design of the building was inspired by the durian fruit (Figure 15). Durian fruit is an exotic fruit that is generally consumed in countries such as Thailand. It has a hard, prickly textured and very resistant shell against physical effects.

Figure 15. Facade of the Esplanade Theatre (Morin, 2018)

It can be said that imitating the durable shell of the durian fruit in the design of the building is a biomimetic design in terms of behavior level and form extent. The façade of the building has kinetic parts. These parts are closed during the hours when the sun is steep and effective and prevent the interior of the building from heating up. In this way, the building, which is located in a country with a lot of sun like Singapore, is protected from the sun by providing sunlight control and avoiding the cost of cooling energy and preventing excessive energy consumption (Toruç, 2021). Kinetic parts on the façade open in the evening hours and contribute to the silhouette of the city thanks to the lights diffusing from inside (Figure 16).

Figure 16. Perspective view of the Esplanade Theatre (Yunci, 2003)

5.4 Qi Zhong Stadium

One of the most famous sports complexes in the world, Qi Zhong Stadium is located in Shanghai (Figure 17). It was designed by Shanghai Institute of Architectural Design & Research and was built in 2005. Inspired by the peony plant which is known as China's national flower, the plant elements were used both at the organism and behavior level (Zeytün, 2014) (Figure 17).

Figure 17. Qi Zhong Stadium and peony flower (Asefi, 2012)

In the design of the stadium, attention was paid to the use of energy, and excessive energy use was seen as a problem. As a solution to this problem, eight-piece metal movable plates were used on the upper cover of the stadium. While creating the cover's form and movement system, the principle that the peony plant moves its petals according to the sun and wind is imitated. (Zeytün, 2014) (Figure 18). Each sheet of metal is approximately 60.96 meters long and weighs 2 tons.

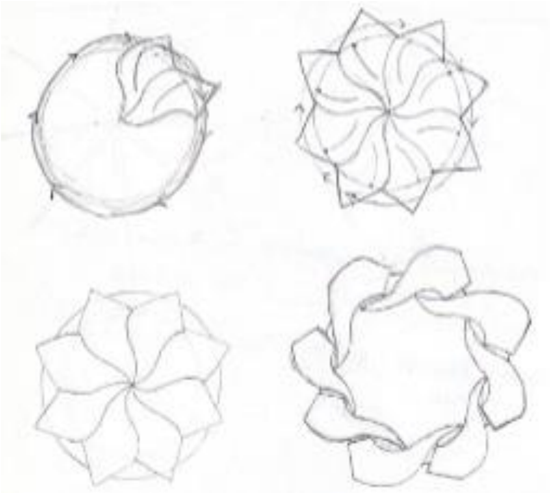


Figure 18. Roof sketches (Cinotti, 2022)

When moving metal sheets are examined in the context of sustainability, it is seen that their movements are arranged in order to reduce the energy spent on heating and cooling in the building. It takes eight minutes for the metal sheets to fully open and close (Cinotti, 2022). When the metal plate is closed, the hot air that rises up is blown back into the stadium and when the same metal parts are opened, air circulation is provided by controlling the cool air coming from outside (Zeytun, 2014). In this way, the stadium can be used in rainy weather and in very hot weather in summer without consuming much energy (Çalış, 2012).

5.5 University of Namibia Hydrology Building

The University of Namibia hydrology building was designed by architect Matthew Parks, using biomimesis with sustainability principles in mind. Architect Matthew Parkes was in Africa for a while to develop architectural solutions to environmental problems, where he studied how flora and fauna can survive in the desert. As a result of his studies, he learned about the Namibian desert beetle, which can trap moisture in the fogs formed by the cold waters of the Atlantic coming to the warm land of the African coast (Tekin & Kurugöl, 2011).

The Namibian Desert is classified as highly arid due to occasional rains, and organisms live in this ecosystem thanks to sources such as moisture, dew, and fog. The Namibian desert beetle, one of the organisms living in the Namibian Desert, has some unique features that it has developed to adapt to the ecosystem it is in. In order to take advantage of the water in the fog, the Namibian desert beetle turns towards the wind and makes its body angle of forty-five degrees, holding the fog droplets with its hardened wings. His head is turned in the direction of the wind. Its hard, bumpy outer wings open against the humid wind. The Namibian desert beetle grabs water thanks to its ridge of small mounds. The surface of the spaces between the mounds is covered with a kind of wax, but there is no wax at the top. This allows the insect to collect water more effectively (Tekin & Kurugöl, 2011).

The design of the University of Namibia Hydrology Building was inspired by the Namibian desert beetle in the organism and behavior phase.

Looking at the cross-section of the building, it is seen that the physical structure of the Namibian desert beetle is mimicked (Figure 19).

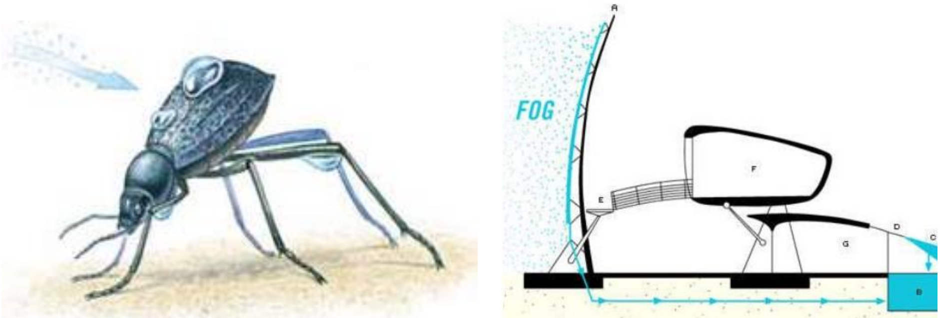
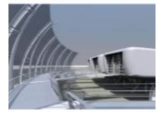


Figure 19. Namibia desert beetle and section of the building (Aslan & Selçuk, 2018)

The use of the biological function of the namibian desert beetle in order to produce and use water from natural resources by considering the sustainability principles of the building is mimicking at the behavior level. A series of arched shells that make use of the water in the fog in the structure are positioned behind a long curtain of nylon mesh that overlooks the ocean and collects the fog as it rotates. This system is combined with the infrastructure of the building. As the curtain made of nylon mesh reaches the saturation point, gravity directs the moisture to the gutters and thus the underground cisterns where the water is kept remain cold and evaporation is prevented (Tekin & Kurugöl, 2011). The water in the fog is a continuous source. Therefore, the collection and use of fog water in Namibia, which has a dry climate, will not detract anything from the environment and will be beneficial by using natural resources to solve the water problems of the buildings and contribute to sustainability.

Table 2. Overall evaluation of the sample buildings (By the authors)

Project Name	**Eastgate Office Building**	**BIQ Building**	**Esplanade Theatre**	**Qi Zhong Stadium**	**Hydrology Building**
Facade					
Function	Office	Housing	Cultural center	Sport complex	University additional building
Inspired From	Termite	Algae	Dorian fruit	Peony flower	Namibia desert beetle
Approach	Solution-based approach	Problem-based approach	Problem-based approach	Problem-based approach	Solution-based approach
Level	Behavior	Organism	Organism	Behavior and organism	Behavior
Extent	Process	Function	Form	Form	Process
Integration of Biomimicry to the Building	Inspired by termite nests, a natural ventilation system was created in the building.	The FBR façade collects energy by absorbing light and generating heat that is not used by algae, which is then used directly for hot water or heating.	Inspired by the peel of the dorian fruit, parts of the façade are closed when the sun is upright and effective, preventing the building from heating up.	With the principle of the peony plant moving its petals according to the sun and wind, the plates on the roof of the building move, air circulation and natural ventilation are provided.	The structure features a series of arched shells that take advantage of the water in the fog and a nylon mesh that overlooks the ocean and collects the fog as it spins, with a design inspired by the Namibian desert beetle.

6. Conclusion

Since the existence of humanity, every society has applied the knowledge gained from nature to the places where they live by examining nature in order to obtain various structural and formal design ideas. Many designers and engineer guided their designs by being inspired by many living creatures in nature. Nature also contains an unlimited number of sources of inspiration that open the horizons of designers in the field of architecture. From building materials to urban fabric; It is seen that the use of biomimicry is increasing day by day in the development of innovative materials, determining the organization of space, shaping the structural masses and creating the urban texture (Yorulmazel, 2020). Today, with the increase in environmental problems, it is seen that the process of being inspired by nature in both architectural designs and other design disciplines focuses on sustainability and energy efficient design issues. Biomimicry, which is based on nature, offers a systematic approach to produce sustainable innovative ideas for systems and to produce effective solutions against energy problems that may arise today and in the future. In this context, when the examples in the study are analyzed, it is seen that biomimicry is used to find solutions to the identified problems in architectural designs at the building scale, and the problems are generally related to the natural environment. When the development of the approach in architecture is examined, it is observed that in the past, biomicry was used in construction techniques and structural systems in building designs, and today, generally, by providing daylight control, natural ventilation and water conservation, energy consumption is reduced and carbon dioxide emissions are reduced in parallel, and structures that produce their own energy are designed. Accordingly, the biomimicry approach is a tool that serves a purpose in architectural design. Considering this feature of biomimicry, life cycles, biological characteristics and survival motives of living organisms should be learned and natural environment-oriented solutions should be found for the architectural design problems and problems encountered today. For this, technological developments should be followed as well as biological science and it should be known that biomimicry solutions can become one of the most sustainable ways of producing an efficient built environment.

Thanks and Information Note

The e-book section complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

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Creating Solutions to Climate Change with Wooden Material: A Workshop Experience

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1. Introduction

Workshops in design education are activities that convey formal and informal knowledge to students on an experimental and experience-based basis, provide students with problem-solving skills, and teach access to information. Bringing together students, academics, and professionals, these studies make knowledge transfer and sharing multidimensional. It provides environments for thinking, criticizing, discussing, and producing while conveying information from literature, life, and experiences. Workshops are process-oriented in the context of the subject they deal with. It creates a working process in which the creativity and motivation of the participants are high, and they cooperate and cooperate within the given time.

This study was presented in the context of "Climate Crisis and Architecture" in the Department of Architecture at Karadeniz Technical University**.** This workshop includes the experiences of the group, which took part in the sub-theme named Awareness stop +1 in this workshop, and the result products within the scope of the workshop. The workshop was aimed to draw attention to the importance of wood material in the process of combating the climate crisis, to emphasize its place in a sustainable architectural understanding, and to raise awareness in the context of the three-day study.

At the end of the workshop process, it has been seen that workshop studies are very important in architectural education, and information sharing is much more efficient among students, academicians, and professionals in this process. It has been understood once again that architectural education workshops, a discipline based on lifelong learning, are an important and necessary part of education and training in this information age.

2. Climate Change and Its Importance in Architecture

The climate is defined as atmospheric events, which occur depending on the region and time and are revealed by other climatic elements such as air movements, air temperature, and air humidity, which are functions of solar radiation, especially the sun (URL-1,2).

the United Nations, climate change refers to changes in temperature and weather patterns over time. Climate change can also occur naturally, such as changes in the solar cycle. However, according to scientists, since the 1800s, fossil fuels such as coal, oil, and gas consumed as a result of human activities have become the driving force of climate change. These fossil fuels produce greenhouse gas emissions, which wrap around the Earth like a blanket, trapping the sun's heat and causing temperatures to rise. Carbon dioxide and methane are examples of greenhouse gas emissions that cause climate change (URL-3).

How are greenhouse gases formed?

The atmosphere of our planet works just like a greenhouse. Almost half of the sun's rays reaching the earth are reflected from the earth. Our atmosphere is composed of carbon dioxide, methane, water vapor, ozone, nitrous oxide, etc., which are also described as greenhouse gases. Thanks to the gases, it sends some of the sun rays reflected from the earth back to the earth. Thanks to the greenhouse gases that act as a blanket, the average temperature on earth; reaches a temperature level of 15°C, which will allow people, animals, and plants to continue their lives. If there were no greenhouse gases, the earth's average temperature would be around -18°C. This natural effect of greenhouse gases is called the "greenhouse gas effect" (URL-4).

90% of the energy consumed in the world and 75% of the energy consumed in Turkey is provided by fossil fuels such as coal, oil, and natural gas. In addition, 50% of the energy consumed worldwide is spent on building construction or usage processes. 50% of greenhouse gases that cause global warming are due to activities associated with buildings (URL-5). Environmentally sensitive sustainable buildings gain importance to reduce the negative effects of climate change and to maintain the balance of the natural system.

The main purpose of sustainable building design is; To increase the use of renewable energy sources by reducing the use of fossil fuels, ensure energy conservation, minimize the amount of waste and pollution, and create healthy and productive environments for the inhabitants (Koçhan &Akın, 2022).

Özcan & Erol (2018) reduce energy use by 24-50%, carbon dioxide emissions by 30-39%, water consumption by 30-50%, solid waste by 70%, and maintenance costs by 13% compared to traditional buildings. For all these reasons, various sanctions, regulations, regulations, agreements, etc., to ensure the sustainability of buildings in the construction sector all over the world, especially in Europe. solutions are introduced and targets are set gradually focusing on 2030 and 2050 for all buildings to be sustainable; people, sectors, and countries are encouraged in this sense (URL-6). The

European Green Consensus, which is one of the studies in which Turkey is also involved and in which it is obliged to make the necessary legal arrangements, and which was announced in 2019, aims to zero its greenhouse gas emissions by 2050 (URL-7).

A sustainable building can be defined as a system that has the characteristics of a process that will exist continuously, without any deterioration in the properties of the existing material, and without any reduction in the material that feeds it (Tufan & Özel, 2018; Nicholson, 2004). Sustainable building materials are materials that consume the least amount of energy during their use and do not harm the environment and human health during the acquisition, processing, use, maintenance-repair, and waste generation of raw (Tufan & Özel, 2018; Sayar at.al, 2009).

Considering the relationship between climate change, sustainable building, and sustainable building materials, wood is undoubtedly one of the building materials that fully comply with the sustainability criteria.

3. The Role of Wooden Construction Material in Creating Solutions to Climate Change

Carbon dioxide (CO2) production is the dominant component of the global warming potential (Güzel & Yesügey,2015). Steel, concrete, and many materials used are natural sources of CO2 has been determined. According to the data obtained, the buildings built cause 40% of the carbon dioxide emissions in the atmosphere (URL-8) (Figure 1). Building structures from wood is one of the solutions to this problem.

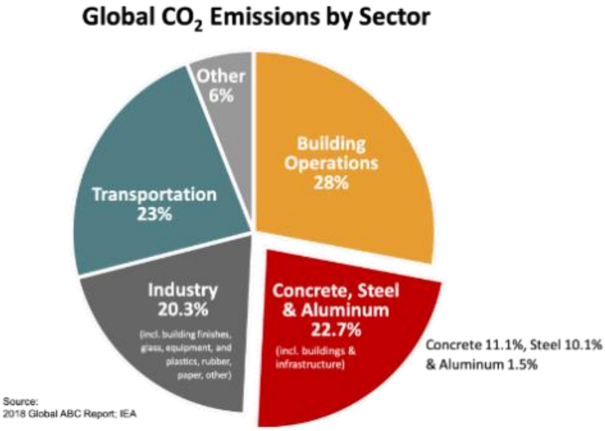


Figure 1. (URL-8)

Bio-based materials such as wood can help transform cities from carbon emitters to carbon sinks (URL-9) because carbon storage is one of the important properties of wood not found in other structural materials (URL-10). As the tree grows, it absorbs carbon, and when it becomes timber, this situation continues and does not release greenhouse gases into the atmosphere. Therefore, wooden structures balance the greenhouse gases emitted by other construction materials and construction activities by storing the ever-increasing value of carbon in their structures (Güzel&Yesügey, 2015).

Wood is a natural building material that is sustainable and renewable and uses less energy in its production than other building materials, including concrete and steel (URL -11). Therefore, increasing the use of wood in our buildings will reduce the carbon effect (Figure 2).

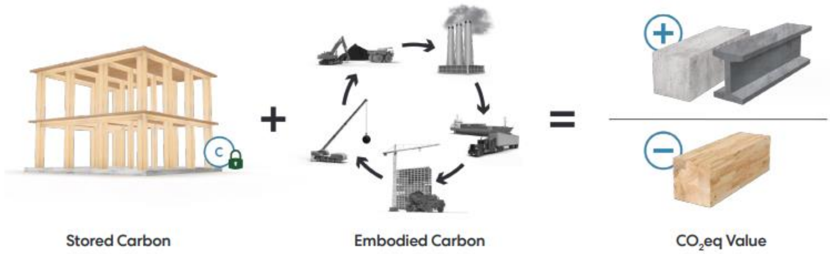


Figure 2. The role of wood use in buildings in reducing carbon emissions (URL-9)

Wood is a material used in the carrier system of traditional buildings, especially in countries rich in forest areas. In our country, the rate of industrialization is generally low and buildings are generally built with on-site construction using concrete materials. In our country, which is in an important position in terms of forest existence, it is necessary to revive the wooden building culture, contribute to the awareness of industrial wood materials with the developing technology opportunities, and encourage the use of wood in building carrier systems by emphasizing the importance of wood material in solutions for climate change. Education is an important step in the process and the environments in which architectural education is given; recognition of wood material is important in terms of knowing the possibilities of its use in construction systems.

4. Workshop Experience

In this study, the experiences of the group, which took part in the workshop with the sub-theme “Awareness Stop+1” in the context of “Climate Crisis and Architecture”, and the results of the workshop were discussed in this study. A workshop named #plusonedegree was held in the context of

"Climate Crisis and Architecture" in the Department of Architecture at KTU.

The aim of the #plusonedegree workshop, organized by the members of the Communication Commission within the Department of Architecture, is to raise awareness of the current climate crisis, which will affect the next hundreds of years and generations if no measures are taken, and to explain the impact and importance of the field of architecture in this crisis. The workshop was held in Erdem Aksoy Experimental Design Laboratory of the Architecture Department on 6-7-8 April 2022 with a group of lecturers from different departments of the KTU Architecture Department and a group of students from different classes. Eight different groups took part in the workshop. The lecturers and students in this group were determined after the announcement made to all department lecturers and students, and 6 students have included in each group of the workshop process, each group's handling of the subject is unique and shaped in a way to be determined by the workshop group coordinators. 4 seminars were given online by experts in their fields (Figure 3) (URL-12).

Figure 3. Posters of the workshop and the seminar has given within the scope of the workshop (URL-12)

4.1. Awareness Stop+1 Workshop

The number 1 group of the workshop, Assoc. Nilhan VURAL and Prof.Dr. Nihan ENGİN and its sub-theme were determined as **Awareness Stop+1** and its hashtag as "#stop".

4.1.1. Aim

This study, as a group, it is aimed to think and discuss the issue of "being a solution to the possible problems caused by climate change by producing an architectural design using wooden structures and construction" and in this context, it is aimed to produce designs/designs with a bus stop function focusing on climate change.

4.1.2. Scope

About the workshop theme, to draw attention to the climate crisis in our world, an existing bus stop located in the center of KTU Kanuni Campus and the empty area around it (Figure 4) are aimed to be redesigned in an integrated Awareness Stop concept to include open, semi-open and closed areas.

Figure 4. KTU Kanuni Campus (URL-13) and study area

The main design criteria of the structure to be designed are that people of all ages and education levels receive information about climate change, have the necessary functions to raise awareness, and that it meets the visitors as living organism through the use of materials. The stop structure, which is thought to be both a meeting and awareness point; designing it in a way that includes the criteria such as energy conservation, water conservation, and material selection that can bring a solution to the climate crisis, as well as spaces that will draw attention to the issue; It is aimed to develop the awareness of individuals coming from the campus and from different parts of the city in this sense. It is thought to use wood in the structure of the buildings. It is planned to evaluate the wooden material, which stores carbon in its structure and continues to store for 80 years when used in the building structure, as a result of the possibilities offered by today's technology.

4.1.3.Method

The following sequence was followed in the conduct of the workshop:

1. Group members were met and the subject was introduced to the students.

2. Literature research and readings within the scope of the subject; industrial wood material, stall, pavilion samples, combating the climate crisis, sustainable design, and waste management (Figure 5).

Figure 5. Group work

3. Short informational presentations on wood, climate crisis, and sustainable design were made. (Figure 6).

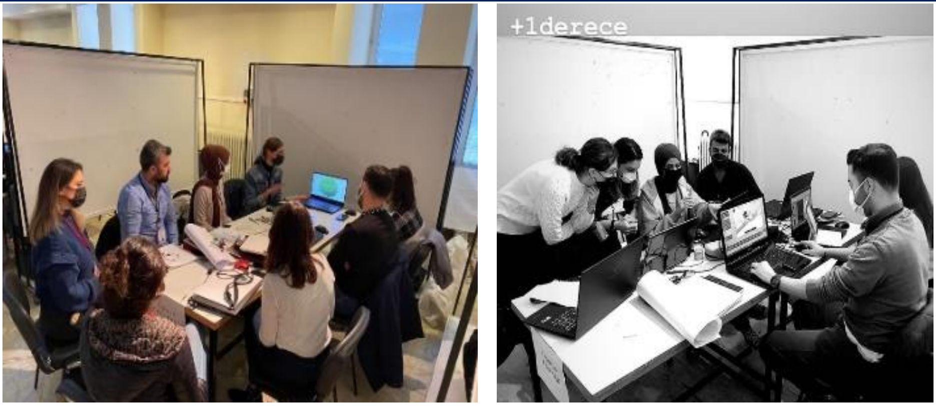


Figure 6. Information presentations

4. The site was visited (Figure 7), and photographed from different directions, and the land analyses (slope, occupancy space, transportation) in the KTU Master Plan were used (URL-14).

Figure 7. Observations made in the study area

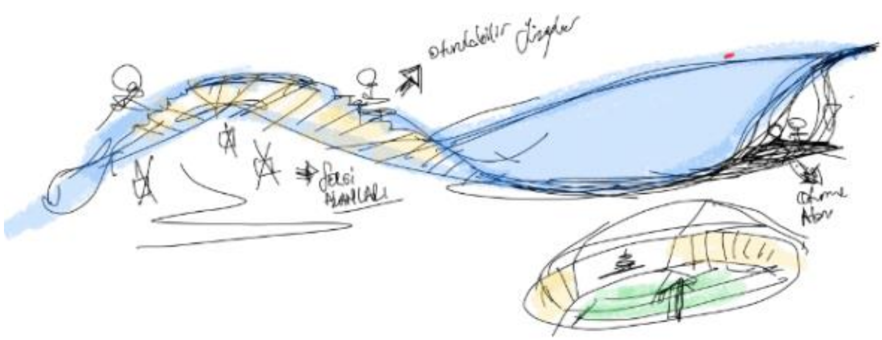
5. Concepts and scenarios for design were created, alternatives were developed, and sketches, models, and modeling studies were carried out. “Living and living spaces, web of life, layer, breath, life cycle, sustainability, route” was determined as the main concepts. The scenarios created are explained in detail below:

Scenarios

Group members created 3 scenarios at the end of the process and designed them accordingly. The 3 scenarios called Life Netting, Living Stop-Living Design, and Layers of Life created by 6 group members in 2 groups, and the visuals of the designs for these scenarios are given below:

Scenario 1:Life Netting

The area to be designed as an Awareness Stop at the upper scale is located in the center of KTU. Especially the fact that there are only pedestrian and vehicle roads until the C gate is located in the north of the area connected to the university by the coastal road and the stop area located in the south of the area has led to questioning what can be done spatially for this area. To reveal the potential life energy of the area, which sees the ring road, airport, and sea from very effective angles, the "Life Netting" extending from the main arteries feeding this area to the station was designed (Figure 8). With this living web, a design idea has been developed that spreads over the area, is carried by curvilinear surfaces that sit on the elevations, is expected, visited, and information is stored.



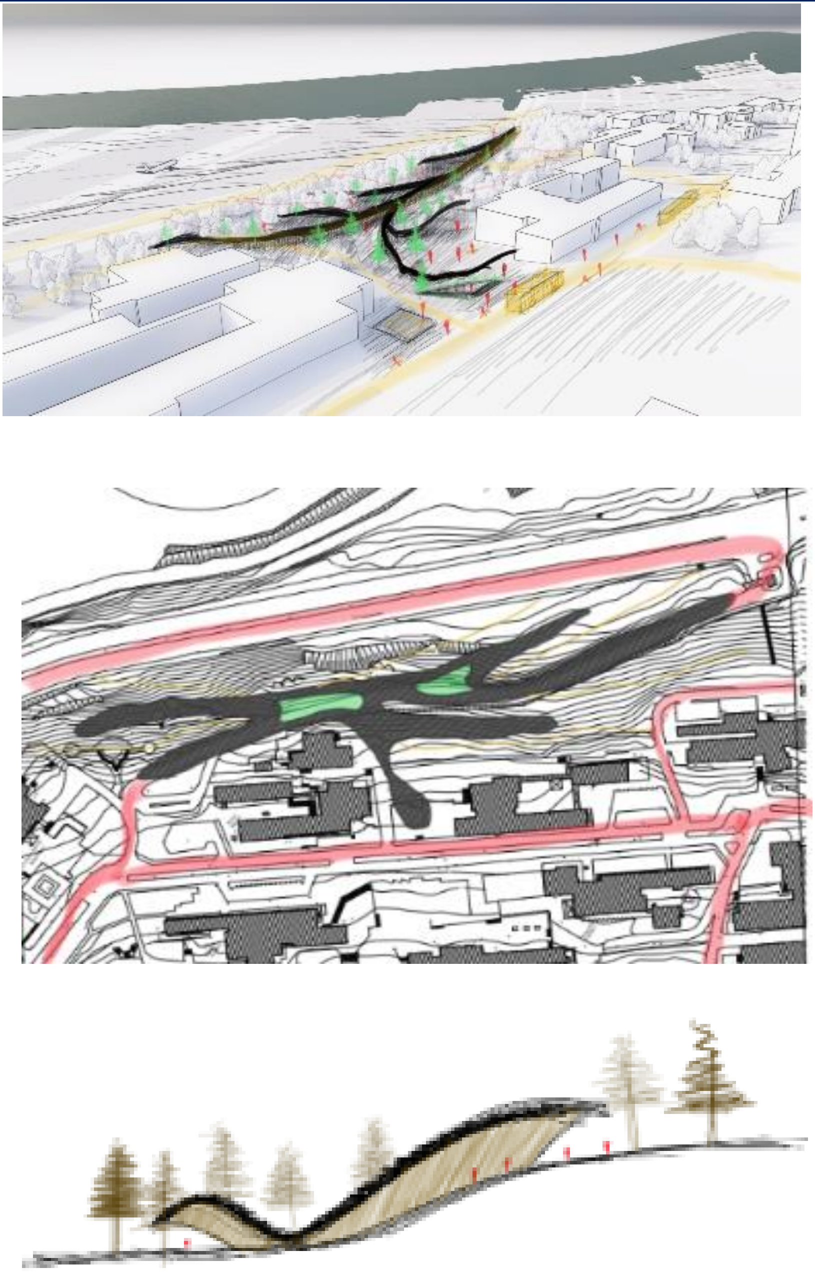


Figure 8. Images of Scenario 1

The stop, which will host all living things, includes areas that will inform users about the climate crisis. Barrier-free areas have been designed that can be easily accessed by everyone, regardless of the old, young, children, and animals. The wood material used in the design converts the stored CO2 into energy and feeds the web of life with this energy.

Rainwater is collected by using the top cover slopes for stray animals and to increase the green area; recyclable plastic waste is used in greenhouse areas. Permanent exhibition areas with the content of the climate crisis transfer information to the user digitally, with sound and light. In the multi-purpose bus stop, which also has underground uses, the problems caused by the climate crisis are shown to people practically. There is also a cafeteria and a sales unit in the area.

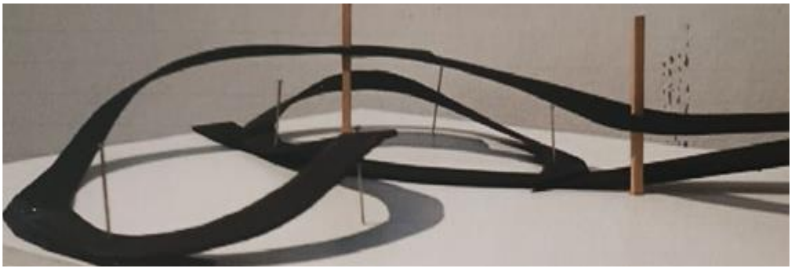
Scenario 2:Living Stop, Living Design

Spaces designed as a part of nature instead of adapting nature with ecological design create a sense of belonging to nature in living things. When we look at the concept of nature and station semantics; For the living, nature has common meanings as the area where life begins and ends, and the stop as the point where the day begins and ends.

The workshop aims to raise awareness about the climate crisis today and in the future, to take a step towards climate crisis awareness, which is determined as a life task, and to design a Living Space/Stop that can be realized in this sense.

In the realized design, since the life of living things starts and ends with the soil, the spaces are designed as a piece of nature instead of being designed about nature. In the design, spaces that can offer life to many living species, that can breathe life into the urban fabric, that lives and that makes them live were provided. The main concept of the design was created in a way that would not harm the existing green texture and land. As trees are the main source of life for living things, they also took on the main tasks in design.

Design; It was created by transforming curved ramps that curve/move into seating units and different spaces that open and close (Figure 9). In the ramps created, systems that store energy as living things move and return the stored energy to the space were envisaged. With the ramps, which are lost among the trees and whose carriers are trees, the circulation of all segments of society was made possible. A large-trunked "Tree", which is at the center of the design and is evergreen for 4 seasons, was defined as "Stop". Routes of 5-10 -15 minutes were created for people waiting at the bus stop, according to their waiting times. On these routes, activities that can raise awareness, inquiry, and awareness with digital glasses and holographic effects were planned. Industrial wood, which stores carbon, was used in the material of the ramp. Rainwater was collected and stored by rain harvesting.



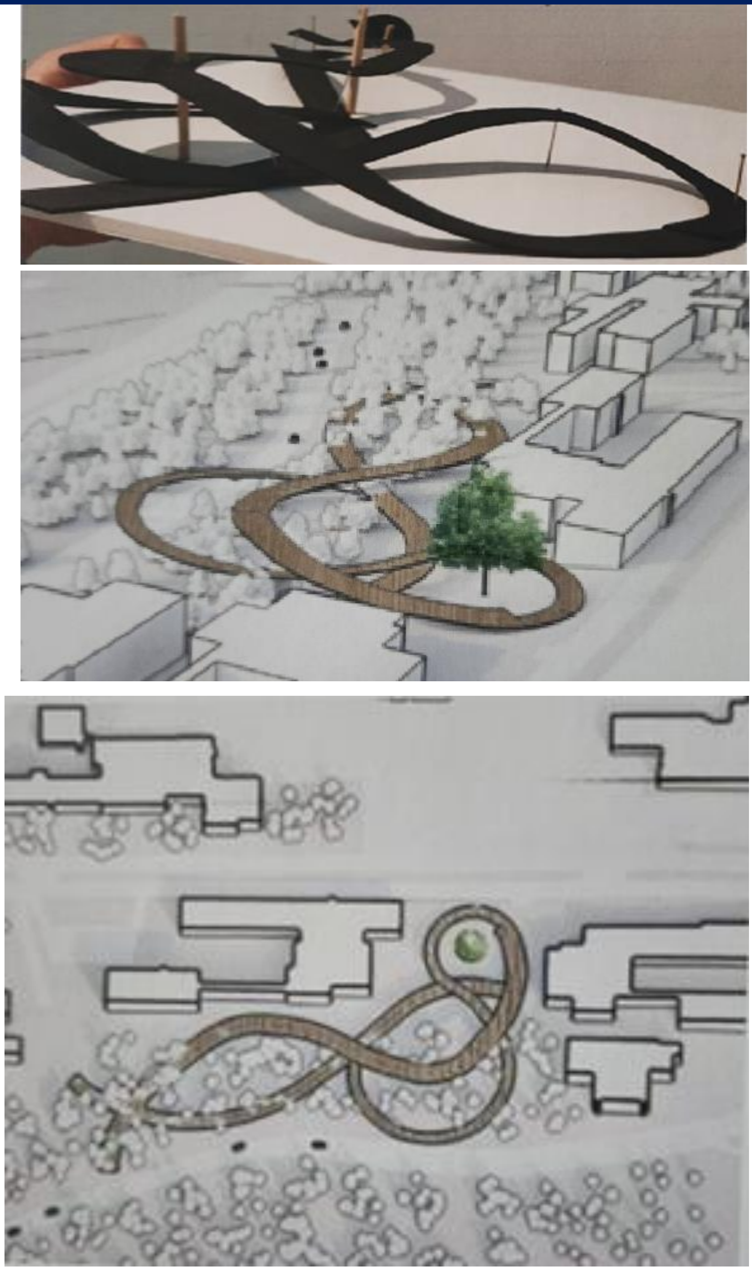


Figure 9. Images of Scenario 2

Scenario 3: Layers of Life

Wood is a natural material produced from wood, a living organism. In the scenario created, the value added by wood to life was evaluated as "Layers of Life" by taking its place in the field with layer abstraction, and it was planned to have different activities and educational workshops in each layer. The cross-laminated timber (CLT) material used in the building structure formed the structure of the "Living Layers" and was integrated with the "Sycamore Trees" in the field. Along with the bus stop, a semi-open amphitheater and a bookcafe area were designed to be used in activities related to the climate crisis (Figure 10).

Figure 10. Images of Scenario-3

The final products were prepared and presented for the general presentation that all workshop groups would attend (Figure 11)

Figure 11. Presentation of final products

The works for the exhibition were turned into posters and exhibited at the Erdem Aksoy Experimental Design Laboratory on May 16-27, 2022 as part of the KTU Architecture Department 2021-2022 Spring Term Traditional Exhibition (Figure 12).

Figure 12. Exhibition environment and workshop poster

5. Results

In the workshop, which focused on the warming of the atmosphere with climate change, the effect of the construction sector on this change, and architectural solution proposals, the sub-theme of the workshop group named Awareness Stop+1;

Where does architecture fit into climate change? What should architects do for a sustainable future? Can sustainability be addressed as a design issue in the project? How can the place and importance of wood material in climate change be increased? What is required for the design and construction of wood construction systems? In the context of questions such as, they were asked to design on the determined area. During the workshop process, the students developed 3 different designs over 3 scenarios,

- revealing the potential life energy of the earth,
- being a part of nature instead of adapting nature with design,
- wood adds to life,

It has produced products that focus on concepts such as the three-day workshop experience in architectural education strengthens the student-student, executive-student, and professional-student communication, and contributes to the thinking power of the designer. It has been thought that students' awareness of climate change has increased, that they can produce original solutions in this context, and that students can come up with creative designs that will create solutions to climate change both in their education life and in their next professional life. The fact that the products designed in similar studies in the future can be applied, built and exhibited at 1/1 scale will increase the awareness of other members of the society about climate change and wood.

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Ethics committee approval is not required for the study, the students in the workshop group were contacted and their approvals were obtained for the publication of the photographs and visuals.

Author Contribution and Conflict of Interest Disclosure Information

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Characteristics of "Historical Günyurdu Village" Traditional Housing Architecture and Conservation Problems

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1. Introduction

Recognition of the significance of cultural heritage and its subsequent conservation began as a means of preserving monumental buildings. Over time, this concept has evolved to encompass the protection of the environment and city as a whole, expanding from the scale of a single building. In 1964, the Venice Charter expanded the concept of conservation to include the intangible aspects of cultural heritage and "simpler" monuments. Since then, there has been growing awareness of the importance of the continuity of traditional houses and rural settlements. The Washington Charter for the Conservation of Historic Towns and Urban Areas (ICOMOS, 1987), which complements the Venice Charter, has expanded the scope of conservation to include settlements and their surroundings. However, it was not until the adoption of the ICOMOS' Traditional Architectural Heritage Charter in Mexico in October 1999 that the criteria for traditional architectural heritage were fully recognized. Elements that make it necessary to pass on traditional buildings to the next generation include a building tradition adopted by the community and passed on anonymously, a local or regional identity in harmony with the environment, consistency in style, form, appearance, or adherence to traditional building types, and effective building design despite constraining factors. In Turkey, laws such as law on antiquities have been enacted to identify and evaluate traditional houses in Anatolia, in parallel with global developments. Owing to Anatolia's multiculturalism and geographical diversity, a heterogeneous building culture has contributed to the spread of cultural richness on a large scale. Rural architectural heritage in Anatolia significantly contributed to the cultural richness of the region. It deserves special importance owing to its formations that are based on cultural activities, the restrictiveness of the natural environment, and a consensus within themselves. However, despite the cultural significance of rural architectural heritage, rural settlements in Anatolia are gradually losing their population owing to changing social dynamics. Consequently, rural buildings that serve as tangible evidence of past lives and cultural values are left unclaimed. This population loss makes rural architectural heritage vulnerable to environmental impacts and puts it at the risk of being lost over time. The disappearance of rural settlements and their architectural heritage can result in the loss of cultural diversity and richness, as well as the loss of an important connection to our past. The preservation and documentation of these settlements and their architectural heritage are essential for maintaining cultural identity and ensuring the transmission of cultural values to future generations. Considering the risks facing rural architectural heritage, it is crucial to thoroughly document and analyze these buildings and settlements as a critical component of Turkey's architectural culture. This documentation should include a detailed understanding of the factors that threaten the survival of these structures as well as possible strategies for their protection and conservation. The situation in Günyurdu Village highlights the urgency of documenting and preserving traditional rural architecture, which forms a crucial part of Turkey's architectural heritage. The village's abandonment and the resulting degradation of its buildings underscore the need for a comprehensive approach to conservation that considers not only the physical structures themselves, but also the social and cultural context in which they exist.

