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Contents

PREFACE

In our book called *Architectural Sciences and Technology, the subjects below have been discussed*:

- Implementation of systems approach in material selection in the building
- Evaluation of climate-compatible elements in rural architecture: case of Diyarbakır province Erimli neighborhood
- Questioning the use of travertine as a construction materials in historical buildings within the context of sustainable architecture: the case study of Evdir Han
- The analyzing of architectural ornaments on historical Antakya houses, pavilion design as an example of the re-ornamentation
- Concept of "Aesthetic Value" lost in the modern-day anthropocene era and lessons to be derived from vernacular Nubian architecture
- Assessment of textile architecture form a sustainability perspective
- Digital fabrication shift in architecture
- Integrating the algorithmic tectonics to the design process with CAD/CAM: challenges and opportunities
- *Evaluation of VR application (CSVR) developed for interior architecture education with the sense of presence scale*
- Energy efficiency in cross laminated timber (CLT) buildings
- Effect of green wall systems on building heating and cooling loads in sustainable design
- Facade damages that may cause / affect building cost items
- Spatial learning through landmarks

I would like to express my gratitude; to the lecturers of the department who contributed to our book with their valuable scientific studies, to the lecturers who contributed to the chapters with refereeing, to the staff of Livre de Lyon Publishing House for their contributions in all the publishing processes of the book in these difficult days of the pandemic process.

I hope our book titled **"ARCHITECTURAL SCIENCES AND TECHNOLOGY"** will be useful for the reader.

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chapter 1

IMPLEMENTATION OF SYSTEMS APPROACH IN MATERIAL SELECTION IN THE BUILDING

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1. INTRODUCTION

Selection of Building Materials is generally an action depending on exclusiveness of each building in terms of function, design and construction technique, construction time and lifetime etc., variability of decision makers, effectiveness in decision, purposes, internal and external environmental conditions, material information, economic and technological possibilities.

Material selection that directly affects the function of the building, more comprehensively its performance, form and cost, is one of the issues that bring decision-makers together directly or indirectly such as legislator, producer, designer, property owner, user, manufacturer, etc. taking part in the life cycle of materials. All decisions in material selection become efficient and lay emphasis in every phase of the building. However, the success of such an important decision depends on decision-makers to fulfill their share of duties, on material information and on availability of information communication. Unless the usage possibilities and limiting conditions of the materials are known, selections cannot be expected to be fit for purpose and correct.

Until the first half of the last century, all properties of limited number of materials were known as a result of long periods of use and information communication was sufficient. Material selection was an action based on good manners and intuition (empirical). However, information communication in material selection was insufficient depending on the development and changes after the second half of the century and the selection action had to be structured in line with the principles of rationality. Many studies have been conducted in the world (please refer to Ref. Anon, 1968;Nilsson, B.I; Samuelsson S.,1984,) and in Turkey (please refer to Ref. Özkan,E., 1976) for the solution of the problem. The aim of a study conducted in Turkey (please refer to Ref. Arioğlu N.,1993; Arioğlu N,.1996,) is to define, in a specific detail, the example implementation of Systems Approach, that will assist in the actions of the designer or design team who are supposed to make a selection on behalf of the user in material selection and that is widely accepted as a research method for young researchers.

2. SYSTEMS APPROACH - SYSTEM

Systems approach is a commonly-used scientific approach as both design and research strategy in the solution of complex problems with many variables and options (Nilsson, B.I; Samuelsson S.,1984,). Systems approach includes "System Viewpoint" and "System Method". "System Viewpoint" depends on the theory that a whole is different from the sum of its parts (Bertalanffy L.V. 1968,Gustavsson, L 1978). "System Method", on the other hand,reviews the working method and all methods that can be used in the system (information collection, identification, model establishing, tests, applications, production analysis, simulation etc.). Just as the system consists of sub-parts as a whole, it becomes the sub-part of an upper system imposing environmental conditions according to the concept of "Hierarchical Order of Systems" of Von Bertalanffy.

In the light of the above-mentioned definitions and explanations, a system can be defined with the following parameters within the framework of the system approach:

1. *Purpose or purposes;* is/are the result or results that are desired to be achieved as the reason for the regulation of the system.
2. *Limitations;* is the upper systems or environment that is outside the system but affects or limits its action.

3. *Sub-parts or sub-systems;* are the feedback and control with "system variables", that include all kinds of objects, facts and knowledge constituting the content of the system and each of which is defined by separate input-output processes.
4. *Management;* is making plans for the system and regulating and controlling the system purpose, content, limitations, properties that should be owned by the system according to these limitations in these plans, (Churchman,C.W 1968).

3. DEFINING THE BUILDING MATERIALS SELECTION SYSTEM WITH SYSTEMS APPROACH

Building Material Selection is a set of sequential processes comprising the key processes in determining the materials that will form the building and the interactions between these processes, in other words, the effects and reactions in requirement - possibility balance.

For example, sequential processes such as within what limitations the user needs can be satisfied, requirement - property transformations, which properties are sought in materials to what extent, reach a rational decision through establishment-assessment of possible options.Considering "Systems Approach" and "Selection Problem", it is stated that the fundamental tool that will put an end to the confusion of concepts in determining where the analysis for the solution of the problem will start and end will be "System Expansion Level"(Toydemir,N.; Ünügür, S.M.1979). The System Expansion Level is defined in the same reference as "Determining at which system level the problem is being discussed.In the light of this comment, there are six levels listed below where materials are hierarchically defined by their functional properties in the "Building Material Selection"

Building
Space (Unit)
Element
Component
Piece
Material

'System Resolution Level'

3.1. System Expansion at Element Level

The most used designing system at the present time is based on existing materials-systems in terms of both the present conditions of our country and the structure of the "Architecture Offices" (Esin,N.1985) carrying out the design action. The way which the designer can follow in this type of designing system is "Architectural design process" (Markus,T.A.1967).

Building materials are determined as schematically illustrated in Figure 3.1 depending on the external and internal environment factors such as natural and artificial environment, user actions, laws etc. and in line with user requirements determined depending on these factors. As it can be observed also in the Figure, a correlation scheme of structure and locations, in other words a schematic design, comes into question according to the decisions from the planning and programming phase of building construction at structure and location levels and this remains within the boundaries of the design discipline. The stage where material selection gains importance is the final design phase and the elements that will form the structure are determined in this stage. Therefore, it is considered proper to perform "System Expansion in Element-Level".

As it can be seen in Figure 3.2, all parameters and processes included by the building materials selection system are also involved in selections in element-level, however, their scope changes.

3.2. Purpose of the Material Selection System

The main purpose of the establishment of the system, and therefore of the system, is to contribute to the national economy by ensuring that source losses are minimized, by solving the problems that cause incorrect material selections across the country. Besides that, it is to provide a basis for the design and development of new materials, to promote the manufacturing of materials at the required quality and level, to directly include the user in the selection,

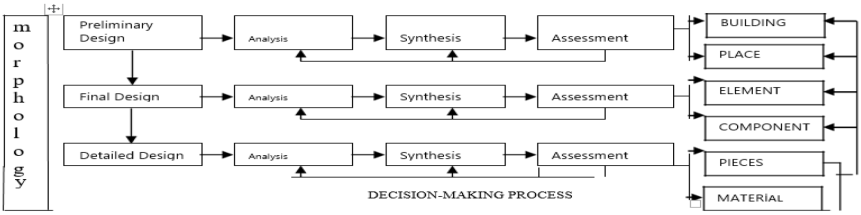


Fig. 3.1. Structure of Archi. Design Process (Markus,T.A., 1967)

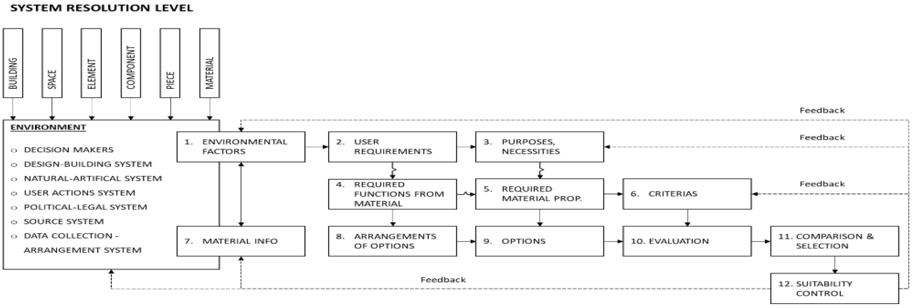


Figure 3.2. Building Materials Selection System Scheme (Arıoğlu,N.1993)

to raise awareness, to help the designer who makes the selections on behalf of the user to make the material selection in line with the main purposes in building manufacturing (suitability, economy, usability, etc.)

3.3. Management of the Building Materials Selection System

We can define the management of the building materials selection system based on the definition of "System Management" as making plans for;

- Defining system parameters with their properties,
- Determining the purposes in the system,
- Determining the necessities and inputs from the system environment,
- Arranging the processes included in the subsystems of the system,
- Verifying the compliance of material selection with feedback

In other words, this is the adjustment of the fundamental processes in the system and the establishment of the relationships between each other and the establishment of the content of "Decision System" system management depending on such relationship order.The fundamental processes in the system and the decision system established by the relationship order between these processes can be expressed schematically as represented in Figure 3.2.

3.4. Environment of Building Materials Selection System-Factors

Upper systems providing limiting and controlling the system inputs and parallel systems in mutual interaction constitute the environment of the system. It is generally recommended to determine the environment in a way to facilitate the actions to take place in the system. Different actions require compliance at different environmental standards and different levels also in the building materials selection system, as in every system. For example, the standards depending on location are also included within the scope of environment in selections at element-level.

The systems included around the building materials selection system form the source of environmental factors and these factors can be grouped into specific titles. For example, T.Sneck groups the factors connected to these environmental systems under four titles listed below for all selection levels.

R1. Factors Related to Human,
R2. Environmental Factors (Natural-Artificial Environment),
R3. Economic Factors,
R4. Regulatory Factors.

In the Japanese Method (Anon1968), all factors connected to the environmental systems are divided into ten fundamental factors and each fundamental factor is divided into ten sub-factors within itself, as illustrated below:

51.0. Water supply and storage
57 Emotion, people, animals and plants
58 Construction works
59 Economy

A. Plowden lists all the factors that may be involved in material selection as follows (Plowden,A.,1972)

AO. Architecture, theory, history, working methods, organisation, etc.
BO. Construction Industry-General (Structure, Economic situation)
CO. Contracts
DO. Design and decoration
EO. External environment (safety, high temperature, frost attack)
FO. Elaborative property (terminatio
GO. …………….
HO. Industrialisation and prefabrication
JO. Combinations
KO. Insulation
LO. Legislation (Laws, regulations, standards)
MO. Maintenance
NO. Custom-Built (non-standard application)
PO. Planning
QO. Quality

As it can be also reviewed from the schematic relations model of the Building Materials Selection System (Please refer to Fig. 2), the systems in the environment of the system are determined and collected under the following titles, by using "Building and Environment" model of Petterson,L.F.-Samuelsson,S.1978:

- Design-construction system
- Information collection, organization and communication system
- Political-legal system
- Natural and artificial environmental system
- Decision makers and decision environment
- User actions
- Source system

The systems no. 1 and 2 in the environment of the system have the characteristics of parallel system, while the others are upper system. A part of the processes in parallel systems in the environment of the system also continues in subsystems.Therefore, this can be effective in determining and controlling the limits adopted by the environment. In addition, the building materials selection system may cause interaction between the upper systems in the environment, for example, it can control the level of manufacturing of building materials, the supply and demand in the material market and the quality of materials by including the user in the selection, due to its role in parallel systems. However, the important point here is to ensure the functioning of the material selection system. Thus, information collection-arrangement and regulation of communication systems, which have the most effective role in material selection, gain importance.