To identify and document the traditional architecture of Günyurdu Village, a study involving on-site investigations was conducted. These investigations focused on determining the construction systems and materials, plan typology, and façade features of the village's buildings. Additionally, the study analyzed various factors that influence the texture of the settlement, as well as the current conditions of the buildings.

This study emphasizes the importance of adopting a holistic conservation approach that considers the cultural and social significance of traditional rural architecture. It also underlines the importance of identifying and addressing the threats that endanger these buildings, such as abandonment, natural disasters, and urbanization. Thus, it will be possible to ensure that the rich cultural heritage of traditional rural architecture is preserved for future generations. The evacuation of Günyurdu Village, which has a rich cultural heritage and served as a settlement for a significant period of time due to dam construction, has left the buildings in the village unattended and unprotected against the effects of time. After more than 700 years of uninterrupted settlement, the village must be researched and documented before it is too late, and conservation possibilities should be brought to the agenda. This study also emphasizes the importance of identifying and protecting other sensitive rural settlements that are at risk of loss over time. In line with all these requirements, this study aims to analyze the settlement texture in Historic Günyurdu Village and document the traditional houses, including their construction systems, materials, plan typologies, and façade features. In addition, this study analyzes the factors affecting the texture of the settlement, evaluates the current condition of the buildings, and highlights possible conservation measures.

2. Material and Method

2.1. Materials

The study focuses on the traditional structures and immediate surroundings of the historical Günyurdu Village, located at approximately 40.02° north parallel and 29.50° east meridian. The village is situated 36 km from Bilecik City center and 8 km from Pazaryeri District center, but has been evacuated due to the construction of a dam pond in 2006 (Figure 1).

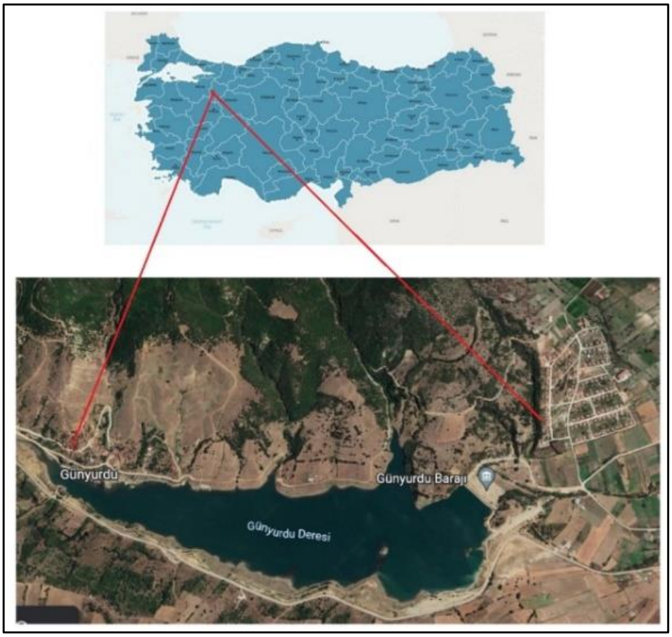

Figure 1: Historic Gunyurdu Village and New Settlement Satellite Image Google Earth 2023

The village of Günyurdu, formerly known as Bakraz, has a rich history and was home to 120 households prior to the dam flooding. However, following the flooding, the number of households has drastically decreased to 13. The construction of the dam resulted in the flooding of 48 houses, the village school, the old cemetery, and the village mosque. In response to this, a new settlement consisting of 123 houses was constructed by the Housing Development Administration of Turkey (TOKİ) approximately 2 km to the east of the original village. This study primarily focuses on the traditional rural dwellings that have become non-functional due to the relocation of the village to the new settlement.

2.2. Method

The study was initiated with a comprehensive literature review. In order to gain a comprehensive understanding of Günyurdu Village, Bilecik Provincial Yearbooks, relevant publications and scientific research were scrutinized. Additionally, the relevant principle decisions issued by the Ministry of Culture and Tourism, General Directorate of Cultural Assets and Museums, pertaining to the conservation issues of civil architectural examples, were analyzed. After the literature review, the study adopted research methods that involved surveying, collecting data, analyzing and evaluating the findings. The survey phase comprised two stages of fieldwork. The first stage involved determining the general characteristics of the settlement and analyzing the factors that influenced the settlement's characterization. In the second stage, inventory slips were created to document and identify the traditional buildings in the village. The inventory slips created during the study include comprehensive information about the buildings, such as their identification, physical condition, functionality, environmental inputs, current functional scheme, and structural integrity and longevity. These data were deemed essential to discuss preservation possibilities for the traditional buildings. All existing traditional buildings were numbered and data collection was carried out based on the inventory slips. Finally, the collected data were transferred to a digital platform, where they were analyzed and evaluated.

3. Findings and Discussion

3.1.Cultural and Historical Characteristics of The Settlement and The General Character of The Settlement's Texture

The Ottoman archive provides evidence that Günyurdu Village was established in the early years of the Ottoman Period, following the conquest of Belekoma and Yarhisar castles in 1299 (Göker, Hergül, & Kahveci, 2019). It became a part of Ottoman territory upon the incorporation of Bilecik into the Ottoman Principality. The village was founded by the Karakeçili tribe members of the Kayı tribe, and gained village status in the 1800s (Göker, Hergül, & Kahveci, 2019). During the 19th century, it was called Bakraz village, and later renamed Günyurdu (URL 1, 2019), as per Ottoman archives (Göker, Hergül, & Kahveci, 2019).

Figure 2: Ottoman Archive Documents Dated 1324 Mentioning The Mukhtar Of Bakraz Village (Göker, Hergül, Kahveci, 2019)

The distinction between "Yörük" and "Manav" is based on the difference in their lifestyles, with "Yörük" being nomadic and "Manav" being settled (Eröz, 1991). Despite this, the residents of Günyurdu Village identify themselves as "Yörük" and hold annual Yörük festivals in September to commemorate Ertuğrul Gazi (Figure 3). However, it should be noted that these festivities were discontinued after the village was relocated to a new settlement area in 2006.

Figure 3: Yörük Festivities Commemorating Ertuğrul Gazi in Bakraz Village

According to the data provided by the Turkish State Institute of Statistics, the population of Günyurdu Village has decreased from 409 in 1990 to 179 in 2021. However, it should be noted that the majority of the current population of Günyurdu Village resides in the new settlement, which consists of 123 houses built by TOKİ, located 2 km east of the old settlement (see Figure 4). Despite the fact that the dam construction caused 48 houses, the village school, and the old cemetery to be flooded, there are still 9 households living in the historical Günyurdu Village.

Figure 4: Günyurdu Village TOKİ Houses (Baran Ergül, 2007)

The main source of livelihood in the historical Günyurdu Village is animal husbandry, which has been the primary occupation of the Yoruks for centuries. The Yoruks of Günyurdu Village continue this tradition by mainly breeding sheep and cows, although water buffalo breeding was also common until the 1960s. The preference for animal husbandry as a source of livelihood in Günyurdu Village has been influenced by various factors, including the character of the built environment and family sizes.

The historical Günyurdu Village is situated at an altitude of 854 meters and exhibits continental climate characteristics, despite being located in the Marmara Region. The settlement experiences heavy snowfall during the winter months. The topography of the area reveals a hilly structure that descends towards the east, with small plains resembling plateaus located in valleys. The village was planned along the northeast-southwest axis (Figure 5).

Figure 5: Historic Günyurdu Village Drone Shot (Baran Ergül, 2023)

Due to its location, Günyurdu Village is in close proximity to popular rural tourism destinations. It is situated 3.5 km away from Kınık Village, which has been designated as a rural tourism village where traditional pottery craft is still practiced, and 4.5 km away from Küçükelmalı Nature Park (Figure 6). The village's location and its picturesque view with the water element added to the landscape, make it an attractive destination for visitors from urban areas, especially during weekends.

Figure 6: Günyurdu Village and İts Distance to Neighboring Villages (Baran Ergül, 2023)

The historic Günyurdu Village exudes a rural landscape with a distinct old settlement character. The traditional village settlement features hills, rocks, agricultural and pasture areas scattered around the settlement, along with the slopes surrounding the traditional houses. The houses in the village are mostly single or two-storey structures, small-scale, simple, and unassuming. These modest and human-scaled buildings emphasize the functionality at the forefront of the settlement's design (Figure 7).

Figure 7: Historic Günyurdu Village (URL1)

There is no clear organization or pattern to the layout of buildings in the village. While there may be some clustering around the roads, the orientation of buildings does not appear to be influenced by the road except for those parcels adjacent to it. Therefore, it may be more accurate to describe the settlement as having an irregular or organic layout rather than a dense or regular texture.

The layout of houses in Günyurdu Village reflects a range of factors, including proximity to roads, neighboring parcels, privacy considerations, and respect for neighbors' rights. This arrangement results in a settlement texture shaped by local social norms and sensitivity to topographical data. In addition to the main residential structures, single-story service structures such as barns, haystacks, warehouses, and toilets are also found in parcels comprising the rural landscape, arranged around residential buildings with no garden walls, fences, or other types of boundaries. The village's settlement character is comparable to the oba settlements of nomadic people, who brought Central Asian life traditions to Anatolia. Before the construction of the dam, there were 120 houses in the village, but today only 65 and their annexes remain standing due to floods and environmental factors. The current population consists of nine households motivated to continue living in the village due to inadequate amenities in newly built houses for animal husbandry purposes, which is their primary source of income. In addition to functioning residences, three recently constructed residential buildings are used as vacation homes. Roads between houses have become dilapidated, making vehicular access to slope-based houses impossible. The village also contains a mosque, a half-flooded school building, and six fountains. The flat area that once housed the mosque and school, now adjacent to the dam lake, can be considered the village center. (Figure 8).

Figure 8: Historic Günyurdu Village Mosque Year of Construction: 1910 (Baran Ergül, 2023)

3.2.Architectural Characteristics of Traditional Houses of Historic Günyurdu Village

While traditional buildings possess unique features that are tied to their location and cultural heritage, such as their construction techniques, building materials, and design, there is still a shared regional character that has developed over centuries of knowledge transfer. In this regard, the traditional houses of Günyurdu Village are consistent with the traditional housing typology found in the Central Anatolia region, showcasing many similarities.

The residential buildings in Günyurdu Village are typically designed in a square or rectangular plan form, with their entrances situated on the front facade. To facilitate natural lighting and ventilation as well as heat conservation, the facades of these buildings feature rows of small windows. Generally, a window-to-wall ratio of approximately 1/2 is employed, with guillotine and rectangular window joineries being the most commonly used types. It is worth noting that some buildings, such as certain mosques, use round-arched windows of the same form to emphasize interior spaces. This design feature provides a departure from typical rectangular forms and adds a unique architectural element to structures.

The traditional houses in Günyurdu Village typically have one or two floors, with ground floors typically built from rubble stone. While the ground floor may have narrower facade openings than the upper floors, complete soundproofing cannot be claimed. Moreover, the residences in Günyurdu Village generally lack garden walls, which serve as a boundary separating public and private spaces. Instead, a single row of stone fences or tree branches is typically found between parcel boundaries of each building situated along the road line. As a result, there is less of a clear-cut distinction between public and private spaces in the village. The primary reasons for this rural practice can be attributed to the community's reliance on animal husbandry, which demands minimal use of gardens. Additionally, the community prefers unobstructed access for their animals to the pastures located just above the village, and they tend to avoid boundaries due to their traditional highland culture (Figure 9).

Figure 9: Residential Structure No. K03 and the Garden Boundary Formed by Tree Branches (Baran Ergül, 2023)

The rural dwellings in Günyurdu Village are situated on irregularly shaped parcels of land that have formed spontaneously along roads that follow the natural terrain structure. As a result, these parcels vary in size and facade view, making uniformity impossible. While privacy is not a significant factor in building formation, care is taken to show respect towards neighboring buildings. The houses are strategically placed to avoid blocking light, air, and views of other houses by utilizing the natural slope of the land.

The precise construction dates of the traditional houses in Günyurdu Village are unknown. However, according to the village residents, these houses have been in use for three or four generations with only minor maintenance and modifications until 2006. While some houses were demolished and rebuilt over time, the existing foundation walls and usable building materials from the old houses were often reused in the construction of new homes.

Apart from housing units, the parcels of land where the houses in Günyurdu Village are located also contain bread baking areas, corrals, and storage spaces. The variety of ads-on to the dwellings in the village is consistent with rural housing typology, as identified by Baran Ergül and Ekşi Akbulut (Baran Ergül & Ekşi Akbulut, 2023). Given the lack of garden walls separating the parcels, structures like bread baking areas and haystacks are typically used for communal purposes rather than private use (Figure 10).

Figure 10: A Haystack Structure in Common Use (Baran Ergül, 2023)

Unlike traditional dwellings where ground floors are typically used as service volumes, the ground floors of traditional dwellings in Günyurdu Village are also used as living spaces. The rooms located on the ground floor are the main unit and serve as the most important element of the living spaces, where daily life takes place in conjunction with other structures such as haystacks and storage areas. The square or nearly square rectangular rooms in Günyurdu Village prioritize functionality by using loaders for the storage of items such as mattresses, rather than relying on furniture. Essential elements such as armories, cupboards, loaders, stoves, and shelves are included in the rooms to cater to the lifestyle requirements. The room serves multiple functions to accommodate the needs of each immediate family within the patriarchal family, including sleeping, sitting, cooking, eating, and washing. As a result, families perform their daily tasks within these rooms. The traditional architecture of this region lacks specialized spaces for kitchens or bathrooms, instead, the hearth serves as the central point of the room and fulfills both cooking and heating functions. A shelf located above the hearth holds a lamp, while niches on either side provide storage for household items. These planning principles reflect the living habits, traditions, and customs of the nomadic period, as well as the needs of the settled order.

In two-story houses, access to the upper floor is gained via a wooden staircase located on the ground floor. The number of rooms on the upper floor varies depending on the size of the house, with two to five rooms being common. These rooms are typically planned to be between 3-4 meters in width and are interconnected via a seating area known as the "salon" in the region, the size of which is dependent on the length of the timber used in the house's construction. The facades of these houses are typically symmetrical, with few projections. Any projections that do exist are eave-like and are created by extending the floor beams along the facade line. To ensure adequate lighting for the rooms and upper floor, windows measuring 75-80 centimeters wide and divided by small registers are used. The traditional houses of the historic Günyurdu Village do not feature semi-open spaces, a design feature attributed to the area's climate (Figure 11).

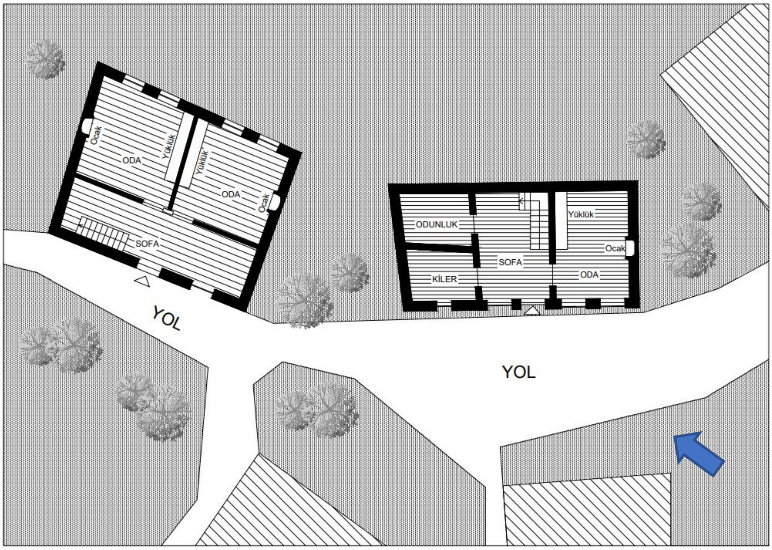

Figure 11: An Example of The Ground Floor Plan Schemes of Traditional Houses in Günyurdu Village (Buildings K51 And K52) (Baran Ergül, 2023)

3.3.Construction System and Material Characteristics of Traditional Houses of Historic Günyurdu Village

The most prevalent construction method for traditional houses in many regions of Anatolia has continued to evolve since the Neolithic period using mudbrick, stone, and wood materials. This construction system typically involves masonry stone for the foundation and ground floor, with mudbrick used to fill the wooden carcasses of upper floors (Kuban, 1995).

The accumulation of knowledge and the easy availability of building materials have led to the widespread use of the aforementioned construction system in the traditional houses of Günyurdu village. The foundation of these houses consists of rubble stone walls with depths that range between 100 and 150 centimeters. These walls typically rise along the ground floor walls, although some dwellings feature a different type of stone masonry above flood level. Adobe mud is commonly used as a binder in these walls, with ground floor wall thicknesses varying between 40 and 55 centimeters (Figure 12).

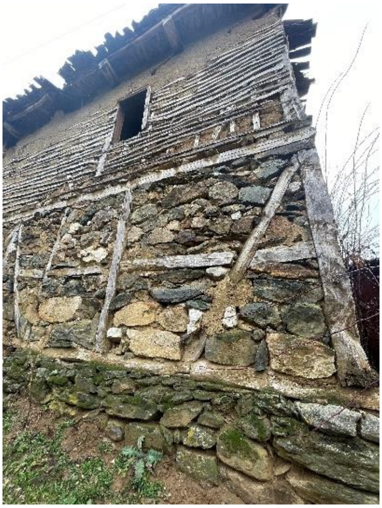

Figure 12: Wall Detail of K43 Residence (Baran Ergül, 2023)

In many of the houses in Günyurdu village, the rubble stone ground floor walls are left unplastered. For the foundation and ground floor walls, stones found in stream beds and valleys are commonly used, while mudbrick obtained locally is used as filling material for the upper floor walls. Mudbrick, often mixed with lime additives, is used as both mortar between joints and plaster on the facade. To improve the workability and structural resistance of the mud, a type with a high refractory clay content is preferred (Figure 13).

Figure 13: Detail Of Plastering With Mudbrick With High Refractory Clay Content (Baran Ergül, 2023)

In Günyurdu village, houses are typically constructed with wooden carriers and filled with adobe or other masonry material, and mudbrick is used as filling material between the wooden beams in the floors. Pine and fir are the preferred wood types, and Kınık Village, located nearby, is a significant source of red clay commonly used for construction.

In the traditional houses of Günyurdu Village, a combination of mudbrick and wood is employed in two distinct construction systems. The first system, known as the "hımış" technique, utilizes masonry material to fill the gaps between variously sized wooden uprights placed both vertically and at angles. The second system, known as the "bağdadi" technique, employs wooden uprights and crosses connected to each other with laterally nailed wooden slats. This system allows for looser filling material to be used between the wooden uprights compared to the "hımış" technique. Both systems utilize the insulating properties of the wooden slats and filling material, providing thermal comfort and structural stability to the houses. The use of locally sourced mudbrick, combined with pine and fir wood, is a testament to the ingenuity and resourcefulness of traditional building techniques in the region (Figure 14-15).

Figure 14 and 15: Two Examples of Baghdadi and Hımış Construction Systems (Baran Ergül, 2023)

The vernacular architecture of Günyurdu Village employs a simple hipped roof structure constructed of wooden framing members, sloping in four directions and covered with clay tiles. The primary structural elements of the pitched roof system comprise natural wooden beams with cross-sectional dimensions of 12/12 cm and 15/15 cm. The eaves of the roof remain uncoated and feature an exposed wooden aesthetic that is typical of the local architectural tradition.

The school building and mosque in Günyurdu Village were constructed with masonry stone walls. However, due to their location, the school building is now submerged under the waters of the dam, while the mosque is no longer in use. Structures intended for storage and animal shelter within the village were primarily constructed using simple mudbrick masonry or wooden frames (Figure 16). In contrast, the new buildings in the village were constructed utilizing a reinforced concrete system (Figure 17).

Figure 16: A barn structure among the residential add-on in the village (Baran Ergül, 2023)

Figure 17: K21 and K25 dwellings built with reinforced concrete construction system and used as weekend houses (Baran Ergül, 2023)

The traditional dwellings of Günyurdu Village serve as a repository of local building practices and customs, and represent the last remnants of a once-thriving building tradition. These structures, built in a vernacular style, played a vital role in shaping the identity of the settlement. However, with the passing of builders and depopulation of the village, these buildings have fallen into disuse and are increasingly vulnerable to deterioration. Therefore, documenting and analyzing these structures is crucial for understanding the village's unique character and exploring methods for preserving them for future generations.

3.4.Structural Condition Analyses and Conservation Problems of Traditional Houses of Historic Günyurdu Village

A systematic and structured approach was employed to analyze and evaluate the traditional houses in Günyurdu Village. Comprehensive detection studies were conducted, and building information sheets were developed to ensure standardized and efficient data collection. These slips contained detailed information such as identification, physical condition, material durability, structural integrity, functionality, and environmental input criteria. These data are crucial in assessing the potential refunctionality of buildings for conservation efforts. This approach allowed for a thorough analysis of the houses' structural conditions, identification of conservation problems, and exploration of possible conservation methods.

Table 1: Table of degrees of structural conditions (Baran Ergül, 2023)

Grade	Poor	Weak	Medium	Good
Category	Demolished	Damaged	Water and Airtight	Optimum
Situation	Most of the walls are missing, there is no roof, no joinery remains intact.	Widespread deterioration of the structure and building components, non-functional or about to become non-functional	Wear and tear at the building material level, neglected, about to lose building performance	Reusable with simple renovation, no major damage, many of the user needs can be met.
Intervention Type.	Restoration, Conservation, Preservation with Refunctioning	Renovation Preservation with Same or Different Function Options	Adaptation of modern techniques, Renovation Rehabilitation, Material Replacement, Expansion	Minor Intervention, Renewal, Expansion

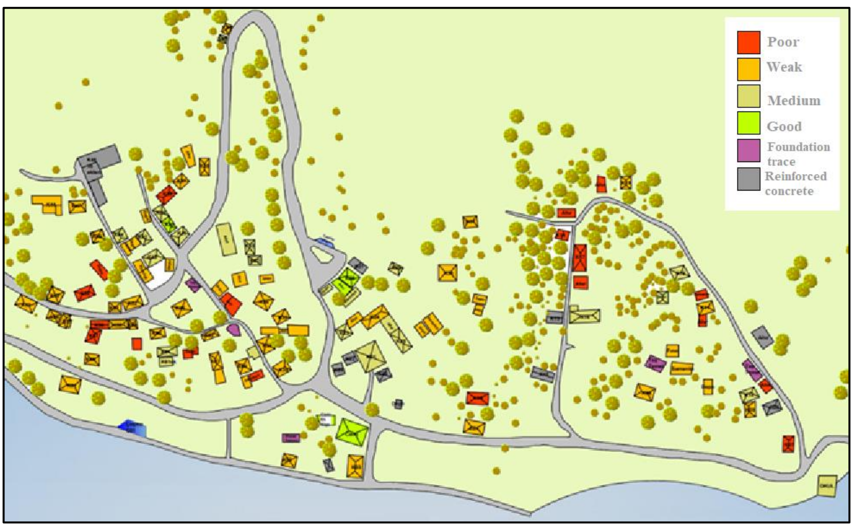

Figure 18: Map Showing the Structural Conditions of Günyurdu Village Dwellings (Baran Ergül, 2023)

According to the structural condition rating table above, eight of the 65 houses in the settlement were new houses built with a reinforced concrete system. Of the original dwellings, 2 (3%) were in good condition, 15 (23%) were in medium condition, 32 (49%) were in weak condition, and 8 (12%) were demolished and dilated (Figure 18-19). Based on the information provided, it can be inferred that a significant portion of the traditional houses in Günyurdu Village are in demolished or dilapidated conditions, with only a small percentage in good or fair conditions. Most of the original dwellings (72%) were demolished or worsened, which highlights the need for urgent conservation efforts. Additionally, the presence of new houses built with a reinforced concrete system suggests a shift away from traditional building methods, which could have implications for the preservation of the local architectural heritage.

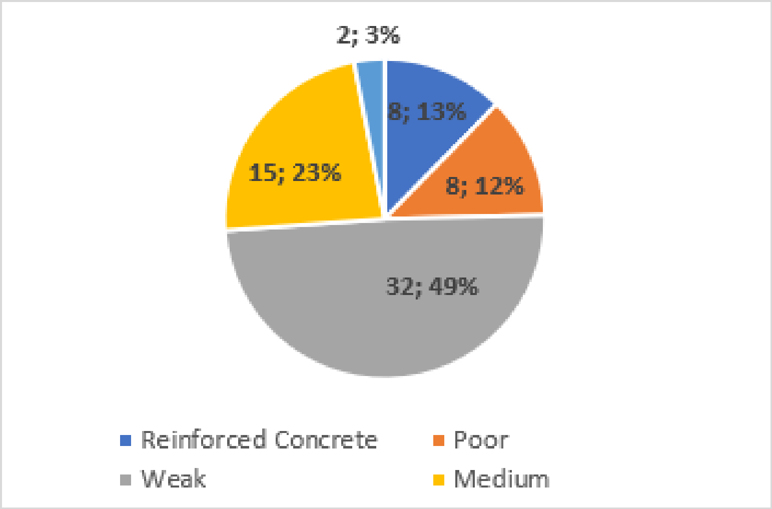

Figure 19: Günyurdu Village Structural Condition Analysis (Baran Ergül, 2023)

Before developing a conservation plan for a historical building, it is necessary to conduct a comprehensive evaluation of the deterioration of the building and the factors that have caused it. This includes examining the physical, environmental, and socioeconomic factors that have contributed to the building's degradation to ensure that appropriate conservation measures can be implemented. To ensure the preservation of traditional buildings in Günyurdu Village, it is essential to examine the underlying factors that cause their deterioration. Flood damage is a significant contributor to internal damage in buildings located in areas affected by rising water levels, while external factors and human neglect threaten the sustainability of structures that are not affected by dam flooding.

At present, interventions to reverse the deterioration caused by location-specific factors are not feasible. Nonetheless, it is crucial to identify the types of deterioration in order to explore possibilities for rehabilitation and establish a strategy for buildings that have become dysfunctional and damaged due to abandonment. To this end, criteria for structural damage and deterioration were established through a review of relevant literature, and a table was compiled based on the structural damages observed in the settlement's dwellings (Gür, 2017) (Table 2).

Table 2: Deterioration of buildings, their causes and frequency of occurrence (Baran Ergül, 2023)

Deterioration in the load-bearing system (internal and external causes caused by users)	**Deterioration of the material (caused by internal and external causes)**	**Distortions in the plan (user induced)**	**Deterioration of facades (external, user-induced)**	**Plastered Surfaces and Finishes**
Deflection from vertical	Physical deterioration (Wood)	Unqualified adds-on	Stains caused by air pollution, sunlight, dampness	Plaster spills
Separation from fire wall or adjacent structure	Fungation		Fragment ruptures	
Floor subsidence	Insects		Bending	Surface pollution
Collapse	Surface abrasions such as scorching, crumbling, dusting, piece breakage etc.		Mechanical deterioration	Capillary / structural cracks
Significant deflection of slabs	Surface pollution		Unqualified adds-on	Surface abrasions such as scorching, dusting, chipping, etc. (stone or brick veneer)
Structural cracks	Salinization, flowering on surface		Unqualified (poor) repair	
	Capillary / structural cracks	Unqualified (poor) repair	Incorrect material usage	
Loss of bearing capacity of the elements as a result of wood diseases / reduction in cross-section	Corrosion of iron components			Salinization, flowering on surface
	Vegetation, mossing		Defective workmanship	Vegetation, mossing

Natural disasters (earthquake, fire, etc.).	Painted / cement plastered surface (loss of water vapor permeability of the surface)	Painted / cement plastered surface (loss of water vapor permeability of the surface)

Very often
Common
Few
Rare

The classification of structural damage is presented in Table 1, which comprises five major categories: structural system, floor plan, façade, materials, and coatings. Priority is given to the structural system because it represents the most significant damage type. Each damage category was ranked according to its relative importance, and the corresponding deterioration criteria were established based on a comprehensive analysis of the most prevalent types of damage in residential structures. Notably, the primary form of structural damage is the physical deterioration of wood and surface abrasions, such as scorching, crumbling, dusting, and fragment breakage, with notable variations occurring in flooring and material degradation. Common types of deterioration include structural and plaster defects.

Anatolia's rural architectural culture is a remarkable aspect of Turkey's built heritage, which is often overshadowed by its urban architecture (Eres, 2016). While there have been various efforts to enhance the planning and physical environmental conditions of rural areas in Turkey, the preservation of rural architectural heritage has only recently emerged as an important issue (Baran Ergül, Acun Özgüler, 2022). The lack of legal regulations and definitions of rural or rural protected areas is one of the primary reasons for this. This underscores the need for legal frameworks to protect rural architectural heritage in Turkey (Eres, 2013). However, legal regulations alone cannot ensure the sustainable transfer of rural architectural heritage to future generations. A comprehensive approach that includes social, economic, and technical dimensions is required to address the challenges and preserve rural architectural heritage.

The involvement of local communities is crucial for the sustainable preservation of rural settlements with historical and cultural value. Günyurdu Village is a case in point where abandonment has led to the loss of traditional features and various problems. Economic and aging reasons make it difficult for villagers to allocate budgets and time for housing, leading to deterioration. Although nine families still reside in the old settlement, some cannot afford to renovate their houses because of a decrease in their source of livelihood, while others face difficulties in maintaining traditional construction techniques. Additionally, technical problems arise owing to a shortage of labor for traditional construction techniques, while the emergence of incompatible new structures contributes to the destruction of the area. Therefore, a holistic approach that considers the social, economic, and technical dimensions is essential to address these problems and ensure the sustainable preservation of rural architectural heritage.

4. Conclusion and Suggestions

The decline of rural populations poses a significant risk to the preservation of traditional rural environments, which have been shaped over generations. As these environments fall into disuse, they become increasingly obsolete and are eventually lost. This loss not only leads to the disappearance of rural architectural heritage, but also the loss of natural habitats, agricultural landscapes, and biodiversity. Stopping and reversing this process of extinction and deterioration is crucial to preserving traditional culture and memory. To achieve this, it is necessary to discuss methods for the protection of depopulated rural settlements, identify conservation problems in rural areas, and offer solutions for improvement. While there are already many academic studies on this subject, it is essential to increase the number of multifaceted approaches, such as the "Live Your Village" project, which offers reference points for villagers and encourages their active participation (Arpacıoğlu, 2013).

Günyurdu Village, with its rural environment, historical features, architecture, and traditional way of life, presents a unique example of a settlement that has managed to maintain its integrity despite numerous challenges. However, depopulation threatens the village's existence. A meticulous documentation and analysis of the village's architectural characteristics and settlement-related data revealed that a comprehensive solution is necessary to address the challenges of human impact, administrative issues, socio-cultural factors, and economic considerations to ensure preservation and sustainability. To develop effective conservation strategies, it is crucial to first identify and assess all the settlement values. This study thoroughly examined the historical, cultural, and overall structural characteristics of Günyurdu Village and found that the buildings within it have been constructed over the course of many years, drawing upon a wealth of accumulated knowledge. These structures are in harmony with the local environment and culture, highly functional, and have demonstrated remarkable resilience over time. Preserving the settlement is therefore critical for its sustainability and longevity and to ensure the continuity of the culture and its historical accumulation (Güler, 2017). To enable the revival of life in Günyurdu Village, it is essential to identify and address the necessary conditions for the refunctioning of its buildings to meet the needs of the human community. Possible options for re-evaluating a settlement include the return of its inhabitants, museumization, tourism, and resettlement. The feasibility of each option must be assessed and decided upon before buildings can be effectively repurposed. In the case of Günyurdu Village, the return of former residents depends on improvements to the physical environment, such as the proximity of the new settlement, absence of security concerns, stable water levels of the dam lake, and presence of families still residing in the village. Resettlement is crucial for preserving the physical infrastructure and intangible cultural heritage of the village, and any plan should be carefully crafted with economic factors in mind.

Günyurdu Village's natural and cultural features, including its water elements and rural environment, make it a promising destination for tourism. Tourism can prevent depopulation and promote participatory rural development. It can also preserve the village's historical and cultural heritage and create economic opportunities for the locals. To make a village suitable for tourism, identifying user needs, selecting appropriate buildings, and maintaining architectural texture and structure are crucial.

Restoration interventions and protection methods are required to prevent deterioration of traditional houses. Interior spaces also require functional transformation. Decision support systems can aid in selecting the appropriate functions for each building. In addition to conservation-oriented structural transformation and tourism, it is important to prevent abandonment in the long term by providing public functions such as education and health through infrastructure works. The demographic structure of the area should be preserved to ensure the transfer of intangible heritage and traditional culture to future generations. To achieve this, it is necessary to inform the local people about the historical nature of the settlement and raise their awareness of its richness.

The sustainability of conservation is a crucial step in the conservation approach, following the identification of the settlement's values, determination of re-evaluation options, and structural transformation strategies. To achieve this, mechanisms that integrate with national policies and define financial resources and tools should be established. It is essential to evaluate and update methods and take rapid action based on cooperation between stakeholders. Administrative mechanisms that can coordinate this should be defined in advance. The project should be open to all relevant fields of expertise and all segments of society.

Thanks and Information Note

The e-book section complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

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An Evaluation of Stone Material Problems in Historic Masonry Buildings: The Example of the Virgin Mary Church in Mardin

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1. Introduction

Historic buildings are important symbols of the cultural heritage. However, many factors affect these buildings negatively. Historical buildings are exposed to damage, including many degradation categories such as cracking, blistering, bursting, fragmentation, discoloration, and biological degradation due to various reasons arising from the external environment, primarily due to atmospheric reasons (Jo & Lee, 2014). Situations such as the complexity of conservation practices and the occurrence of situations that require urgent intervention in historical buildings often necessitate the detection of material deterioration in the mentioned buildings in a limited time. Various standards for intervention methods at this stage are crucial in obtaining reliable results. Cesare Brandi on this subject; 1906-1988, the father of the modern conservation theory, offered a phenomenological and ontological approach by separating the restoration issue from other modern approaches to conservation (Brandi, 2005) and argued that the ontological approach should be developed by adapting it to new conditions. According to Brandi, some integrated aspects within the complex architectural ontology should be privileged when doing conservation practices (Meraz & Magar Meurs,2019). In this context, various countries have put forward conservation standards that make ontological classifications in the field of restoration. In the documents presented, suggestions are made to clearly define material problems and create a common understanding using terminologies that can be shared by people from different backgrounds, from different regions, or with different mother tongues (Delgado Rodrigues, 2015). For this purpose, commissions have been established in various countries, especially in Italy, to examine the changes in stone material in the field of stone material protection and establish standard methods for monitoring the intervention.

The Italian Standard, Normal 1/88, published in Italy in 1990 and which can be used for mapping stone deterioration, is called "Alterazioni macroscopiche dei material lapidei: lessico." Each of the 27 terms in this glossary is illustrated with photographs and a graphical chart (NorMal 1/88, Italian recommendation for classification of damage in the stone monument, 1990) as well as a classification of brick wall deterioration that deals with the deterioration of the entire wall. This document has been developed in conjunction with an expert system abbreviated MDDS, which stands for "Massage Damage Diagnostic System," and all damage types covered in the document present a system aimed at assisting decision-makers in diagnosing the source of deterioration and selecting appropriate methods and materials for brick wall restoration.