This parallel system (Please refer to Ref.Arıoğlu,N.1993 section: 4) is excluded from the scope, due to the limitation in the study.Brief descriptions of the systems in the environment of the building materials selection system are given below respectively.

3.4.1. Design and Construction System

In order to create the required artificial environment rationally, the planning and programming of the entire process of the building manufacturing is approached within the framework of the design process. Design and construction systems are reviewed as a whole, although they contain different areas of expertise (Archers,L.B.1969).

Inputs for fundamental purposes are formed in line with the fundamental and tactical decisions (Sey,Y.1966)within the framework of the aforementioned holistic view,in these parallel systems located included in the environment of the building materials selection system. The mentioned decisions can generally be grouped under three titles:

- Initiative - Organizational Decisions,
- Financing Decisions,
- Technical Decisions.

3.4.2. Information Collection, Organization and Communication System

It is a whole, including collection, organization, supervision and distribution of the information needed by those who take part in the material selection as well as the construction sector, enabling them to communicate with a common language. A part of these studies towards wholeness can be reviewed from the references between (Arıoğlu,N.1986) and (Çoker,B.1979).

3.4.3. Political-Legal System

It is a system including management, evaluation and controls of the building materials in their manufacturing and uses at different levels. How and within what limits the purposes determined in material selection in the system should be achieved are determined by laws, statutes, regulations, specifications, standards according to the degree of significance in the implementation.

3.4.4. Natural and Artificial Environmental System

It is a system including natural environmental factors that determine the user needs in the building materials selection (climatic conditions, vegetation, topography, geological structure, etc.) as well as limitations from artificial environment at an upper level depending on the manufacturing levels. The factors in the natural and artificial environmental system can be generally grouped under the following titles:

Factors of the natural and artificial environment are generally classified as shown below:

o Load-strength	o Sound
o Water, moisture, and other liquids	o Light
o Temperature	o Other building materials
o Fire	o Animals, plants, microorganisms
o Air, gas, dust, smell	o Reinforcement and tools
o Electricity	

3.4.5. Decision Makers and Decision Environment

Persons, institutions or organizations involved in the building materials selec-tion can be divided into two groups in terms of motivations for their participa-tion in the material selection process and purposes of their functional actions:

- Regarding requirements (user, designer)
- Regarding technical and economic possibilities (Property Owner-Investor, Producer-Contractor, Material Manufacturer-Seller)

3.4.6. User Actions

As it can be concluded from the system of Building-Environment-Actions-Targets-Cost of Markus (please refer to (Markus,T.A.1967).), the require-ments such as protection, social and economic benefits, happiness etc. expected by the user from the building depend on the actions and the physiological, psychological and sociological distinctive characteristics of the user in these actions. Such distinctive characteristics of the user define their requirements and constitute a part of the factors arising from the environment in the selec-tion, because the expected properties can be obtained from the materials from the defined requirements.

User actions can be generally determined using the four different approaches listed below, depending on the intended use (Parson,J.D.1972):

- According to the structure and stages of the life process in which the actions take place,
- According to the main action groups arising from the general society organization of the user communities at a certain stage of social, cultural, economic and technological civilization and of the individuals living in these communities, depending on the basic user needs,
- According to the actions taken within the various “functional units” (housing, working, etc.) and the physical shell depending on them (residence, office),
- According to structural or procedural solutions covering components such as all kinds of situations, movements, processes, enabling each action or sub-action to occur.

The first approach is used in very special cases, the second approach is mainly used to determine the general functional zones for designing the settlements in various scales, the third approach is used to determine the actions directly related to the function of the building, while the fourth approach is used to determine the design decisions such as vehicle, equipment and location dimensions.

The third approach is an approach to assist in building a model related to the functional organization of building materials. In particular, the main action in the structure according to the function of the structure and sub-actions as components of the main actions constitute the general structure of the classification.

3.4.7. Source System

It is a system including the conditions of obtaining and using materials at the level of equipment, components and elements that will form the structure (stock status, tool-workmanship requirement, transportation, unit cost etc.) as well as the conditions of the amount of money allocated for the entire construction and the conditions of obtaining and using it.

3.5. Determination of Environmental Factors

The systems in the environment of the building materials selection system-constitute the source of environmental factors. However, the factors related to the locations in the "Artificial Environment system" among these environmental systems and some regulations (heat, sound, etc.) and standards in the "Political-Legal System" are more binding factors in the selection at element-level.

In order to determine environmental factors, the checklist given in Table 3.1 is formed by gathering the factors in all environmental systems. Attention is paid to ensure that the checklist can be used not only at element-level but also at all selection levels. The main factors and sub-factors in the "Japanese Method" in classification (Anon 1986) are adapted to the content of this study and the classification structure is quoted fromÖzkan,E,1976.

3.6. Subsystems of Building Materials Selection System-Processes

The system includes subsystems regarding the transformation of the user needs into the properties expected from the material within the framework of the possibilities and limitations determined by the environment, to what extent these properties are sought and how to choose the most suitable one of the possible options on the market. Cronberg lists these sequential processes in

Table 3.1. Environmental Factors Checklist

a. Structure-User Actions (Domestic actions) General Physical-mental state Social structure Relaxation-sleeping habits Eating-cooking habits Cultural and educational background Health-hygiene habits Internal-external relations Entertainment-hobbies Morals	b. Other Building Material-Related Factors General Related to other buildings Building-related Place-related Element-related Component-related 6. ----------
c. Temperature-related Factors General Sun temperature Heat caused by chemical actions Heat caused by actions Heat caused by electrical devices Temperature changes Low temperature Freezing and frosting ---------- 9. -------	d. Sound-related Factors General Impact sound (walking-hitting) Exterior noise (traffic) Loud noise, screaming Rhytmic sound ---------- Music sound ----------
e. Light-related Factors General Exterior light (natural light) Interior light (artificial light) Light colour, brightness Infrared radiation Ultraviolet rays Radioactive radiation Other --------- 9. ---------	f. Water-Moisture-Other Liquids 0. General 1. Natural reserves-Precipitation regime 2. Ground water level 3. Urban water 4. Water pressure 5. Flood 6. Dirty water (waste water) 7. Leakage, flux, splashing 8. Air humidity-ambient air humidity 9. Other liquids
g. Electricity-related Factors 0. General 1. Electric current 2. Static electricity 3. Induction 4. High voltage 5. Electric leakage 6. Electrical appliances ---------- 9.----------	h. Vertical Load and Forces 0. General 1. Its own load 2. Utility load 3. Snow load 4. Load that wearing and maintenance may cause 5. Forces that the load may cause ---------- 9. ----------

Horizontal load and forces (earthquake-wind) Fire	l. Service life m. Construction system-decisions n. Legislation and institutions o ---------- p. Equipment and tools (technology) r. Labour s. Production-climate relation t. Sources u. Experience v. Production rate
Other factors 0. General 1. Animals 2. Plants 3. Microorganisms 4. Gases 5. Dust 6. Accidents 7. Robbery 8. Air pollution 9. ------------	y.Cost 0. ---------- 1. Tool, compound cost 2. Labour cost 3. Shipping-storage cost 4. Equipment cost 5. Electricity consumption 6. Fuel consumption 7. ---------- ---------- 9. ----------

the content in “Relationship Model Between User Action-Object To Be Used” (Cronberg,T.1973) as determination of user needs, required artificial environment, expected performance, physical properties, physical objects.

In the Japanese Method, the processes in the system content are listed as selection of performance requirements, transformation into properties, assessment of material options, selection of methods for evaluation of properties, selection of methods for material selection.

In the Nilsson-Samuelsson Method, the processes are listed as formulation of needs, determination of options, review of the properties of selected options, interim control, assessment and control (Nilsson, B.I; Samuelsson S.,1984).

In light of the above-mentioned similar studies, these subsystems given in can be determined as listed below:

- User Requirements,
- Functions,
- Properties,
- Criteria,

- Options,
- Assessments,
- Comparison-Collection,
- Suitability Control.

3.6.1. User Requirements

User requirements that can be determined depending on the determinative and limiting factors arising from the systems in the environment of the systemcan be defined as "Conditions required to be satisfied for user actions to be carried out in the most effective way" (Atasoy,A.1973) or "Criteria which is related to the purposes, special conditions, actions included, uses of a proposed structure, which must be sufficient for the user, and which is defined before design" (Şener,H.1977) and they can be grouped in following three levels (Ertürk,Z.1977):

- The level that is not biologically harmful to human life,
- The level that enables a comfortable life in a person's subjective assessments,
- The level that enables a person to be productive at their work.

3.6.2. Functions of Building Materials-Determination of Requirements and Functions

Material selection is generally the process of optimization of the requirements and possibilities for specific purpose or purposes. In this regard, physical and some time-measurable behaviors arising from the relationship between requirement-opportunity determined depending on environmental factors can be defined as a task or a function. Therefore, the function of the material can be defined as the level of satisfying user requirements and requests of the physical form behavior.

Transformation of user needs into the functions expected in the material gains importance in the determination of material functions. Such transformation process can be performed as in the methods based on performance approach (Please refer to Ref.Sneck,T.1972,Anon 1968, Cronberg,T.1973, Atasoy,A.1973).

Checklist of "Functional Requirements" is represented as given in Table 3.2, in a structure similar to the checklist of environmental factors, for easy correlation between factor-function.

Table 3.2. Functional Requirements Checklist

Use-related Functional Requirements a. User-related General Dimensional suitability Formal suitability Colour suitability Texture-pattern suitability Easily-cleaned ----------	b. Other Building Material-Related Factors General Structural environment suitability Structural suitability Place suitability Suitability with other elements Suitability with other compounds ----------
c. Temperature-related General Sun protection Protection against heat caused by chemical reactions Protection against heat caused by actions Protection against heat caused by electrical vehicle Protection from temperature changes Protection from low temperature ----------	d. Sound-related Factors 0.General 1.Protection from impact sound 2.Protection from exterior noise 3. Protection from interior noise 4.Making no sound 5.Having the sound heard 6. ----------
e. Light-related requirements 0.. General 1. Providing sunlight 2.Providing artificial light 3.Spreading the light evenly 4.Controlling the infrared rays 5.Protection against ultraviolet rays 6.Protection against radioactive rays 7. -------	f. Water-humidity-other liquids related 0. General 1. Protection from rain 2. Protection from ground water 3. Providing enough humidity 4. Prevention of water leakages 5. Not being influenced by the pressure changes 6. Protection from water flood 7. Supplying clean water 8. Deportation of dirty water 9. Protection from acidic and salty water
g. Electric-related Factors General Protection from electric currents Protection from static electricity ---------- Protection from electric leakage ---------- Supply of enough current for electric devices ----------	Related to vertical load and forces General Transportation of fixed loads safely Transportation of occupying loads safely Transportation of snow loads safely Diğer yüklerin taşınması Transportation of other loads Protection from forces caused by loads ----------

Related to horizontal load and forces (wind-eart-hquake) requirements Fire-related requirements	Other requirements General Animal-related protection-care Plant-related protection-care Protection against microbes and insects Protection against gases Protection against dust Protection against accidents Protection against robbery Protection against air pollution
l. Service life requirements **Construction-Related** **Functional Requirements** m. Construction system-related requirements n. Legal and institutional requirements o. ---------- p. Equipment and devices (technology) related requirements r. Labour requirements s. Construction-climate related requirements t. Source usage-related requirements u. Experience level v. Production rate-related requirements	y. Cost-related requirements General Tool-part and compound cost-related Labour cost-related Transportation-storage cost-related Vehicle cost-related Electric waste amount Fuel waste amount --------- z.

3.6.3. Properties of Building Materials

Depending on the functions assumed by or expected from the material, the distinctive properties of materials that can fulfill these functions gain importance in the material selection.Therefore, the properties are included in the scope of "expected properties" in the study.

The properties expected from building materials can be determined according to the designated functional requirements depending on the level of selection. However, in cases where material properties are not sufficient to fulfill the designated functions, the necessity may arise for orientation to material combinations (composite materials) or material development (new materials); instead of a single material.

Material properties are classified and arranged for different purposes in different sources, please refer to Ref. (Özkan,E.1976), (Cronberg,T.1973), (Saarimaa,J.1970), (Akman,S.1980).

Element properties can be determined depending on the functional requirements as "expected" properties of use and construction within the framework of the constraints imposed by the environment. Although the classifications imposed for different purposes are not directly useable in material selection,a “checklist of property” is formed by benefiting from their contents. This list is structured in a structure similar to other checklists, in order to make easily the transformation of Effect-Function-Property. (Please refer to Table 3.3.).

Table 3.3. ‘Properties’ Checklist

USE-RELATED PROPERTIES a. User-related General Dimensional properties(width, height, length, depth etc.) Formal properties (being in the square, concavity, curvature) Colour (bright, dark, colourful, mixed, natural) Texture and pattern (rigidness, softness, flatness, roughness) Clearing, maintenance-related properties ----------	b. Properties related to other materials General Structural environment-related Structure-related Place-related Related to other elements Related to other components ----------
c. Temperature-related properties General-spongy or fibrous structure Structural environment-related Structure-related Place-related Related to other elements Related to other compounds	d. Sound-related properties General-compact structure Compact sound impermeability Soundproof ambience Average soundproofing Acoustic absorptivity Soundproof ---------- ----------
e. Light-related properties General (enough space/natural light) Light transmittance Light reflection 3. Colour of light 4. Shadowing 5.Resistance towards dangerous lights 6.Change of properties under the lights 7.------------	f.Water-humidity and other liquids-related 0.General (closed pores-water sliding) 1. Water emission 2.Water permeability- impermeability 3. Humidity absorption-stabilisation property 4.Not leaking water 5.Resistance towards water pressure 6.Behaviour in soakage 7.Lack of equipment 8.Resistance towards other liquids
g. Electric-related properties 0.General 1.Electric current 2.Static electricity 3.Induction 4.High voltage 5.Electric leakage 6.Electrical appliances 7.----------	h. Vertical load and forces-related properties General Pressure resistance must be high Tensile strength must be high Flexional resistance must be high Erosion resistance must be high ----------

Horizontal load and forces (earthquake-wind) 0.General 1.High shear strength 2.High torsional resistance 3.High impact resistance	j. Fire-related properties
k. Other properties General Resistance towards animal attacks Plant-related Resistance towards microorganisms Gas impermeability-gas emissions Dust sticking-not raising dust Preventing accidents Resistance towards robbery 8.Emitting smell	l. Service life-related properties 0.General 1.Solidity 2.Easily fixed
CONSTRUCTION-RELATED PROPERTIES m. Properties related to construction systems n. Properties related to laws and regulations o. Ease of construction p. Equipment and tools (technology) related r. Labour s. Construction-climate relation-related t. Source-related properties u. Experience v. Production rate	y. Cost-related properties 0.General 1.Tool-compound cost 2.Labour cost 3.Transportation-storage related 4.Vehicle cost 5. Electric consumption 6.Fuel consumption

Elements can be composed of different components according to their locations in the building and the functions assumed by them. It is also necessary to determine by which components the properties expected from the elements can generally be provided. In this regard, determination of properties can be conducted in two stages.All properties expected from the element are determined in the first stage; these properties are distributed to the components in the second stage. (Please refer to Table 3.4).

Table 3.4. Distribution of Required Properties of Furniture into Compounds (Arioglu, N., 1979)

Components / Properties	Coating	Base	Body	Ceiling
1.Sound-related	X	X	X	X
2.Temperature-related	X	X	X	X
3. Water-related	X			
4. Clearing	X			
5. ----------				

Component / Place / Properties	Coatings	Bases	Bodyes	Ceilings
	A B C D	A B C D	Same in all Places	A B C D
1.Sound-related	X X X X	X X X X	X	X X X X
2.Temperature-related	X X		X	
3. Water-related	X	X		
4. Clearing	X X X X	X		X X X X
5. ----------				

A, B, C, D: Types of Places

3.6.4. Criteria

Criteria are the property values expected from materials according to the distinctive properties to be included in the selection, or in other words the determined purposes and difficulties, in order to determine the superiority of materials, which are able to meet the designated purposes, to each other, according to the limits set by the environment in material selection. Therefore, criteria are determined by the properties expected from the materials, but depending on the requirements. However, while some of the criteria can be expressed in measurable quantities regarding the level of development, the other part depends on abstract values due to inability to measure the require-ments and characteristics depending on human nature.

3.6.5. Determining the Criteria at Element Level

Criteria are determined depending on the determined purposes and obligations and the properties expected from the elements.

Criteria are generally intended for three different purposes, which are stated below;

1. The criteria for the purposes of health and safety and mainly related to the use of materials are mandatory criteria in the fields of earthquake,

fire, heat, noise, etc. which are determined by the relevant provisions and regulations of the zoning law and non-compliance of which is legally considered a crime.

2. Criteria for the purpose of economy are "protective" criteria that generally include economic and technological issues and that are related to construction. For example, total gross square meter cost of the element,labor force requirement, equipment-tool requirement, production speed etc. are protective measures.
3. Criteria for the purposes of compliance and practicability are generally

"optional" criteria, depending on the property of the building and decision makers, including aesthetic and statistical issues.For example, ease of construction of the element, relationship between construction-climate, resource use, appearance (related to property of texture-pattern-color), experimentation and accumulation of knowledge are optional criteria. However, it is deemed appropriate to arrange as given in Table 3.5. in a structure similar to structure of the other checklists, in order to establish the relationship between Effect-Function-Property-Criteria (Please refer to Table 3.5.).

Table 3.5. 'Criteria' Checklist

Criteria Depending on Use a.Related to User Body and Actions General 0. General 1. Dimensional 2. Formal 3. Color 4. Texture, pattern 5. Cleaning 6. ………	h. Vertical Load and Forces resistance 0.General 1. Pressure resistance 2.Tensile strength 3.Bending strength 4.Erosion resistance (rigidness) 5.Density ---------- 9. ---------
b. Other 0.General 1.Related to structural environment 2.Structure-related 3.Place-related 4.Related to other elements …………	i. Strength for horizontal load and lateralforces 0….. 1. Earthquake activity (quality) factor 2. Pressure resistance 3.Tensile compressive 4……….
c.Related to Temperature and Heat Emission 0. General 1. Resistance to heat penetration 2. Thermal conductivity coefficient 3. Heat accumulation property 4. Cooling off period coefficient 5. Thermal expansion coefficient 6. Heat penetration coefficient 7. Thermal inertia 8. Frost resistance	j. Fireproof 0. 1. Fire Retardant class 2.Flame spread index 3.Fuel presence index 4.Smoke density index k…….. l. Service life

d.Sound and soundproof 0.---------- 1.Compact resistance 2.Sound resistance 3.Acoustic absorptivity coefficient (α) ---------- 9.----------	**Construction-related criteria** o. Easy to construct p. Related to equipment and vehicles Wheeled cars Heavy vehicles (crane etc.) Equipment r.Labour in production – installation s.Production climate relationship
e.Light-related 0.General 1.Sunlight factor 2.Duty cycle 3.Light transmissant coefficient 4.Wilting under the light ---------	t.Source use Supply value, kg/m2 Number of pieces-piece/ m2 Number of compounds-amount/ m2 Labour, man-hour/ m2 Vehicle-hour/ m2 6.Fuel ton/ m2 7.Transportation ton/ m2
f. Water-humidity-impermeability related 0.General 1.Sorptive water penetration coefficient 2.Saturated moisture content 3.Steam penetration resistance 4.Flood resistance ……………. 9.Steam transmission coefficient	Experiences ---------- Inland m2/year Abroad m2/year Production rate Number of pieces and mounting Compound production and mounting
g. Electricity-related Factors 0.General 1.Electrical resistance 2. Electrical conductivity coefficient ---------- 9.----------	Cost Total gross m2 cost Tool, part, compound and cost TL/m2 Labour TL/m2 Shipping-storage TL/m2 ---------

3.7. Classification of Elements and Element Variables

Classification is made as given in Table 3.6., considering the location and functions in the building as a fundamental property in the classification of the elements that physically satisfy one or more of the functions of the building.

Physical functions to be assumed by the element depend on the variability of the components that will constitute it, while the nature of the components depends on the variability of the parts or the equipment that makes up the parts. Therefore, component, part and equipment are defined and classified as element variables.

Table 3.6. Elements Ea – Ez

General	----------
Bases	Electrical (lightning-communication) system elements
Floor mat	Health equipment
Suspended slab	Environmental equipment (fixed, moving) elements
Roofs	----------
Exterior walls	Framing system elements
Interior walls	Shell elements
Stairs	----------
Freight elevators and elevators	z.