Another document by Jose Delgado Rodrigues, a 26-term proposal for the nomenclature of forms of stone decay in monuments, was produced within the framework of the Petrographic Group of the ICOMOS Stone Committee. This proposal was used by the LNEC in 2004 as a basis for the publication of a glossary containing concise definitions in Portuguese, including terms related to stone, masonry, and plaster degradation, in which each term is associated with a graphic table (Henriques et al., 2004). Written by Fitzner et al. (1995), updated by Fitzner & Heinrichs in 2002, a color and graphic scheme is proposed in the same way as found in the Italian Standard Normal 1/88, and the document on classification/mapping of weathering forms presents the mapping of stone damages, illustrated classifies document corruption patterns by type and intensity.

Another document was prepared by a group of experts from Germany (VDI 3798, 1998), the VDI, "Verein Deutscher Ingenieure / The German Engineers' Association" This document is a German terminology list of 14 terms with definitions and drawings. The Italian Standard and the Fitzner system recommended a graphical representation of decay patterns. Another document, The web site (http://www.qub.ac.uk), a 30-term illustrated dictionary edited by Queen's University of Belfast (England), offers a comprehensive set of weathering features, including monumental degradation patterns and references to anthropogenic damage. 'ICOMOS-ISCS: Illustrated glossary on stone deterioration patterns' published by ICOMOS in 2008, ICOMOS International Scientific Stone Committee (ISCS), ISCS dictionary, created a scientific language on stone degradation events and processes.

Mapping of stone surface patterns has long been used as a non-destructive technique in various previous studies in the literature for detailed documentation of degradation (Fitzner, 2002). Mapping and classification can be adapted for degradation patterns caused by various weathering events (Cutler et al., 2013). The application provides important information about the ongoing aging processes, especially after being supported by information from analytical techniques and environmental measurements (Adamopoulos & Rinaudo, 2021).

In this context, Hatır et al. (2021) discussed the deteriorations (cracks, discontinuities, contour scaling, missing pieces, biological colonization, presence of higher plants, sediments, flowering, and loss of frescoes) observed in Gümüşler Archaeological Site and Monastery. In the study of Patil et al. (2021), some laboratory tests and in-situ investigations were carried out to examine basalt's weathering pattern and behavior in a stone monument. In addition, the monument mapping method was used for detailed documentation of weathering forms. The weathering pattern, forms, and results obtained after detailed studies have concluded that the causes of basalt deterioration are primarily due to air pollution and climate. Kramar et al. (2011) characterized the limestone from mineralogical, chemical, and petrophysical aspects and investigated the degradation events of limestone in two monuments exposed to indoor and outdoor environments. In situ examination of the two monuments through monument mapping identified degradation phenomena such as granular disintegration, flaking, chipping, efflorescence, crusting, and microorganisms. As a result of the study detected a wide variety of weathering forms on the monument, characterized by loss of stone material, discoloration/accumulation, and separation. In addition to the color change, it was observed that the most critical deterioration in the interior and exterior of the examined monuments was the formation of soluble salt. It has been determined that salt causes different types of deterioration under different environmental conditions; its crystallization leads to the scaling and crumbling of limestone and the formation of crusts and efflorescences, while magnesium sulfate hydrates occur only as a bloom indoors. The properties of limestone are similarly affected in natural rural environments. It has been concluded that the separation will affect the behavior. In the study of Bozdağ et al. (2019), deteriorations on a stone monument were used together with non-destructive testing methods with the method of deterioration type classification according to the methods recommended in ICOMOS-ISCS (2008). Adamopoulos & Rinaudo (2021) used mapping defined by standards to explain weathering categories and calculate damage indices. The study of Delgado Rodrigues (2015); proposed a methodology for identifying and classifying conservation problems and preparing documents in conservation interventions and used a common terminology, ICOMOS, decay patterns to describe degradation patterns on established heritage. Siegesmund & Snethlage (2011) presents the main methods used to characterize stone deterioration in structures, classify weathering forms, and describe them. Following the latest proposal from ICOMOS (International Council for Monuments and Sites), a short, illustrated glossary is provided, and mapping techniques and problems are discussed. The study of Delgado Rodrigues (2015); proposed a methodology for identifying and classifying conservation problems and preparing documents on conservation interventions. It used ICOMOS degradation models, which give common terminology to describe the degradation patterns on the established heritage. Siegesmund & Snethlage (2011) presented the main methods used to characterize stone deterioration in structures, classify weathering patterns, and explain them. They presented the final proposal of ICOMOS (International Council of

Monuments and Sites) and included a short / illustrated dictionary. He discussed mapping techniques and problems.

As seen in the literature, degradation patterns are the visible consequences of the influence of environmental factors on stone objects. Identifying and documenting stone material problems in historic masonry structures is fundamental to identifying conservation needs and defining appropriate conservation actions. According to Delgado Rodrigues (2015), Study tools and mapping methodologies such as the ICOMOS Dictionary and Fitzner et al. (1995) can meet the stated requirement. However, these methodologies may only sometimes be suitable for interpreting the construct-specific situation. Identification, characterization, and mapping of degradation patterns by the geographical contexts of countries are the most appropriate procedures. Because degradation patterns are fingerprints linked to the genetic contexts of the cultural past, for this reason, it is essential to systematically sample the studies on the determination of material problems in the geographical context. In this context, this study aims to assess the visual detection and documentation of material problems in a masonry building in the city of Mardin, which is especially important to Turkey's historical architecture.

2. Material and Method

Information about the Mardin Virgin Mary Church, which constitutes the primary material of the research, is given in Section 2.1, and the method of the study is explained in Section 2.2.

2.1. Material: Church of the Virgin Mary

The structure examined in the study is the Church of the Virgin Mary in Mardin. The building is a unique cultural monument that survives despite being exposed to many environmental influences.

Located in Mardin Cumhuriyet Square, the Virgin Mary Church was built by Patriarch Antun Semheri in 1895 as a church belonging to the Syriac Catholic community. The church, which has a patriarchate next to it and does not have a congregation, was transferred to the Ministry of Culture in 1988. The restored church has been used as a museum since 1995 (Ministry of Culture and Tourism, 2012). The Virgin Mary Church is in urban conservation (Figure 1).

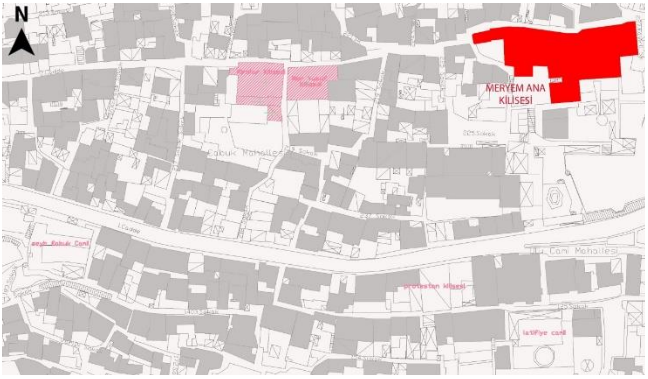

Figure 1. Location of the Virgin Mary Church in the City (Karataş, 2016)

2.1.1. Properties of Plan and Façade

The building has a rectangular plan scheme consisting of the main prayer hall and the courtyard. In the study, it was preferred to number the facades on the plan to enable the material problems to be documented and read practically. The façade, which is used as a place of worship and located in the north of the courtyard, is named “wall 1”, the facade to the east of the courtyard is named “wall 2,” and the facade to the west of the courtyard is named “wall 3” (Figure 3).

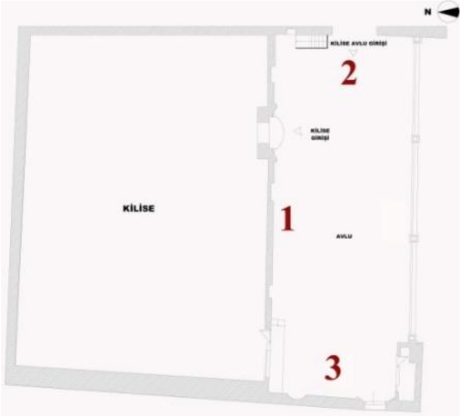

Figure 2. Ground Floor Plan and Wall Numbers (Karataş, 2016; Mardin Artuklu University, Faculty of Architecture Archive)

Smooth-cut stone was used on all the walls on the exterior of the building, and rubble stone was found on the inner parts of the double-skinned walls. The entrance facade of the building (wall 1) has two floors and opens to the south. The main entrance door to the place of worship is on a deep and high niche. The niche protrudes slightly. It is framed by a rectangular molding with two rows of muqarnas. There are four window spaces on the ground floor and a door that is not original. There are eight windows on the second floor. Round and pointed arches can be seen above the windows on the ground floor. On the second floor, some windows are placed in a three-section arched niche (Figure 3).

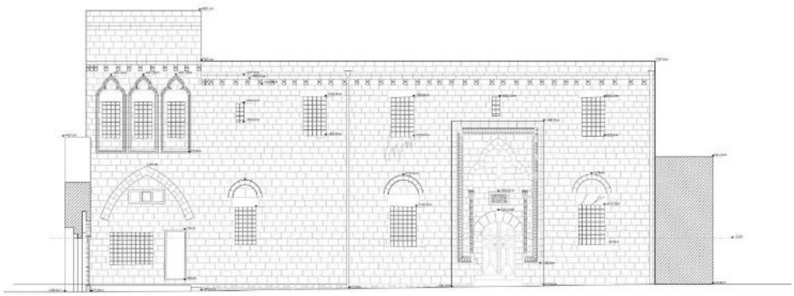

Figure 3. Wall 1 – External View

(Mardin Artuklu University, Faculty of Architecture Archive)

On the far right of wall 2 is a pointed arched iwan that provides the passage to the courtyard. To the west of the iwan is a pointed arched niche in the lower part and a window in the upper part. The grooved decoration seen at the junction of the roof cover and the body wall adds movement to the façade (Figure 4).

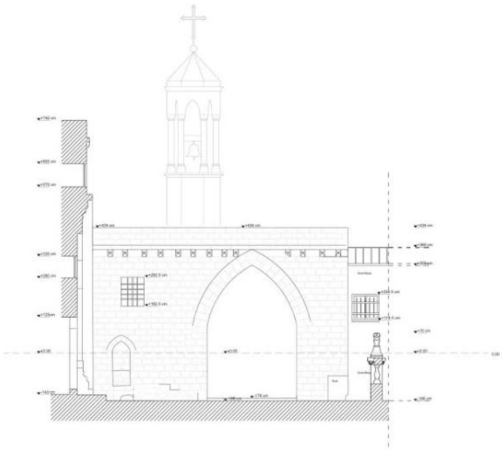

Figure 4. Wall 2 – External View

(Mardin Artuklu University, Faculty of Architecture Archive)

The wall richest in ornaments is wall 3. It is a single story. A door is placed on two columns far west of the wall and framed by two rows of moldings. An ornamented inscription is east of the door (Figure 5).

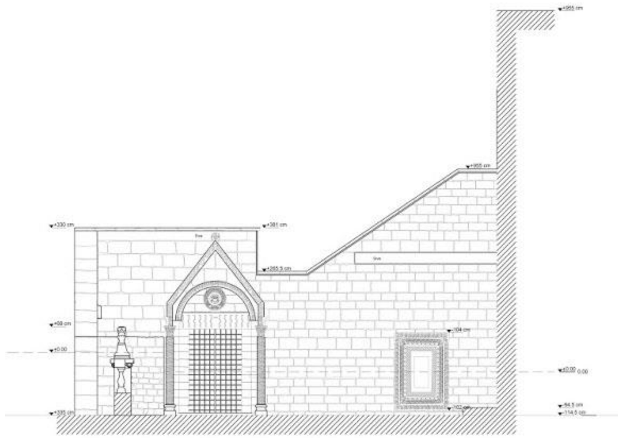

Figure 5. Wall 3 – View from the Courtyard

(Mardin Artuklu University, Faculty of Architecture Archive)

2.1.2. Construction Technique and Material Properties

The church was built using the masonry technique. The primary building material is yellow limestone extracted from the region. Local yellow limestone was preferred for structural purposes in the church. Local limestone of a reddish color, which is soft, was used in the ornamental areas. The window and door frames are wooden. Metal material is preferred for door hinges, belts, door locks and bolts, door knockers, rings and handles. Local 'ınkara' mortar (consisting of limestone powder, fine sieve sand, and slaked lime) was used as the binding mortar in the construction.

2.2. Method

Within the scope of the study, the relevant literature was scanned, a classification of material problems based on literature data was made, and visual analysis forms were used. The first of the forms used within the scope of the study is a chart that will enable the identification of the original elements and materials of the building (Figure 6).

Figure 6. Materials Used in the Virgin Mary Church.

BUILDING ELEMENTS				MATERIALS								
				Stone								
				Debris	Freestone	Face stone	Brick	Wood	Metal	Mortar	Plaster	Paint
VERTICAL BEARING	SINGLE BEARING	Column		-	-	+	-	-	-	+	-	-
	CONTINUOUS BEARING	Wall		-	+	+	-	-	-	+	-	-
HORIZONTAL BEARING	FLOORING	Curvilinear	Vault	-	-	+	-	-	-	+	-	-
STAIRS				-	-	+	-	-	-	+	-	-
WALL OPENINGS	WINDOW	Lintel and Jamb		-	-	+	-	-	-	+	-	-
		Case		-	-	-	-	+	-	-	-	-
		Wing		-	-	-	-	+	-	-	-	-
		Sill		-	-	+	-	-	-	+	-	-
		Supplementary Element		-	-	-	-	-	+	-	-	-
	DOOR	Lintel and Jamb		-	-	+	-	-	-	+	-	-
		Case		-	-	-	-	+	+	-	-	-
		Wing		-	-	-	-	+	+	-	-	-
		Sill		-	-	+	-	-	-	+	-	-
		Supplementary Element		-	-	-	-	-	+	-	-	-
AUXILIARY ELEMENTS	RAILING			-	-	+	-	-	-	+	-	-
	MOULDING			-	-	+	-	-	-	+	-	-
	COATING			-	-	+	-	-	-	+	-	-

Another form used within the scope of the study is a chart for the detection and documentation of stone material deterioration (Figure 7). Table 2 used within the scope of the study is based on a problem classification based on literature review. According to this; problems in masonry, surface loss, fragmentation, formation of gap/ hole, pitting, cracks, spalling, foliation, discharge of jointing, surface contamination, shell formation, efflorescence, crystallization, formation of plant, formation of moss, corrosion (rust stain), tear, loss of form were examined under a total of seventeen different titles (Karataş & Perker, 2017).

Figure 7. Church of the Virgin Mary / Observation Form for the Determination of Material Problems

NATURAL STONE BUILDING ELEMENTS			PROBLEMS																		Faulty Repairs		
			Loss of surface	Fragmentation	Formation of gap/ hole	Pitting	Cracks	Spalling	Foliation	Discharge of jointing	Surface contamination	Shell formation	Efflorescence	Crystallization	Formation of plant	Formation of moss	Corrosion (Rust stain)	Tear	Loss of form	Colour change	Use of cement	Painting the stone	Other
VERTICAL BEARING	SINGLE BEARING	Column	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
	CONTINUOUS BEARING	Wall	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	-	+	+	-	-	-
HORIZONTAL BEARING	FLOORING	Curvilinear / Vault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STAIR			-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	+	-	-	-
WALL OPENING	Window	Lintel/jamb	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Door	Lintel/jamb	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-
AUXILIARY ELEMENT	Railing		-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	Moulding		-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	Coating		-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-

Loss of surface is the washing and dissolution of the stone surface occurring due to the reasons caused by internal causes or due to external factors such as water, wind, wetting, drying, and the wear of the stone material over time.

Fragmentation; Fragmentation occurs on the stone's surface due to the cracks caused by several impulses or effects originating from other sources by generating pressure on the internal structure of the stone and the force applied by these cracks on the other parts of the stone.

Gap –Formation of Hole; the volume created by the holes, which humans or other reasons may cause, becomes unguarded against various impacts, and these reasons also accelerate the other deterioration processes.

Pitting; the stone's surface takes a deteriorated, pitted appearance over time due to atmospheric effects such as sun, water, wind, wetting, and drying. The cross-section of the stone is reduced due to the emptying of the surface due to the pits, and the deterioration area is increased because of the pitting of the surface. Therefore the wear of the stone is accelerated.

Cracks; may occur due to earthquakes, tremors, various loads, settlement of the buildings, or the pressure on the stone caused by a metal element, which has been corroded, behind the stone.

Spalling; is the formation of swellings, which are seen in thin swellings and exfoliations on the surface of the stone material due to the outer atmosphere on the structures.

Foliation occurs due to the swelling of the surface of the stone material in the form of layers due to various atmospheric impacts and taking an appearance of the leaf, and the processes result in shedding in the later stages.

Discharge of jointing is the destruction of mortar, used as the binding material in the gaps in stone structures, for different reasons, and its surroundings become unprotected.

Surface contamination is the deterioration seen as a thin grey layer on the surface, occurring on the stone structures due to air pollution.

Shell formation is the deterioration seen in a thick shell, generally in dark grey–black color, on the surface, occurring on the stone materials due to air pollution.

Efflorescence is the formation of salt accumulation on the surface of the stone material due to external atmospheric impacts.

Crystallization is a type of deterioration seen on marble.

Formation of plant; is a type of deterioration caused by the seeds, which settle into the small gaps within the walls and enroot within this environment in time, and cause other various deformations such as cracks and fragmentation on the stones surrounding due to the damages on the structure of the stone caused by the roots.

Formation of moss; as a damp environment is needed for the formation of moss, this dampness is present here. Stone starts to decompose and becomes mossy after a while if the damp causing this is not removed, as the mosses release many diluted acids and cause the rock to dissolve very slowly. This moss is seen here.

Corrosion (Rust) stain; the iron element used in the windows and railings corrode in the structures. As a result, it is seen that it leaves stains in different colors ranging from brown to red on the stone with the impact of the rain.

Tear; occurs on the surfaces of the materials as a result of human-originating causes.

Loss of Form; loss of form and legibility of the outer contours of the decorations on the stone surfaces, in whole or part, is called the loss of form.

Change of color; is defined as the coloration, discoloration, darkness of the damp area, and staining on the Stones due to the chemical change occurring on the minerals forming the stone with the effects of daylight, water, moisture, or any flow (washing as a result of the corrosion of metals, etc.).

Defective repair; is faulty applications made to repair, use of cement, or coating with inappropriate material (Karataş & Perker, 2017; Megep, 2013).

3. Findings and Discussion

This section presents the findings regarding the material deterioration in the building based on building elements.

3.1.Vertical Bearings

Twenty-one columns and the main walls carry the top cover of the place of worship. Efflorescence was observed in the decorations of the columns built using cut stone material (Figure 8). Loss of form was observed in some column decorations in other parts of the building.

Figure 8. Efflorescence on the columns

Rough-cut stone masonry was used on the inner side of the walls of the main prayer hall, and cut stone masonry was used on the outer side. Smooth-cut stone masonry can be seen on the interior walls. Problems such as surface loss, surface contamination, rust stain and efflorescence were observed on wall 1 (Figure 9). Problems such as color change, surface contamination, and efflorescence were observed on wall 2 (Figure 10).

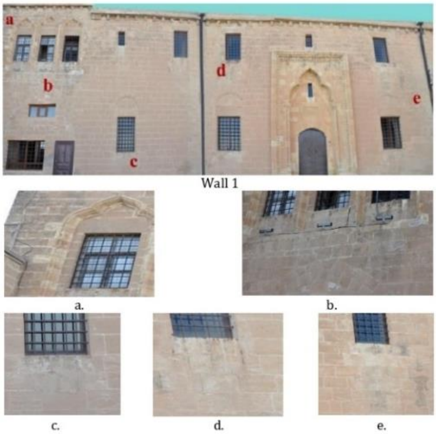

Figure 9. Material Problems on the Wall 1: a. Surface Loss and Surface Contamination, b. Efflorescence, c. Rust Stain, d. Rust Stain, e. Color Change

Figure 10. Material Problems on the Wall 2: a. Color Change, b. Efflorescence, c. Surface Contamination

Surface loss, loss of form in ornaments, color change, and flowering problems were observed on the wall 3 (Figure 11). Problems such as color change and efflorescence were encountered on the interior wall surfaces of the building.

Figure 11. Material Problems on the Wall 1

3.2.Horizontal Bearings

The upper cover of the building consists of vaults. The upper cover of room 1, seen in Figure 11, is a pointed vault. The upper cover of rooms 2 and 4 are cross vaults. Material problems were not observed in the vaults.

Figure 12. Space Numbers on Plan (Karataş, 2016).

3.3. Stairs

Problems such as tear, efflorescence, formation of moss, and color change were observed on the stairs made of smooth-cut stone material (Figure 13).

Figure 13. Material Problems on Stairs

3.4. Wall Openings

There are windows and doors as wall spaces in the building. Surface loss was observed on the stone lintels and jambs on windows. Stone material was used in the lintel, jamb, and threshold sections of the doors in the building. Surface loss was observed on the lintels and jambs of the doors while efflorescence and tear were observed on the thresholds (Figure 14).

Figure 14. Material Problems on Wall Openings

3.5. Auxiliary Elements

Floor coatings, railings, muqarnas, and moldings are considered auxiliary elements in the building. In Figure 10, efflorescence was observed on the flat floor in the room marked with number 2, and tear was observed on the courtyard floor, room number 3 (Figure 15).

Figure 15. Efflorescence on Floor Coatings

There is surface contamination on the muqarnas and moldings on the courtyard railing of the building, and the decorations above the entrance door of the main prayer hall (Figure 16).

Figure 16. Surface Contamination on Railing

4. Conclusion and Suggestions

According to the data from the observations, efflorescence is the most common problem in the building elements produced with stone materials in the Virgin Mary Church. In addition to this problem, surface pollution, color change, surface loss, and tear problems are seen in the building. The least common problems in the building are loss of form and formation of moss, respectively.

This result is similar to many studies that deal with limestone in different geographical contexts, especially Kramar et al. (2011) study. It has been determined that the most critical stone material deterioration in the interior and exterior of the monument examined in the study is the formation of soluble salt. This determination obtained in the study, Kramar et al. (2011) supports the findings obtained in the study results. The results confirm the fact that due to the properties of limestone, natural stone is similarly affected in natural rural environments and produces similar types of deterioration. In addition, research has shown that salt causes different types of deterioration on the stone in different environmental conditions. Crystallization of salt led to limestone exfoliation, physical disintegration and formation of crusts. These results supports Kramar et al. (2011) that salt crystallization exerts different kinds of pressures on the stone in indoor and outdoor environments. According to the results, the findings obtained in other similar studies. This supports the facts that the crystallization of salt causes more physical disintegration on the natural stone outdoors, and that it forms crusts on the stone in indoor environments.

In addition to this problem; the most serious damages seen in the structure after salinization are surface loss and physical disintegration type problems. According to the findings obtained in the study, such problems occurred mostly on the facades of the buildings exposed to rain. This result shows that the surface loss and physical disintegration of the stone material in the building occur due to the atmospheric water effect. These findings reveal that visible abrasions are observed more on facades that are in direct contact with rain water. Due to the increase in the volume of the stone minerals absorbing moisture in the structure, further deterioration by applying pressure on the stone confirms the results of various studies in the literature (Perry & Duffy, 1997). The intensity of the deterioration caused by the effect of water in the structure is so intense that it can be seen with the naked eye. This finding also supports the studies emphasizing that the effect of intense water on limestone, which is a soluble stone, increases the loss of mass and strength on the surface of the stone (Iucolano et al.,2019; Dursun & Topal,2019; Beck & Al-Mukhtar, 2014; Germinario et al.,2020; Gulotta et al., 2018)

Considering the observational findings from this study, it will be beneficial to map the existing material problems at different scales via computer-aided design (CAD) or geographic information systems (GIS).

It is thought that diagnosis, cleaning, and consolidation processes are needed in order to find solutions to the stone material problems observed in the building. Before cleaning, it is essential to diagnose the characteristics of the stone type, the current condition of the stone, the other materials it is used with, and the nature of the pollution. The appropriate cleaning method should be chosen without forgetting the specific usage conditions, benefits, and drawbacks of each method used in removing the impurities. Depending on the level of surface loss, consolidation can be applied. Using water repellants and surface protectors after cleaning and strengthening applications will be beneficial.

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Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

Lale Karataş contributed to research design, data improvement, drafting, field studies, analysis and visualization.

Z. Sevgen Perker contributed to research and methodology design, data interpretation, writing and editing.

There is no conflict of interest.

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An Observational Research for the Determination of Stone Material Problems in Mardin Kasımiye Madrasa

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1. Introduction

Studies investigating what factors cause the deterioration of stone material are especially important for cultural heritage. In world literature, there is much research about the causes of the deterioration of the stone material used in historic buildings. The literature includes water effect, temperature changes, biological factors, pollutants, salts, human-induced causes, and earthquakes as factors of stone material deterioration (Adamopoulos & Rinaudo, 2021; NorMal 1/88, Italian recommendation for classification of damage in the stone monument, 1990).

Various studies report that there are mass losses and strength reduction on the surface of the stone as a result of the effect of water and moisture (Şimşek & Perker, 2019; Iucolano et al., 2019; Aly et al., 2020; Dursun & Topal,2019; Ergüler & Shakoor, 2009; Beck & Al-Mukhtar, 2014; Bustamante et al., 2020; Germinario et al., 2020; Ergin et al., 2021; Bonazza et al., 2017; Gulotta et al., 2018). Hemeda (2021) explained that the effect of groundwater in the Egyptian pyramids on the stability of the pyramid is the biggest problem. Gandah (2015) confirmed the results of Hemeda (2021) with the finding that groundwater around the Egyptian Khufu pyramid is the most significant factor in stone degradation. Gandah (2015) proposed a methodology to reduce groundwater contacting the pyramids to prevent stone material damage.

Alves et al. (2021) reported that water causes various substances to dissolve in the stone material. Water often contains salts, biological agents, and various water-soluble substances. These substances can cause the accumulation of various substances in the petrographic content of the stone (Dˇoubal, 2017; Dal, 2021). In addition, as a result of the absorption of moisture by stone, an increase occurs the volume of the stone surface. As a result of the increase in the volume of the stone, it creates pressure on the stone. Thus, the stresses increase causes some decay, such as cracks and fragmentations. (Perry & Duffy, 1997). In addition, water causes material loss when water contacts the stone surface. Winkler(1997) reported that stone surfaces show erosion on the façades on the rain-exposed side of stone structures. The study explained that less material damage occurred on the facade surfaces on the sheltered side.

Temperature change is another critical factor affecting the deterioration of stone material. Various studies have reported that temperature changes cause physical disintegration by creating different stresses in the internal volume of stone (Khanlari et al., 2014; Villacreses et al., 2021; Reader, 2001; Rossi,2019; Ito et al., 2021). It is known that freeze-thaw cycles play an essential role in stone materials' mechanical and physical resistance. Temperature differences can cause damage to the stone surface depending on various factors (wind, wetting-drying cycle, rain, and pollution). These damage types have been reported as spalling, fragmentations, pitting, and cracks.

Various pollutants can also damage stone structures. Substances such as sulfate, soot, and nitrogen emitted from the surrounding vehicles cause a change of color in the stones, especially with the effect of precipitation (Grossi et al., 2007; Ambrosini et al., 2019; Corvo et al., 2010; Comite et al., 2017; Comite et al. al., 2020; Falchi et al., 2019; Gibeaux et al., 2018).

Basu et al. (2020) concluded that air pollutants are the most critical factor affecting the deterioration of stone structures, especially in cities such as London.

Salts and the crystallization process are other significant problem that damages the stone. Various studies have been carried out to determine the harm of the crystallization process and salts to stone material. Especially in limestone-type stones, it has been determined that salts cause damage types such as cracks and efflorescence due to the wetting-drying cycle (Derluyn et al., 2018; Sandrolini et al., 2011). Madkour & Khallaf (2012) reported that salt crystallization is the main problem affecting the pyramid degradation process.

Faulty repairs are another factor of damage that creates irreversible damage to stone structures. Cementitious mortars, which are generally used for repair purposes, contain high amounts of soluble calcium. These mortars can lead to the formation of calcium sulfate salt in stone structures. Calcium sulfate salt is a substance that causes a color change in the stone. In addition, due to the permeable chemistry of many mortars, such as lime mortar, the stones are exposed to water circulation within their internal structure (Duffy et al., 1993; Arroyo et al., 2013). Arroyo et al. (2013) conducted a study to determine the damage caused by the stone structures in Naples. In this study, they reported that the mortar compositions used to restore stone structures in the city caused more significant decay after restoration.

Earthquake effect is defined as another critical factor that causes damage to stone structures. Many studies have determined that crack-type damages occur in stone structures due to earthquake-induced tremors (Hemeda et al., 2018; Ahmed,2021; Fahmy et al., 2022).

The damage factors described above are generally valid for all natural stone types. In the relevant literature, there are also studies investigating limestone problems. Limestone consists of at least 90% of calcite minerals. Calcite mineral is a substance that dissolves as a result of the effect of water. As a result of the interaction of water and calcite, limestone may be primarily dissolved. Various studies concluded that water and soluble salts in the stone cause surface loss, efflorescence, and fragmentation damage on the limestone (Bradley & Middleton, 1998; Cardell et al., 2003; Corvo et al., 2011; Fahmy et al., 2022). Studies conducted in different countries have stated that the geographical area significantly affects the type of damage. Delgado Rodrigues (2015) have suggested that stone material problems should be investigated by considering geographical region factors. Investigating the causes of material problems in buildings is essential for conservation interventions.

Located in Turkey, the province of Mardin is an important city famous for its structures built from local limestone. Historic buildings in the region are defined as Mardin Urban Protected Areas. The Kasımiye Madrasa, the subject of this research, is an essential structure in the mentioned region. Topography, climate, local building materials, cultural elements, and unique features form Kasımiye Madrasa. The building has been exposed to various environmental influences over the years. The condition of the structure should be monitored regularly to ensure its sustainability. This study aims to investigate the natural stone problems of Kasımiye Madrasa by an observational method.

2. Material and Method

Information about the Mardin Kasımiye Madrasa, which constitutes the primary material of the research, is given in Section 2.1, and the method of the study is explained in Section 2.2.

2.1. Material: Kasımiye Madrasa

The structure examined in the study is the Kasımiye Madrasa in Mardin. The building is a unique cultural monument that survives despite being exposed to many environmental influences.

Kasımiye Madrasa is located in the Mişkin District, southwest of Mardin (Figure 1). The construction of Kasımiye Madrasa started during the Artuqid period (1102-1409). The construction of the building was completed during the Akkoyunlu period. The madrasa was used as a military mansion for many years. It is known that the madrasah was repaired in 1967 and 2007 (Altun, 1971). In 2009, a landscape project was applied.

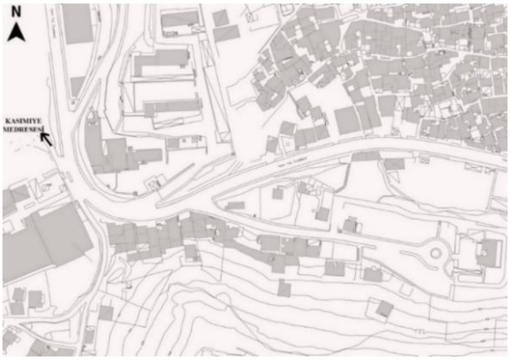

Figure 1. Location of the Kasımiye Madrasa in the city (Karataş, 2016)

2.1.1. Properties of Plan and Façade

In the study, it was preferred to number the facades on the plan to enable the material problems to be documented and read practically. The entrance façade of the building (facade 1), the façade opening to the side courtyard (facade 2), and the four façades (facades 3-4 -5-6), centered on the inner courtyard are named (Figure 2).

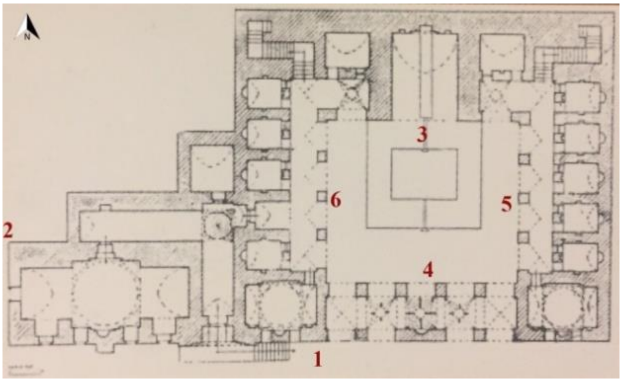

Figure 2. Ground floor plan and wall numbers (Karataş, 2016)

The entrance façade of the building (wall number 1) has two floors and is described as the south façade. The portal is located on this façade as a deep niche filled with muqarnas. Colorful stones were used on the facade. The portal is located on the symmetry axis of the façade. There are four rectangular windows and a central half-domed plaster on the western façade of the portal on the ground floor. Three barrel-arched windows are on the upper part of the detail on the second floor. The dome of the masjid is a bulbous dome. There are two rectangular windows to the east of the portal. In the area between the masjid and the tomb, which is covered with a dome, four closed oval niches belong to the portico (Figure 3).

Figure 3. Wall 1 – external view

The eastern façade (wall 2) is the façade of the place of worship in the building. The main façade wall is arranged to extend to the east. There are two window areas on the façade (Figure 4).

Figure 4. Wall 2 – external view

The northern façade of the madrasa courtyard (wall number 3) has two floors. In the middle, on the symmetry axis of the façade, there is an iwan.

(vaulted space recessed from a central court). To the east and west of the iwan are barrel(gothic) arch cloisters opening to the courtyard. The gothic arch of these porticoes on the ground floor should be ornamented. In part behind the façade porticoes are four wooden doors belonging to the rooms. There are decorations where the main walls integrate with the roof (Figure 5).

Figure 5. Wall 3 – view from the courtyard

The south façade of the courtyard (wall number 4) has a single story. There are porticoes on the façade. An iwan (vaulted space recessed from a central court) is in the middle of the façade. The orle (molding) is located at the intersection of the facade wall and the roof (Figure 6).

Figure 6. Wall 4 – view from the courtyard

The east side of the courtyard (front number 5) is two-story and consists of porticoes with barrel arches. Behind the porticoes, the door and window openings of the rooms can be seen. On the ground floor and the upper floor, there are four rectangular wooden windows and four wooden doors (Figure 7).

Figure 7. Wall 5 – view from the courtyard

The west side of the courtyard (wall numbered 6) has two floors. The four vaulted rooms in the front form the porticoes. On the façade behind the portico are the rooms' doors and windows at the back (Figure 8).

Figure 8. Wall 6 – view from the courtyard

2.1.2. Construction Technique and Material Properties

The primary construction material of the building is a local stone, a yellowish-colored limestone. Other original materials used in the building are basalt, brick, wood, metal, and local mortar. Yellowish limestone (hard) was widely used for structural purposes in the madrasa. On the portal, a soft reddish limestone was used for decorative purposes. Windows and doors are wooden. Metal materials are used in door hinges, door locks and bolts, door handles, rings, and handles.

2.2. Method

Within the scope of the study, the relevant literature was scanned, a classification of material problems based on literature data was made, and visual analysis forms were used. The first of the forms used within the scope of the study is a chart that will enable the identification of the original elements and materials of the building (Figure 9).

Figure 9. Materials used in the Kasımiye Madrasa

BUILDING ELEMENTS				MATERIALS								
				Stone			Brick	Wood	Metal	Mortar	Plaster	Paint
				Debris	Freestone	Face stone						
VERTICAL BEARING	SINGLE BEARING	Column		-	-	+	-	-	-	+	-	-
VERTICAL BEARING	CONTINUOUS BEARING	Wall		+	+	+	-	-	-	+	-	-
HORIZONTAL BEARING	FLOORING	Curvilinear	Vault	-	-	+	-	-	-	+	-	-
STAIRS				-	-	+	-	-	-	+	-	-
WALL OPENINGS	WINDOW	Lintel and Jamb		-	-	+	-	-	-	+	-	-
WALL OPENINGS	WINDOW	Case		-	-	-	-	+	-	-	-	-
WALL OPENINGS	WINDOW	Wing		-	-	-	-	+	-	-	-	-
WALL OPENINGS	WINDOW	Sill		-	-	+	-	-	-	+	-	-
WALL OPENINGS	WINDOW	Supplementary Element		-	-	-	-	-	+	-	-	-
WALL OPENINGS	DOOR	Lintel and Jamb		-	-	+	-	-	-	+	-	-
WALL OPENINGS	DOOR	Case		-	-	-	-	+	+	-	-	-
WALL OPENINGS	DOOR	Wing		-	-	-	-	+	+	-	-	-
WALL OPENINGS	DOOR	Sill		-	-	+	-	-	-	+	-	-
WALL OPENINGS	DOOR	Supplementary Element		-	-	-	-	-	+	-	-	-
AUXILIARY ELEMENTS	RAILING			-	-	+	-	-	-	+	-	-
AUXILIARY ELEMENTS	MOULDING			-	-	+	-	-	-	+	-	-
AUXILIARY ELEMENTS	COATING			-	-	+	-	-	-	+	-	-

Another form used within the scope of the study is a chart for the detection and documentation of stone material deterioration (Figure 10). Figure 10, used within the scope of the study, is based on a problem classification based on a literature review. According to this, problems in masonry, surface loss, fragmentation, formation of gap/ hole, pitting, cracks, spalling, foliation, discharge of jointing, surface contamination, shell formation, efflorescence, crystallization, formation of plant, formation of moss, corrosion (rust stain), tear, loss of form were examined under a total of seventeen different titles (Karataş & Perker, 2017).