Table 3.7. Components (Ba0-9) – (Bz0-9)

a. General		f. Exterior Walls		l. Electricity (Lightning-Communication System Components)	
b. Bases		1.	Wall outer covering	1.	Telephone, telex, fax equipment
1.	Equipment	2.	Wall body	2.	Signal, ring, alarm equipment
2.	Plates	3.	Wall interior covering	3.	Keys, sockets, plugs
3.	Beams	4.	Windows-shop windows.	4.	Heating, boiling, lightning equipment
4.	Consoles	5.	Insulation	5.	Columns, cables
5.	Stakes	6.	Doors	6.	Generator, motor, transformer etc.
6.	Caissons	7.	Grilles	m. Health Equipment Compounds	
7.	Shoes	8.	Equipment	1.	Clean water columns
8.	----------	9.	----------	2.	Sewage columns-storm drain
9.	----------	g. Interior Walls		3.	Shafts
c. Floor mat		1.	Coverings	4.	Faucet, bathtub, bidet, lavatory lid
1.	Floor bed	2.	Wall body	5.	Taps, batteries etc.
2.	Blockade	3.	Doors	6.	Water clearing equipment
3.	Floor body	4.	Service window	7.	Water tanks, water pumps
4.	Levelling concrete	5.	Insulation	8.	Other equipment
5.	Insulation	6.	Grilles	9.	In land
6.	Floor covering	7.	----------	n. Environmental (Fixed and Moving) equipment	

7.	Equipment	8.	Equipment	1.	In the kitchen
8.	----------	9.	----------	2.	In storages, entrances, halls, and corridors
9.	----------	h. Staircase		3.	In offices and managements
d. Suspended slab		1.	Staircase top coating	4.	In bath, fitting rooms, cleaning places
1.	Floor covering	2.	Staircase frame	5.	In study rooms-Libraries
2.	Floor body	3.	Staircase subcoating	6.	In stopovers
3.	Ceiling cladding	4.	Stairs	7.	In prayer places
4.	Underlay	5.	Stair rail	8.	In bed and recreation places
5.	Suspended ceiling	6.	----------	9.	In land
6.	Insulations	7.	Equipment	o. -----------------	
7.	Equipment	8.	----------	p. Framing system elements	
8.	----------	i. Freight Elevators and Elevators		1.	Columns
9.	----------	1.	Freight elevators chimney compounds	2.	Beams
e. Roof		2.	Elevator chimney compounds	3.	Laced Beams
1.	Roof outer covering	3.	Elevator cab	4.	Outer covering
2.	Roof body	4.	----------	5.	Interior covering
3.	Roof interior covering	9.	Equipment	6.	Insulation
4.	Insulations	j. Heating, air-conditioning service compounds		7.	Equipment
5.	Rain gutter, flume	1.	Hot, cold water columns	8.	----------
6.	Luminaires-windows-chim-neys	2.	Radiators	r. Shell Compounds	
7.	Lightning rod	3.	Taps, vanes, valves	1.	Shell body
8.	Equipment	4.	Boilers, pumps, storages	2.	Shell outer covering
9.	----------	5.	Air condition equipment	3.	Shell interior covering
		6.	Parking heaters	4.	Insulation
		7.	Other equipment	5.	----------
		8.	In land	8.	Equipment
		9.	----------	9.	----------
			k. ----------		z. Equipment

Table 3.8. Parts PA – PZ

A.	J. Curled tiles
B. Full blocks	K. Flat tiles
C. Spaced blocks	L. Elastic mat-rolls
D. Tiles	M. ----------
E. Flat profiles (full-empty)	O. ----------
F. Framed profiles (full-empty)	P. Rigid slabs
G. Round profiles (full-empty)	S. Flexible tiles
H. ----------	T. ----------
I. Cables	Y. Combining pieces

I. Components

The components specially formed as a result of combination or forming of tools and parts for a specific place and function in the structure are shown in Table 3.7 based on the elements (symbolic) classified as shown.

II.Parts

The parts, which are effective with fundamental form properties with a combination of one or more of them in the formation of the element or components, are classified as given in Table 3.8.

III.Materials

Equipment that makes up elements, components and parts are fundamental mass materials and mixtures and composites thereof, obtained as a result of natural and artificial processes, generally without a geometric dimension that can be defined, and classified as given in Table 3.9.

3.8. Options

Option can be defined as a whole formed by a qualitative and quantitative series of things providing the opportunity to achieve a solution or a purpose for the specified problem (Özkan,E.1976).

The possibility of making a selection between two or more solutions (achieving the purpose) arises with the assessment of the options. Forming the material optionsis the sequence of processes for determining the materials that can qualitatively and quantitatively meet the properties expected from materials.These processes depend on the data obtained as a result of determination of purpose, functional requirements, based on the level of selection on

Table 3.9. Materials Ga0-9 - Gz0-9

a. General		h. Metal (Other compounds)		p.Grout-Concrete	
b. Natural Stones		1.	Aluminum and its compounds	1.	Gypsum mortar
1.	Granite	2.	Copper and its compounds	2.	Asbestous, magnesillious
2.	Basalt	3.	Zinc and its compounds	3.	Cement mortar
3.	Marble	4.	Lead and its compounds	4.	Lime mortar
4.	Sandstone	5.	Chrome and its compounds	5.	Cement-lime mortar
c. Floor mat		6.	Nickel and its compounds	6.	Concrete and mixed concrete
1.	Portland cement	i. Silicates (Glasses)		7.	Concrete-sandstone
2.	High-strength cement	k. Wood		8.	Concrete-sandstone-foamed
3.	High-strength cement	1	Pine	r.Aggregates and fills	
4.	Sulphate-resistant cement	2.	Nut	1.	Gravel
5.	Trass cement	3.	Ash tree	2	Slag, ash etc.
6.	Slag cement	4.	Hornbeam	3	Sand
d. Lime		5	Poplar	4	Pumice
1.	Unhydrated lime	6	Fir	5	Pearlite etc.
2.	Dead lime	7	Mahogny	6	Ballast, stone chips
3.	Dead dust lime	8	Oak	s.Binder	
4.	Dolomitic lime	l. Natural Fibres		1.	Natural
5.	Water lime	1.	Wood fibres	2.	Synthetic
e. Plaster		2.	Plant fibres	t.Combiners	
1.	Common plaster	3.	Animal fibres (wool, hair)	1	Source
2.	Compounded plaster	4.	Fungus, bark	2	Plummet
3.	Grout plaster	5.	Wood particle	3	Glass cement
4.	Moulding plaster	6.	Wood shavings	u.Preservatives (General)	
5.	Papier-mache plaster	7.	Cane, withe etc.	1	Preservative against rust
6.	Marbelite	m.Artificial Fibres		2	Preservative against insects
7.	α type plaster	1.	Glass wool	3	Preservative against fire
f. Clay (earthenware and ceramic)		2.	Asbestos fibre	4	Preservative against fire
1.	Kaolinic	3.	Stone wool	5	. Preservative against water and humidity
2.	Halloisitic	4.	Mineral fibres	8	Stiffener
3.	Montmorillonitic	5.	Ceramic fibres	v.Paints	
4.	Illitic or bravesitic	n.Synthetics		y.Interrelated Tools	
5.	Speolitic	1.	Plastics	1	Water
6.	Speolitic	2.	Rubber	2	Fuels

7.	Paligorskit	3.	Bitumen (Asphalt cement, coal tar)	3	Acids
g. Metal		4.	Mastic	4	Alkalis
1.	Pig iron (casting)	6.	Added substances (Sica,tricosal)	5	Fertilisers
2.	Iron (casting)			6	Explosive materials
3.	Steel-soft			6	Cleaning tools
4.	Steel – hard				
5.	Corrosion resisting steel				

the one hand, and on the material information that exists or should be obtained on the other hand. However, a group of options that seem appropriate for the purposes can be formed in special cases, based on the presuppositions. But, such an approach has a risk of adhering to the will of decision-makers rather than purposes; therefore, rational choice can be prohibitive.

A classification structure containing all the options and the development of a matrix based on this structure gain importance in the arrangement of material options. In this regard, tables in various systems containing material classifications, for example BIC System Table-6, can be used, (Please refer to Ref.Anon,1973 and Anon,1991).

3.8.1. Determination of Element Options

In the light of the information collected and organized in stage 5.7., the element options formed by determining and combining variables at the level of components, parts and equipment that can meet the expected properties of the element, the relationship between function-form-fundamental material, in other words, that have the possibility of meeting in terms of quality and quantity,can be determined in three stages:

In Stage 1, the options at component-level are reviewed in functional term and determined considering the "properties expected from the components" of which possible component arrangements are determined in 6th step. However, the determined component arrangements may be many in some elements, which may cause the element options to increase more than necessary, therefore may lead to more difficult detailed assessment. In this regard, a pre-evaluation is performed at component-level and options are eliminated.

In Stage 2, the options at part and equipment level for the component layouts remaining as a result of elimination, in other words the options in terms of

Required Property / Options	a	b	c	d	e	f	Total Multiplication
A	X	XX	X	X	X	XXX	9
B	X	X	XX	XXX	XX	XX	11
C	X	X	X	X	X	XX	7
D	X	XX	XX	XX	XX	XX	11

Fig. 3.3. Scheme of Methods to Be Used in the Election of Element Variables

Tablo 3.10. Function-Form Relationship Options(adepted anon 1970)

<table>
<tr><th>COMPONENT (a_{0-9})- z_{0-9}) / PARTS A – Z</th><th>(a) Component general</th><th>(b) Key components</th><th>(c) Slab layer c.</th><th>(d) Interm. flooring c.</th><th>(d1) Floor laying</th><th>(d2) Floor body</th><th>(e) Roof component</th><th>(e1) Ext. Covering</th><th>(f) Exterior wall componet</th><th>(f1) Ext. Covering</th><th>(f2) Body</th><th>(f3) Int. Covering</th><th>(f4) Insulation</th><th>(g) Interior walls</th><th>(h) Staircase</th></tr>
<tr><td>A.Parts–General</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>B.Full Blocks</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>C. Spaced Blocks</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>D.Tiles</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>-----</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>K.Ondule Sheets</td><td>X</td><td></td><td colspan="13" rowspan="8">E.g. B (f) Filled block outer wall body

C (d2) Space block (asmolen) flooring body
D (e1) Tile roofing
K (e1) Ondule sheet roofing
L (e1) Flat plate roofing
P (d2) Rigid plaque flooring body
R (d1) Rigid tile flooring coating
S (d1) Flexible tile flooring coating</td></tr>
<tr><td>L.Flat Sheets</td><td>X</td><td></td></tr>
<tr><td>M.Flexible mattress – rolls</td><td>X</td><td></td></tr>
<tr><td>N. -----</td><td>X</td><td></td></tr>
<tr><td>O. -----</td><td></td><td></td></tr>
<tr><td>P. Rigid Plates</td><td>X</td><td></td></tr>
<tr><td>R. Rigid Tiles</td><td>X</td><td></td></tr>
<tr><td>S. Flexible Tiles</td><td>X</td><td></td></tr>
</table>

function-form, fundamental material-form, function-form-fundamental material, are determined. The options are eliminated also at this stage.

In Stage 3, the element options are formed with the material at equipment

Table 3.11. Options of Function-Form-Main Material Relation (adepted anon 1970)

PARTS A – Z / MATERIALS $a_{0-9} - z_{0-9}$	a. Tools-general	b. Natural stones	b1. Granite	b2. Marble	f. Clay	g. Iron- steel	h.Metal (other)	h1.aluminium	k. Wood	k4. Hornbeam	l. Natural fibres	l6. Wood particleboard	m. Artificial fibres	m1. Glass wool	n. Synthetics	n1. Plastics	P. Mixtures	p5. Cement	p6. Concrete	z.--------
A. General	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
B. Full blocks	X																			
C. Spaced blocks	X																			
D. Tiles	X																			
E. Flat profiles (full – empty)	X																			
F. Framed profiles (full – empty)	X																			
G. Round profiles (full – empty)	X																			
I. Cables	X																			
J. Nets– straws	X																			
K. Curled tiles	X																			
L. Flat tiles	X																			
M. Flexible mat – roll	X																			
P. Rigit tiles	X																			
R. Rigit slabs	X																			
S. Flexible tiles	X																			
Y. Combining pieces	X																			

Examples:
Bb1.-Granite blocks
Cf.-Spaced (clay) block
Dp6. -Concrete tilesConcrete tiles
Eh1.-Aluminum profile (flat)
F g. - Iron profile (T,L,I)
Gn1. -Plastic pipes
Kp2. -Asbestos cement curled sheet
Ll6.-Wood particleboard
Mm1. -Glass wool tiles
P5.-Cement coating
Pp6.-Concrete slab
Rb3.-Marble tile
Rk4.-Hornbeam parquet
Sn1.-Plastic tile

Table 3.12. Options of Function-Form-Fundamental Materials Relation (adepted anon 1970)

PARTS A – Z / MATERIALS $a_{0-9} - z_{0-9}$ \ COMPONENT $(a_{0-9}) - (z_{0-9})$	(a) Component – Gen.	(b) Main compounds	(c) Floor mat	(d) Suspended slab	(d1) Floor laying	(d2) Floor body	(e) Roof	(f) Exterior walls	(f1) Exterior cov.	(f2) Body of wall	(f3) Interior cover.	(f4) Insulation	(g) Interior walls	(g1) Covering	(g2) Body of wall	(g3) Doors	(h) Stairs r	(l) Electrical sys.	(m) Health	(n) Space equip.	(z) ....
A. Parts – General	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B. Full blocks	X	X	X	X		X		X		X			X		X		X				X
C. Spaced blocks	X		X	X		X															
D Roof tiles	X						X														
G Round bars (full-empty	X	X	X	X			X										X	X	X	X	
K. Curled bars	X						X	X	X												
L. Flat sheeds	X						X	X	X		X	X	X	X						X	
R. Rigid tiles	X	X	X	X			X	X		X							X			X	
S. Flexsible tiles	X	X	X	X													X			X	
a. Materials-General	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
b. Natural stones	X	X	X	X	X		X	X	X	X	X		X	X	X		X			X	
e. Plaster	X									X	X	X	X	X	X					X	
f. Clay(baked)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
g. Iron-Steel	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
h. Metal (other)	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	
h1. Alüminyum	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	
k. Wood	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	
k1. Glass	X																				
l. Natural fibres	X						X		X				X	X	X	X				X	
l6. Wood fibres	X						X	X	X	X	X	X	X	X	X					X	
m. Artificial fibres	X						X	X			X	X	X	X		X		X	X	X	
m1. Glass wool	X		X				X	X			X	X	X	X		X			X	X	
n. Synthetics n1.	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	

and part level determined in stage 2 for the component layouts determined in stage 1.

Element variables are defined and classified in order to perform the processes at these stages. The matrices reported in Tables 3.10, 3.11 and 3.12, in a structure similar to “Matrix of Part Categories” in the “BIC System” (Anon,1970) and containing the relationships between function-form, fundamental material-form and function-form-fundamental material, are prepared for easy determination of element variables.

On the other hand, in the elimination of element variables, it is deemed appropriate to use the method, in a structure similar to the structure of “Crossed Chart” (Desqupta,A.K.;Pearce,D.W.1974) and reported schematically in Figure 3.3. While the options belonging to the variables are listed on the vertical axis in the method, the distinctive properties expected from the variables are listed on the horizontal axis. Pure (for example X-average, XX-good, XXX-very good etc.) relative values are given to the options and summed up, depending on the ratio of including the expected properties. The option with the highest totalvalue or the options with approximate values will be selected.

3.9. Evaluation

This can be defined as the processes involving the measurement to what extent the material options formed within the framework of the determined purposes, requirements and properties contain the expected properties or their suitability for purposes.

The criteria to be used in the assessment are the values belonging to properties that can be criteria determined based on user requirements. These values can be grouped under two concepts as “Use Value” and “Change Value”.While the use value defines the total of the values of the properties of the option regarding use and construction, in other words the subjective value, the change value defines the total cost or objective value of the option.

Assessment scales and relationships between performance-cost-benefit can be used in the development of the method to be used in the assessment of the options. (Desqupta,A.K.;Pearce,D.W.1974)..

3.9.1. Evaluation of Element Options

Problems occur in the assessment of the established element options, due to the measurement of properties with different measurement units and the variability in the significance levels of properties. These problems encountered in the assessment are solved by using the methods listed below:

1. The properties of options determining both the use values and the change values will be measured in a single scale and "interval scale" will be used to determine how much the options include these properties and to what extent the difference value between them is. (Please refer to Arıoğlu,N.1993).
2. The properties expected from the options must be transformed into a value that will allow measurement and the unit must be determined, in the interval scale that seems sufficient for the assessment.For this purpose, it is deemed appropriate to use the "benefit" as a unit in determination of "use values" and the "cost" for "exchange values" of the options, benefiting from relationships between performance-benefit and performance-cost. The fact the properties expected from the options are transformed into a single scale based on a single unit, measured in specific scales, is reported in the studies of "Cost - Benefit" and "Cost-Performance, Performance-Benefit", (Parson,J.D.1972).
3. By giving specific weighted scales to the criteria defined as expected property values according to their significance levels, the variability of the significance level of the properties is also reflected in the assessment.

The steps listed below will be followed in the assessment of element options, (Please refer to Ref.1 and 2

Step 1: Determination of the Significance Level of the Criteria: the weighted score of the criteria determined in step 7 of the selection method is measured. Criteria determining the use value of the element (criteria related to use and construction, other than Construction Cost) is scored as a total of 100 points as reported in the formula below:

$$\sum_{i=1}^{n} q_{ki} = q_{k1} + q_{k2} + \cdots + q_{kn} = 100$$

Criteria determining change value and directly related to cost are scored again out of 100 points in total, according to the significance level in the following ratio;

$$q_d = q_y + q_o = \%70 + \%30 = \%100$$

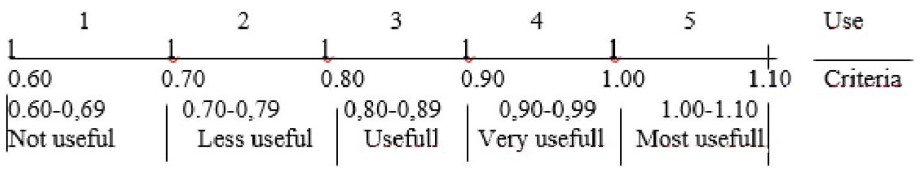
qki : Total significance level of i n. criteria determining the use value
qd : Total of significance level of the criteria determining the change value
qy : Significance level of the construction cost

qo : Significance level of the repair cost

Significance levels of the criteria determining the use value can be determined by considering the contribution to the whole system, according to the location of the element in the structure as well as "necessity", "protective" and "optional" natures of the criteria.

Step 2: Determination of the Benefit Values of Options: My - repair cost of each option is calculated. In addition, it is determined to what extent it contains the expected properties related to use and relative values ranging from 1-5 are given according to the benefit rates at the interval scale for each property and Y-benefit values are determined.Concrete values belonging to the options are determined by calculation or experiments, while the abstract ones are determined based on the similarity or value judgments.

For example, if the lower limit value expected for heat insulation property is calculated as Rmin = 0,70 m2hoC/KCal (thermal conductivity resistance) and the values of the options are calculated as R1 = 0,70, R2 = 1.08, R3 = 0,77, R4 = 0,85, benefit values of these options are S1 = 2, S2=5, S3 = 2, S4 = 3 scores, according to the benefit scale reported below.



Step 3: Determination of the Weighted Scores of the Options: the weighted scores of the options are calculated with the aid of the following formula expressing the multiplication of the significance levels determined in step 1 and the benefit values determined in step 2:

$G_{\ell i} = q_{ki}$ x $Y_{\ell i}$	$G_{\ell i}$: ℓ weighted score for i property of the option
$G_{\ell y} = q_y$ x $M_{\ell y}$	$G_{\ell y}$: ℓ weighted score for construction cost of the option
$G_{\ell o} = q_o$ x $M_{\ell o}$	$G_{\ell o}$: ℓ weighted score for repair cost of the option
k : indices related to use	$Y_{\ell i}$: ℓ benefit value for i property of the option
y : indices related to construction	$M_{\ell y}$: ℓ construction cost value of the option
o : indices related to repair	$M_{\ell o}$: ℓ repair cost value of the option
ℓ : indices related to option (ℓ = 1,2,…..n)	q_{ki} : significance level of the criteria based on i property
i : indices related to property (i= 1,2,…..n)	q_y : significance level of the construction cost
	q_o : significance level of the repaircost

For example, the weighted scores of S1 Option are determined as follows:

Weighted scores related to use	Weighted scores related to cost
G11 = qk1 x Y11	G1y = qy x M1y
G12 = qk2 x Y12	G1o = qo x M1o
: : :	
G1n = qkn x Y1n	

Step 4: Determination of the Use and Change Values of the Options: Use values of the options are calculated by summing up G weighted scores determined for each expected property of the use and construction of the options, while change values are calculated by summing up weighted scores related to cost, as follows.

$$G_{lK} = \sum_{i=1}^{n} G_{l1} = G_{l1} + G_{l1} + G_{l2} + \ldots + G_{\ln}$$

$$G_{lD} = G_{ly} + Glo$$

GℓD = Gℓy + Gℓo
GℓK : ℓ use value of the option
GℓD :ℓ change value of the option
Gℓy : ℓ weighted score of the construction cost of the option
Gℓo : ℓ weighted score of the repair cost of the option
For example, use and change values for S1 Option are determined as follows:

$$G_{lK} = \sum_{i=1}^{n} G_{l1} = G_{l1} + G_{l2} + \ldots + G_{\ln}$$

$$G_{lD} = G_{ly} + Glo$$

GK : Use Value
GD : Change Value

The values in the content of all steps are gathered together as given in Table 3.13, for easy comparison and selection process.

3.10. Comparison and Selection

This can be defined as the process of the determination of the most suitable option among the options which are formed in order to meet specific user requirements and which are determined to what extent containing specific properties as a result of assessments. The following issues gain importance in comparison processes:

Table 3.13. Evaluation Summary Example (Arioğlu N.,1993)

PROPERTIES	CRITERIA			OPTIONS							
		Sembol No	Importance (g) Weight	S_1		S_2		S_3		S_4	
				Benefit	Weight	Benefit	Weight	Benefit	Weight	Benefit	Weight
Heat emittance	Compulsory		q_{k1}	Y_{11}	G_{11}	Y_{21}	G_{21}	Y_{31}	G_{31}	Y_{41}	G_{41}
Soundproof		2	q_{k2}	Y_{12}	G_{12}	Y_{22}	G_{22}	Y_{32}	G_{32}	Y_{42}	G_{42}
Fireproof		3	q_{k3}	Y_{13}	G_{13}	Y_{23}	G_{23}	Y_{33}	G_{33}	Y_{43}	G_{43}
---------		4	q_{k4}	Y_{14}	G_{14}	Y_{24}	G_{24}	Y_{34}	G_{34}	Y_{44}	G_{44}
Manpower general	Protector	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------
Tools											
Production speed											
Service life											

Texture-colour	Optional										
Suitability with other materials											
Construction-climate relation											
Experience accumulation											
---------		n	q_{kn}	Y_{1n}	G_{1n}	Y_{2n}	G_{2n}	Y_{3n}	G_{3n}	Y_{4n}	G_{4n}
USAGE VALUES			$\sum_{i=1}^{n} q_{ki} = 100$	$G_{1K} = \sum_{i=1}^{n} G_{1i}$		$G_{2K} = \sum_{i=1}^{n} G_{2i}$		$G_{3K} = \sum_{i=1}^{n} G_{3i}$		$G_{4K} = \sum_{i=1}^{n} G_{4i}$	
Construction cost		Y (TL/m²)	$q_y = \% 70$	M_{1y}	G_{1y}	M_{2y}	G_{2y}	M_{3Y}	G_{3Y}	M_{4Y}	G_{4Y}
Maintenance cost		O (TL/m²)	$q_o = \% 30$	M_{1O}	G_{1O}	M_{2O}	G_{2O}	M_{3O}	G_{3O}	M_{4O}	G_{40}
CHANGE VALUES			$Q_d = p_y + q_o = \% 100$	$G_{1D} = G_{1Y} + G_{1O}$		$G_{2D} = G_{2Y} + G_{2O}$		$G_{3D} = G_{3Y} + G_{3O}$		$G_{4D} = G_{4Y} + G_{4O}$	

- Comparison of materials at the same level with the same technique,
- Integrity of the techniques used in the comparison of various properties,
- Performing comparisons based on numerical results, instead of "compliance-non-compliance",

The methods in the Japanese Method can be used in determining the way to be followed in the selection process.