Figure 10. Kasımiye Madrasa / Observation form for the determination of material problems

NATURAL STONE BUILDING ELEMENTS			PROBLEMS																		Faulty Repairs		
			Loss of surface	Fragmentation	Formation of gap/ hole	Pitting	Cracks	Spalling	Foliation	Discharge of jointing	Surface contamination	Shell formation	Efflorescence	Crystallization	Formation of plant	Formation of moss	Corrosion (Rust stain)	Tear	Loss of form	Colour change	Use of cement	Painting the stone	Other
VERTICAL BEARING	SINGLE BEARING	Column	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+	-	-
	CONTINUOUS BEARING	Wall	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	+	-	-
HORIZONTAL BEARING	FLOORING	Curvilinear / Vault	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
STAIR			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-
WALL OPENING	Window	Lintel/jamb	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Door	Lintel/jamb	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-
AUXILIARY ELEMENT	Railing		-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	Moulding		-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	Coating		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-

Explanations of the types of problems in the form are as follows:

The problem of surface loss occurs through the washing and dissolving of the stone surface. This problem can be caused by internal or external factors such as water, wind, humidity, dryness, and abrasion.

Fragmentation is a problem that occurs in the form of cracking and crumbling in the stone's internal structure for various reasons.

Gap –Formation of Holes; small-scale voids forming on the stone for various reasons. As a result of void formation, the structure becomes vulnerable to various effects. This also accelerates other degradation processes.

Pitting is damage to the stone's surface that deteriorates over time due to atmospheric effects such as sun, water, wind, and humidity. The cross-section of the stone decreases due to notching. Surface erosion increases the area of deterioration. This accelerates the erosion of the stone.

Cracks are the type of problem that occurs due to the pressure exerted on the stone by various loads or worn metal elements behind the stone.

Spalling can be defined as the formation of bubbles that manifest themselves in the form of volume increase and flaking on the stone surface due to the external atmosphere.

Foliation-type deterioration can be explained as the formation of a layer-like appearance on the stone's surface due to various atmospheric effects swelling the stone's surface in layers.

Discharge of jointing type deterioration is the destruction of the mortar used as a binder on the wall surfaces for various reasons, and the surrounding of the stone becomes vulnerable to damage.

Surface contamination type damage is the deterioration seen as a light gray layer on the surface of masonry structures due to air pollution.

Shell formation type damage, usually dark gray-black, is the deterioration of thick crust on the stone's surface due to atmospheric pollution. Efflorescence is the formation of salt accumulation on the stone's surface under the influence of external air.

Crystallization is a type of deterioration that occurs in marble-type stone material.

Formation of a plant is a type of problem that occurs when seeds accumulate in small spaces in the wall and take root over time. It can cause various deformations, such as cracks and fragmentation in the stone.

Formation of moss is a problem of stone decomposition due to moss formed on the moist stone surface.

Corrosion (Rust); visual or physical problems may occur in the stone material due to corrosion of the metal elements used with the stone.

Tear can be defined as deformation due to erosion on the material surface over time.

Loss of Form can be defined as the complete or partial disappearance of a stone's outer contours and the ornamental form's incomprehensibility.

Change of color is a problem that occurs as the color of the stone changes due to chemical changes in the minerals within the stone, which is exposed to sunlight, water, moisture, or any effect.

Defective repair is a problem caused by choosing the wrong material for repair (Karataş & Perker, 2017; Megep, 2013).

3. Findings and Discussion

This section presents the findings regarding the material deterioration in the building based on building elements.

3.1.Vertical Bearings

The use of columns can be seen on the lower and upper porticoes of the passage from the madrasa rooms to the courtyard and on the south façade of the masjid section. There are 15 columns on the first floor and eight columns built with rectangular forms on the second floor. Loss of surface, pitting, change of color, and defective repair are observed on the columns (Figure 11-13).

Figure 11. Loss of surface and pitting on the columns

Figure 12. Change of color on the columns

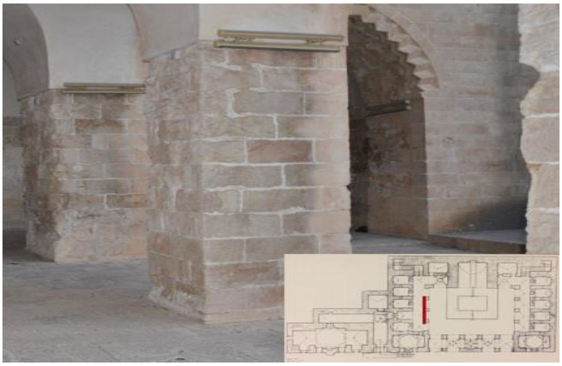

Figure 13. Defective repair on the columns

The walls of Kasımiye Madrasa are double-walled, internal (body) and external (cladding). Smooth-cut stone was used in the covered parts of the walls, and rubble stone was used in the body parts. The wall thicknesses in the building vary between 1 m and 2.55 m.

There are loss of surface, fragmentation, pitting, discharge of jointing, change of color, and defective repair. In the local ınkara mortar used in the building, swelling and exfoliation-type material loss is observed (Figure 14-17). The material problems seen on the facades of the building are visually mapped and explained in the section below.

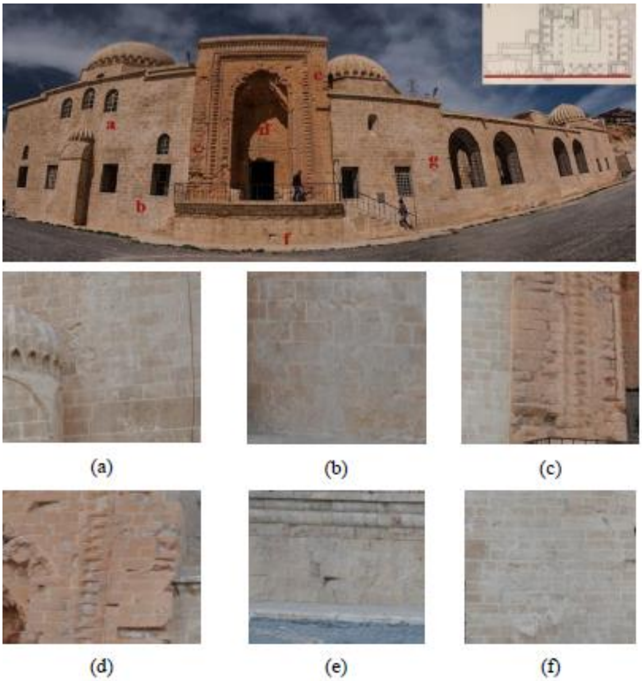

Figure 14. Deteriorations on the north wall of the madrasa facing the courtyard: pitting (a, b), discharge of jointing (c), loss of surface (d, e), fragmentation (f)

Figure 15. Change of color on the west facade of Kasımiye Madrasa

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

Figure 16. Deteriorations on the walls of the eastern facade of the building facing the street: change of color (a, d) defective repair (b) pitting(c)

(a) (b)

Figure 17. Deteriorations in the wall on the south façade of the building facing the courtyard: change of color, defective repair (a), loss of surface (b)

3.2.Horizontal Bearings

It used domes and vaults as the roof cover of the building. There is a star vault at the intersection of the corridor and the entrance corridor in the courtyard. The rooms to the west of the portal are covered with muqarnas-filled and squinched bulbous domes on the east and west. The iwan in the north of the courtyard is covered with a barrel (pointed) vault. There are two barrel-vaulted rooms on the right and left of the iwan. A barrel vault in the middle covers the single-story portico on the south façade. To the east of the portico is a place used as a muqarnas domed tomb. The east and west aisles are covered with cross vaults. The vault of the portico on the ground floor was plastered during the repair of the 2000s. The upper floor west portico was built of brick, and the east portico was built using rubble stone. The madrasa room at the back is covered with a barrel vault. The original roof of the madrasah was built from soil-type building material. In 2007, the roof was covered with limestone. Changes in color are observed in the dome and vaults of the building (Figure 18).

Figure 18. Change of color in the domes and vaults

3.3. Stairs

The stairs are made of smooth-cut stone. Stairs have a change of color and tear-type stone material damage (Figure 19).

Figure 19. Material problems on stairs

3.4. Wall Openings

In the frames of doors and windows, cracks, tears, and changes of color are observed. Fragmentation was observed in the lintels and jambs used in the windows. There is a material loss in the door lintel and jambs. There are signs of tears on the door sills. There is a change of color in the arched parts of the building (Figure 20).

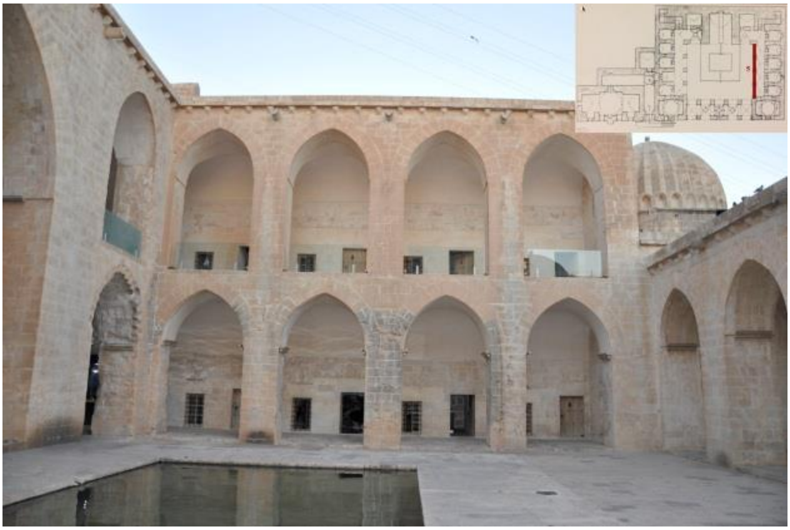

Figure 20. Material problems on wall openings (color change)

3.5. Auxiliary Elements

Floor coatings, railings, muqarnas, and moldings are considered auxiliary elements in the building.

There are changes in color and tear-type damage on the courtyard floor coverings. No deterioration was observed in the other elements of the cover (Figure 21).

Figure 21. Change of color and tear on floor coatings

4. Conclusion and Suggestions

In the study, field studies were carried out to determine the stone material problems of Kasımiye Madrasa and to evaluate which factors damage the durability of the building materials of the monument.

At the end of the study, some main types of problems are observed on the walls of Kasımiye Madrasa. The types of deterioration are loss of surface, pitting, change of color, discharge of jointing, and fragmentation. Such problems are thought to be caused by various environmental conditions, especially the temperature differences between day and night. Stone material damages detected in the structure show that temperature changes cause changes in the stone material volume. Physical fragmentation was thought to occur by causing different stresses in the petrographic structure of the volume to increase and decrease the cycle of the stone. This finding confirms the studies researching in different countries which temperature differences caused some decays such as loss of surface, pitting, change of color, discharge of jointing, and fragmentation on the stone (Khanlari et al., 2014; Villacreses et al., 2021; Reader, 2001; Rossi,2019; Ito et al., 2021).

The color changes seen on the stone elements of the building may have occurred due to the intense sun rays, especially during the daytime.

In addition, it is estimated that another problem seen in the building is related to the construction technique of the monument. The walls in Kasımiye Madrasa have two parts. Stones with different characteristics of stone types were used in the body and covering parts of the walls. The different behavior of stones used in the different environmental conditions may be the reason for the weathering in some parts of the building (Karataş et al., 2022) since studies point to such problems in the literature. So, it is recommended to examine the issue in depth at the structural level (Fahmy et al., 2022).

Another important finding is the damage or destruction of mortars. These damages were repaired with cement-added mortar in the building. However, it has been determined that efflorence occurs at the points where such applications are made.

In order to ensure the sustainability of the building, it will be beneficial to use non-destructive and digital methods to help monitor the life cycle of the building as well as observational studies. In particular, combining different techniques, such as terrestrial laser scanning, a non-destructive technique, with analytical techniques can significantly assist in diagnosing materials and decays. As a result of a detailed diagnosis, it should be determined whether cleaning and consolidation are required. In the selection of cleaning and repair materials, the behavior of these materials against environmental effects should be considered. In addition, the compatibility of the repair materials with the original stone material of the building and its overall durability should be evaluated.

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Ethics Committee approval was not required for the study.

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Lale Karataş contributed to research design, data improvement, drafting, field studies, analysis and visualization.

Z. Sevgen Perker contributed to research and methodology design, data interpretation, writing and editing.

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The Effect of Material Technology on Architecture

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1. Introduction

"Building" can be defined as the embodiment of an architectural design idea with materials. Every idea is embodied by a material, and every idea has a material solution. In the structure; the building material used in coating, filling, insulation, and the creation of load-bearing and non-load bearing structural elements has gone through various stages from the first ages to the 21st century, and with the advancement of science and technology in each period, it has started to serve different purposes for the designer and the user, as well as its current uses. In this respect, the material plays an important role in a building's ability to serve the purpose for which it was designed.

The industrial revolution has been a period of great changes in terms of building materials. With the invention of steel and concrete and the beginning of the mass production process, a transition has been made to a period that will help the designer to design large span and high-rise buildings with any form that the she/he wants to design, instead of low-rise, limited-span and limited-form structures.

Since the 1960s, technological developments observed in building materials have been made in the material; has ensured that the structure is at a level that will meet the needs of the user and the environment. The innovative materials produced in this process began to react to external stimuli by enveloping the structure like a living organism and had features such as shape changing, color changing, self-cleaning, etc. according to the need. With these materials, which are called smart materials, a new era has been began in building materials.

However, the increased use of materials and energy consumption, as well as the risk of depletion of resources in the near future, has caused designers to start designing by bringing the concept of sustainability to the forefront. Therefore, architects have started to turn to renewable resources that consume less energy in the design phase, can produce some of the energy needed by the structure when necessary, and have the least waste production. With the emergence and consideration of the concept of sustainability, many architects have started to prefer materials that will create natural waste and not harm the environment and living things in their designs. At this point, the architect is expected to contribute to sustainability by combining the right design approach with the appropriate material (Hagan, 2001). While some architects do this by combining innovative materials with traditional materials, a certain part of them aims to use the material in the structure with minimal intervention, without changing the physical and chemical properties of the material too much, without applying complex production processes, as in the early ages.

Along with the Covid-19 epidemic, which emerged in the last months of 2019 and affected almost the whole world, the importance of choosing the right material in building design has emerged from a different aspect. Due to the fact that hygienic conditions in buildings become of primary importance during the epidemic period, holistic consideration of materials in the transformations and new additions to be made, choosing materials that improve air cleanliness, quality and comfort conditions and that are easy to clean, encourage designers to choose materials that adapt to changing conditions in the decision-making process. (Biçer, 2021).

Despite the developing technology, changing and diversifying building materials, it is of great importance for the architect to choose the right material suitable for the design, in the creation of the form and the load-bearing system of the building, in the protection of the structure and the facade against adverse environmental factors, in providing conditions suitable for the function of the building, and in protecting the health of the user. The selected material should be produced according to the designed forms, it should be economical, and the combination details with different materials should be applicable. In this process, digitalization, software technologies and computer aided design tools that develop with material technology help to detail and produce materials in accordance with the design.

In this context, the effects of all these developments in material technology and the constantly changing user needs/requests over time on the building design, the process of changing the forms of the buildings with the material, the development in material technology coming together with computer technology to embody the architect's design idea, the design of structures that are compatible with the environment and adaptable to changing conditions will be discussed within the scope of the study. The changes created by the use of materials in the architectural field, the point of material technology and its effects on the design process will be examined through examples.

2. Historical Process of Building Materials

From the earliest ages, people have started to build various sheltered areas for themselves in need of protection from external effects (climate, animal attacks, etc.). For this purpose, they used the materials found in their surroundings and designed structures to the extent of the flexibility provided by the material. With the development of technology, the removal of limits in accessing materials and the production of materials that do not exist in nature with various methods, the boundaries in building design have expanded day by day compared to the previous period, and with the 21st century, these limits have reached the point of removal.

The industrial revolution, on the other hand, was the turning point of the process in which the borders began to expand. With the invention of concrete and steel and the start of mass production, the construction industry has made a leap forward, and has transitioned to a process that allows large-span structures, removes limits in the form of buildings, and allows the construction of high-rise structures in narrow areas to respond to rapid population growth. Changes in material technology started with the period when the material in nature was used as it is in the early ages, and continued with the period when smart materials were produced and used with the interventions made up to the nano-sized parts of the material with the end of the 20th century and the beginning of the 21st century (Figure 1).

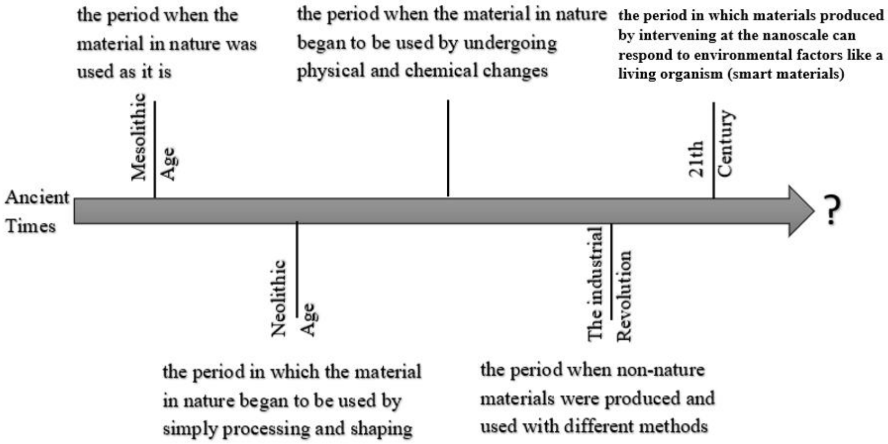

Figure 1. Change processes in material technology

Since architectural practice requires a broad knowledge of storylines, from the physical properties of materials to the principles of visual perception, it is not surprising that research subdisciplines within architecture bring together a wide variety of paradigms (Erdinç & Biçer, 2020). In this context, when we look at the overall process, the leap point of the developments in material technology can be seen as the Industrial Revolution. While traditional materials such as stone, wood, terracotta, adobe and glass were used in building design before this period, the use of concrete, steel, composite and polymer-based materials began intensively with the Industrial Revolution. In this period, mass production possibilities developed in material production technology and thus it has become possible to use materials that were previously discovered but whose production possibilities are limited in construction production. With the use of steel as a building material, there has been a rapid increase in the construction of reinforced concrete and steel structures, and these materials, which removed the boundaries of architects in building design and started a new era in design by replacing traditional materials. Since the structure and form of the building are directly related to the material used, the change in the material has greatly affected the design in this direction. In particular, the performance of the materials used in the structure under vertical and horizontal loads is important in dimensioning the building elements and determining the span dimensions of the units. For this reason, the change in material selection is reflected on the building elements and therefore on the building design.

Technology has not only been limited to playing an active role in the implementation of the desired design in the building form, but has also been effective in shortening the construction times despite the more complex forms and the structures growing horizontally and vertically. The ability of concrete to take plastic shape, to give the desired shape according to the mold in which it is poured, and to be able to continue the vertical construction of the structure without interruption, thanks to the rapid gain of strength, allowed the completion of the structures in a much shorter time and in a rapid manner compared to the construction times with traditional materials. Likewise, the mass production of steel materials in factories and then the rapid assembly of steel materials on the construction site using bolts or welding also shortened the construction times.

However, this rapid construction caused negative effects such as increased energy consumption, harmful gases released to nature, non-recyclable and continuously accumulating wastes, decreasing fossil fuels and natural resources in the 1990s. In order to reduce these negative effects, the search for new materials has started. In this process, smart materials used in fields such as space, machinery, electronics and vehicle sectors have also started to be used in the construction sector, which is responsible for 36% of total energy consumption and 39% of $CO2$ emissions in the world (International Energy Agency, 2019). Smart materials, which are defined as materials that detect any environmental change and adapt to the ambient conditions by reacting appropriately to the stimulus that causes this environmental change, have started to be preferred instead of conventional materials that do not show any quality change in the face of environmental conditions, increase energy consumption and $CO2$ emissions in the face of stimuli, causing the need for additional solutions (Jani et al., 2014; Rogers, 1988). Smart materials, which have positive features in terms of energy consumption and user comfort also have negative features such as waste generation, not knowing exactly the negative effects they will cause in long-term use, the formation of problems caused by production and use in materials (color fading, unbalanced spread of light from the facades to the interior, the negative effects of nano particles on the health of the user through respiration. etc.), high production and application costs due to the fact that their use is not widespread. This has caused some architects to return to natural/traditional materials that exist in nature as in the early ages in the construction design, which will not create waste when the end of their useful life (bamboo, waste wood materials, insulation materials created from natural materials such as coconut fiber, adobe, etc.).

3. Structural Reflections of Developments in Materials Technology

The rapid development in material technology with the industrial revolution has also had serious effects on building design. These changes are in different ways such as form changes in pre-industrial revolution structures and post-industrial revolution structures, spans passed, increase in floor heights, variation of coating material textures and colors and therefore change of perception created in the user, change of urban texture on a large scale, façades that work like a living organism by responding to different needs become designable, mechanical and visual moving surfaces can be applied in the structure has found a place. In order to reveal these changes, examples with different material uses were discussed within the scope of the study. These examples are; Traditional residences in Kemaliye County include the California Academy of Sciences Museum, Al-Bahr Towers, Harbour Kiosk, Louis Vuitton Foundation Museum, Manifesto Eco House, Algae House and London Olympic Shooting Range.

3.1.Kemaliye District Traditional Residences

Erzincan Province, Kemaliye District and its villages are located in the Eastern Anatolia Region and contain original examples of Anatolian residential architecture. Figure 2 shows the residential architecture in Ergü village of Erzincan province, Kemaliye district. In these buildings, which were built using traditional materials such as stone, wood and adobe, the limited dimensions of stone and wood materials were effective in determining the opening dimensions and floor heights of the buildings. The houses were built with mixed construction technique. While the rubble stone masonry walls with wooden beams and mud mortar were used up to the main floor level, a wood carcass system with adobe filling was applied on the main floor and roof floors. The exterior of the wooden frame walls is covered with vertically arranged pine wood boards. The roofs of the houses, which are built as flat roofs, are covered with river stones/piers on a layer of soil called "gavcin", which is unique to the region. In the 1950s, these areas were covered with sheet metal material to protect the vertical wood-clad facades and earthen roofs from heavy snow and rain (Figure 2). The sheet metal material, which was preferred as an economical solution at that time, ensured that some of the houses remained intact, but also caused the existing texture of the region to deteriorate (Korkmaz & Akdemir, 2015).

Figure 2. Erzincan Province, Kemaliye District, Ergü Village residential texture (© Korkmaz, E.)

The number of floors of Kemaliye residences is shaped according to the sloping land on which the building is located. Residential buildings consist of three to four floors in accordance with the slope. The spatial dimensions of the buildings were determined by the dimensions of the wooden beams used (6.50-7.00 m) (Korkmaz & Akdemir, 2015) (Figure 3).

Figure 3. Erzincan Province, Kemaliye District residential texture (Korkmaz, E.)

3.2. California Academy of Sciences

Following the destruction of most of the buildings of the California Academy of Sciences in the 1989 Loma Prieta earthquake, the construction of a new academy museum in San Francisco was completed in 2008. Designed by Renzo Piano Building Workshop (RPBW) and Stantec Architecture, eight buildings from the old structure have been demolished and the remaining three buildings have been preserved as part of the project. The building, which was designed by considering the concept of sustainability, includes planetarium, aquarium and exhibition areas. On top of these areas is the green roof with 1.7 million natural plants in containers made of biodegradable coconut fibers, referred to as the "living roof". One of the two domes on the roof is above the planetarium and the other is above the rainforest exhibition area, and above the domes there are circular skylights that open and close automatically and provide natural ventilation to the museums. The moisture of the soil in the roof layer, combined with the phenomenon of thermal inertia, significantly cools the interior of the museum. Thus, the need for air conditioning in the common areas on the ground floor and in the research offices along the façade is eliminated (Figure 4) (California Academy of Sciences, 2009).

Figure 4. California Academy of Science (ArchDaily, 2008)

All functions in the structure are arranged around a courtyard, which serves as an entrance lobby and an important center for collections. This attachment point is covered by a concave glass canopy with a web-like structure resembling a spider's web. The ceiling, which consists of triangular glass panels on this area with an opening of 22 m in one direction and 30 m in the other, is carried by steel beams and horizontal support elements connected to these beams (Figure 5). With this system, openings up to 29 meters can be easily passed at some points of the museum (Arkitektuel, 2019; RPBW Architects, 2009).

a. b.

Figure 5. California Academy of Science (a: Finotti, L., 2019; b: © tim Griffith, Arkitektuel, 2019).

When constructing the new building, eco-friendly materials were chosen to minimize the environmental impact of the project. Instead of using typical fiberglass or foam-based insulation materials, the project used a type of thick cotton batting made from recycled denim, which provides an organic alternative to formaldehyde-laden insulation materials. The fact that it retains more heat, absorbs sound better than spun fiberglass insulation and is safer to use for the assembly team was an important factor in the choice of this material (California Academy of Sciences, 2009).

9,000 tons of concrete and 12,000 tons of steel from the destroyed buildings were recycled to be used in other projects, and 95% of the steel used in the newly designed building was also produced from recycled resources. In addition, the concrete, which is widely used throughout the museum, is composed of 15% fly ash and 35% slag. This use of recycled content has also prevented the release of more than 5,375 tons of carbon emissions (California Academy of Sciences, 2009; RPBW Architects, 2009).

Photovoltaic cells were placed between the two glass panels forming the transparent canopy around the green roof, making it possible to provide more than 5% of the electricity needed by the museum. Design decisions such as the choice of materials taken into consideration while designing the building, the use of recycled materials, the positioning of the spaces and the provision of natural lighting and natural ventilation, rainwater recovery, water use in the building and energy production were effective in obtaining the LEED platinum certification of the museum (California Academy of Sciences, 2009).

3.3.Al-Bahr Towers

Designed by architect Abulmajid Karanouh (Aedas), the 29-story, 145 m high Al-Bahr Towers, consisting of two circular shaped towers, were built in Abu Dhabi in 2012. It is stated that the design concept of the structure is based on the fusion between bio-inspiration, regional architecture and performance-based technology. Abu Dhabi's location in the desert climate zone, which reaches a temperature of 49 °C in the summer months, and the high humidity of the region, have led designers to design adaptive facades in the structure. It is aimed that the façade adapts to the changing sun direction during the day and responds to external stimuli and meets the comfort of the users. For this purpose, a dynamic shading system that works automatically with 21st century technological possibilities has been designed, inspired by the "Mashrabiya", an Islamic shading, natural ventilation and privacy tool, and the shape of the honeycomb. The designed shading system is placed on a curtain wall with a height of 4200 mm and a width of 900-1200 mm, and the curtain wall is separated from the dynamic shading system by an infrastructure with movable joints (Figure 6) (Attia, 2017).

The dynamic shading system consists of triangular units such as origami umbrellas. The triangular units function as separate shading devices by folding and unfolding at various angles in response to the movement of the sun to block direct solar radiation. Each shading system element is designed as a unified system, 2.8 m from the main structure. The shading system consists of stainless-steel support frames, aluminum dynamic frames and fiberglass mesh filling. The folding system works to transform the shading curtain from a continuous cover to a mesh-like pattern to provide shade or light. Each shading device is covered with a series of stretched polytetrafluoroethylene (PTFE) panels. This way, when the shading device is turned off, the residents of the building can still see from the inside out. In total, there are 1049 shading devices in each tower, each weighing about 1.5 tons (Attia, 2017; AHR Global, 2017).

Figure 6. Al-Bahr Towers and facade shading elements (Designboom, 2017)

The shading curtain is computer-controlled to respond to optimal sun and light conditions. The shading devices are broken down into pieces and are powered by solar tracking software that controls the order of opening and closing according to the angle of the sun. In cloudy weather conditions or under strong wind conditions, a series of sensors integrated into the building shell send the registered signals to the control unit to turn on all the units. The system works with a preset automatic control technology that follows the path of the sun throughout the year and is updated every 15 minutes using a light meter and an anemometer on the roof. If weather events vary, the automatic program is invalidated (Attia, 2017).

The smart façade, together with the solar panels used for hot water heating and the photovoltaic panels on the roof, minimizes the need for interior lighting and cooling, reducing total carbon dioxide emissions by over 1750 tons (approximately 40%) per year. With these features, the project was included in the Chicago-based Tall Building Council and Urban Habitat's "Innovative 20" list of buildings that challenge the typology of tall buildings in the 21st century (Attia, 2017; Designboom, 2017; Delmatic, 2017).

3.4.Harbour Kiosk

Harbour Kiosk designed by LAAB Architects is known as the first kinetic public architecture in Hong Kong that innovatively combines parametric architectural design with engineering. It is a robotic architecture that combines a food kiosk and a mechanical room. The building also activates the public space it surrounds with the systematic transformation it undergoes to transform the moving images of the cinema into the kinetic movement of architecture. The structure was inspired by local market stalls in Hong Kong, which expand when open and mingle with the public, and return to a compact and secure form when closed. The structure, which turns into an awning automatically by opening the door during the day, is requested to turn into a compact shape by closing it at night. In addition, with the wave generator system located on the mobile outer shell, it is aimed that the wooden wings move in waves throughout the day and resonate with the harbour waves, thus establishing a link between people, architecture and nature (Archello, 2020; LAAB, 2020; ArchDaily, 2019).

Figure 7. Harbour Kiosk, Hong Kong (Archello, 2020)

Behind the profiled wooden wings, which are movable, there is a robotic arm supported by 49 linear motion systems that enable this movement to take place (Figure 8). On the outer shell are used wooden slats with a three-layer profile. The wooden profiles used are PEFC certified red balau wood and have been chosen as a sustainable façade material due to its robustness, hardness, lightness and cost-effectiveness. The wood is coated with special exterior polish to provide better resistance to UV rays and termites. Each wooden pallet is precision-crafted with digital fabrication and local craftsmanship (Archello, 2020; LAAB, 2020; ArchDaily, 2019).

Figure 8. Harbour Kiosk section (LAAB, 2020)

The Harbour Kiosk also provides water and electricity to the Avenue of the Stars, on which it is located, and provides a light show every night at

20:00 pm. The architects and engineers working on the project developed four prototypes in two years to optimize the parametric design and kinetic system so that the structure could withstand the typhoon season in Hong Kong (ArchDaily, 2019).

3.5. Foundation Louis Vuitton Museum

The construction of the Foundation Louis Vuitton Museum in Paris, designed by Frank Gehry, was completed in 2014. The 48-metre-high building consists of white blocks (known as “icebergs”) surrounded by twelve giant glass “sails” covered with fiber-reinforced concrete panels and supported by wooden beams (Figure 9). While the sails give the museum a sense of transparency and movement, 3584 custom-made curved laminated glass panels with a total surface area of 13.500 m2 are used on these forms. Each of the panels exhibits different bending radii (from nearly straight to 3 m) and bending orientation different from the major vertical axes of -90 to 90°. These panels have been individually developed using a design software program specially adapted for the aerospace industry to match the shapes drawn by the architect. Spherical bearings are used that allow movements and rotations in the structural system, support the inner steel façade, carry vertical loads of 1400 kN each, and allow sliding movements along an axis while resisting transverse forces (Mageba, 2015; Archello, 2015).

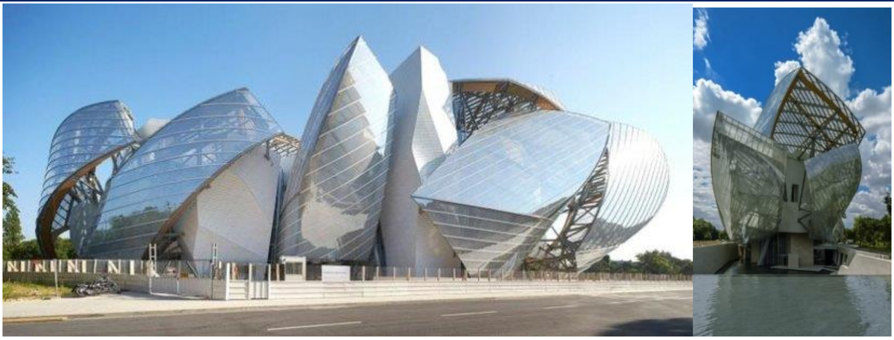

Figure 9. Foundation Louis Vuitton Museum, Paris (ArchDaily, 2014)

For the 12 single canopy construction of the building, a total of 779 m3 of glulam was produced, with beam lengths of up to 28.2 m, cross-section dimensions up to 40 x 40 cm – 40 x 120 cm, with 222 single and double slopes (Figure 10). The structural core of the museum consists of a series of solid volumes called icebergs, supporting the floating glass canopies covering the entire building. Structurally, icebergs are designed as concrete and steel frames. The facade is covered with 16,000 ceramic tiles. Each element has different geometry to follow the straight lines and various surfaces of the façade. More than 2000 aluminum wall panels have been designed and manufactured to achieve a support structure for ceramic tiles. Each of these panels exactly follows the exterior geometry of the façade surface and contains reinforcement elements located under each joint between the ceramic tiles. The panels are connected to the steel or concrete structure with specially designed spacers. The gallery sections of the building are covered with white fiber reinforced concrete called Ductal (Archello, 2015).

a. b.

Figure 10. Foundation Louis Vuitton Museum structural system (a: Archello, 2015; b: ArchDaily, 2014)

The structural setup of the Louis Vuitton Museum consists of glass sails supported by stainless steel struts on the main frame made of structural steel and glulam. In the construction, electronic files and 3D data exchange files were used, together with the supply of complex drawings for the production of load-bearing system elements, coating materials and joining elements, each of which has different forms. Exchange files from these data were transferred to Tekla software for BIM collaboration and detailing. Thus, the production of materials to be used in the building was carried out. The only part that was not produced with Tekla software was the bent or corkscrew glulam beams provided with the Digital Projects software (Archello, 2015).

The project has become an international catalyst for innovation in digital design and construction, setting a new standard for the use of advanced digital and fabrication technologies. More than 400 people have contributed to a common 3D digital model that intelligently adapts itself to design requirements and is hosted on the web with design models, engineering rules, and assembly constraints. The glass panels that make up the facade and the concrete panels used in the cladding are simulated using mathematical techniques and molded using advanced industrial robots, all automated from the shared 3D model. New software has been developed specifically to share and work with the complex design (ArchDaily, 2014). In 2016, artist Daniel Buren revealed the Foundation Louis Vuitton Museum in a new light through the game of projection, reflection and transparency with the Observatory of Light Project. The structure's 12 "sails" made of 3,600 pieces of glass are covered with bright colors, white and clear lines (Fig. 11). The application, consisting of 13 colors, created visual reflections that change constantly inside and outside the building, depending on the time of day and the season. Daniel Buren presented the building designed by Frank Gehry with colorless transparent elements and white coatings under a new light and color, creating transparency and contrast both inside and out. The appearance and perception of the building has completely changed with the applied coloring interventions (LVMH Group, 2016).

a. b.

Figure 11. Foundation Louis Vuitton Museum, Paris (a: Push Foundation, Arkitektuel, 2017; b: LVMH Group, 2016)

3.6. Manifesto Eco House

Manifesto Eco House, designed by James & Mau Architecture, was built in Chile in 2009. In the building designed as an environmentally friendly structure, designers evaluated waste materials and used recycled wooden pallets and containers. The two-storey building, which has a total floor area of 160 square meters, has a system that uses a combination of renewable energy, bioclimatic design, recycled/reused materials and non-polluting building materials. The structure is constructed from three shipping containers, using prefabricated and modular components. One of the containers was divided into two parts and placed at two points on the ground floor far from each other. Thus, both more space was obtained on the ground floor and the fulcrum points where the containers used on the upper floor would sit were created (Figure 12) (James and Mau Architects, 2009).

Figure 12. Manifesto Eco House, Chile (James and Mau Architects, 2009)

The structure is made from 85% recyclable, recycled or ecological materials. Containers and pallets are recycled; the wood used for the folding wall is taken from sustainable forests; recycled cellulose, which is used for thermal insulation; cork used for floor insulation is an ecological material; the galvanized steel used for the interior structure was recycled, recycled wood was used in the construction of kitchen furniture, wardrobes and stair treads, and finally ecological ceramics and paints were used in the project (James and Mau Architects, 2009). The designers used solar panels in the building and used wind to meet the energy needs of the building. Thanks to the bioclimatic design and the installation of alternative energy systems, approximately 70% of the energy needs can be met. The closing and opening of the large glass areas on the lower floor with wooden pallets used as shading elements eliminates the separation of interior and exterior and provides efficient natural ventilation and natural daylight in the structure. (Designboom, 2014; İpekçi et al., 2015; Tandoğan, 2018)

3.7. The BIQ House

Designed by Austrian architects Splitterwerk and Graz and built in 2013 in Hamburg, Germany, where the cold northern European climate prevails, the four-story BIQ House is the world's first bio-adaptive façade. The photo-bioreactor facade, which features a double shell facade created to contribute to the energy needs of the building, creates a buffer zone between the indoor and external environment with the existing algae-forming technology and produces bioenergy while providing solar energy to the building. The project uses 129 photo-bioreactor algae facade panel systems with a surface area of 200 m^2 and these panel systems provide a thermally controlled microclimate, noise reduction and dynamic shading around the building (Arup, 2014). These photobioreactors produce algae biomass and heat as renewable energy sources in a low-energy residential building. Microalgae are grown in flat-panel glass bioreactors placed in southwest and southeastern elevations, and each flat-panel is 2.5 meters high, 0.7 meters wide (Figure 13). These panels form the core of all energy processes and enable the conversion and distribution of different types of energy, meeting the building's heat and electricity needs (Wurm, 2013).

Figure 13. The BIQ House, Hamburg (Detail, 2013)

The control of the nutritional support of algae is carried out by the building energy management system, which also ensures the harvest of algae, regulates the internal and external cycle system, controls the building service system with the help of an interface, monitors the content of algae and the temperature of the environment. Since the temperature must be below 40°C in the fixed production process, the excessive heat generated by the sun at certain times is thrown out of the system by heat exchangers. This excess heat, which is formed and thrown out of the system, is used to provide hot water when necessary, and at other times it is collected in the ground with geothermal wells (Wurm, 2013). Wells store heat between 16 and 35 degrees depending on the season and a heat pump is used to pump the water back into the system when a higher temperature is required for heating and/or hot water (Build Up, 2015).

The biomass produced by the system is collected and stored near the biogas production machine at regular intervals (Kükdamar, 2017). Up to 80% of the biomass is converted to methane in an off-site outdoor biogas plant and then returned to the building to generate electricity and heat (Wilkinson et al., 2016).

3.8. Olympic Shooting Venue, London

The London Olympic Shooting Venue, which was established in London for the 2012 Olympic and Paralympic Olympic games, was designed by Magma Architecture. The structure consists of an area where shooting competitions are held from 10, 25 and 50 meters. The design team aimed for the range to evoke the perception of flow and precision that exists in shooting sports, and to have a dynamic and curvy space design. The façade and interiors of the three shooting venues were covered with a double-curved white membrane material with colored openings, and the tension points of the membrane created the movement on the facade and indoors (Figure 14) (Frearson, 2012).

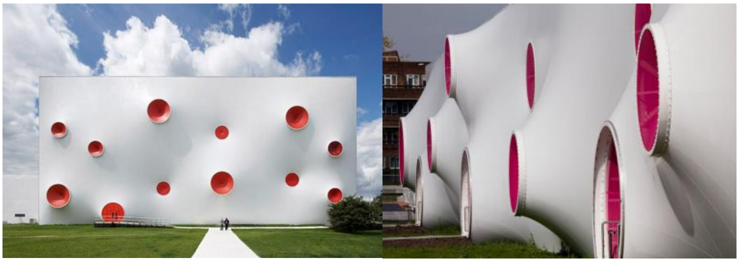

Figure 14. Olympic Shooting Venue, London (Magma Architecture, 2012)

Tension points have been created to prevent the phthalate-free PVC membrane, which has a total usage area of 18.000 m2, from fluctuating in the wind, and these tension points also create the openings of the building and provide natural ventilation inside the building (Figure 15). The tensioning detail is created using modular steel components (Frearson, 2012). Three indoor shooting venues were completed using approximately 1,200 tons of steel and covered with plywood. The translucent façades created in the two shooting venues in the building minimize the need for artificial lighting and ventilation in the interior (Arkitektuel, 2018).

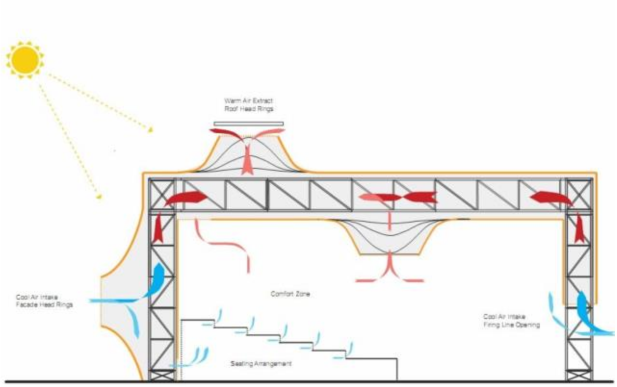

Figure 15. London Olympic Shooting Venue section (Arch2O, 2018)

The materials in the structure designed in line with the principles of sustainability were preferred as reusable or recyclable. The structure is also designed to be dismantled and reinstalled at any location. Regarding their designs, the architects stated, "We are trying to be part of a new paradigm in architecture that is based on creating an expressionist, non-linear form and facilitated by new materiality and the latest technologies" (Arch2O, 2018).

4. Conclusion and Suggestions

The developments in material technology have created great changes in the field of architecture as well as in all sectors. The material, which is one of the indispensable elements of the design, is used at every point of the building from the foundation to the final finishing layer, and it enables the design to come out of abstract thought and become concrete. The materials preferred depending on the function, aesthetic setup, size, user needs and environmental effects of the space have shown various changes over the centuries with the development of technology. This situation has eliminated many of the limitations in the production of the material and its application to the design. Thus, wider openings, higher-rise buildings, complex forms, energy efficient buildings, structures that adapt and react to environmental conditions have become applicable. With the change of the materials used, different types and shapes of building structures began to be designed, and many types of structures from temporary to permanent found application. With the point reached by technology in the 20th century and 21st centuries, materials engineers started to design and produce materials that would respond to the changing living conditions and the needs arising from these conditions. In this process, digitalization and software technologies developed with material technology allow the production of materials designed in complex forms and different contents at levels that can be almost non-existent.

All these developments have caused the understanding of architectural design to change. In order to reveal these changes, the example of buildings built with traditional materials and structures with different characteristics built using technology and material types in the 2000s were examined within the scope of the study. Wood, which is one of the traditional building materials, has been shaped only without any process for centuries as in the case of Kemaliye district and used with its existing dimensions in nature. The limitation of dimensions in nature and the difficulty of supplying materials with the same dimensions have led to the limited span dimensions in buildings. But the technology is used not only for the production of new materials, but also for the improvement of the properties of existing traditional materials. With the developments in materials and production technologies, materials such as laminated timber and glulam whose raw material is wood have started to be produced. This allows the production of wood material (glulam) in both the desired curvature and the desired size, as in the Foundation Louis Vuitton Museum, and has successfully created the form that the designer wants to achieve and the spans she/he wants to pass.

The steel material that emerged with the industrial revolution was used as a structural material or a supporting material for structures such as the California Academy of Sciences, Al-Bahr Towers, Foundation Louis Vuitton Museum, and the London Olympic Shooting Venue, and in all these projects, openings that cannot be obtained with traditional materials are passed and to construct high-rise structures in narrow surface areas.

In the 1950s, the vertical wooden facades and earthen roofs of the houses in Kemaliye District and Ergü Village were covered with metal sheet to protect them from heavy snow and rain. The fact that sheet metal is economical and easily accessible, and that there is no suitable insulation material for these traditional houses with a unique earthen roof setup, has been an important factor in the selection of this material. By the 2000s, insulation and protection materials with advanced features started to be produced with technology and the limitations in accessing the material were removed. An example of this has been implemented at the California Academy of Sciences. Instead of plastic-based insulation materials, which do not exist in nature and do not disappear when turned into waste, a kind of thick cotton batting made of recycled denim is used, which provides an organic alternative to formaldehyde-laden insulation materials. In addition, in order to reduce waste generation within the scope of the project, the concrete and steel obtained from the demolished buildings were recycled and used in other projects. Similarly, the Manifesto Eco House is made of 85% recyclable, recycled or ecological materials. The residence, which was built using waste wooden pallets and containers, has become able to meet approximately 70% of its energy needs thanks to its bioclimatic design and the installation of alternative energy systems.

Many materials unearthed by the observation of living things in nature, on the other hand, show physical or chemical changes by reacting to environmental conditions and external stimuli like a living organism. Thus, the structure to which the material is applied is protected from external factors and it becomes possible for the building to produce its own energy in the 21st century, when fossil fuels are at the point of exhaustion. The BIQ House example, which was designed using the photo-bioreactor algae facade panel system in order to reduce energy consumption, also draws attention with the use of different materials. Microalgae grown in bioreactors meet some of the building's energy needs and ensure that the electricity and heat needs of the building are met.

On the façade of Al-Bahr Towers, a dynamic shading system that works automatically with 21st century technological possibilities has been used. Working by folding and unfolding at various angles in response to the movement of the sun, the system transforms the shading curtain from a continuous drape into a mesh-like pattern to provide shade or light. In the Harbour Kiosk, which is another example where material and computer technologies are used together, the robotic arms supported by 49 linear motion systems create a movable outer shell in the structure, allowing the wooden wings on the shell to resonate with the waves in the harbour throughout the day. With this movement, the designer aimed to establish a connection between people, architecture and nature.

As a result, the examined examples reveal the point where material technology, which has undergone a certain change and development since the early ages, has reached the 21st century. The finding of new materials with different properties day by day, the reinterpretation of existing materials by improving their properties, the increase in material diversity and the use of materials in combination with technologies in different sectors affect architectural design significantly. Being aware of this situation, it is important for designers to carefully follow the developments in material technology and to reveal the unlimited potential in building design with the right material selection, without consuming natural resources and without harming the nature.

Thanks and Information Note

The article complies with national and international research and publication ethics.

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There is no conflict of interest.

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Utilization of Thermo-Responsive, Shape Changing Smart Materials in Adaptive Facades

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1. Introduction

Today, studies continue to increase towards the 'dynamic' design of the building shell, which is an interface between the exterior and interior space, in order to improve the energy performance of the building and the interior space user comfort. In Europe, this process continues with increasing incentives for buildings built after 2020 to be almost zero-energy. The aim of nearly zero energy building designs requires the development of new concepts, materials, technologies. One of the promising solutions to achieve this aim is the dynamic, adaptive design of buildings (Aelenei et al., 2016; Hraska, 2018; Yoon, 2019). By adapting the buildings, it is expressed that the building adjusts itself to adapt to environmental factors such as heat and light, and as a result of this adaptation, improving the user comfort in the interior space and reducing the building’s energy requirement (Altın & Orhon, 2014; Orhon, 2016). The adaptive design strategy also offers new aesthetic possibilities for buildings. However, for the implementation of adaptive design strategies, adaptive materials, elements and systems need to develop and their application potentials need to reveal.

Many motion control technologies have been developed and continue to be developed in the context of the requirements for the realization of the motion of adaptive facades. It is possible to collect these motion control technologies under two groups as active and passive by focusing on energy efficiency. In active motion control technologies, sensors are required at the stage of sensing environmental stimuli, and energy is consumed by motorized systems during the realization of motion. In passive motion control technologies, the material used in the facade both functions as a sensor and reduces the need for power sources for the realization of motion (Loonen et al., 2013; Orhon, 2016). The development of passively operating systems based on material properties is related to many disciplines in the context of the production of new materials and the discovery of advanced properties of existing materials. In addition, it is a subject that is in the focus of research today in order to reveal its potential in architecture. Adaptive facade prototypes are also developed with systems based on shape-changing smart materials, in which passive motion is realized. The materials used in this context can be adapted by changing their shape under the influence of various stimuli such as heat and light (Addington & Schodek, 2005; Orhon, 2013; Yoon, 2019).

The aim of the study is to examine the facade prototypes developed with thermo-responsive, shape-changing smart materials that give hope for the adaptation of building facades with minimum energy and to try to develop suggestions for the future. In this context, within the scope of the study, first of all, thermo-responsive, shape changing smart materials will be classified and the technical properties of each material type will be examined. Prototype examples for each material type will be examined and their innovative features that contribute to the adaptation of facades will be indicated. As a result, the study will contribute to the literature in terms of introducing the innovative properties of thermo-responsive, shape changing smart materials and revealing the benefits of these materials for adapting building facades with minimum energy.

2. Thermo-Responsive, Shape Changing Smart Materials

In the study carried out by (Addington & Schodek, 2005), in the classification made for smart materials, they were basically collected in two separate groups as materials that make quality change and that make energy conversion. In this study, adaptive materials that change shape with the effect of heat, which are within the scope of quality change, will be discussed. These thermo responsive, shape-changing smart material types will be examined under three titles as shape memory alloys, shape memory polymers and thermo bi-metal materials. These materials still continue to develop in parallel with the developments in material technologies. These materials don't yet have applications on the building facade. However, with the development of prototypes, applications are likely to become widespread.

2.1. Shape Memory Alloys

Shape memory alloys are defined as materials that can return to their original state with the effect of heat after being deformed. The memory property of these materials is due to its different crystal structures at different temperatures. With the realization of the conversion to each other of the martensite and austenite phases in its crystal structures, the material can change form. Shape memory alloys are in the martensite phase when the temperature is low and can easily deform under the influence of force in this phase. When the temperature is high, it is in the austenite phase and in this phase, the material can return to its original form in memory (Atasoy et al., 2018; Ergin & Girgin, 2019; López et al., 2015; Toptaş, 2006; Toptas & Akkus, 2007; Yoon, 2019).

The three basic methods used to heat shape memory alloys are summarized as follows (Ergin & Girgin, 2019; Toptaş, 2006), (Figure 1):

a) Passing electric current: Applicable when using a small diameter shape memory alloy wire or spring, the advantage is ease.

b) Wrapping up the shape memory alloy element with an external heating wire.

c) Exposing the shape memory alloy element to thermal radiation: It is a method that doesn't require an additional heating system.

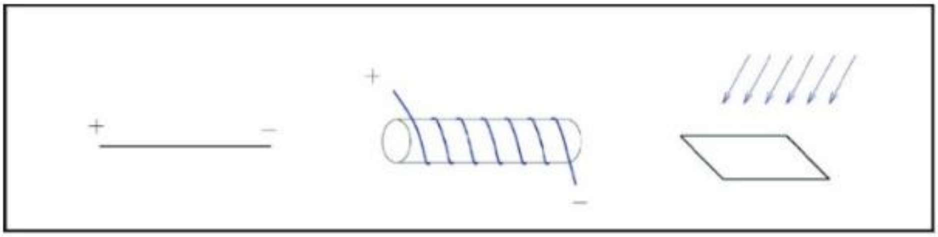


Figure 1. Methods of heating shape memory alloys (Ergin & Girgin, 2019; Toptaş, 2006)

The conversion temperature from the martensite phase to the austenite phase and from the austenite phase to the martensite phase are different. This is due to the combination in different proportion of metals in each alloy (Atasoy et al., 2018). It can be said that all shape memory alloys don't have a constant temperature value in the conversion between phases. The composition ratios of the metals in the alloy determine this temperature value. In this case, the applications of shape memory alloys in different disciplines can be realized for different purposes.

Shape memory alloys are produced in wire, spring, tube, strip or other forms. These materials can be used in different forms for every design.

Nickel-titanium and copper-based alloys are the most widely used as shape memory alloys. However, the nickel-titanium alloy is corrosion resistant (Atasoy et al., 2018). This situation provides an advantage in terms of the use of the alloy in the building facade.

2.2. Shape Memory Polymers

Shape memory polymers are materials that change shape in response to various stimuli. Thermo-responsive shape memory polymers are similar to shape memory alloys in terms of working principle. It is a smart material that can return to its original shape from its deformed state with the effect of temperature increase (López et al., 2015; Yoon, 2019).

Shape memory polymers (SMP) are being extensively researched as a thermo-responsive smart material with the potential to activate shading devices that can be applied for adaptive façades. Shape memory polymers have a glass transition temperature (Tg) value, which is one of the fundamental properties of polymeric materials. When these materials are heated to a high temperature above the glass transition temperature without applying any external force, large elastic deformations occur. Also, the memory of this material can be pre-programmed and the material can transform into several pre-programmed forms. Therefore, the use of this material in adaptive building facades is promising in terms of reducing the system complexity consisting of sensors, motors, electronic circuits (Clifford et al., 2017; Yoon, 2019).

Compared to shape memory polymers, shape memory alloys, properties such as lower cost and thermal conductivity encourage the use of this material (Yoon, 2019). In addition, the lightness and high deformability of the material are useful properties for architectural applications. There are material types with different qualities according to the production method and chemical structure of SMPs. Depending on the type, these materials have a wide range of Tg values from -70°C to +100°C. There are four different types of shape memory polymers depending on its availability in the market and its application in different sectors. These are named as pellet, resin & hardener, solution and filament. In SMP technologies these types provide 7 different glass transition temperatures (Tg) of 25, 35, 45, 55, 65, 75 and 90°C (Yoon & Bae, 2020), (Figure 2).

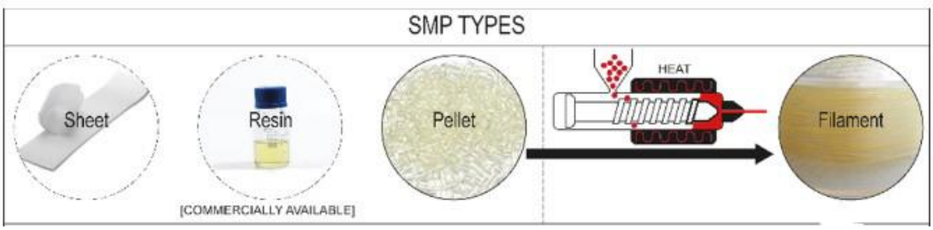


Figure 2. Types of shape memory polymers (Yoon & Bae, 2020)

2.3. Thermo Bi-Metal Materials

Thermo bi-metal materials are obtained by combining metal sheets with different expansion coefficient. In these materials, a form changing motion such as bending in one direction happens with the effect of heat. Bending motion in one direction is a result of metals with different expansion coefficients arranged in layers (Juaristi, Monge-Barrio, Knaack, et al., 2018; López et al., 2015; Tekin, 2019; Yıldırım, 2020).

Thermo bi-metals can be included in the family of shape memory materials. However, the working principle of thermo bi-metals is the opposite of shape memory alloys. While shape memory alloys can return to its original shape from the deformed state when a certain high temperature is reached; thermobimetals can return to its original shape when the heat effect disappears, that is, when it cools (Juaristi, Monge-Barrio, Sánchez-Ostiz, et al., 2018), (Figure 3).

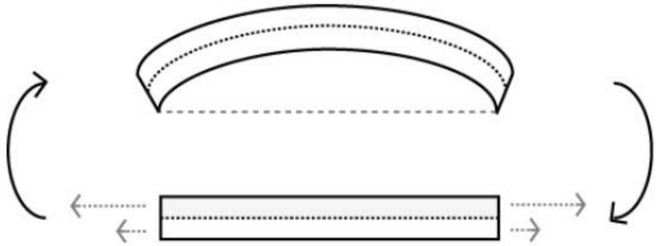


Figure 3. Working principle of thermo bi-metals with heat change (Juaristi, Monge-Barrio, Sánchez-Ostiz, et al., 2018)

The development level of building technologies and technical limitations in material technologies create some disadvantages in the use of adaptable materials on the building facade. By understanding and defining these disadvantages, it is possible to integrate adaptive material systems to the facade and to use it together with other building technologies and building materials (Addington & Schodek, 2005). When thermo bi-metal material work on the facade for a long time, it is affected by ultraviolet radiation. In this case, these materials may degrade mechanically. Therefore, if it is to be used on the facade of the building, positioning it between glass panels can create a design alternative (Juaristi, Monge-Barrio, Sánchez-Ostiz, et al., 2018).

Thermo bi-metal material production isn't limited to the use of two metal layers. It can also be obtained by combining three or more layers with different expansion coefficients. With this method, the composite material can be given features that will increase its performance. For example, there are types with increased strength by using a copper or steel layer on the surface of the material. It can be positioned in the desired layer by selecting the material according to the qualities desired in the composite material (Tekin, 2019) , (Figure 4).

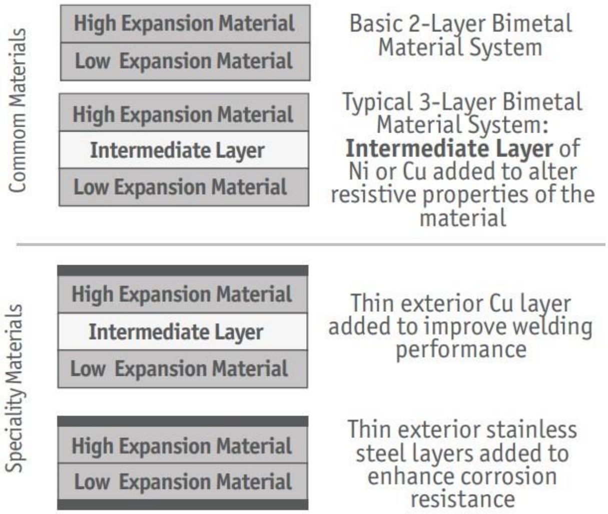


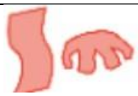
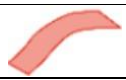
Figure 4. Configuration alternatives of thermo bi-metals *(Engineered Materials Solutions Wickeder Group, n.d.)*

2.4. Comparison of Thermo-Responsive, Shape-Changing Smart Materials

To explain the adaptive working behavior of thermo-responsive, shape-changing smart material types, their morphology, format, control mechanism, usability as actuators, and output or motion type are listed in Table 1. Shape memory alloys can happen wire, spring and sheet format.

Shape memory polymers can be in the form of sheet and free. Thermo bi-metal material can only be in sheet form. As a control mechanism, the shape memory alloys carry out the contraction-relaxation motion, shape memory polymers only carry out state transition and thermo bi-metal material carry out the expansion and curvature. Table 1 shows that all three material types can work as actuators. As an output or motion type, the shape memory alloys carry out rotating and retracting motion, shape memory polymers carry out motions such as rotation, bending, deforming, elasticity, thermo bi-metal material carry out bending and opening motions (Yoon, 2018).

Table 1. Comparison of Thermo-Responsive, Shape-Changing Smart Materials, Adapted from (Yoon, 2018)

Material	Morphology	Format	Control	Actuator	Output
SMA (Shape memory alloy)		Wire, Spring, Sheet	Contraction Relaxation	+	Rotating Retracting
SMP (Shape memory polymer)		Sheet, Free-form	State Transition	+	Rotating Bending Deform Elasticity
Thermo bi-metal		Sheet	Expansion Curvature	+	Bending Opening

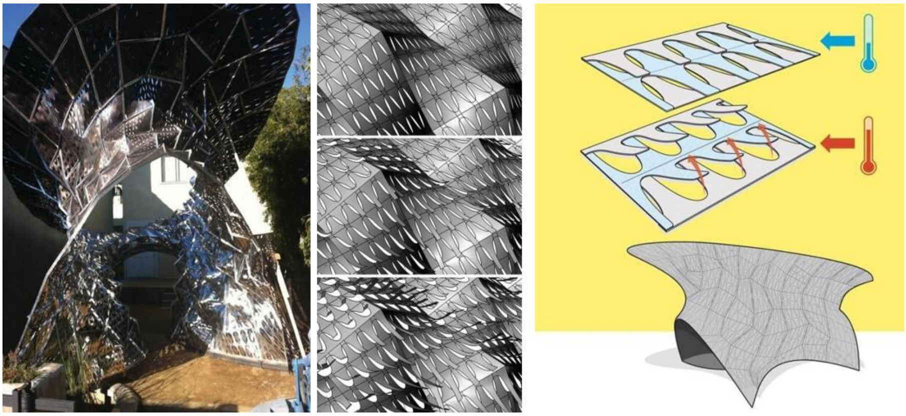
3. Utilization of Thermo-Responsive, Shape Changing Smart Materials in Adaptive Facades

3.1. Aplications Using Thermo-Responsive, Shape Changing Smart Materials

In this section, prototypes of thermo-responsive, shape changing smart material used in facade applications will be examined.

3.1.1. Bloom

Bloom application, in which material testing of thermo-bi-metals is carried out by Doris Kim Sung, is a research project that works as shading device and ventilation system. The project consists of self-bending thermo bi-metal modules with the effect of temperature without any mechanical system. When the temperature rises above 22 °C, the thermo bi-metal modules bend. This case creates shaded areas under the shell and at the same time, air passes through the shell. Bi-metal modules flatten when the temperature drops below 22 °C. The study is a material experiment to test this material before it is used in a building shell. With the use of thermo bi-metal panels in the building shell, it is predicted that the need for air-conditioning systems will either decrease or not, thus it will have positive effects on energy consumption (DOSU Studio Architecture, 2011; López et al., 2015; Orhon, 2016; Tekin, 2019), (Figure 5).



(a) **(b)**

Figure 5. The appearance of the thermo bi-metal panels **(a)** in the shell; **(b)** working principle (Xululabs LLC, 2012)

Approximately 14,000 laser-cut thermo bi-metal panels were used in the Bloom (Orhon, 2016). These panels are framed with aluminum material and joined with rivets. The structure is designed as a light and flexible system that can support itself. The number of riveted joints has been increased to increase resistance at some points of the Bloom shell (DOSU Studio Architecture, 2011; Xululabs LLC, 2012). There are no two similar parts in the shell. Each piece is designed differently from each other. The pieces show different behavior in their position according to the angle of the sun (Rosenfield, 2012).

3.1.2. The Air Flower

Air Flower prototype is a project developed by Lift Architecture. It is aimed to ventilate the interior space with the Air Flower prototype, in which the shape memory alloy wires shorten with the effect of heat increase and as a result, the triangular panels open up (*Air Flow(Er)*, 2018; Ergin & Girgin, 2019; Lift Architects, n.d.), (Figure 6).

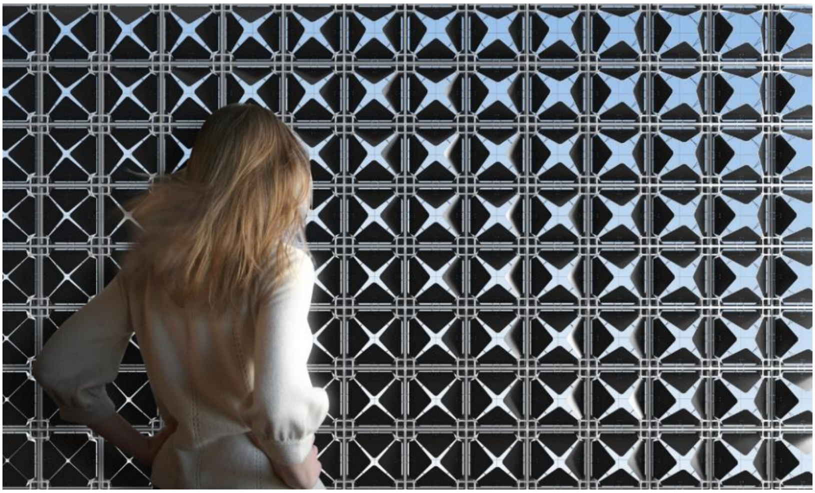
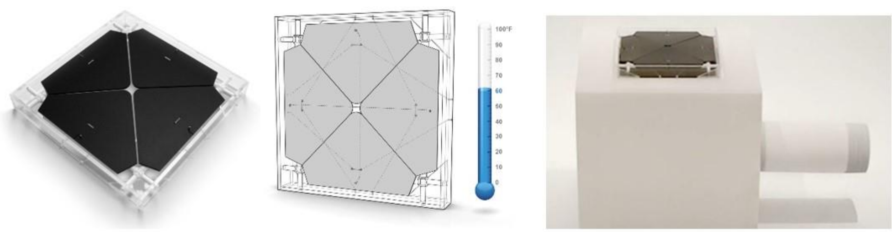
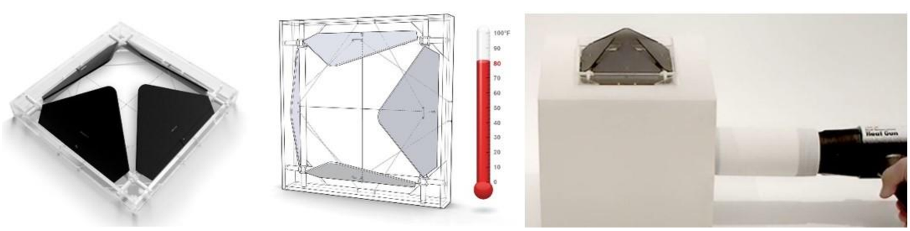


Figure 6. Appearance of the Air Flower facade (Lift Architects, n.d.)

In the Air Flower project, an experiment was carried out to test the prototype. In this experiment, the prototype is placed on a wooden single-volume box. Then, the temperature of the volume was increased by giving heat with a hot air gun through a hole to box, which is closed in four sides. As can be seen in Figure 7, the shape memory alloy wires shortened simultaneously with the temperature increase and the panel was opened. When the hot air was terminated, the volume began to cool. With the relaxation of the wires, the panels began to close. With this experiment, the applicability of a material-based passive ventilation system that doesn't consume energy has been tried to be proven. In addition, the panels are designed as modular so that they can be applied on every building facade (Lift Architects, n.d.).



(a)



(b)

Figure 7. Working principle of the Air Flower with temperature change **(a)** closed position; **(b)** open position (Lift Architects, n.d.)

Approximately 27°C is a threshold temperature value for the shape memory alloy used in this prototype. When the alloy wires are heated above 27°C, the panels open. When the air temperature drops below 16°C, the alloy wires start to relaxation and the panels are closed by the elongation movement in the wires (*Air Flow(Er)*, 2018).

3.1.3. TUB project

In the TUB project carried out by Victor Li, Maximilian Quixk and Moritz Funck in 2016, a shading element prototype was developed that performs opening and closing motions through shape memory alloy springs. Folding techniques were used in the form-finding process of the prototype, which consists of six identical perforated panels in the form of a perpendicular trapezoid. MDF board is used for the panel material. Copper rings are integrated into each MDF board to attach the shape memory spring. In order to create the connections that will allow the opening and closing movement of the prototype, the panels are connected to each other with shape memory springs. Both ends of the shape memory springs are combined with copper rings integrated on the panels. Thus, all panels used in the prototype are integrated with each other via shape memory springs. In this system, in which six panels are in a motion relationship with each other, central heating is made with an external heat source and all panels are closed together as a result of the shortening of the springs. Thus, daylight control is aimed. When the heat effect disappears, the panels perform an opening movement with the effect of the elongated springs. While developing the prototype, the experiments were carried out using MDF boards. However, fabrication with light metal or bioplastic materials has been recommended for commercial applications (Li et al., 2016), (Figure 8).

(a) (b)

Figure 8. TUB Project **(a)** Production of the Prototype; **(b)** Open position of panels at low temperature values (Li et al., 2016)

3.1.4. SMP baseline cell prototype

In the study (Yoon, 2019), a cell-type shading element prototype was developed, which is adapted to the climate conditions of Seoul, South Korea, and performs an opening and closing motion with thermo-responsive shape memory polymer activation. Besides shading, visual permeability is also aimed with the opening-closing motion typology in the prototype (Yoon, 2019).

This prototype was modeled using Rhinoceros and Grasshopper. Solar radiation and thermal simulations were performed and energy performance evaluation was made. With the aim of developing alternatives of the prototype in future studies, SMP Baseline Cell Prototype has been described as the first stage of production. The form of the shading cell is limited to a simple circular element in order to make the transition from prototype design to production easier and to make the behavior analysis of the material easier. The circular panel is made of polymer plastic based ABS sheet. Shape memory polymers were used as activators to rotate the circular ABS sheet. In order to test the behavior of the material with experiments, the shape memory polymer was produced by three-dimensional printing method, which allows rapid manufacturing. The SMP material was chosen as a type which glass transition temperature (Tg) is 25 °C. Because, in the climate analysis for Seoul, the most appropriate activation temperature of an element that will operate responsive to heat on the façade was determined as 25 °C. The SMP activator produced for the behavioral analysis test was agglutinated to the circular ABS sheet with Cyanoacrylate-based glue. While determining the position where the SMP activator will be agglutinated on the circular plate, the center of gravity of the plate has been shifted so that the SMP can create the effect that can rotate the plate (Yoon, 2019), (Figure 9).

(a) **(b)**

Figure 9. SMP Baseline Cell Prototype **(a)** Open-closed position according to temperature; **(b)** Adaptive movement in the simulation model (Yoon, 2019)

As seen in Figure 10, a heating cabinet was used to carry out the experiment of the prototype. By means of the heat test of the model, the bending angle and time of the SMP activator, the rotation angle and time of the ABS sheet were measured. The behavior of the prototype was simulated in the Grasshopper program using the obtained data (Yoon, 2019).

Figure 10. SMP Baseline Cell Prototype Components and Heat Test Setup (Yoon, 2019)

SMP material is sensitive to moisture. Therefore, if this material is used on the building facade, it should be considered together with a covering element to protect the material from climatic conditions. In the research (Yoon, 2019), this requirement of the material was not considered and a preliminary study was made for future studies (Yoon, 2019).

3.1.5. The swirl-type shading device

The swirl-type shading device prototype was designed for the south-facing glass facade of an office building in Seoul, South Korea. With the shading performance, it is aimed to reduce the heat gain of the building and to increase the daylight comfort level in the interior space. In the design of the prototype, a combination of rotation and folding motions was used as the kinetic system. Thus, the prototype performs an opening and closing motion. As a result of these design decisions, the form of the prototype was obtained as a swirl (Yoon & Bae, 2020).

The Swirl-type shading device makes shading by performing a closing motion when the temperature value reaches the glass transition temperature (Tg). When the temperature drops, shading isn’t necessary. The pushing force of a mechanical device is used to open the Swirl-type shading device (Yoon & Bae, 2020), (Figure 11).

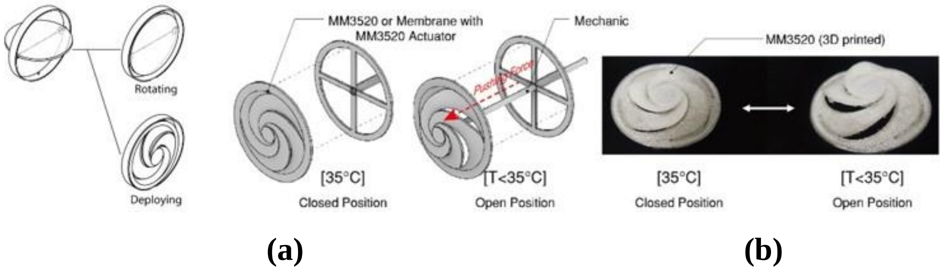


Figure 11. (a) Design of prototype; **(b)** 1:3 SMP model of the swirl-type prototype (Yoon & Bae, 2020)

In order to reach the sustainability goal of the developed prototype performance evaluation was carried out using simulation methods. For this, a simplified prototype was modeled in the Rhino/Grasshopper program and thermal comfort and daylight analyzes were performed. It is aimed to obtain an optimized design by creating different scenarios in the analyzes. In the scenarios, different values are considered for the circle diameter of the prototype placed on a circular base. In addition, cases where the prototype performs only rotation or only deploying, or combinations of these movements are analyzed (Figure 12). Among the scenarios, the most positive result was obtained for the model in which the circular form with a diameter of 600 mm performs the deployment and rotational motions together (Yoon & Bae, 2020), (Figure 13).