3.10.1. Comparison and Selection of Element Options

Use and change values of the options will be taken as basis for comparison. The option with the highest (GK) Use Value in "benefit scale" and the lowest (GD) Change Value in "cost scale", among the options established and assessed in order to meet specific user requirements, is the best and most appropriate option satisfying the user requirements.However, in the case where the change value of the option with the highest use value is higher than the change values of other option, the following ways will be followed:

- The option with the highest use value will be selected or,
- The option with the lowest change value will be selected among the options with approximate use value.

3.11. Compliance Control

It can be defined as processes for,

- Determining possible errors (deficiencies and error) and thus the compliance of the selection method,
- Transferring the obtained tests and observations to the "Information Communication Center",

in the selection process ending with the determination of the most suitable option.

Compliance control can be conducted by repeating the processes in the method and the selection result with feedback.

Step 1. The processes listed below are controlled with the help of the process control card I, including all factor-functional requirement-property-criteria that may be in question at element-level.

Control of processes:

- Are the effects included in environmental systems fully determined?
- Is the effect-functional requirement transformation complete and appropriate?
- Are all the purposes and necessities determined?
- Is the requirement-property transformation determined exactly?
- Are the limit values of the criteria determined completely?

Step 2. Review of material information and examination of the result according to the established information sheets

Step 3. The processes listed below are controlled with the help of the process control card II.

- Are all options to meet the expected properties approached?
- Are the options eliminated according to the appropriate criteria?
  - At element-level,
  - At component-level,
  - At equipment-part-level.

Step 4. By refilling the process control card III;

- Significance level of the criteria,
- Weighted scores of the options,
- Use and change values will be controlled.

Step 5. Conformity is checked according to the purposes and requirements in the process control card IV and analyzed according to similar examples. At this stage, controls of the common functions of the element with other elements may be required at location level.

Step 6. Information about the option, compliance of which is tested, and the obtained results are transferred to the information communication center. A summary report and microfilm of the entire project can be recorded and sent to the center.

Examples of Process Control Cards are given in Table 3.14.

Table 3.14. Examples of Process Control Cards (Arioğlu N.,1993)

PROCESS CONTROL CARD NO: I			
Effects	Requirements	Properties	Criteria
…	…	…	…

PROCESS CONTROL CARD NO: II					
Tool-Part	Criteria	Compound	Criteria	Element	Criteria
…	…	…	…	…	…

PROCESS CONTROL CARD NO: III									
Options		P1		P2		P3		P4	
Criteria	q	Y	G	Y	G	Y	G	Y	G
	q1	Y11	G11	Y21	G21	Y31	G31	Y41	G4
	-----	------	------	------	-----	------	-----	-----	------
	qn	Y1n	G1n	Y2n	G2n	Y3n	G3n	Y4n	G4n
Use Value	100	G1K		G2K		G3K		G4K	
Construction Cost	qy	M1y	G1y	M2y	G2y	M3y	G3y	M4y	G4y
Maintenance Cost	qo	M1o	G1o	M2o	G2o	M3o	G3o	M4o	G4o
Change Value	100	G1D		G2D		G3D		G4D	

PROCESS CONTROL CARD NO: IV	
Objectives-Obligations	Suitability Point
Objectives …………	
Obligations …………	

4. CONCLUSION

Considering that it will guide young researchers, an application example of the "systems approach", which is widely accepted in basic sciences worldwide, is given as a problem solution method in the study.

A "material selection method" developed based on the systems approach is defined in specific detail in order to assist the actions of the designer, that is supposed to be selected on behalf of the user in the selection of materials in the building, to solve the problems that cause incorrect material selection, to minimize resource losses, to encourage the manufacturing and use of new materials, to select materials for basic purposes such as suitability, economy and usefulness.

As a result, it is intended to emphasize that young researchers will achieve the benefits listed below by using a specific method:

- It ensures that all alternatives can be obtained at the design stage and prevents renunciations observed in a single alternative.
- It provides the optimization of time and cost.
- It enables the collaboration between creative thinking and logic.
- Use of criteria based on "user requirements" in the assessment of alternatives indirectly contributes to the economy by reducing the need for product replacement.
- The method enables the use of techniques and practices developed in other disciplines in the study.

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chapter 2

EVALUATION OF CLIMATE-COMPATIBLE ELEMENTS IN RURAL ARCHITECTURE: CASE OF DIYARBAKIR PROVINCE ERIMLI NEIGHBORHOOD

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1. INTRODUCTION

Due to the rapid depletion of natural resources and global warming, measures to reduce energy consumption have become necessary. The construction sector has a large share in energy consumption. Nowadays, it is generally accepted that the construction industry accounts for approximately one third of the total energy consumption worldwide and this figure may vary depending on the type and location of the building (Nguyen et al.2011). Contrary to what is thought, energy is consumed not only during the use phase of the buildings but also during the construction phase. For this reason, it is very important in terms of energy efficiency to be able to build structures that require minimum energy both during the construction phase and during the use phase. Local houses in rural areas stand out with their efficient design features in terms of minimum energy consumption. Local houses have been very important examples of energy efficiency for designers as they contain accumulated knowledge to adapt to the climate (Avcı, Beyhan, 2020).

Local architecture not only constitutes an important part of the history of the region to which it belongs, but is also a constant source of information on issues related to sustainable and environmentally friendly architecture. Solutions for each region are directly reflected in the clothing styles worn, day-night working patterns and the construction of buildings and the activities carried out within them (Al-Hinai et al., 1993). Depending on the qualitative and quantitative parameters of the building, meeting the performance criteria that it will show against the physical environmental conditions is important in determining the comfort level that should be formed within the building.

Energy requirements for a comfortable indoor environment are created by building envelopes, routing, shading and natural ventilation, together with energy efficient systems and equipment (Oropeza-Perez, Østergaard, 2014). It creates a unique identity for local architecture with traditional solutions developed with the concern of adapting to rural architecture, geographical and climatic conditions. At the same time, natural ventilation, sunbathing and shading strategies, and easy accessibility to local materials during construction will guide new buildings in terms of climate-compatible construction.

The most important factor that determines the architectural identity in rural settlements is the residential buildings. The ability of the residences that meet the housing and living needs of the household, as well as the desired comfort level of the users, is an important factor in the maintenance of the local architectural identity (Ergin 2015).

In this context, the main objectives of the study are:

1. Researching and exploring climate-compatible strategies of the houses designed in rural architecture in Erimli Neighborhood of Diyarbakır,
2. Identifying and proposing appropriate solutions in the current design aiming at sustainable architectural solutions,
3. To evaluate the importance of preserving local residences that constitute examples of rural architecture in Erimli Neighborhood of Diyarbakır.

Dwellings representing local residences, which are among the examples of rural architecture in Erimli Neighborhood of Diyarbakır, have been comprehensively researched to understand their climate-compatible strategies and their effectiveness in providing human comfort.

2. METHOD

In this study, the design strategies compatible with the hot dry climate characteristics of the local architectural dwellings in the Erimli Neighborhood of Diyarbakır were examined. The dwellings in the settlement have been evaluated in terms of design criteria such as building materials, construction techniques, orientation and building form. The method used in this study is based on the preliminary qualitative analysis, diagnosis and evaluation of the climate-compatible elements of the rural settlement and dwellings of the Erimli Neighborhood of Diyarbakır by in-situ investigations and observational analyzes. In the study, the settlement and the dwellings in this settlement were evaluated with all their characteristics and climate-related planning approaches were investigated. In addition, climate-compatible design strategies were examined under two headings: Region and City Scale, Neighborhood and Building Scale. In the Region and City Scale; macroclimatic conditions, orientation of dwellings, shading and sunlight conditions, natural ventilation conditions were investigated. In the Neighborhood and Building Scale, building materials and construction techniques, heating and cooling strategies, use of local resources such as water were analyzed in terms of adaptation to climate.

3. EVALUATION OF ENVIRONMENTAL FACTORS

3.1 Regional and City Scale Climate-Compatible Design Strategies

3.1.1 Geographical Condition

Diyarbakir province in Turkey's Southeastern Anatolia region is located between the 38 ° 85 'and 41 ° 68' east longitude and 37 ° 06 'and 39 ° 06' northern latitudes. Corresponding to the Tigris Section in the eastern half of the Southeastern Anatolia Region, Diyarbakır province and its surroundings consist of different geomorphological units. From north to south, there is the Southeastern Taurus mountainous unit, to the south of this mass there are a series of depression areas and a belt of Border folds. In the center is the Diyarbakır basin and in the southwestern part is the Karacadağ plateau. Diyarbakır province is divided into two different basins. While Çüngüş and Çermik surroundings are included in the Fırat basin in the west, there is a large area of the Tigris basin in the east (Durmuş, 2018).

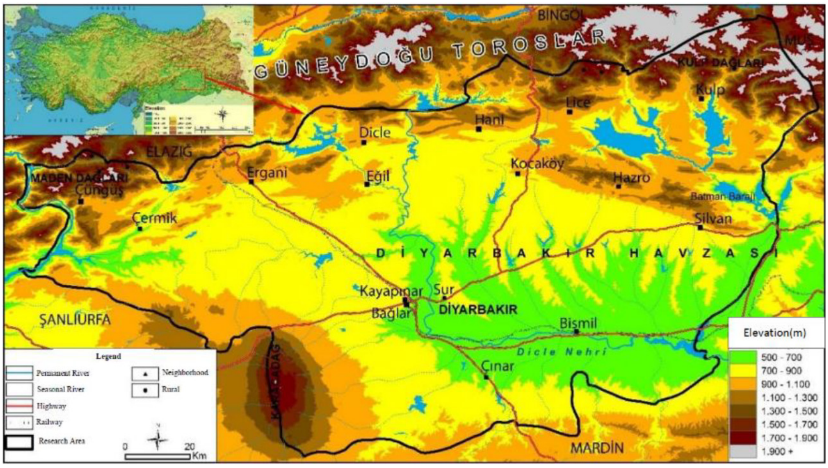

Figure 1. Topographic situation of Diyarbakır province and its surroundings (Durmuş, 2018)

The Diyarbakır basin consists of a large bowl covered with a pit in the middle and relatively new strata, and its sides surrounded by older land. It includes plains, hilly areas, plateau areas and wide-bottomed valleys. While the lands of the basin consist of the Tigris river and its branches in the east, the Euphrates River collects the waters of a small area at the western end. In the northwest-southeast direction, the Tigris River, which passes through the basin, combines Ambar, Pamuk streams in the north and Kulp and Sason (Great Brightness) streams that originate from the mountains in the northeast to form the Batman Stream. 31% of the basin lands correspond to the plain and 69% to the plateau areas (Sözer, 1969). Sur District to which the study area is connected is located on the banks of the Tigris River. Its surface area is 438 m² and it is 660 meters above sea level. Erimli Neighborhood, which has been chosen as the study area, is 21 km away from Diyarbakır city center.

3.1.2 Climatic Condition

Diyarbakir is under the influence of arid climate which is a defining feature of Southeastern Anatolia Region of Turkey (URL1) (Figure 2.). Summers are dry and hot, and winters are cold. Diyarbakır province, which is 670 meters above sea level, is divided into two different basins. While Çüngüş and Çermik surroundings are included in the Euphrates basin in the west, there is a large area of the Tigris basin in the east. Different temperature and precipitation values are observed in both basins in terms of climate. While 800-1250 mm of precipitation is recorded in the settlements established on the southern slopes of the Southeastern Taurus, 450-600 mm of precipitation is recorded at the basin floor in the central parts and 600-800 mm of precipitation recorded on the Karacadağ volcanic mass, which lies between the southwest of Diyarbakır and the northeast of Şanlıurfa (Durmuş, 2018).

According to the measurements made between 1939-2018, the annual average temperature is 15.7°C. The highest temperature in Diyarbakır was measured as 46.2°C on 21.07.1937. The lowest temperature was measured as -24.2°C on 11.01.1933. According to the average values realized between 1929-2018, the average highest values in terms of monthly average temperature values were measured as 38.5°C in July and the average lowest values were measured as -2.6°C in January. Annual average rainfall is 469.6 mm. The average number of rainy days in Diyarbakır was the most in February and the least in August. Average monthly precipitation was 68.0 mm maximum in February and the lowest was 0.4 mm in August (URL1) (Figure 3).

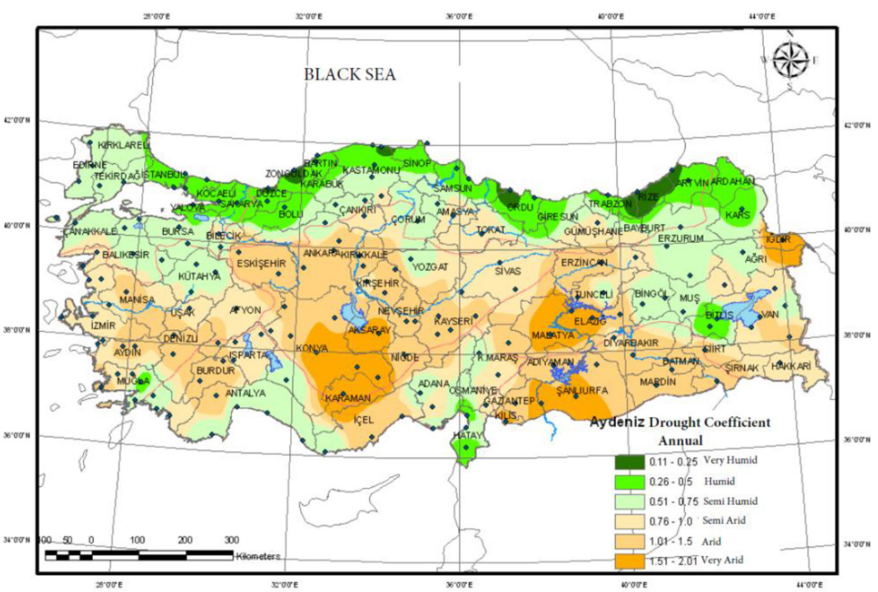

Figure 2. Turkey's annual drought coefficient according to the General Directorate of Meteorology (2016)

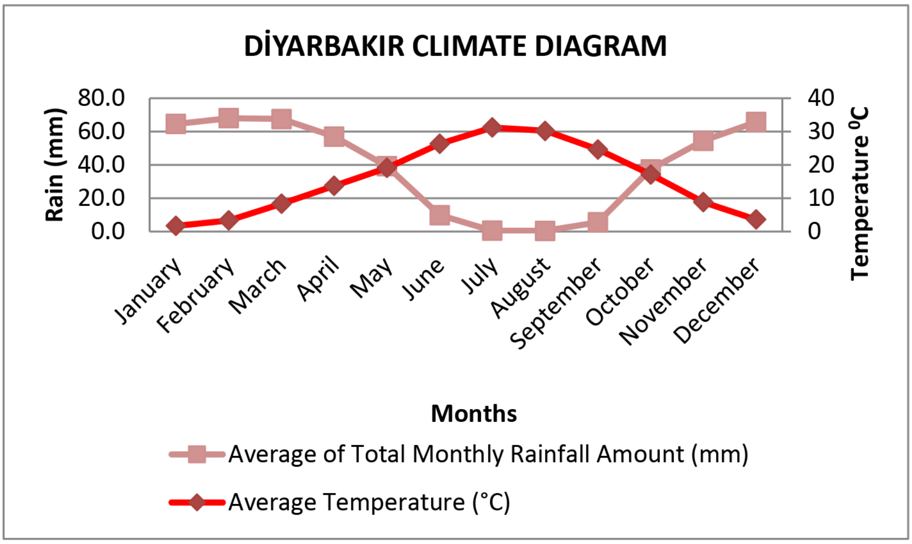

Figure 3. The monthly average temperature and precipitation values of Diyarbakır (1929-2018) (URL1)

3.1.3 Climate-Compatible Design Strategies

In the Southeastern Anatolia Region, the continental climate is very hot and dry in summers and cold in winters. The low level of relative humidity in the region is the cause of dryness. This situation has led to the development of passive strategies that show high cooling performance in the buildings in the region.

The settlement characteristics of Diyarbakır, where the study area is located, represents the strategies developed against the hot-dry climate of the Southeastern Anatolia Region. The relative position of the buildings constitutes the character of the settlement. It also determines the protection levels of buildings from solar radiation and wind (Erdemir, 2014). Aiming to reduce the surfaces exposed to solar radiation in regions with hot-dry climates caused buildings to be constructed in as compact forms as possible (Tuncer, 1999). Considering the traditional streets in the hot-dry climate zones, settlement density is frequently encountered (Ayçam, Akalp, Görgülü, 2020).

The use of a courtyard enriched with water and plants is seen in Diyarbakır traditional houses as a planning strategy compatible with hot-dry climate (Dizdar H., 2009). Since the courtyards, which control the external elements, cause a temperature difference between the interior and exterior of the building envelope, the internal temperature is higher than the outdoor temperature during the night hours in winter, and it has a lower value than the outdoor temperature in the summer because it creates shadow effect (Sinou, 2007).

While courtyard-centered planning features are observed in traditional houses in the city center of Diyarbakır, in the rural settlement Erimli Neighborhood, courtyard use is not encountered, but sofa-centered planning features are observed.

Erimli Neighborhood benefits from the climatic advantages of the Tigris River located within the borders of Diyarbakır province. Erimli Neighborhood is bordered by Gencan Neighborhood, which is 2.3 km to the north, Kardeşler Neighborhood, which is 5.7 km to the south, Sarıkamış Neighborhood, which is 5.2 km to the east and the Tigris River, which is to the west. Diyarbakır-Erenli Road, which is the main road axis in Erimli Neighborhood, divides into some secondary roads and continues until Hani District. Erimli Neighborhood is located on the western slope of a hill with a low elevation, close to the plain. Erimli Neighborhood, which is located on a slope with its back to the east, provides optimum settlement conditions for hot-dry climates.

3.2 Climate-Compatible Design Strategies at Neighborhood and Building Scale

Erimli Neighborhood is close to the Tigris River (Figure 4.a.). The neighborhood, which is established approximately 1.2 km away from the Tigris River, benefits from the climatic advantages provided by the river. Located in the northeast of Diyarbakır, Erimli is 21 km from Diyarbakır center. It is also known as the village that grows the largest watermelons in the Watermelon Festivals in Diyarbakır. The village of Erimli shows the characteristics of a rural settlement, but in 2008 it was connected to the Sur District of Diyarbakır and defined as a neighborhood (URL2). It is possible to see examples of local tissues in the settlement, which still preserve its rural architectural identity to a great extent.

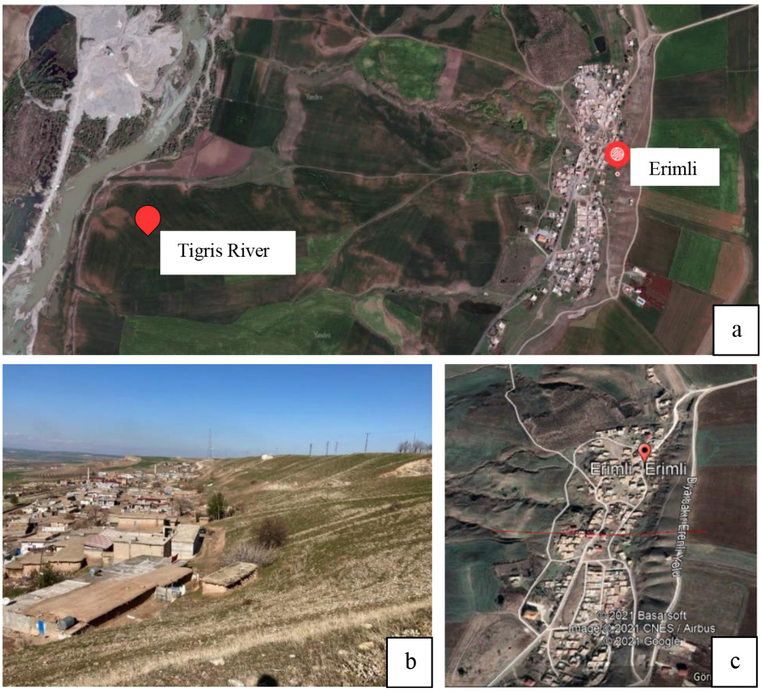

Figure 4. a. The location of Erimli Neighborhood with respect to the Tigris River (URL3) b. c. Slope view of Erimli Neighborhood

The settlements in the Erimli Neighborhood are located on the slope between the Tigris River with an altitude of approximately 600 m in the west of the settlement and the hill at an altitude of 770 meters to the east of the settlement, at an average height of 710 m to 737 m. (Figure 5.c.).

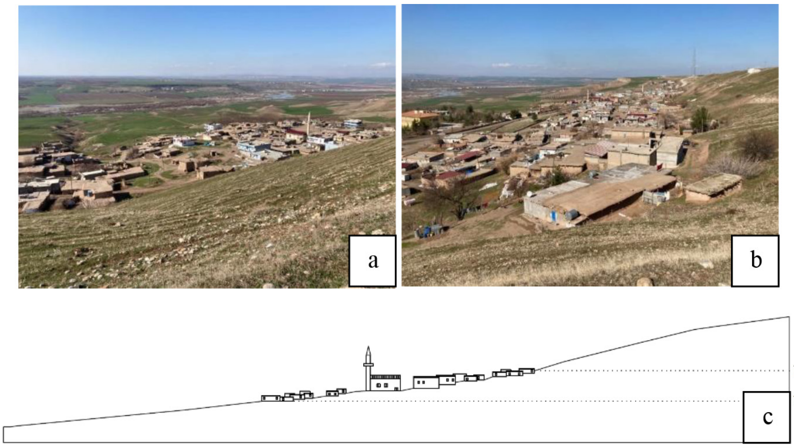

Figure 5. a. b. General view of Erimli Neighborhood c. Settlement silhouette of Erimli Neighborhood

The reason for the location of the settlement area at these levels is the climatic and agricultural advantages provided by the Tigris River. The fact that it is located close to the river is effective in the microclimatic features of this settlement in the hot and dry climate. In addition to the climatic factor, it can be said that the economic factor is an important factor in the selection of rural settlements (Ergin, 2020).