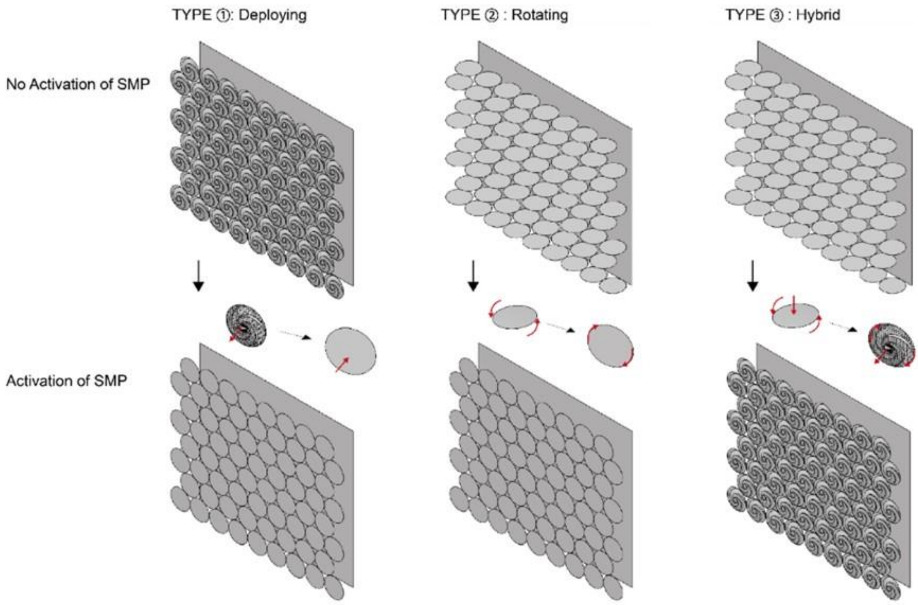


Figure 12. Operating scenarios of SMP shading devices (Yoon & Bae, 2020)

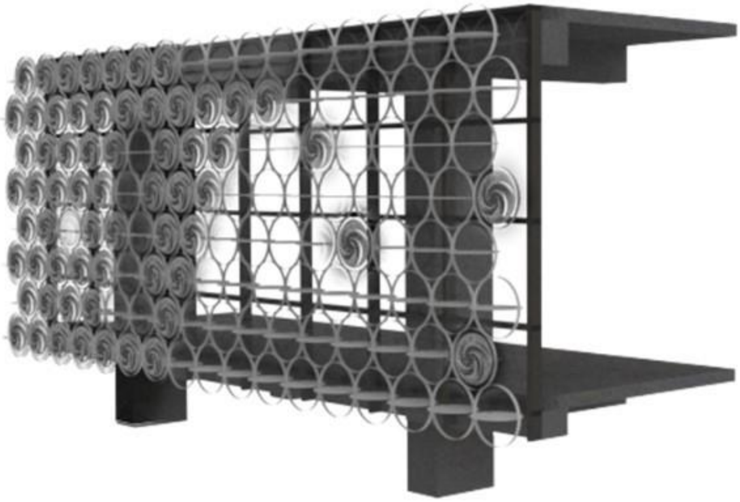


Figure 13. Appearance of Optimized performative SMP shading device in facade (Yoon & Bae, 2020)

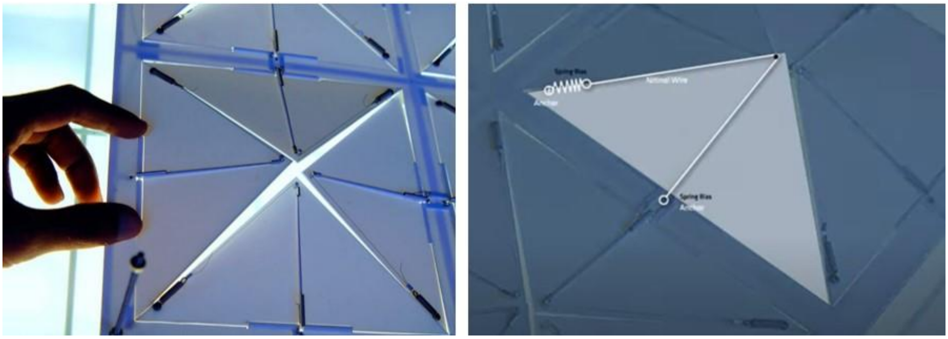
In this study, the researchers went one step beyond the prototype design and production with shape memory polymers and tried to show the effect of the shading device with SMP on the thermal and visual comfort of the building. In this context, the obtained simulation results will be a source for the further development of prototype productions in future studies.

3.1.6. Pixelskin02

Developed by Sachin Anshuman in 2006, Pixelskin 02 is the continuation of the Pixelskin 01 prototype previously developed by O. Void, Chief Organizer of the GCU Glasgow Smart Building Lab (Anshuman, n.d.; Ergin & Girgin, 2019). Pixelskin02 provides daylight control as a shading element. It also creates electrographic surfaces with the integration of lighting (Anshuman, n.d.; Loonen, 2010; Tashakori, 2014), (Figure 14).

Figure 14. Appearance of prototype modules in facade (Anshuman, 2014)

The Pixelskin 02 prototype consists of four triangular panels that perform opening and closing movements via shape memory wires. Electric current is used to activate the shape memory wires. There are 255 different positions between the open and closed states of the panels (Anshuman, n.d.; Loonen, 2010; PixelSkin02, 2009; Tashakori, 2014), (Figure 15).



(a) **(b)**

Figure 15. (a) Appearance of prototype (PixelSkin02, 2009); **(b)** Working principle of prototype (Anshuman, 2014)

3.1.7. InVert auto-shading windows

InVert auto-shading windows is a facade prototype developed by Tbm-Designs that includes the application of thermo bi-metal material. It was secured with U.S. Utility Patent. Experimental studies are still ongoing for the commercialization of the prototype design. In the prototype, a design that can cover the entire facade was obtained by using many thermo bi-metal sheets. The prototype consists of three layers. Thermo bi-metal material layer was applied as the middle layer placed between two glass panels. The working principle of this façade system, which is composed of three layers, is thermo-responsive. When the sunlight reach the outer surface of the facade system, the heat passing through the glass heats the space between the two glass panels where the thermo-bi-metal material layer is placed. With the increase in temperature in this space, the thermo bi-metal small sheets are bended independently of each other. Thus, shading is provided and the passage of light into the interior space is prevented. In addition, the increase in heat gain of the space is prevented. Depending on the intensity of daylight, the interior can be darkened at different levels and shaded (Sung et al., 2018), (Figure 16).

Figure 16. Motions of thermo bi-metal sheets in facade (TBM Designs, 2020)

In the InVert auto-shading windows system, the thermo bi-metal material functions as a sensor and actuator and works with completely zero energy. It doesn't require any external power source support, control mechanism or user control. In addition, it is stated by Tbm-Designs, who carried out the study, that the facade system can reduce the building cooling loads by approximately 25%. (Sung et al., 2018; TBM Designs, 2020), (Figure 17).

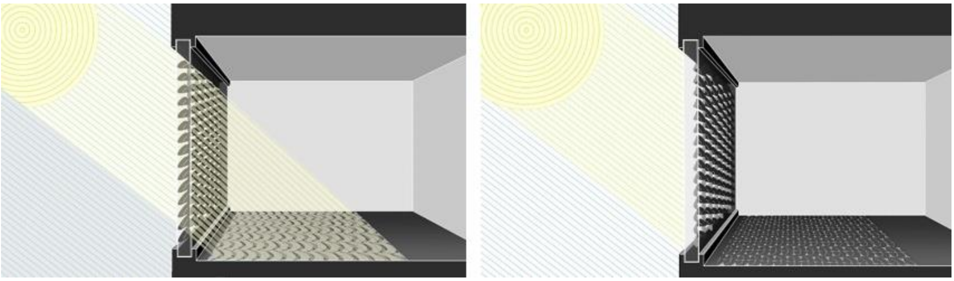


Figure 17. Shading effect of thermo bi metal sheets in interior space (TBM Designs, 2020)

3.2. Classification of Properties of Adaptive Facades Using Thermo-Responsive, Shape Changing Smart Materials

For Thermo-Responsive, Shape-Changing Smart Prototypes, the implementations examined in section 3.1 are classified within the framework of the prominent features in adaptive facades, as seen in Table 2. Implementation methods, control mechanism, power supply support, movement type and functions of these materials in adaptive facades are examined (Table 2).

Table 2. Classification of Thermo-Responsive, Shape-Changing Smart Prototypes

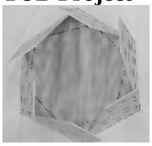
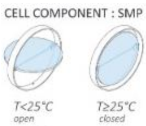
Prototype	Material Morphology Format	Control	Power Supply Support	Motion Type	Functions
Bloom  **(DOSU Studio Architecture, 2011)**	Thermo bi-metal  Sheet	Expansion Curvature	-	Opening Closing by twisting	Shading, Daylight Control, Ventilation
Air Flower  **(Lift Architects, n.d.)**	SMA Shape Memory Alloy  Nitinol Wire	Contraction Relaxation	-	Opening Closing	Ventilation
TUB Project  **(Li et al., 2016)**	SMA Shape Memory Alloy  Nitinol Spring	Contraction Relaxation	External heating	Opening Closing	Shading, Daylight Control

Table 2. Classification of Thermo-Responsive, Shape-Changing Smart Prototypes (continued)

Prototype	Material Morphology Format	Control	Power Supply Support	Motion Type	Functions
SMP Baseline Cell Prototype  **(Yoon, 2019)**	SMP Shape Memory Polymer  Sheet	State Transition	-	Opening Closing by rotating	Shading, Daylight Control, Visual Comfort, Thermal Comfort
The Swirl-type Shading Device  **(Yoon & Bae, 2020)**	SMP Shape Memory Polymer  Free-form	Rotating Deploying	Mechanic pushing force	Opening Closing as hybrid by rotating and deploying	Shading, Daylight Control, Visual Comfort, Thermal Comfort
Pixelskin02  **(Anshuman, 2014)**	SMA Shape Memory Alloy  Nitinol Wire	Contraction Relaxation	Electricity Current	Opening Closing	Daylight Control, Visual Comfort
In Vert Auto-Shading Windows  **(TBM Designs, 2020)**	Thermo bi-metal  Sheet	Expansion Curvature	-	Opening Closing by twisting	Shading, Daylight Control, Visual Comfort, Thermal Comfort

Thermo bi-metal material is generally applied in the form of a sheet on the facade and it performs bending behavior with the effect of heat. Thus, opening-closing movements are observed on the facade. In prototypes where thermo bi-metal material is used, an external power source isn't needed for the movement to occur. It is predicted that these prototypes will provide shading and ventilation in adaptive facades. It hasn't been applied in facades yet, and the studies are generally at the level of material experiments.

Shape memory alloys can generally be applied in the form of wire or spring on the facade, and it return to its original form with the effect of heat. These materials perform contraction and relaxation movements as a control mechanism. The alloy can be heated by various methods in order to be realized movement of the prototype. It is predicted that these prototypes will provide shading, ventilation and visual comfort in adaptive facades.

Shape memory polymer can generally be applied as a sheet or free form on the facade, and it transitions to another form in its memory with the effect of heat. It can work as actuators for the movement to occur, but it may sometimes need an external power source. With the use of these prototypes on the adaptive facade, it is aimed to control daylight with shading and to improve visual and thermal comfort in the interior space.

4. Conclusion and Suggestions

Adaptive façade systems are gaining importance day by day in the context of the zero-energy building objective. Especially sun-adapted facade systems are being developed widely. However, system components such as sensors and actuators used in the developed adaptive systems consume energy. With the development of material technologies, studies are carried out on the use of smart materials working with minimum or zero energy as sensors and actuators on the facade.

The following results have been reached and suggestions have been developed in the use of thermo-responsive shape changing smart materials examined in this study on adaptive facades:

- Within the scope of the examined examples, thermo-responsive shape changing smart materials perform the sensor function on the facade and eliminate the need for sensor systems.
- Solar heat is often sufficient as an activator. However, for some prototypes, a heat effect is created in the material by using various heating methods.
- In the prototypes examined, the need for an external power source is minimal or the material can operate without the need for a power source with its own qualities. This is promising for the future in the context of the zero-energy building objective.
- The prototypes examined are mostly used for shading and ventilation purposes on the façade and for the improvement of visual and thermal comfort in the interior space. Thanks to all these functions, it can be predicted that the heat gain of the buildings in the summer period and the heat loss in the winter period can be reduced. Therefore, it can be predicted that by reducing the heating and cooling loads of the building, an economic contribution will be made to the buildings.
- Within the scope of the examined examples, the studies are generally in the prototype development stage. Analyzes made with simulation programs are also of great importance in order

to be able to start applications on the facade of the building. Therefore, analyzing environmental performance by using both simulation and experimental methods will create an idea in terms of the applicability of prototypes and will support the use of these materials in adaptive facades.

Information Note

The e-book section complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

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The Use of Autonomous Robots in The Construction Industry

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1. Introduction

Digitalization brought about by Industry 4.0 and technological innovations developed to improve existing problems not only in the construction sector but also in all sectors has affected the way all sectors do business. However, it is also known that the construction sector has not progressed at the same pace as other sectors in terms of using technology and keeping up with digital transformation. The construction industry is one of the oldest and largest economic sectors not only in Turkey but also in the world. As can be seen in Figure1 according to Global Data 2021, the construction industry represents one of the largest sectors in the global economy, with nearly $10 trillion spent each year, accounting for 13% of the world's Gross Domestic Product and employing 7% of the world's working population. (McKinsey & Company, 2017)

Figure 1. Construction industry quantitative data (McKinsey&Company,2017)

It is a vital industry that connects communities and provides jobs, creating buildings and spaces that improve the society in which we live and work, and on which we move. Despite such a large impact on the world economy, as Figure 2 shows, the productivity growth of the construction sector has averaged only 1% over the last 20 years.

Other sectors have transformed themselves, boosting productivity. In manufacturing, lean principles and aggressive automation have been transformative. As the world continues to be more automated and documented, supply chain digitization strategies are quickly adopted. For example, automated package handling not only optimizes the actual process of moving the package, but it also drastically improves the process of documenting the package's handling. As automated robotics become more involved, they can simultaneously track packages digitally, therefore documenting every step of a package's journey while ensuring operational supply chains are as optimized as possible. (Autonomous robots in manufacturing pros and cons, 2022)

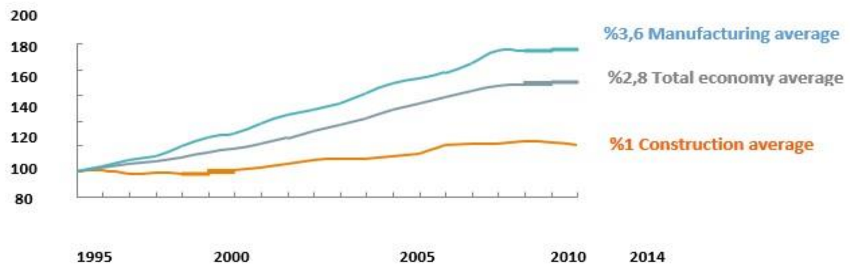

Figure 2. Globally, labor-productivity growth (McKinsey&Company, 2017)

It is not easy to make assumptions about how productive a sector should be compared to others. But again, as can be seen in Figure 2, it is clear that the construction sector is underperforming, with growth of 0.1 percent, compared to 2.8 percent growth in the world economy and 3.6 percent growth in manufacturing. While the US, for example, including agriculture and manufacturing, has increased productivity by a factor of 10 to 15 since the 1950s, the productivity of construction is stuck at the level of 80 years ago. If construction labor productivity could catch up with the progress made by other sectors over the past 20 years, or the overall economy, it is estimated that this could increase the value added of the construction sector by $1.6 trillion a year. This is equivalent to Canada's GDP, or meeting half of global infrastructure needs, or increasing global GDP by 2 percent a year (McKinsey & Company, 2017).

When the studies are analyzed separately, it is revealed that the following problems have been experienced in the construction sector over the years.

- Compared to other sectors, productivity in the construction sector is quite low. Since 1950, labor productivity in the construction industry has been defined as 50%. (U.S. Chamber of Commercial Construction Index, 2021).
- There are difficulties in finding experienced and educated labor force. 83% of the companies operating in this sector state that it is difficult to find experienced, educated workers. Literature sources indicate that this situation is not sustainable. (Stephen,2013).
- Cost and schedule overruns are the norm in the construction sector. As seen in Figure 3 Large projects across asset classes typically take 20

percent longer to finish than scheduled and are up to 80 percent over budget. (McKinsey & Company, 2013)

- Over 40% of workers surveyed spend at least a quarter of their work week on manual, repetitive tasks, with email, data collection, and data entry occupying the most time (McKinsey Global Institute, 2017).

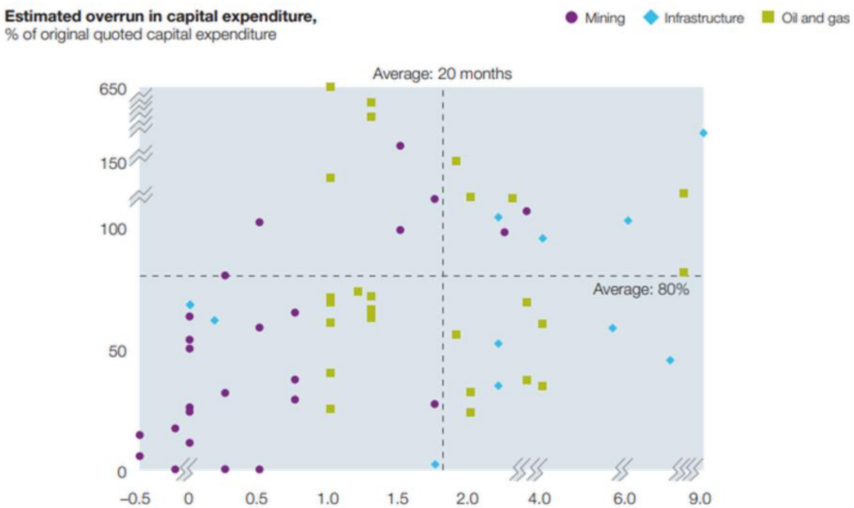

Figure 3. Delay beyond originalsSchedule (years) (McKinsey & Company, 2013)

- According to reports from the US Bureau of Labor Statistics and CPWR, on average 53% of fatal accidents on construction sites between 2003 and 2010 were caused by vehicle or equipment rollovers and collisions (U.S. Bureau of Labor Statistics, 2013). This results in approximately $13 billion in damages annually in the US. (CPWR, 2008).

- On a typical construction site, labor and heavy equipment must work together. This increases safety risks (Hung, Liu, Liang & Kang,2016).

Blind spots around the equipment are the main cause of such accidents (Teizer Allread & Mantripragada, 2010). Figure 4 shows the causes of the accidents. 93.5 % of accidents results from human error (Winkle, 2016). Human errors can occur in all human activities throughout an organization. Errors in construction projects can be due to various factors, including errors related to investors, users, suppliers, etc. Other factors that can affect individual decisions, leading to errors, include the quality of education, working experience under pressure, workload, fatigue, workplace ergonomics, working hours, social climate, etc. Errors can be considered as a chain of events, including causes, human errors, defects, consequences, etc.

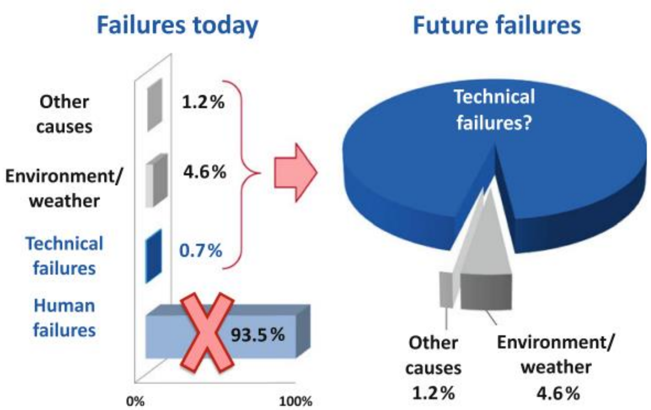

Figure 4. Causes of accidents (Winkle, 2016).

Some human errors in the project include errors in civil and architectural design, errors by consulting companies and their employees, and errors related to construction plans, building supervision, construction operations, contractor's office, construction materials, construction equipment, and regulations (Chan & Sarvari, 2022). With full automation, there would be no more human error. However, the proportion of technical faults may be perceived considerably enlarged in future. (Winkle, 2016).

- According to statistics, the death rate in the construction industry is 4.24 times higher than that in all other industries, and more than 60,000 workers die on construction sites worldwide every year, representing one fatal accident every 10 minutes. Further, the ILO estimates that the construction sector in industrialized countries employs between 6% and 10% of the workforce but accounts for between 25% and 40% of work-related deaths. Equally significant is the impact of work on the health of construction workers. The ILO estimates that 30% of construction workers in some countries suffer from back pain or other musculoskeletal disorders (Lingard, 2013).

1.1. Industry 4.0

The difficulties mentioned above are not only experienced in the construction sector. Similar problems are also experienced in other sectors depending on the way of doing business. The concept of Industry 4.0 and the technological innovations created by this concept have emerged in order to respond to such problems.

The level of development created by Industry 4.0 and the technologies that have been implemented in recent years have been on the agenda of organizations aiming to create faster, more flexible, higher quality and more efficient production ecosystems (Aladağ, 2022). Below describes a few technological innovations that have entered our lives with the introduction of Industry 4.0. Autonomous Robots are one of these technologies (Öztuna, 2017).

Autonomous Robots: While autonomous robots in cooperation with humans provide flexibility, quality and efficiency in production, they provide a safe work environment by undertaking dangerous and risky jobs in terms of human health.

Augmented Reality: By coordinating real and virtual elements with each other, it enables users to obtain flexible and real-time information, while also bridging the gap between physical and digital environment.

Additive Manufacturing: Additive manufacturing, also known as three-dimensional printing, is a process for producing even highly complex designed products, layer by layer, effectively and in a short time, by taking the part layer directly from the three-dimensional digital model data.

Internet of Things: The technology that enables all objects to access the internet, interact and communicate with other devices.

Simulation: It is the exact imitation of the operation of a real-life system or a process in the computer environment. In this way, the problem is detected and instantly solved. More efficient and flexible production systems are created.

Big Data: Storing, analyzing, interpreting the exponentially increasing data rate, and understanding customer profiles and consumption habits in this way creates an opportunity to highlight businesses that are constantly competing with each other in today's global world.

Cloud computing: It means providing faster, innovative and flexible resources and economic scaling by providing computing services over the internet.

Horizontal/Vertical Integration: It ensures that all stakeholders and functions inside and outside the enterprise coordinate with each other to facilitate production, increase resource efficiency and achieve optimization in the global supply chain.

Cyber Physical Systems & Security: It refers to the network of objects and systems with each other over the internet and the virtual environment that emerges with the simulation of real-world objects and behaviors in a computer environment.

1.1.1. Autonomous Robots and Their Uses

Technological advancements and innovations are increasingly shaping production environments and ways of doing business, and even eliminating traditional approaches to production, bringing new and more dynamic perspectives to production processes. The introduction of Industry 4.0 and emerging technologies and practices have breathed new life into manufacturing ecosystems. Autonomous robots, which constitute the main line of this study, are one of the technological developments and innovations such as artificial intelligence, augmented reality, internet of things, big data and analytics, cloud computing, smart factories, additive manufacturing, cyber-physical systems within Industry 4.0 (Almada-Lobo, 2015).

In terms of autonomous robots, Industry 1.0 covers the most primitive stage of the use of machine equipment, 2.0 includes simple robots that can perform a single task, off-site manufacturing robots, 3.0 includes exoskeletons, customized manufacturing robots and 3D printing equipment. Therefore, the current time period is defined as the Industry 3.0 era for the construction industry. Industry 4.0 is thought to include the development of autonomous robots with human characteristics (perception, decision-making, learning, etc.), robots that can communicate with themselves, and robots that can multitask. Figure 5 summarizes this process.

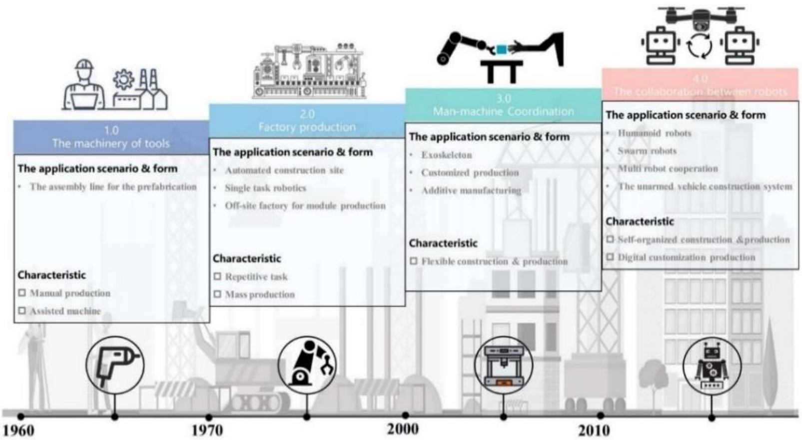

Figure 5. Development levels of autonomous robots by years (Wang & Sadick,2022).

2. Research Methodology

In recent studies, the use of Autonomous Robots in the construction sector is shown as a solution to the long-standing problems of low development rate and low productivity level of the construction sector compared to other sectors. In this study, which aims to investigate the extent to which autonomous robots can be a solution to the above-mentioned sectoral problems, literature research on the subject was conducted and application examples defined in the literature were tried to be defined. The methodology of the literature study is described below. (Figure 6)

1. Literature study: The study area of this research consists of academic studies published in different databases such as Scopus, Google Academy, Asce, ScienceDirect between 2002-2022. Two books written by Thomas Bock and Thomas Linner, who are known for their research and articles in the field of Autonomous Robots; Site Automation Automated/Robotic On-site factories and Robotic Industrialization were examined. The reason why the article research is mostly based on 2013 and later years is that since Autonomous Robots are a digital technology, studies in the past years will be full of dreams and goals. Instead, it was thought that reading recent articles would lead to more realized studies and aims to develop these works in the future.

2. Identification of keywords: Academic studies analyzed during the research: Autonomous Robot, Construction robots, BIM, autonomous data collection, Industrial automation and construction, Human-robot collaboration, Autonomous construction, Automation, Robotics and automation, Industry 4.0, Digitization. In Figure 7, the keywords are caricatured according to their frequency of use in the reviewed articles.

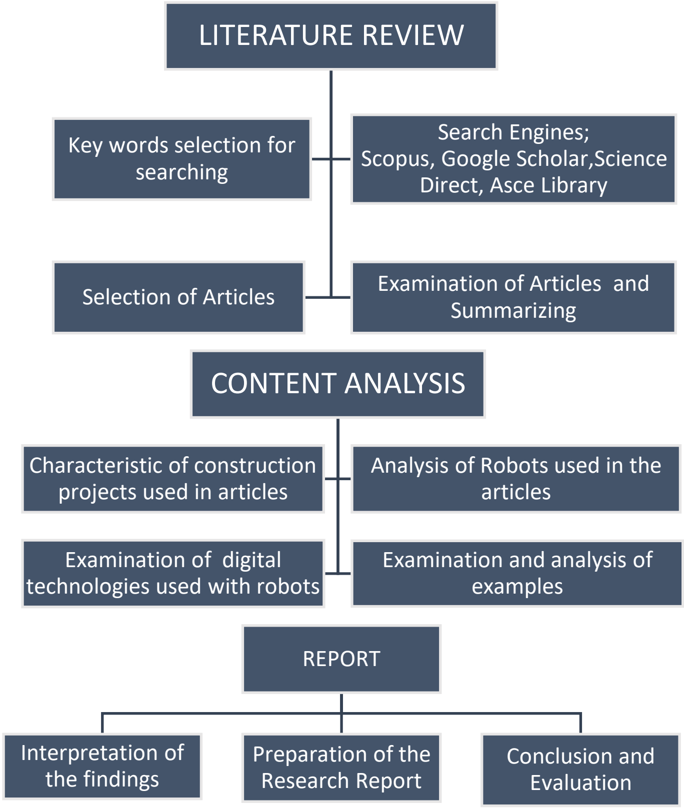

Figure 6. Research Methodology

Figure 7. Cartoonization of keywords according to frequency of use

3. Sources accessed: In the study, ScienceDirect, Scopus, Asce Library and Google Scholar databases were searched between 2002 and 2022 using the keywords determined and a total of 1876 studies were reached. 664 of them are publicly accessible. Articles without open access could not be analyzed. These studies were eliminated and reduced to 61 studies because they did not comprehensively discuss all sub-technologies, definition details, classifications and examples of Autonomous Robots.

4.Classification of sources according to purpose: As can be seen in Figure 8, the distribution of the sources examined by years is concentrated between 2013 and 2022. The number of studies conducted in recent years shows an increase compared to 2002. Since the development levels of countries in digital construction processes are taken into account, the study is concentrated in USA, China, Germany, UK.

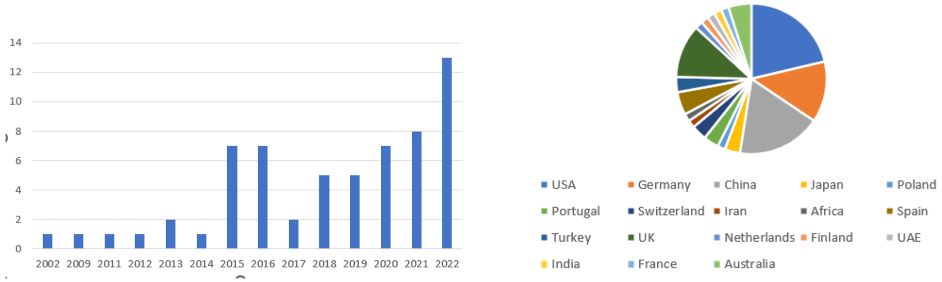

Figure 8. Distribution of articles read by year and by country

4. Evaluation of the information obtained: The information obtained as a result of the literature research on Autonomous Robots has been classified. The subject is discussed within the scope of usage areas of autonomous robots, definition and development of autonomous construction robots,

related applications and usage areas of construction robots.

3. Findings and Discussion

3.1. Usage Areas of Autonomous Robots

In the literature study, it is possible to see that Autonomous Robots can be used in different fields in many sectors.

Mining: Autonomous robots have been used in the mining industry for years. They work in the regulated environment of the mine site, which is not as variable as the construction site. In the mining industry, which has a limited number of external stakeholders compared to the construction industry and operates with a smaller workforce on site, autonomous transport trucks have been commercially available for many years from world-renowned large-scale suppliers. However, these vehicles operate in the more regulated environment of mine sites, as opposed to complex construction work sites. In the mining sector, the biggest obstacle to the increased use of similar robots on the construction site is the chaotic conditions that characterize many large-scale construction sites.

While automated tunneling has generally advanced in the mining industry, tunneling is recognized as an important technique for the construction of infrastructure elements used for transportation and utilities. Today, the autonomous movement of a tunneling machine has been demonstrated by a company operating in Austria. The system controls the steering for 18 independent axles and allows human teleoperators to take control in exceptional cases (Gleeson, 2019). A Malaysian contractor has also developed an autonomous tunneling machine, the A-TBM, and currently operates 10 autonomous machines across the country. (Byrd, 2020).

Agriculture: Industrial robots working in or on fields and farms are called agricultural robots. Agricultural robots perform tasks such as picking and placing, seeding, weeding, pruning, phenotyping. A simple picking action involves discovering with the help of a camera where the plant to be harvested (such as fruit or vegetables) is located. The robot also checks whether the plant is mature enough to be harvested. Some robots are equipped with solar panels that help them work in a 100% environmentally friendly way without any pollutant emissions. Using robotics in agriculture helps reduce food waste worldwide (Important areas of robotics, 2022).

Home Affairs: There are vacuum cleaners, window cleaners, pool cleaners and lawn mowers for household chores. These robots were created to make our lives easier by doing household chores for us. The most famous of these robots is the Ubtech Lynx robot. Smart vehicles can be controlled with Alexa. It can also talk and chat about the weather, news and recipes. The robot can manage our calendar and remind us to do to-dos or reply to important emails. The robot uses facial recognition to recognize people and call them by name. Another company announced in 2015 that their robot chef, which was introduced as a prototype in 2015, is ready for sale. With a capacity of more than 5,000 recipes, this robot can prepare delicious meals and wash the dishes at the same time thanks to its detailed arms (Important areas of robotics, 2022).

Health Sector: Another use of autonomous robots is in hospitals. With the pandemic, they have become widespread with a significant increase in the need for labor. Robots safely screen incoming patients for infection and direct people with viral symptoms to areas where doctors can safely see them. Surgical robots emerged in the mid-1980s. They are used in surgeries such as cardiology, gynecology, urology, thoracic surgery, where surgical procedures are usually performed through only small incisions in the human body. Thanks to robots, operations can be performed with high precision through these small incisions and the risk of infection is reduced. In 2014, the first robots were produced to perform catheterization and heart surgeries. Companion and therapeutic robots, such as Paro, comfort patients with mental health problems with a system of sensors, microphones and cameras. (Important areas of robotics, 2022).

Logistics Sector: On the theme of healthcare and logistics, in 2017, the UAE's Ministry of Health and Prevention installed a robotic pharmacy to dispense and deliver medicines. Thanks to the use of barcodes, the robot can dispense up to 12 prescriptions in less than 60 seconds. This remarkable time-saving technology also ensures that the right medicines are dispensed from a store of up to 35,000 (Sagar, 2022).

Automotive Sector: The area of research that has attracted the most interest is driverless cars, which began to develop in the 1990s. While driving, the on-board computer analyzes the environment with advanced artificial intelligence (AI) methods based on data from the vehicle's many sensors. This means that the driver can relax and do other activities, such as writing emails or reading books, especially on controlled-access highways. The Waymo test car is an example of this level (Important areas of robotics, 2022).

Manufacturing Sector: The use of autonomous robots in manufacturing is widespread in industry. Robots called SCARA and Cartesian are used for pick and place operations. They have several degrees of freedom, but are mostly in the same plane. A robotic arm like this can accurately pick and place about 120 items per minute. Cylindrical robots, on the other hand, are often used for coating, trimming, spot welding and assembly. Polar robots are used for injection molding or welding.

In the production of construction materials such as cement, steel, aluminum, glass and wood etc., the degree of automation is very high almost up to 100% (Bock & Abderrahim, 2008).

Military: Military robots are used to perform military tasks that can be classified as prevention or intervention. Bomb detector and disposal robots are for prevention. These robots are usually small and lightweight, consume low energy and can be used to replace humans in extremely dangerous situations. They typically have a high-resolution camera and a robotic arm that can be fully controlled by humans (Important areas of robotics, 2022).

Emergency Situation: Rescue robots are used in areas where human intervention is dangerous or not possible, for example in earthquake, flood, hurricane or fire emergency areas. Rescue robots enter emergency zones to find people in trouble. The robots can show the rescue team the exact location of a trapped or lost person (Important areas of robotics, 2022).

Exploration and Observation: Robots can also be used for exploration and observation. One main area of application is space exploration. Researchers are working on robots for observation and humanoids to replace astronauts in the future. The Mars Exploration Rovers (MERs) are the most famous space robots. The first robot, Sojourner, was launched in 1997. Spirit and Opportunity followed in 2003 and both landed successfully on Mars after about six months and 100 million kilometers. These robots have many tasks to fulfill, including landing, navigating, adapting to the environment, overcoming difficult terrain and communicating in space. They are also resistant to extreme cold and heat (Mars Exploration Rover, 2023).

Security: In 2017, Dubai Police announced and demonstrated a robot that allows people to report crimes, pay fines and more, as part of a project to create a robotic police force by 2030 (Robot police officer goes on duty in Dubai, 2017).

3.2. Definition and Development of Autonomous Construction Robots

Autonomous construction robots are defined in the literature as in Table 1 below. Based on these definitions, autonomous construction robots are defined as "Semi-autonomous or autonomous equipment that can be remotely controlled, semi-autonomous or autonomous equipment that increases the quality and speed of construction and helps to save costs as part of any construction process on or off the construction site."

3.3. Related Technologies

Today, many digital solutions are intertwined. Autonomous robots also benefit from many technologies while working. The applications used by construction autonomous robots in the construction industry and brief information about these applications are given below.

Table 1. Autonomous construction robot definitions (Wang, 2022).

Author	Definition	Year
Whittaker	"A construction robot is a robot that constructs, meaning builds, and yet such robots do a lot more; they exhibit flexibility in the roles they play and the equipment they use, and they perform tasks of a complexity that previously required human control"	1986
Skibniewsk	"Engineering or performance of any construction process, on-site or off-site, by means of teleoperated, numerically controlled, semiautonomous, or autonomous equipment"	1992
Stein at all.	"Construction robots are ingenious machines that used intelligent control but varying in sophistication and generally designed to increase speed and improve accuracy of construction field operations"	2002
Mahbub	"The use of self-governing mechanical and electronic devices that utilises intelligent control to carry out construction tasks and operations automatically"	2008
Saidi at all.	"Construction robotics is an advanced form of mechanization (automation) in which an endeavor is made to automate some industrially important operation and thereby reduce the cost of this operation by either removing a human operator from the control loop, or enhance operational efficiency through machine control systems"	2016
Kamaruddin at all.	"Robotics comprises the ability of the same tooling which had the multi-axis flexibility to conduct diversified tasks"	2016
State Adm. for Market Reg.	"Construction robot is used in engineering construction, decoration, repair, and inspection in the construction industry"	2018
Robotic Industries Association	"Construction robots are professional service robots currently used in the construction of new buildings"	2018

Machine Learning: There are types of machine learning that actively test models against environmental factors. If you have a project in an area known for bouts of heavy rain, artificial intelligence can be used to help test certain structures to see how they react. Machine learning strengthens the BIM model by providing the best ways to avoid hazards and dangerous areas before the project starts (Construction Robots and Different Types of Machine Learning: How AI is Changing the Industry).

Computer Vision: high-resolution cameras mounted on drones can scan the construction site and create a 3D model in real time. This way, construction project managers can have more context on the project without the hassle and risk of physically going and inspecting it. Some drones measure the quantities required from the air to make topographic surveys (Javaid ,2023). Intelligent inspection tools can scan video footage of construction sites to detect defects such as cracks in walls, as seen in Figure 9.

Figure 9. Red areas (incorrect areas) are shown in picture (Javaid ,2023)

GPS: Autonomous robot (with GPS technology) can detect and avoid obstacles, dynamically adapting to the ever-changing complexity of construction environments. This robot can be mounted on a robot and supports level 4 autonomous exploration tasks without the robot having to "learn" about its environment in advance (Aerial Autonomy Level 4).

SLAM: A vehicle or robot equipped with simultaneous localization and mapping finds its way around an unknown location by identifying various landmarks in its surroundings. It does this in a way that is quite similar to how a human can do the same. A cleaning robot is one of the best examples of how simultaneous localization and mapping works. Without SLAM, a cleaning robot would move randomly across the floor. It would not be able to detect obstacles, which means it would constantly bump into chairs or feet. Also, it would not be able to remember the areas it had previously cleaned (Url 1)

LIDAR: LiDAR technology (short for light detection and ranging) uses light energy to collect data from a surface by shooting a laser at a target and measuring how long it takes for that signal to return. This data can then be used to create highly accurate 3D models and maps. Because LiDAR requires little or no light to operate, a LiDAR-equipped SLAM system can collect precise, highly accurate data about any obstacle or landmark that may be difficult for the human eye to observe. 2D LiDAR SLAM is widely used in warehouse robots, and 3D LiDAR SLAM is used in everything from mining operations to self-driving cars (Url 1)

Virtual Reality: Implementation of virtual reality (VR) technology offers greater safety and convenience in remote working.

Artificial Intelligence: AI-powered surveillance makes it easier for construction managers to monitor everything from materials to workers. With AI, surveillance can observe and report as scheduled and report suspicious behavior to those responsible. An out-of-place tool or a worker doing something they shouldn't be doing is considered suspicious behavior. AI can also track who should/should not be on site. Our construction sites are vulnerable to theft and criminal activity. But with AI, you can make sure your site is safe. For example, an AI solutions company, is working wonders with its fleet of autonomous robots that map and monitor work in real time (Javaid ,2023).

Augmented Reality: Integrating remote inspection with an Augmented Reality (AR) technology can help the inspector to verify the BIM data with the implementation status as planned. (Halder et al., 2022).

BIM: The automation of BIM model creation and update from an existing construction is an active application in order to reduce time and labor consumption, track construction status, supervise the building quality process and detect defects that are not easily detectable by humans (in inspection-control processes). Mobile robots, whether ground or airborne, play an important role in the automation of BIM modeling by capturing building data using sensors such as laser scanners or cameras, processing them into the system, and relating them to a pose in their frame of reference (Sanches et al.,2021).

Digital Twins: With Deep reinforcement learning in a digital twin environment, it can be tested whether a robot has learned the items requested from it.

3D Printing: 3D printers are autonomous robots. For example; As seen in Figure 10, robot uses a 3D printing robotic arm to print stainless steel bridges in the air. It was used for one of Amsterdam's most famous canals.

Figure 10. Robot printing the bridge (Melenbrink et al., 2020).

Internet of Things: The IoT sensors attached to physical assets collect real-time sensor data from a construction site and transmit the data to the digital twin. Then, "as-is" building information modeling (BIM) can be updated based on "as-designed" BIM and IoT sensor data collected from the site. Some companies use IoT technology to do this, with programs that automatically distribute reports and images (Lee et al., 2022).

Deep Reinforcement Learning (DRL): RL is thought to be well-suited for robotics task planning and control; because instead of meticulously programming high-dimensional robot movements step-by-step in a manual manner, RL can be used to train robot behavior autonomously (Plaat et al.,2020).

Simulation: Simulating models also provides accurate information in real time. This helps employees to recognize errors or identify problems with existing plans (Lee et al., 2022).

3.4. Development Levels of Autonomous Robots

The categorization system developed by the Society of Automotive Engineers, which rates self-propelled vehicles from 0 to 5, provides a widely recognized measure for autonomy (On-Road Automated Vehicle Standards Committee, 2018). These standards are not intended for construction robots but can be a guide for evaluating construction robots. The ranking takes into account Levels of Autonomy (LoA):

LoA 0: No automation. Even with advanced sensing capability, the system does not control any degree of freedom.

LoA 1: Operator assistance. The system adjusts a single degree of freedom (such as raising or lowering a leveling bar) while the operator controls the rest. Primitive The Brick-road-laying machine and Autonomous trucks are examples of this level.

LoA 2: Partial automation. The system can control multiple degrees of freedom simultaneously but requires a human operator to recover from failures and manage other functions. Examples of this level are the Masonry Robot and Robots Used in Rebar Tying Process.

LoA 3: Conditional automation. The system can operate all degrees of freedom simultaneously under some conditions. The system can be programmed to request operator assistance when needed. Sheet piles driving robots and some bricklaying robots are examples of this level.

LoA 4: High automation. The system can autonomously execute tasks under certain field conditions. The system does not require human assistance and can adapt to unexpected disturbances. Autonomous trucks is an example of this level.

LoA 5: Full automation. The system can autonomously complete tasks under any site conditions where construction can reasonably be expected to take place.

3.5. Usage Areas of Construction Robots

This section presents a brief overview of the different types of autonomous robots used in the construction industry. According to the literature research, there is no uniform standard or usage area of construction robots today. Autonomous robot technologies used in the construction industry can be grouped into four general categories.

3.5.1. Off-Site Prefabrication

Prefabrication is a building technique where parts have been made separately and put together on-site. When we talk about off site prefabrication, three things should come to our mind. Building component manufacturing (BCM), Large-scale prefabrication (LSP) and Additive manufacturing (3D printing).

This type of robots can be applied to the prefabrication of timber, masonry walls, roof panels, concrete floors, concrete, and steel. The BCM refers to combining low-level component (concrete, steel, timber, brick) into higher level component based on automated robotic system and LSP utilizes the high-level building component in integrated building modules like kitchen or bath module (Bock, 2015). For example, Bock introduced that the multifunctional template unit that can flexibly produce concrete floor, concrete wall, and roof panel (Bock, 2007). For timber prefabrication, the robotic prefabrication system needs to integrate with sensor-based feedback mechanisms to meet strict regulatory requirements (Willmann et al., 2016). Additionally, the application of robot arm also requires larger space to place and transport (Svoboda & Usmanov, 2011).

Considering the adoption of each category in the construction industry, off-site prefabrication can significantly help with the advancement of building materials, which follows the same logic and principles of the manufacturing industry. Several building components and structures have already been constructed successfully in this way.

Metal Welding Robot: One bridge in Amsterdam has been manufactured by Metal Welding Robot with gas metal arc welding using basic elements of 5 mm stainless steel rods that are extruded to form an 8 m-long bridge to be installed as a single piece on site. The project was intended to be completed on-site but has been fabricated in a controlled factory setting instead because of safety concerns (Melenbrink et al., 2020) (Figure 11).

Figure 11. A steel bridge is made as 3D printing (Melenbrink et al., 2020).

3.5.2. On-Site

This category includes autonomous robots that can be used directly on the construction site to create structures and buildings.

Tracking Helmet: Tracking helmet includes 360-degree data capture and display, daily progress comparisons, BIM integrations with Procore, Autodesk BIM 360 and PlanGrid. This Track uses computer vision and machine learning to recognize, track, and quantify work-in-place. Tracking helmet enable us to track and validate fast and easy to percent complete, quantity installed, and rate of work. With this technology during the invoice (progress payment) period, you have a trusted record of progress to verify percent complete and also you can know how much time was actually spent and what materials were used sets you up for better forecasting and estimating.

In a recent survey of its customers, this product found that 67% of customers reported saving thousands of dollars on average on project costs thanks to this tracking helmet, while 74% saved multiple hours per week. These savings are a result of tracking helmet ability to increase site coordination, reduce rework costs, and provide a trusted, complete record of site status (Rathmann, 2022)

As seen in Figure 12, Tracking helmet enables us to create the necessary visual reports by coloring the actual works with different colors, as seen in Figure 13, it prepares level by level progress reports via BIM, and as an be seen in Figure 14, present a comparison graphic of the actual works by dates.

Figure 12. Progress via BIM is colored (OpenSpace, 2023).

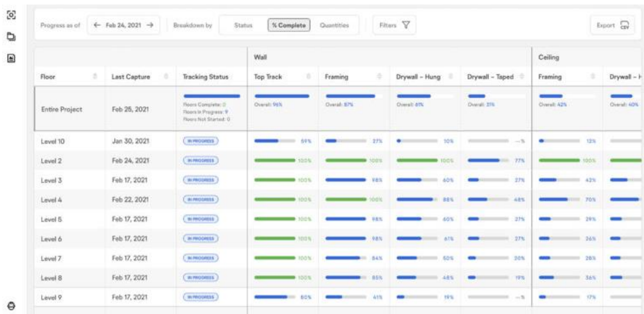

Figure 13. The progress of the relevant work items on all floors has been calculated (OpenSpace, 2023).

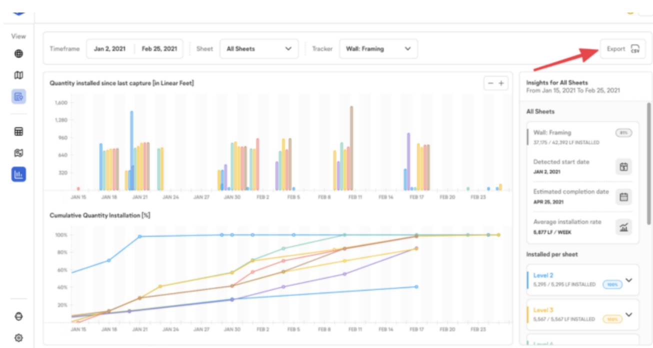

Figure 14. The assembly was compared according to the floors via BIM (OpenSpace, 2023).

The Brick-Road-Laying Machine: Launched 8 years ago, it is the most primitive form of automation and of this category. It is a semi-autonomous machine and is used for road construction. The Brick-road-laying machine is a six-meter-wide machine that can pave an entire street in one go, including edging. The dimensions and scheme are adjustable. The stones are manually placed on the cutting board. Then, the rack slides the stones with the right side up. When the cutting board is full of stones, the rack starts the robot via a push button. (Figure 15)


Figure 15. Placing stones into machine (Coxworth 2010)

Wall Masonry Robot: Masonry is a time-consuming, repetitive and labor-intensive occupation that often leads to back injuries. It is therefore the perfect line of work to be performed by robots. USA based company developed a robot, a bricklaying robot, in 2014. Robot can lay around 2,000-3,000 bricks per day using its combination of a conveyor belt, a robotic arm and gripper and a concrete pump. Electrical power and air are provided by an on-board propane generator and the robot is equipped with a laser and suite of sensors which allow it to measure critical operational variables including orientation, angles, depths and distance (Bogue, 2018).

One thing to be noted that this robot does not fully automate the bricklaying process. As seen in Figure 16, The robot picks up the bricks, applies the mortar and positions the bricks on the wall but still requires a human to work alongside to smooth over the mortar before it places further bricks. An Indiana-based construction company has incorporated the robot into its construction projects, increasing daily bricklaying capacity by 400 percent (Carlson, 2017). At one project in Indianapolis, the average mason lays 400 modular bricks on a good day. After purchasing, the company claims they are now laying more than 2,000 bricks a day. Its record is over 3,000 (McClister, 2018). By comparison, a human builder will average around 400-500 bricks per day.

Figure 16. Brick wall robot working in site (Dakhli & Lafha, 2017)

Australian-based another robot which is an automated bricklaying system which is able to configure house structure from a 3D CAD model without human intervention. The robot is composed of three parts: a carrier device, a 6-axis industrial robot arm and a manipulator. It uses 3D computer-aided design software to draw a residential model, automatically judge the position of bricks, and grabs bricks with suction cups. The robot arm with six degrees of freedom can realize the installation of bricks in all directions

(Zho at al., 2022). The robot can finish laying 1,000 bricks in one hour which is not possible for human worker. (Figure 17)

Figure 17. Robots completing a sample building (Melenbrink et al., 2020).

Humanoid Construction Robots Laying Drywall: According to a 2013 Oxford University study that quantifies the likelihood of job automation, it actually places the extremely specific job of 'Drywall Installer' at a 79 percent chance of being replaced by robots (Frey and Osborne, 2013). For this reason, we will examine below special robots for drywall works.

a) Plasterboard Wall Builder: Developed to build plasterboard walls, the Robot first maps its surroundings and detects objects using high-precision AI markers (Lee, 2018). In Figure 18, the robot's walking in the direction of the plan (bottom) and object detection example of this robot can be seen by looking at the front-bending (top), front and rear extended leg (bottom) and environment map of the robots for humanoid movement.

This robot can pick up and move a material, pick up drywall and then screw it into place (Figure19). It can automatically recognize equipment, pick it up and use it. It can move drywall even when it can't see in front of it because it knows the positions and locations in the room. Unlike a human being, it doesn't determine by eye.

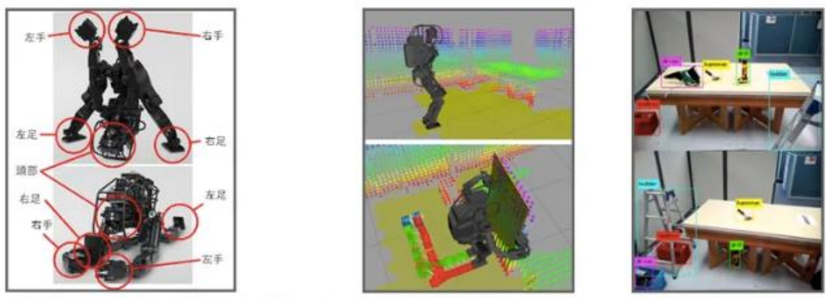

Figure 18. Humanoid movements of robots (Lee, 2018)

Figure 19. Development of a humanoid robot prototype (Lee, 2018).

b) Drywall Robot: This Drywall robot aims to support workers in interior drywall finishes, including mudding and sanding. The robot consists of a mobile platform with an arm capable of using two end effectors: a sprayer to apply the drywall mud and a sander attached to a vacuum to smooth the surface. The robot has two LiDAR sensors to map and calibrate the workspace. Force sensing and compliance with the tools ensure a quality finish. The robot is mainly autonomous, requiring attention from the operator for 30% of the operation time. Drywall robot improved costs by 8%, considering the weekly capacity of two robots working simultaneously on drywall finishing (Brosque & Fischer, 2022). In Figure 20 we can see an airport which coats by drywall made with this Drywall robot. A worker can operate more than one machine at the same time.

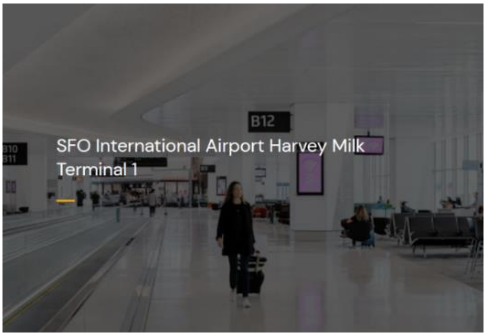

Figure 20. Robots are changing construction (Brosque & Fischer, 2022).

c) Multifunctional Field Robot: This robot can screw, lay bricks, carry up to 500 kg and measure with its laser level. Apart from these, it can also monitor the construction site with a camera and can give a report according to it (Figure 21).

Figure 21. Multipurpose robot (Brosque & Fischer, 2022).

Robots Used in Rebar Manufacturing: Rebar tying is one of the most labor-intensive tasks on construction projects, requiring repetitive torso bending and twisting movements to complete a single tie. Musculoskeletal injury, the most common type of construction worker injury, is caused by the conditions experienced by workers tying rebar.

Large projects require many repetitive rebar tying tasks. The robot developed for rebar tying is an autonomous robot that knows where and what to do thanks to its navigation. As seen in Figure 22, it can tie 1100 reinforcements per hour and can work day and night, in the rain and in all conditions.

The robot achieved cost savings of 29%, considering a weekly service cost of $3,600 for the 1,982,064 m2 bridge construction project and a traditional labor rate of $100/h. **(**Brosque & Fischer, 2022).

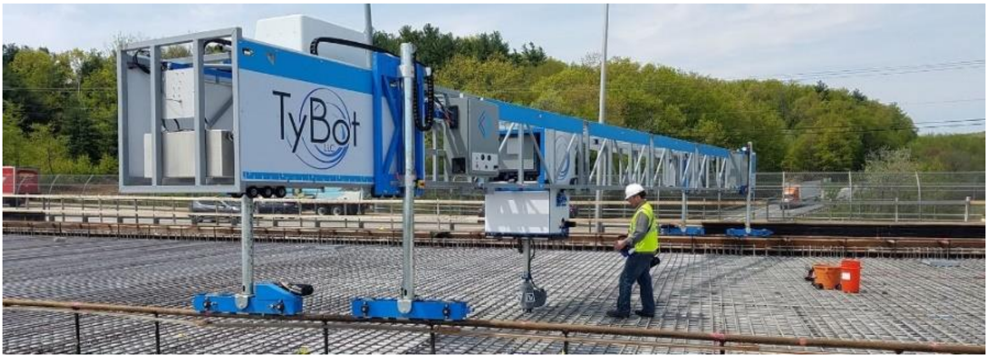

Figure 22. The robot is tying the rebars (Melenbrink et al., 2020).

Painting Robot: Painting Robot is an autonomous robot, which can operate alongside human workers on a construction site. The robot arm is equipped with a 3D scanner that can 3D scan indoor structures and act accordingly. It can also perform automatic path planning. It operates using batteries for indoor operations. A fully functional Painting Robot can be seen in Figure23.

Figure 23. Painting robot developed for interior of buildings (Khadka, 2021).

Drilling Robot: The semi-automatic drilling robot is customized for roof assemblies. (Figure 24) Robot is offered as a drilling service. The robot costs approximately EUR 1200 -/day to rent out and can achieve around 900 holes daily, which translates to approximately EUR 1.33 -/hole.

Figure 24. Drilling Robot (Chen & Ilbeigi, 2022)

Considering the cost of drilling one hole manually being around EUR 5, - in Germany as a best-case scenario, major financial savings can be inducted in a major construction project. Concretely, EUR 367.000, - can be saved per 100.000 holes (Ghammad et. al., 2022).

3.5.3. Exoskeletons

Wearable devices that work together with the user as opposed to a robot which performs the task autonomously (Delgado et al.,2019). Exoskeletons can help construction workers to reduce the high impact of their job and to improve their productivity by allowing them to lift heavy loads, reduce fatigue, facilitate the use of tools in awkward positions, etc. (Bock et al., 2012; Looze et al., 2016) Exoskeletons can also contribute to reduce injuries and to maintain a healthier workforce (Alwasel et al., 2012). This is of extreme importance as the repetitive and physically demanding tasks carried out by construction workers can lead to severe strain, injuries, and permanent disabilities (Ray & Teizer, 2012). In addition, exoskeletons can be a solution to the challenges presented by an ageing construction workforce (Marley,2015), by enabling older workers to continue working on site and carrying out physically demanding tasks.

Wearable Robots: As seen in Figure 25 wearable robot is an exoskeleton to support skilled workers and reduce fatigue (Bock et al., 2012). This wearable robot augments its wearer by reducing gravity-induced forces at the shoulder to perform chest to ceiling level tasks with less effort.

Figure 25. Wearable robot supporting worker (Bock et al., 2012)

The system balances the combined weight of the wearer's arm and tool and quickly adjusts for different support levels and angles. An anthropometric profile and adjustable sizing allow for natural movement and intuitive awareness of the wearer's position within tight spaces. The strength of the worker increases up to 80%, according to Engelhoven et al.(2018). Exoskeletons and humanoid robotic technology not only allow augmenting human abilities but creates tools that are capable of autonomous decision making and performance in order to achieve certain goals as agent of a human being especially in dangerous, dirty and tedious construction activities (Bock et al., 2012).

3.5.4. Drones and Autonomous Vehicles

This category includes terrestrial, aerial, or nautical vehicles that can be piloted remotely, or which are autonomous. These vehicles can be used for various tasks including (1) accessing extreme and dangerous environments, thus removing human workers from high-risk areas; (2)

surveying and monitoring tasks; and (3) automated excavating, demolition, and transportation of materials (Bock at.al., 2012).

However, drone-based autonomous robots only require an operator on the ground to control the flight path and camera monitoring the drone. Therefore, they have been exploited in visual inspection and damage detection of construction structures, e.g., building damage (Elghaish et al., 2021). With a remote sensing system mounted on drones, high-resolution images can be obtained from decimeters to centimeter scale (Li & Liu, 2019). Capturing images at appropriate scales allows us to autonomously perform comprehensive damage assessment by determining different levels of damage evidence from complete collapse to cracks in buildings. As seen in Figure 26, Drone-assisted surveillance robots have also demonstrated the potential to identify and report defects on tunnel lining surfaces (e.g., water leakage, spalling, and cracks) and some drone can be used for material transportation (Yang et al., 2022).

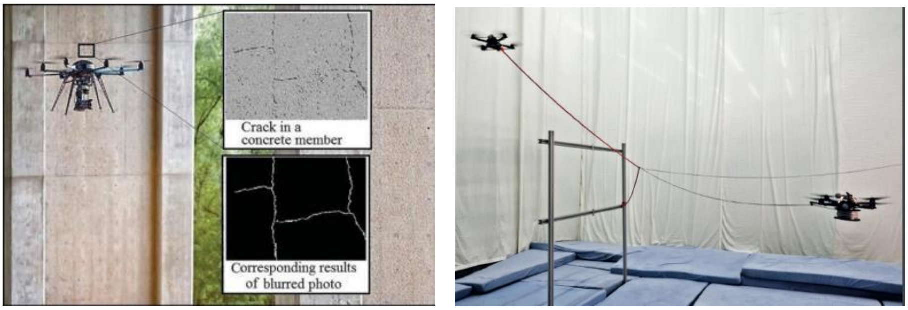

Figure 26. Usage of drone (Yang et al., 2022).

As seen in Figures 27 a company that builds bamboo structures wrapped in fabric wraps the structure by throwing a composition such as mud or cement into the fabric with the help of drones.

Figure 27. Bamboo structures are covered with cement with drones (Bogue, 2018).

“Smart Construction” is used for excavation and earthmoving operations. This system uses drones to map a site in 3D and uses this information to guide self-driving vehicles (Bogue, 2018).

Autonomous Trucks: Autonomous construction vehicles such as dozers, excavators, load-carriers and haul trucks can be used for excavating and grading soil on the construction site. One operator can supervise several autonomous machines working simultaneously. Another, smaller kind of autonomous or semi-autonomous construction vehicles are called rovers. They are able to follow workers around on the construction site carrying tools and materials. The autonomous vehicles operate by means of LiDAR sensors detecting obstacles in the surroundings, inertial measurement units (IMUs), and global positioning system (GPS) technology. This allows the vehicles to know their exact position on site, and typically a geofence prohibits the vehicles from operating off-site (Autonomous construction vehicles, 2019).

a) Excavation Trucks: Automated mature technologies used for site preparation. As seen in Figure 28 (A) Robot with an jackhammer attachment used for demolition, operated from a distance. (B) Machine retrofits conventional earthmoving equipment with autonomy kits. (C) This Excavator for an Autonomous Purpose is capable of autonomously digging trenches defined in a CAD model (Looze et al., 2016) For the use of autonomous trucks, customers consistently see a 20-30% increase in productivity and an equivalent cost reduction (Moore, 2021).

Figure 28. Autonomous trucks (Melenbrink et al., 2020).

b) Autonomous Software for Excavation Trucks : A software has been developed by an American company for use in excavation trucks.As seen in Figure 29, This software is installed on excavators to enable the machines to operate autonomously. It includes an all-weather enclosure, proximity radar, 360° cameras, GPS, and a powerful liquid-cooled computer. When this command is activated to dig from point A to point B, it autonomously digs the desired places. With its tracking system, the machine can see its surroundings from good angles.

Figure 29. The truck which the software is installed performs autonomous excavations. (Melenbrink et al., 2020).

c) Autonomous Rover

The French company uses an autonomous rover, on to follow construction workers around on site, carrying tools and materials. Autonomous rover as seen in Figure 30 can carry 300 kg and was originally design for the logistics industry (Autonomous construction vehicles, 2019).

Figure 30. Autonomous Rover will follow workers carrying heavy items (Hassan, 2018)

Sheet Piles Driving Robot: A design and prototype for a novel autonomous sheet pile driving robot has been presented for working with small-scale sheet piles. The robot is designed to carry a payload of sheet piles into a target setting and drive them into the ground in sequence, producing a sturdy wall that could, e.g., serve as a check dam to reduce flash floods in an arid environment. The robot uses a vibratory hammer to insert sheet piles into soil and makes use of its own weight to help drive piles to greater depth without needing to carry excessive additional mass for that purpose. This represents a departure from conventional pile driving, where a heavy crane is used only as a counterweight to the bias mass, which does the work of driving the pile. At its current scale, this robot is capable of shallow anchoring tasks that require driving rebar stakes ~20–30 cm into soil, such as conducting geological surveys, securing formwork for foundations, anchoring meteorological stations and other landscaping tasks (Looze et al., 2016). As seen in Figure 31 (A) A GPS-enabled pile driving machine places piles in precise locations (Hovila, 2021), (B) The Silent Piler leverages against previously driven piles to press piles deep into soil. (C)An autonomous robot capable of carrying a cache of small sheet piles and driving them using a vibratory hammer and its own body weight (Melenbrink & Werfel, 2019).

Figure 31. Sheet piles driving robot examples (Melenbrink et al., 2020).

Printer Robot : Printer robot, an autonomous mobile robot that prints plans from building information models directly onto the floor, automating one of the most manual processes on job sites. This robot lays out floor plans up to 10 times faster than traditional crews while guaranteeing accuracy up to 1/16 of an inch. As seen in Figure 32, it prints instructions directly on the floor so that crews know exactly what to build where.

Figure 32. Printer Robot can draw one-to-one with the project (Badré, 2020).

4. Conclusion

With the information obtained from the literature and the usage possibilities revealed in this study, Autonomous robots have many benefits in the construction sector, which are summarized below;

-Reducing labor costs, personal errors, re-compensation processes and risk rates,

-Robots could be the only viable alternative for construction and manipulation tasks in environments that are hazardous or inaccessible for humans, e.g., disaster areas, extraterrestrial surfaces, inside mines, or undersea (Soleymani et al.,2014).

-Providing a more flexible production system,

-Ensure consistent quality control across projects,

-Increase the amount of output and productivity,

-Meet the shortage of skilled labor,

-To have the ability to work continuously in production environments where the lights are off,

-To have the ability to achieve results faster and more accurately than human beings,

-Increasing delivery speed and quality and consequently customer satisfaction

-To be able to translate into high profit returns and ensure economic sustainability

-Work in place of operators in hazardous, unpredictable and risky working environments, thus contributing to the improvement of safety and occupational health,

-Replacing operators in monotonous, boring and repetitive tasks, enabling operators to focus on tasks that cannot be automated and require strategic rather than muscular effort (Thangavelautham at.al., 2020).

-The use of autonomous robots, for example in rebar tying technology, can not only reduce the incidence of injuries to workers, but also increase the efficiency of time spent working.

-Increase investment in construction projects due to shorter construction time, faster availability of investment and faster return on investment,

-To be able to work in more meticulous and precise measurements, to increase quality,

-Creating the possibility of continuous work,

-With the developed dynamic safety system, robots can detect people around them, calculate the distance between them, and thus prevent occupational accidents,

-Ability to carry heavy loads, perform dirty or hazardous work, or work in hard-to-reach places and in unfavorable physical positions,

-Solving the problems of low productivity in construction as it helps to reduce many manual processes,

-Creating benefits such as reducing construction waste and emissions (Çengelci & Çimen, 2005),

-Increasing productivity and reducing costs through automation,

-Creating repeatable processes,

-Reducing labor costs due to its role in economic sustainable development, reducing the number of raw materials, wastage and waste, increasing the quality, efficiency and flexibility of production by reducing the margin of error of the operators it works with,

-Improving, accelerating, and supporting sustainable development through advances in robotics and artificial intelligence (Bogue, 2018).

-Automation and robotics in construction provides more precise and uniform quality product compare with products produced by experienced worker (Iniyan & Prabakaran, 2022).

-There is a vision which image that construction sites will be human-free by 2050. Instead, teams of robots will be constructing structures with dynamic new materials, and drones will by flying overhead, constantly scanning and monitoring progress. Concurrently, the collected data will be used to predict and solve problems before they turn into real issues, and all with limited human involvement. The role of the human overseer will be to remotely manage multiple projects simultaneously, accessing 3-D and 4-D visuals and data from the on-site machines, ensuring the build is proceeding to specification (Innovation 2050, 2020).

Despite this development in the world, there are some factors that hinder the development of the use of Autonomous Robots and digitalization in the construction sector;

a) Social Factors

-There are many social issues to take into account when discussing robotic applications in construction. One of these concerns issue is the fear of job loss. One big fear for the rise of robotics is that workers may lose their jobs to a machine. They do not want an automated robot to do the job they, as a human, are paid to do. The robots make the job easier and potentially lower costs of production since they are not necessarily subject to negotiation of hourly wages. A robot is a one-time investment that will pay for itself over time. With a robot there are no unions to worry about, no healthcare costs, just maintenance costs. This job substitution could also be seen as a good thing. Instead of humans being in charge of the simpler jobs that robots can do, they could potentially be hired to perform maintenance checks on the robots instead. With the rise of robotics comes the rise of those with knowledge in robotics to work on them (Iniyan & Prabakaran, 2022).

-The widespread use of robots in everyday life can cause people to worry about them and develop a negative attitude towards robot adoption. Market demand is limited by negative perceptions due to lack of understanding.

-It is well known that practitioners are reluctant to innovate in the highly conservative construction industry.

-They will not adopt technological innovation made in one company unless all other competitors are making technological innovations. The risk aversion climate of the construction industry may hinder the adoption of construction robots by protectionism and conservatism.

b) Technical Factors

-Robots should be made more situationally aware and capable of making decisions and gathering information.

-Despite the recent advances in robotic technology, it is still challenging to create a safe work environment when robots and humans work together in a close proximity (Youa, 2018).

-Human workers are still more reliable, more efficient and cheaper in most cases. For example, while an autonomous mobile robot is comfortable doing even a very simple brickwork in an area full of obstacles, the robot will face many uncertainties and will struggle to make the right decision. The humanoid characteristics of robots need to increase.

-However, to accomplish more complex tasks and get more benefit from an autonomous robot in a dynamic construction site environment, robotic construction technology must go beyond mere autonomy and be truly adaptable to site conditions.

-Unlike manufacturing robots used in automotive industries, autonomous robots must be designed with special consideration for challenges such as human-robot interactions. Exoskeletons, for example, require a high degree of automation and human-robot interaction.

-Today's construction sites and methods are designed for humans. Future construction sites and methods will be more efficient if they are designed with autonomous robots in mind.

-The materials used in construction also need to be developed in parallel with the use of autonomous robots.

c) Cost Factors

-To understand whether it is worth developing a robot to automate a construction task, you first need to understand the task well enough to judge whether robotic automation will add significant value; otherwise, the innovation will not be adopted by the industry. Even technically impressive advances in industry research, such as the automated construction of CMU walls or 3D printing with concrete, have not been widely adopted, possibly because they fail to deliver cost savings over traditional methods.

-It remains to be seen whether it is worth the risk to companies because of the high costs involved.

-In order to understand if it is worth developing a robot to automate a construction task, one must first understand the task well enough to judge whether robotic automation would add considerable value; otherwise, the innovation will not be adopted by the industry. Even technically impressive industry research advancements such as automated building of

CMU walls or 3D printing with concrete have not seen widespread adoption, likely because they have not been able to demonstrate cost savings over conventional methods. Correctly identifying the added value in a construction task is not necessarily obvious. For example, the invention of the concrete hose pump was a transformative innovation, because it meant that the many workers who were once needed to shuttle wheelbarrows full of concrete around the construction site could be replaced by a single worker with a hose. The hose operator's work can be further automated with semiautonomous mechanization or be completely replaced with a fully autonomous solution, but neither would have as dramatic an effect on the productivity (i.e., value add) of the task. Similarly, the invention of drywall (sheetrock, plasterboard) replaced the time-consuming processes of lath and plastering walls, drastically reducing the amount of labor required for wall finishing. Replacing a drywall worker with a current state-of-the-art humanoid robot does not add value (Melenbrink et al., 2020).

d) Political Factors

Supporting the implementation of construction robots should be encouraged by Governments, as it is the case all over the world. It is possible through R&D investment and by providing incentive schemes. For this reason, studies should be carried out, strategies should be adopted, infrastructure should be supported, incentives and allowances should be published to increase the use of digital solutions and therefore autonomous robots in the construction sector with Government Incentives (Wang & Sadick,2022).

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Analysis of Erasmus+ Eco-Friendly Robotics Project Participants' Awareness Levels in Context of Sustainability, Green Buildings and Recycling Concepts

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1. Introduction

Sustainability means using these resources according to needs without harming the natural cycles of resources and energies in nature. According to Aklanoğlu (2009), the concept of sustainability is a concept that aims to ensure the continuity of the functions of any ongoing social, economic and ecological system without consuming the energy resources used and to get maximum efficiency. In today's world, where the demand for natural resources and energy is increasing as a result of rapid population growth, industrialization and urbanization, sustainability and sustainable (green) buildings have become an important goal on the agenda of all countries. Sev (2009) states that sustainable architecture aims to produce buildings that prioritize the use of renewable energy sources, use energy, water and materials effectively, and give importance to the health and comfort of people, while also considering the future generations in their current conditions. In this process, the quality of space, which has subheadings such as air, lighting and acoustics, is considered very important in terms of directly affecting human health. In this context, the selection of building materials that make up the architecture from environmentally friendly materials and the use of green energy sources have also been a matter of sensitivity. Kaya, Dal & Aşkın (2019), stated that sustainability is a very broad concept that basically prioritizes the protection and continuity of the natural environment and includes social and economic dimensions, and that sustainable development can only be achieved if environmental, economic and social sustainability are provided together. Kaya, Dal &

Aşkın (2019), underlines that universities have great duties in sustainable education and that universities are the most important educational institutions that contribute to the spread of sustainable and ecological practices and a sustainable life style in the society due to their innovative and pioneering role in society. As the interest in sustainable campuses increased, sustainable international indexes began to be used. These; The Green League, Environmental and Social Responsibility Index, and GreenMetric are evaluation methods (Kaya, Dal & Aşkın, 2019).

The Integrated Building Design Approach is a process-oriented method for making major improvements in the energy and environmental performance of buildings. This method adopts a holistic building approach and emphasizes the interaction between performance areas (such as energy and daylight saving and indoor quality) as well as giving importance to individual performance issues (Güzer & Kahraman, 2016).

According to Gökmeral (2014), the solution for a quality life in buildings is hidden in a design approach that is in harmony with nature and people, where consumption is controlled. To reach this solution in building design, a holistic perspective that embraces all dimensions of sustainability is required. Focusing on truly sustainable design, Gökşen, Güner, & Koçhan, (2017) suggest that the integration of creativity, innovation, recycling and technology in studies is possible with cooperation. In such a design, it can be implemented with an integrated design management with the contribution of many experts. In Sustainable Environmental Development; Ertem, (2020), Geçimli & Kaptan, (2019), production of products from recycled materials and renewable resources, recycling of wastes, Yılmaz, (2003), more common and widespread use of renewable resources, accumulation and protection of energy resources, environment pollution is prevented. The importance of recycling and other environmental protection behaviors in the process of eliminating environmental problems is increasing in the world (Schultz, 2002). (Erten, 2004), the solution of environmental problems can be achieved by raising awareness of people about the environment. The way for people to gain knowledge, attitude and awareness about the environment can be through environmental education (Çimen & Yılmaz, 2012). Within the framework of this purpose, the Erasmus+ program, supported by the European Union, started to be implemented as of January 1, 2014; It is the general name of the umbrella program that includes support for different age groups and different target groups in the fields of education, youth and sports. Within the Erasmus+ Program, support for school education, higher education, vocational education, adult education and youth continues as in previous programs. The program also aims to provide more effective tools to promote cooperation between different sectors in line with the objectives of the Europe 2020 Strategy.

This study has been prepared within the scope of "Green Houses" themed activities with the cooperation of Afyon High School and Afyon Kocatepe University Social Sciences Institute Art and Design Department, which is the coordinator country Turkey branch, within the scope of "Erasmus+ Environmentally Friendly Robotics Projects". This study aims to emphasize the importance of space design, the use of environmentally friendly materials and the concept of recycling, which have an important place within the framework of the "Integrated Building Design Approach" (BBTY), which is also defined as "Green Buildings", and in this context, " It aims to inform the participants within the scope of "Erasmus+ Environmentally Friendly Robotics Projects" about the subject and to measure their awareness levels.

1. Erasmus+ Project Description

Specific to the field of school education, in addition to improving the quality of education, the program aims to strengthen cooperation between schools and education staff in their countries. The target audience of school education activities consists of public or private institutions and organizations and administrators, educators, teachers and students in these institutions. Within the scope of the Erasmus+ project, there are many projects carried out jointly with different countries abroad in our country. Within the scope of these projects carried out; inferences about the project are made, new proposals are developed and an awareness about the subject is created. Dolapçıoğlu & Girişken (2022) stated in their article titled “European Union Projects within the scope of Erasmus+ project: Erasmus+ in Erasmus+ Program and Action Plans”, that the program was first implemented in the European Union member and candidate countries between 2014-2020 periods. Emphasizing that the program has been renewed in the 2021-2027 period and has become a program that can be applied individually as well as education, training, youth and sports fields, he added that it continues as a mobility (action-based) program that supports the personal and professional development of citizens. Erasmus+ programs aim to support young people with non-formal learning practices as well as education and training. This support is multifaceted, including socio-emotional and cognitive. On the other hand, the aim of the Erasmus+ program is to provide sustainable growth by supporting the personal development of people in the fields of education, training, youth and sports through lifelong learning. Kıratlı, (2019) in his study on "Evaluation of Erasmus+ Projects Conducted in High Schools According to Project Cycle Management"; The perceptions of teachers and school administrators who act as the coordinator and partner of any European Union project under the Erasmus+ program regarding the project cycle (determination of the project idea, analysis, planning, budget, implementation, monitoring and evaluation) management for the Erasmus+ program and aimed to present their assessments.

Within the scope of the content of all Erasmus+ projects carried out, there are basic objectives such as increasing the awareness of students and general participants of cultural heritage, increasing their learning performance, increasing their foreign language education and digital competencies, forming the basis of inclusive education, and enriching the learning environment.

1.1. Erasmus+ Environmentally Friendly Robotics Projects

Environmental problems are among the main problems that concern the whole world. The main idea of this project is to develop students' 21st century skills by challenging environmental problems and empowering eco-friendly robots. The aim of this project is to help students focus on issues related to the natural environment (renewable energy, recycling, climate change, etc.), to work with educational robots to find solutions to environmental problems, to destroy negative prejudices about robots and to find solutions to global problems with educational robots. In order to be environmentally friendly schools, sharing good practices/experiences, strengthening the professional profiles of teachers, learning cooperation with different cultures, and increasing the academic success of students in STEM lessons with educational robots (VEX, LEGO EV3) are among the aims. Within the scope of the project, in order to find creative solutions to environmental problems through Robotics; Green Houses in Turkey, Green Schools in Macedonia, Green Blue Ocean in Estonia and Green Nature themed activities in Spain are planned. Information about the project, which was carried out under the leadership of Afyon High School, which constitutes the Turkey branch of the coordinator country within the scope of "Erasmus+ Environmentally Friendly Robotics Projects", is presented in Figure 1.

Imprint of the Project		**Project Promotional Poster**
The Name of Project	ERASMUS+ Environmentally Friendly Robotics Projects	
Project Partner Countries	Turkey, Macedonia, Estonia, Poland, Portugal, Spain	
Project Number	2020-1-TR01-KA229-092387	
Project Process	2020-2022	
Project Coordinator	Afyon Lisesi/Meral Hitit	

Figure 1. Imprint of the Project and Promotional Poster (URL 1)

2. Material and Method

The study covers the activities related to the promotion of Environmentally Friendly Green Buildings held in Turkey, the coordinator country, within the framework of "Erasmus+ Environmentally Friendly Robotics Projects" and the analysis of the data obtained as a result of the activities.

2.1. Project Method and Process

The project is a qualitative academic study with literature review and field research elements, and a quantitative academic study using survey and analysis methods based on the opinions of the project participants.

Within the scope of the project, Erasmus+ Projects participants; Six schools from Turkey, Portugal, Estonia, Poland, Spain and Macedonia were identified as having experience in robotics and the environment. The scope of the study was created by the instructors and students who took part in the Erasmus+ project, hosted in our country and participated from Turkey. The participant group includes eight instructors and thirty-six students from six different countries (Picture 1).

Picture 1. Project Participants (URL 2)

In the first stage of the study process, preliminary information about the project content was given to the participants within the scope of the project. This information was given with a presentation prepared in English, taking into account the educational background of the participants, their age ranges and their participation from different countries. Within the framework of the event; Project participants, consisting of trainers and students from different countries, were informed about recycling, sustainability and environmentally friendly green buildings by making presentations (Figure 2).

Figure 2. Presentation Contents

In the second stage, after the presentation, a questionnaire was applied to the project participants in order to measure their awareness of recycling, sustainability and environmentally friendly buildings. The questionnaire consists of two different parts, including demographic questions and 5 open-ended questions. The open-ended questions in the survey are as follows:

Question 1. Have you participated in any environmental projects at your school?

Question 2. What do the concepts of recycling, sustainability and environmentally friendly buildings mean to you?

Question 3. Could you give examples of activities, studies and projects related to recycling, sustainability and environmentally friendly buildings in your country?

Question 4. Do you know of any projects, places, buildings or organizations around the world regarding the concepts of recycling, sustainability and environmentally friendly buildings?

Question 5. What do you think can be done for the future of our world, considering the concepts of recycling, sustainability and environmentally friendly buildings? Do you have a project or idea you want to talk about?

After the questionnaires were made, the exhibition of functional products obtained from the recycling of waste materials was visited and the students were asked to share their experiences. The data obtained as a result of the survey were analyzed in the context of the projects carried out by the countries on the subject, the awareness levels of the students on recycling, sustainability and environmentally friendly buildings.

Finally, an exhibition of products designed by Afyon Kocatepe University Faculty of Fine Arts students, including the concepts of sustainability and recycling, was prepared for the participants invited within the scope of the project (Picture 2).

Picture 2. Exhibition space (URL 2)

3. Findings and Discussion

The questionnaire was applied to eight instructors and thirty-six students from six different countries that make up the project group. The project group was analyzed according to country, gender and age criteria and the participant profile was determined. In Table 1, the country and gender relations of the study group were examined, and there was no significant difference between the numbers of male and female participants. While Turkey, which hosted the project, has the highest number of participants, Estonia has the lowest number with four participants. The country with the highest proportion of female participants is seen as Spain. Portugal, on the other hand, was determined as the country with the highest proportion of male participants.

Table.1 Project Group Country-Gender Relationship (n=44)

	Female	**Male**	**Total**
Spain	4	1	5
Macedonia	3	2	5
Portugal	1	5	6
Poland	3	3	6
Turkey	9	9	18
Estonia	1	3	4
Total	**21**	**23**	**44**

Table 2 shows that 82% of the project participants are between the ages of 12-18. Participants over the age of 18 consist of trainers who act as project coordinators.

Table 2. Project Group Country-Age Relationship (n=44)

	12-18 Age	Base 18	Total
Spain	4	1	5
Macedonia	4	1	5
Portugal	4	2	6
Poland	4	2	6
Turkey	17	1	18
Estonia	3	1	4
Total	**36**	**8**	**44**

In Table 3, the gender-age relationship of the project participants is given. In line with these data, approximately 24% of the female participants and 13% of the males included in the project are in the over 18 age group.

Table 3. Project Group Gender-Age Relationship (n=44)

	12-18	Base 18	Total
Female	16	5	21
Male	20	3	23
Total	**36**	**8**	**44**

3.1. Analysis of Data and Findings

In this part of the study, the data obtained from the answers given to the survey questions applied to the project group were evaluated. The questionnaire applied to forty-four participants from six different countries consists of five open-ended questions. The main reason for using the open-ended question model is to allow participants to provide feedback in their own words, allowing for details that might be overlooked.

The data obtained within the scope of the applied questionnaire were analyzed within the scope of quantitative research methods. The data collected in the study where content analysis was applied; conceptualized according to the country, gender and age criteria of the participants and the themes were reached based on the concepts. In this context, the themes were tabulated and presented according to the order of the survey questions.

Question 1. Have you participated in any environmental projects at your school?

Within the scope of the study, with the first question of the survey; It was aimed to measure the general level of activism of the participants about the study subject. When the data obtained are analyzed according to the country criteria, a total of forty participants from six different countries stated that they participated in at least one environmental project, while only four of the Turkish participants gave a negative answer. Since the rate of participants who responded positively was determined as 91%, it was concluded that the activity level of the study group was high (Table 4).

When the data obtained from Question 1 were analyzed according to age criteria, all participants over the age of 18 stated that they participated in at least one environmental project, and four people who gave a negative answer are in the 12-18 age group. In this context, it is concluded that only 12.5% of the participants between the ages of 12-18 do not take any action regarding the environment (Table 5).

When the answers to the question in question were analyzed according to the gender criterion, three participants who gave negative answers were determined as female and one participant as male. There is no significant difference in terms of gender in the measurement of the level of activism regarding the environment (Table 6).

Table 4. (Question 1 - Country Relationship, n=44)

	Yes	**No**
Spain	5	
Macedonia	5	
Portugal	6	
Poland	6	
Turkey	14	4
Estonia	4	
Total	**40**	**4**

Table 5. (Question 1 - Age Relationship, n=44)

	Yes	**No**
12-18	32	4
Base 18	8	
Total	**40**	**4**

Table 6. (Question 1 - Gender Relationship, n=44)

	Yes	**No**
Female	18	3
Male	22	1
Total	**40**	**4**

Question 2. What do the concepts of recycling, sustainability and environmentally friendly buildings mean to you?

Within the scope of the second question of the questionnaire, when the answers given by the participants were evaluated; Except for only two participants, it was observed that all of them defined all three of the aforementioned concepts. The two participants in question explained at least one concept and did not comment on the others. This result shows that the level of knowledge of the project participants about the mentioned concepts is quite high. In addition, it is concluded that the concepts explained within the scope of the presentation in the project process are adopted and correctly perceived.

Question 3. Could you give examples of activities, studies and projects related to recycling, sustainability and environmentally friendly buildings in your country?

In the second question of the applied questionnaire, it was aimed to measure the awareness levels within the scope of recycling, sustainability and environmentally friendly buildings, which are the concepts determined within the framework of the study. Awareness levels of twelve themes derived from the answers given were determined on a country basis. All participants of the six countries give examples of activities, studies or projects with the theme of recycling related to environmentally friendly buildings; It is an indication that the level of awareness of the participants on this issue is high (Table 7).

Table 7. (Project Examples and Country Relationship, n=6)

Examples (Themes)	Country Names	Ratio
Recycle	Spain, Macedonia, Portugal, Poland,	%100
Solar panel	Spain, Poland, Turkey, Estonia	%67
Wind Panel	Spain, Poland, Turkey, Estonia	%67
Public Space Cleaning	Spain, Portugal, Poland	%50
Nature Friendly Building	Poland, Turkey, Estonia	%50
Solid Waste Plant	Macedonia, Turkey	%33
Textile Recycling	Turkey, Estonia	%33
Electronic Waste Collection	Portugal	%17
Waste Oil Collection	Portugal	%17
Carbon Capture Device	Poland	%17
Geothermal energy	Turkey	%17
Green roof	Spain	%17

Question 4. Do you know of any projects, places, buildings or organizations around the world regarding the concepts of recycling, sustainability and environmentally friendly buildings?

In the fourth question of the questionnaire applied within the scope of the study, it is aimed to measure the knowledge level of the participants about the actions and practices carried out within the scope of the three concepts. When the answers given were analyzed, it was obtained that at least one participant from six countries had knowledge about a national or international organization/project. Among the examples mentioned, it is seen that the organization with the highest recognition rate is "Greenpeace" with 83%. Another data obtained within the scope of the analysis is that, apart from the participants from other countries, Turkish participants gave many organization examples from different fields (Table 8).

Table 8. (Organization Examples – Country Relationship, n=6)

Examples (Themes)	Country Names	Ratio
Greenpeace	Macedonia, Portugal, Poland, Turkey,	%83
Team Trees	Turkey, Estonia	%33
Team Oceans	Turkey	%17
Ecoscoles	Portugal	%17
International Zero Waste Day	Turkey	%17
World Cleaning Day	Estonia	%17
Nature Friendly Building	Portugal	%17
Green Roof Building	Spain	%17
Carbon Capture Device	Poland	%17
Nıvogo	Turkey	%17
Tubitak	Turkey	%17
Bilsem	Turkey	%17

Question 5. What do you think can be done for the future of our world, considering the concepts of recycling, sustainability and environmentally friendly buildings? Do you have a project or idea you want to talk about? The last question of the questionnaire was answered by 66% of the participants. In terms of percentage, the country with the lowest number of answers is Macedonia, and the countries where all participants responded are Spain and Estonia (Table 9). While all of the participants over the age of 18 gave active answers, the response rate of the participants between the ages of 12-18 was determined as 58% (Table 10).

Table 9. (Country - Response Rates, n=44)

	Answered	Ratio	Not Answered	Ratio
Spain	5	%100		
Macedonia	1	%20	4	%80
Portugal	5	%83	1	%17
Poland	4	%67	2	%33
Turkey	10	%56	8	%44
Estonia	4	%100		
Total	**29**	**%66**	**15**	**%34**

Table 10. (Age – Response Rates, n=44)

	Answered	Not Answered
12-18	21	15
Base 18	8	
Total	**29**	**15**

4. Conclusion and Suggestions

New searches have been made to reduce the negative effects of increasing industrialization and environmental pollution and decreasing natural resources. With these pursuits, concepts such as sustainability, green buildings and recycling have gained importance today. The concept of sustainability is defined as the ability of a system to continue its work without interruption and degradation, without being depleted by excessive use or overloading the vital main resources of the system. The concept of green building, on the other hand, is explained as a construction method that has less negative impact on the environment, produces healthier buildings with low maintenance costs, and uses resources efficiently. The term green building, also known as sustainable building, high performance building, and green construction, is used interchangeably to describe basically the same thing. The concept of recycling, on the other hand, is the recycling of recyclable waste materials that are out of use as raw materials, through various recycling methods, into the manufacturing processes. When these concepts are examined in detail, they basically contain the same goals and objectives. Their main goal is to build healthy, safe and durable structures for users and nature.

Today, many projects and activities are carried out in order to increase the consciousness level and awareness of users within the scope of these concepts. These projects are supported by different boards and organizations in Turkey and abroad. This study was carried out within the scope of Erasmus+ Environmentally Friendly Robotics Project and its participants were determined as six schools from Turkey, Portugal, Estonia, Poland, Spain and Macedonia experienced in robotics and the environment.

In this study, it is aimed to measure the level of consciousness and awareness of the participants within the scope of Erasmus+ Environmentally Friendly Robotics Projects about the concepts of environmentally friendly green buildings, recycling and sustainability. There are 8 trainers and 36 students from six different countries, including Turkey, in the participant group of the project. Participants' awareness of the subject was measured using a semi-structured questionnaire based on age, gender and country criteria. In the prepared questionnaire, five open-ended questions were asked to the participants about the concepts of environmentally friendly green buildings, sustainability and recycling. As a result of the survey form, the data obtained from the answers of the participants were analyzed within the framework of the study objectives and the following results were reached.

As a result of the study, it is seen that the number of male and female participants participating in the project is close. Therefore, the gender factor cannot be taken as a basic criterion in the analysis. It is seen that 82% of the participants in the project are between the ages of 12-18 and the rest are over the age of 18. According to the data obtained from the survey, it is seen that the participants between the ages of 12-18 have less awareness of the mentioned concepts compared to the participants over the age of 18. Age factor was determined as an effective factor on the formation of awareness and consciousness level. In line with the survey data, it was concluded that the awareness levels of Turkey, Portugal, Estonia, Poland, Spain and Macedonia countries participating in the project were similar.

In line with the answers given to the survey questions applied within the scope of this study, it was seen that the participants had knowledge about the concepts of sustainability, green buildings and recycling, and that they had a certain level of consciousness and awareness. In addition, it has been determined that the working group has knowledge about national or international organizations and projects that have a high level of action, can produce innovative, activist and creative thoughts and projects.

Within the scope of the study, the answers of the participants to the survey questions were also analyzed thematically. Featured themes;

- Creation of international green energy projects
- Creating innovative projects for the protection of energy, water and natural resources
- Developing and disseminating solar and wind panel technology
- Dissemination of recycling practices
- Expanding the use of electric vehicles
- Creating projects for more renewable and green energy use
- Expanding the use of rechargeable batteries
- Active use of robotic technologies in plastic waste cleaning
- It has been determined as the dissemination of the use of waste sorting machines.

It is seen that the common tendency of all the participants whose answers were analyzed is the theme of education and awareness raising. Suggestions offered within the scope of this purpose;

- Creating school projects and including them in the course with the aim of adopting the concepts within the scope of the project to the younger generation.
- Carrying out studies to integrate these concepts into daily life.
- Developing awareness of nature conservation
- Supporting the concept of less travel,
- Increasing consumer awareness of shopping,
- Creating public opinion in order to increase the awareness of individual responsibility
- Creating projects to increase knowledge and awareness about climate change

- Punishment of nature destruction
- It is gathered under the headings such as carrying out studies for the adoption of clean energy and clean environment principle.

Thanks and Information Note

The e-book section complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

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All authors contributed equally to The e-book section

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From Concept to Implementation: A Detailed Study of Landscape Design Process for Uşak OSB Technopark

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1. Introduction

To satisfy the increasing demands of diverse landscape design styles with high quality and efficiency, designers must possess extensive and multifaceted professional knowledge and technology encompassing various fields (Sun et al., 2021). The landscape design process involves several interrelated steps, including defining the project site and context, analyzing landscape structure and function, master planning utilizing an ecosystem approach, designing specific landscape elements, and monitoring and adapting the design over time (Lovell and Johnston, 2009). Understanding the site's physical, cultural, and social features is essential for landscape design. The topography, soil, climate, vegetation, history, and community must all be considered to identify the positive and negative characteristics that may impact the landscape design. A comprehensive understanding of the project site and its surroundings is paramount, followed by scrutinizing the design's structure and purpose. In addition, user opinions and needs are among the factors that need to be identified (Metin and Türker, 2022). Only by acknowledging and grasping these intricate linkages can designers develop a conceptual framework for landscape design that views the landscape as a dynamic, interconnected system. Employing an ecological approach enables designers to produce designs that are not only adaptable and sustainable but also more resilient and long-lasting, considering changing situations. Designing individual landscape components requires applying design concepts like scale, proportion, color, texture, and shape. These elements combine to produce esthetically pleasing and functional parts that harmoniously fit the overall design concept. Developing a comprehensive and coherent conceptual framework that accounts for the environment as a complicated and ever-changing system is essential. By adopting a holistic and integrated approach, landscape designers can conceive designs that can withstand time and environmental conditions. The complexity of the landscape design process is needs meticulous attention to every detail and thorough consideration of each phase to produce a successful and long-lasting result. The interaction of urban people with the natural environment is essential for their physical and psychological health (Metin, 2022). Using natural aspects in urban landscape design aims to bring people closer to the environment. This attempt depends on creating a visually beautiful and functional landscape. Thus, the planting phase of landscape design carries a great deal of weight and importance (Sarı and Karaşah, 2018). Lastly, monitoring the design and making any necessary adjustments is paramount. Evaluating the landscape's performance and identifying areas for improvement can help maintain the desired functionality. Designers must remain attentive to topography, identify opportunities.

This study examines a landscape design project prepared for the Uşak OSB Technopark at the request of the Rectorate of Uşak University, taking into account the principles of landscape design and planning, from conception to implementation.

2. Material and Method

The primary material for this study is Uşak OSB Technopark, located within the boundaries of the Uşak province (Figure 1). The study area is the Uşak OSB Technopark area located in parcel 3/123. The Uşak OSB Technopark has an open area of 6,000 m^2, a closed area of 3,716 m^2, and a leasable space of 2,066 m^2 and is located in the Uşak Organized Industrial Zone.It is approximately 20 kilometers away from the city center of Uşak. Due to its location on the Uşak-Izmir highway, the Uşak OSB Technopark Building is close to other cities and only 200 km away from İzmir Port. Following the Council of Ministers resolution dated December 19, 2015, and published in the Official Gazette on March 23, 2016, with registration number 13540, Zafer Technopark Inc. began operations in 2016 by signing the first leasing agreements.Afyon Uşak Zafer Technology Development Zone is the first Technopark established under the partnership of Afyon Kocatepe University and Uşak University. It is a corporation with 17 partners, including 15 public and private sector entities in the two provinces. Zafer Technopark Inc. operates under the supervision of the board of directors under the company's articles of association, within the scope of the Technology Development Zones Law No. 4691. The region has three Technopark areas, two in Afyonkarahisar and one in Uşak(Zafer Teknopark, 2023).

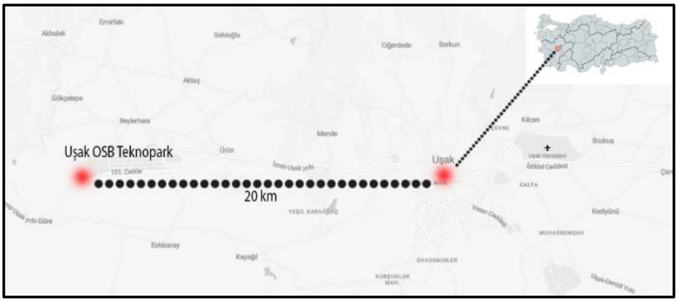


Figure 1. Location of the study area

This study aims to examine in detail the design process of the landscape design project implemented for the Uşak OSB Technopark. In this context, in this study, the stages from the project's design process to the implementation process are explained in detail. The project area is shown Figure 2. The project's desired landscape design areas are shown in green colored in Figure 2.The project area of this study consists of 6 steps in the landscape design process:

- Preparation of area inventory and analysis,
- Determination of needs,
- Preparation of functional diagrams
- Development of conceptual design plans,
- Preparation of final design plan.
- Implementation

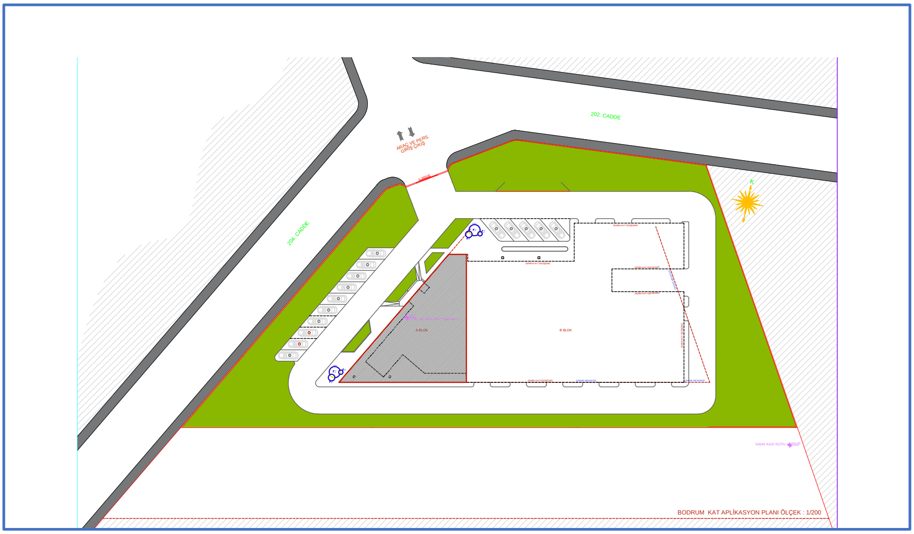


Figure 2. The project area

3. Findings

3.1.Determination of needs

During the phase of consultation with the technopark managers, a paramount requirement was identified as the creation of a space that not only satisfies the social and recreational needs of the employees but also adheres to the overall vision of the Technopark. This requirement was further articulated with the exigency of a garden area that is aesthetically pleasing and functional where employees can socialize with colleagues.

Additionally, the managers strongly emphasized the criticality of incorporating eco-friendly and sustainable practices in the garden's design, ensuring its environmental responsibility and contribution to the technopark's sustainability objectives. A planting design that crafts a visually stunning and tranquil environment for employees to indulge in was ardently desired. The managers were interested in using diverse local plants to ensure that the garden melds seamlessly with its natural surroundings.

Finally, managers wanted the garden to be low-maintenance and cost-effective, with ease of maintenance and minimal maintenance and resource requirements.To recapitulate, the requirements distilled from the consultation phase comprised the need for a social and recreational space that adheres to the Technopark's overall vision, the integration of sustainable practices, the infusion of plants and greenery, and the imperative for a low-maintenance and cost-effective design that is environmentally responsible.

3.3. Development of conceptual design plans

Before creating the concept plan, the project area was thoroughly examined to understand its natural and built environment. The northwest part of the project was selected as the focal point due to its potential to attract many visitors. Collaboration with the managers ensured that the design met their expectations and desires.

A formal and contemporary design style was selected with the building's lines, creating an overall cohesive and visually appealing environment. A wooden amphitheater, wood decks, and lush green spaces were strategically placed to imbue a relaxing atmosphere, providing visitors with a cozy environment. Achieving a balance between fullness and emptiness was given significant consideration throughout the project. The incorporation of open and green spaces within the design was done to evoke a sense of harmony, thereby avoiding overcrowding and facilitating smooth transitions between the various regions of the space. User-friendliness was a critical factor in the design process, with particular consideration for impaired visitors. Figure 3 shows a concept drawing of the upper part of the project site.

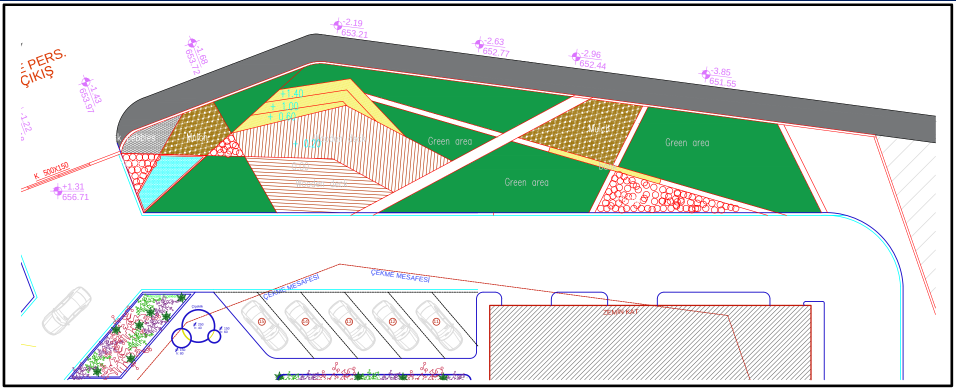


Figure 3. Concept drawing of the project

The managers' request for gazebos and simpler seating units triggered a complete redesign of the area, creating an informal space. The first concept for the landscaping project is shown in Figure 4, which combines the managers' preference for a landscape with plants and lots of open space with a thorough plan created for the whole site. A rock garden and a greeting area of suitable plant species were built at the entrance to foster a warm enviroment. A plant design with a shaded effect was added to the western side of the parking lot. Simple, open seating spaces are included in the design to create an aesthetically pleasing and functional space. The overall objective of the project's landscape design was to create a practical yet hospitable setting by striking a balance between functional and beauty.

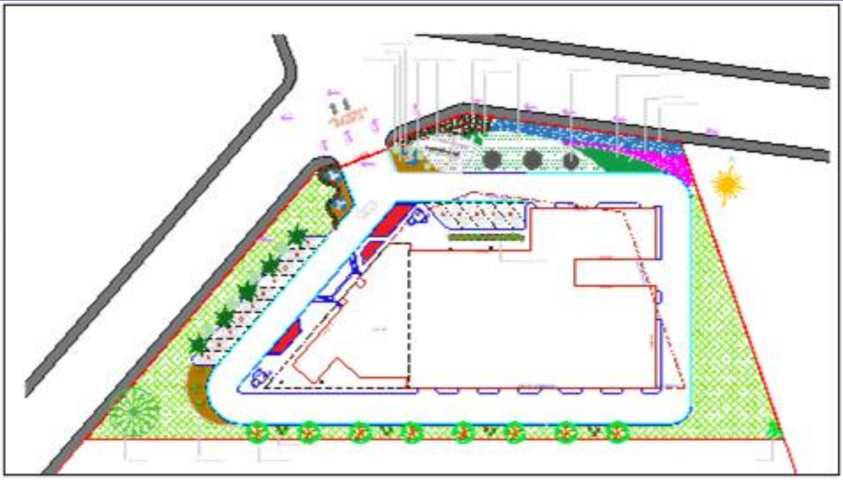


Figure 4. The first concept for the landscaping project

The managers' meetings for the concept project revealed that the initial scheme could not have been more practical because of worries about the expense of the gazebo and seating units. As a result, the project was changed, and a new strategy was adjusted. This revision procedure would be more financially feasible.

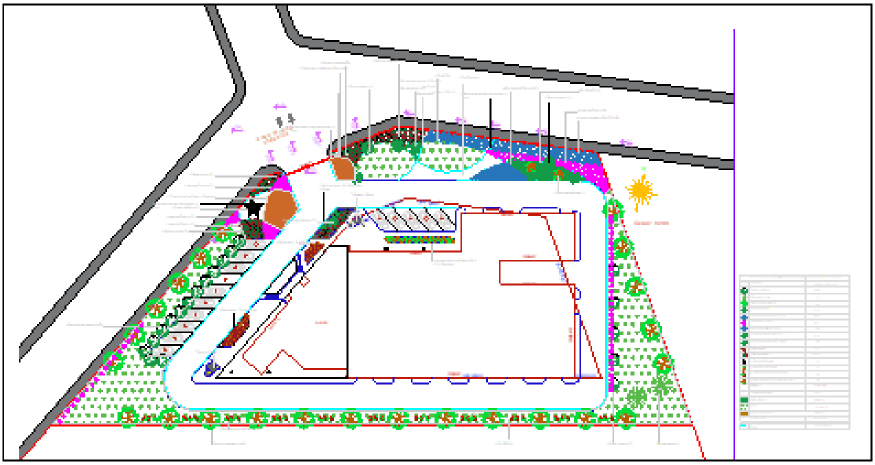
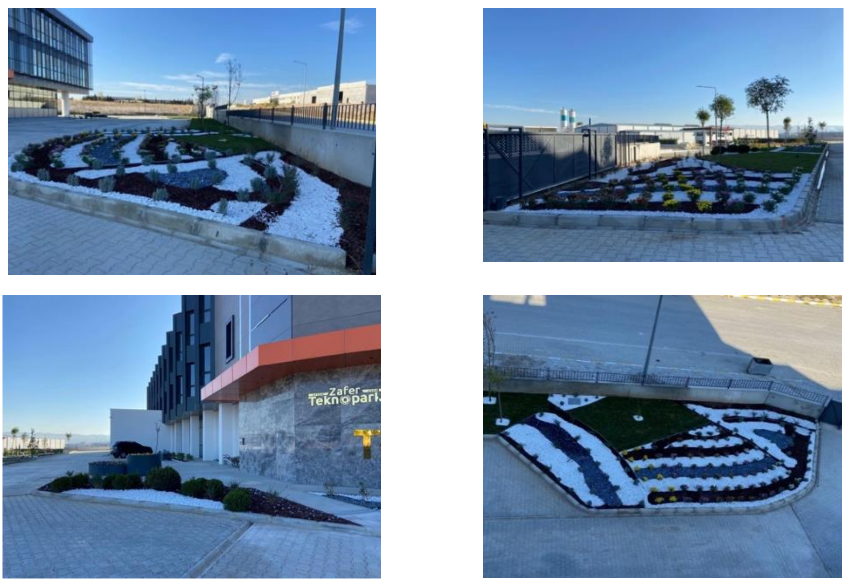


Figure 5. The project's final version

Figure 5 shows the project's final version. The gazebo and seating units were eliminated to reduce costs. The final project includes a diverse selection of plant species well-suited for the project's environmental and aesthetic goals. The plant list used in the final project is as follows: *Albizia julibrissin, Salix babylonica, Magnolia soulangeana, Aesculus hippocastanum, Aesculus hippocastanum, Juniperus horizantalis "Blue Chip", Lavandula officinalis, Festuca glauca "Elijah blue", Buxus sempervirens ball, Rosa Meiland, Gaura lindheimeri, Cortaderia Selloana, Chaenomelse speciosa "Gaujardii", Hydrangea macrophylla "Marechal Foch," Viola sp, Chrysanthemum sp., Sedum acre.* A total of 1248 m^2 of lawn area was created.

3.4.The implementation of the project

The project was implemented after the design phase. Figure 6 shows the post-implementation photos of the project.



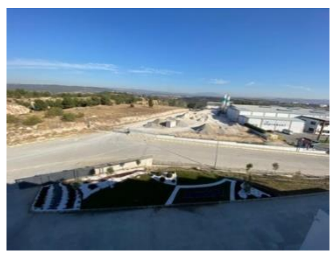


Figure 6. Post-implementation photos of the project.

A private firm implemented the project but encountered several issues during this phase. These included:

• **Lack of qualified workers:** The execution of the design successfully was hampered by the absence of qualified workers resulting in a negative outcome that impacted the project's aesthetic appeal. The workers were insufficiently experienced in planting correctly, resulting in numerous problems (Figure 6).

• **Absence of a landscape architect:** Another problem was the lack of a landscape architect to supervise the implementation and ensure adherence to the original design. As a result, there wasn't any landscape designer to ensure proper planting and coordinate the workers to accurate execution of the design.

• **Plant selection:** Using plants not the intended size or type and failing to employ the specified number of plants negatively impacted project functionality and aesthetic.

• **Implementation changes:** Project managers and landscaping company made changes during project execution without consulting the designer. These changes may have compromised the project's overall vision and functionality, leading to further issues and delays.

4. Conclusion and Suggestions

This study aims to present the design and implementation process of the landscape project for the Uşak Technopark in the Uşak Organized Industrial Zone. This project spanned the design phase to the implementation phase. As a significant technological innovation and development center within the Uşak Organized Industrial Zone, Uşak Technopark required a design that reflects its importance and improves its functionality. Once the Technopark building was erected, a landscape project was necessary to create a sustainable, functional, and visually appealing environment.

The Uşak Technopark area underwent a complex and multi-stage process for landscape project design and implementation. From the designing to the implementation stage, the project faced several issues.

Freedom of design in the project hindered the creativity of the designers. This situation caused negative results in the implementation phase.In addition, the lack of professionalism and substandard performance of the landscape company that made the application further increased the project's problems and prevented the originality of the design. The changes the management and landscape firm made without asking the designer during the implementation phase harmed the project.

The study suggests defining a clear and specific set of objectives and goals before embarking on any project's design and implementation phases. This approach lays the groundwork for a seamless and harmonious execution of the project, with the outcome closely mirroring the original vision.

In conclusion, the present study highlights the critical role of design freedom and constraints in landscape design projects and their impact on the creative process and outcome. The study suggests that careful consideration of these factors can enhance the success of landscaping projects, ensuring that they meet the intended objectives of functionality, appeal, and sustainability.

Author Contribution and Conflict of Interest Disclosure Information

There is no conflict of interest.

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