The settlements in Erimli Neighborhood, which is located on the slope facing west, developed in a linear direction on the north-south axis of the slope. In this settlement feature, the dwellings form a shield for each other against the winds from the north.

The middle part of the settlement axis forms the center of the neighborhood. Here, there is a coffee house, mosque, condolence house used as a common area. The main road axis in the direction of the linear settlement passing in front of the coffee house and the mosque divides into secondary roads and provides access to the dwellings (Figure 6**.).**

Figure 6. View from the settlement center

The traditional adobe buildings in the settlement are single storey. There are also two-storey examples of reinforced concrete structures built in recent years. The buildings are not in a certain order and have an organic order developed in line with the needs of the residents.

The gardens of the dwellings with garden areas in the settlement are separated by walls. In the garden areas, there is a food store and poultry house in accordance with the needs of the residents. The construction technique of these spaces is the same as those of the dwellings, and the building materials are adobe (Figure 7.).

Figure 7. Garden use

3.2.1 Distances and Positions of Structures in reference to Each Other

The orientation of the structures, distances and heights are important in hot-dry climatic regions in terms of protection from solar radiation, creating shadow effects and taking advantage of controlled wind effects. In settlements that feature hot-dry climate regions such as Erimli Neighborhood, the build-ings should be positioned close to each other to provide shade and windows should be opened in appropriate directions for maximum protection from solar radiation.

The buildings are located at close distances to each other. As a result of the frequent placement of the structures in the settlement, the distances between the dwellings have created streets of various widths. These distances vary between 1 meter and 3 meters (Figure 8.b-c-d.). In addition to the dwell-ings separated by garden walls, there are also adjacent dwellings (Figure 8.e.). The close positioning of the structures throughout the settlement is intended to protect against incoming sunlight. Providing a dispersed settlement by keeping the building distances short is also an advantage in reducing the speed of the wind and protecting it from its negative effects. Factors such as climate, common needs, family bonds, andsocial relations were determinant in the distance of the buildings. Garden areas are a decisive situation at the distance of the dwellings to each othe r.

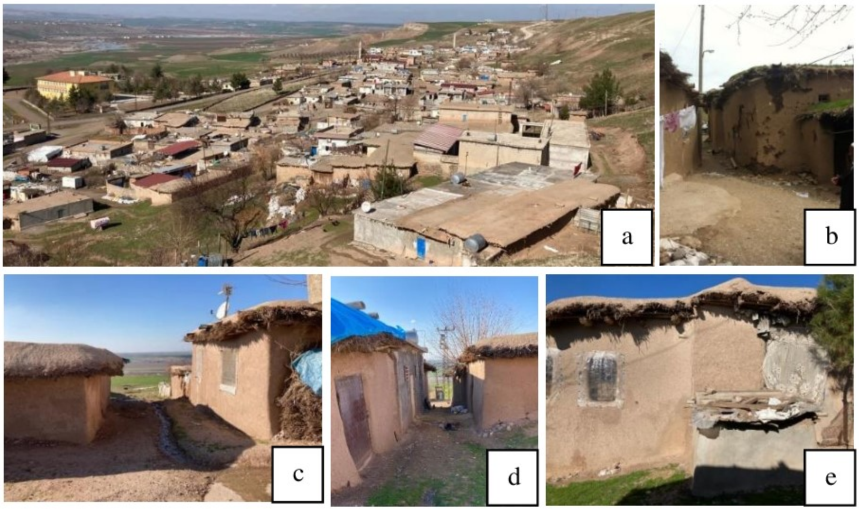

Figure 8. a. General view of the settlement density of Erimli Neighborhood b. c. d. e. Distances between dwellings

3.2.2 Orientation

Depending on the geographical characteristics of the area where the settle-ments are located, the amount of solar radiation affecting the outer surface of the building affects the average radiative temperature affecting the building. Therefore, the amount of heat passing through the building envelope changes the inner surface temperature of the envelope and consequently the inner temperature values. Correct decisions in terms of orientation ensure that the interior temperatures of the spaces are kept at the desired level. For this reason, the orientation of the buildings is an important parameter in terms of minimum energy consumption in providing indoor climatic comfort.

Buildings in hot-dry climates should be oriented for the purposes of pro-tection from solar radiation and maximum benefit from the cooling effect of wind. In the hot period of the year, the solar radiation coming to the buildings should be minimized and the buildings should be directed to protect them from solar radiation. While the cooling wind effect at night is desirable in these regions, the drying effect of the dust that is likely to be carried by the wind is undesirable as it will increase the temperature felt.

The buildings in the Erimli Quarter were created by taking into account the hot-arid climatic conditions, except for the challenging situations caused by parceling. Although it is close to the Tigris River, the orientation of the structures has not developed towards the west direction where the river is located. While the buildings are generally positioned with their long facades facing south, it is also possible to see examples directed towards the east. In both cases, windows with a width of 100-110 cm are often planned on the south facade in terms of both numbers and dimensions in order to protect from the solar radiation coming from the east-west direction. In difficult situations caused by parceling, although the entrance doors are opened to face the street, the windows are positioned to the south. Opening windows in the south direction reduces the heat gain by preventing the solar radiation coming from the east-west direction. In this way, even though the outdoor temperature reaches high degrees in summer, indoor temperatures are kept at the desired level. Directing the most used places and windows to the south is effective in reaching the sufficient level of illumination. Window joinery is on the inner surfaces of the walls and provides protection from solar radiation. In general, it is seen that the houses are planned with appropriate orientation in terms of protection from solar radiation, controlled wind gain and lighting.

3.2.3 Building Form

In hot-dry climates, the building form is important for the control of environmental factors such as protection from solar radiation, shading and wind effect. The outer surface of the building is the part where the building is open to climatic effects. The form of the building determines the size of the outer surface of the building and determines the level of climatic effects. Non-scattered building forms are suitable for hot-dry climate regions in terms of reducing external surfaces exposed to solar radiation. Plans with inner court-yards formed by building masses are also suitable for this climate zone.

The structures in the settlement are mostly formed in rectangular and compact form. In addition to the rectangular form, there are also dwellings formed in an almost square form. There are also residences that have lost their compact form with the additions made over time and that cannot be defined as rectangular or square. Besides these, there are no examples of houses with courtyards. There are also dwellings in dispersed form, which were not used as residences when built, but later used as residences.

3.2.4 Planning Features and Space Organization

The traditional adobe buildings in the settlement are single storey. There are also two-storey structures built as reinforced concrete in recent years. The dwellings with gardens in the settlement are separated from each other by garden walls. Entrance to the dwellings is provided from the garden area. There are examples of plans with and without a sofa in the settlement (Figure 9.a-b.).

Figure 9. a. An example of a plan with sofa b. An example of a plan without a sofa

The main spaces in the settlement are the rooms and sofas. Generally, entrance to the houses is made from the sofa and the organization of the space is is sofa-centered (Figure 10.a.). The most frequently used places to protect from undesired solar radiation in the settlement with hot-arid climates are planned on the south facade. (Figure 10.b.). Due to the parceling conditions, the most used rooms in some houses are placed on the east facade.

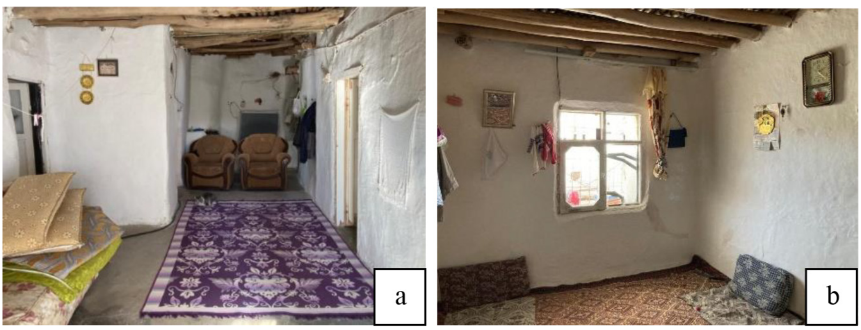

Figure 10. a. View from the sofa b. View from the room

In the settlement, 'tandır' sections (a handmade oven type covered with clay for baking bread and cooking) with separate entrances, planned inde-pendently of the residences, are seen (Figure 11.). The top cover of this tandır section has a small top window that only functions as a chimney. The fact that the outdoor temperature is quite high during the summer months and the need to lower the indoor temperature caused these sections to be built inde-pendently of the dwellings. Some dwellings have a stove inside the kitchen for bread and cooking purposes (Figure 12.c). These stoves are used in the cold period of the year, and heat gain is provided to the indoor environment during the winter months.

Figure 11. Views from inside and outside of the tandır section

Dwellings, which are generally composed of single-storey houses, have a sofa, room, hall, kitchen, bathroom, toilet and warehouse. In the rooms that are mostly used to meet the heating need during the winter months, stoves are used (Figure 12.a.). Stoves are also used in bathrooms in order to increase the heat gain and to meet the hot water need for washing (Figure 12.b.).

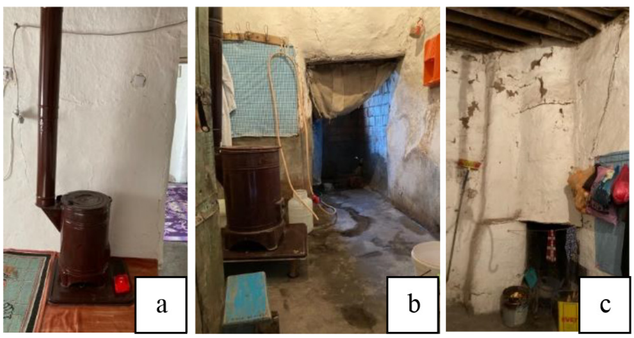

Figure 12. a. b. Wood burning stove used for heating c. Use of the stove

Although the outside temperature reaches high degrees in summer, the windows opened on the right facades and in sufficient size meet the need for cool air (Figure 13.). In addition, the high pressure that occurs as a result of the water of the Tigris River warming less than the land during the day, allows the breeze to blow towards the settlement. These breezes allow residents to have cool and humid environments in the summer months, unlike the hot and drying air of the region. The frames of the windows are placed on the inner surface of the wall. This use provides protection from precipitation effects and wind.

Figure 13. Examples of windows

3.2.5 Building Envelope Features

The building envelope consists of the components of the buildings such as walls, windows, doors, roofs and floors. In hot-dry climates, the features of the building envelope are important in keeping the indoor temperatures in balance. Due to the large daily temperature difference in these regions, the heat storage capacity of the building envelope should be high. By using mate-rials with a long time-lag, the effect of high temperatures should be reduced by delaying the transfer of the heat stored during the day to indoors.

In the residential buildings, the walls are the main bearing element of the applied masonry system. The walls, which function as a bearing element, are made of adobe. The use of adobe building materials on walls is a strategy that is compatible with the hot-dry climate seen in the settlement due to the advan-tages of its heat retention and long time-lag. Thickness of materials with high heat storage capacity determines the effect of thermal mass in the envelope. Thickness increment increases this effect. The outer wall thickness of the buildings in the settlement is generally 80-85 cm, which provides this effect. The inner walls of the buildings are approximately 55-60 cm thick.

Figure 14. Examples of walls

The upper floor of the buildings is composed of an earth flat roof. Wooden rafters with an average diameter of 10 cm were placed on the wall in the short direction of the room. After the rafters were covered with materials such as wood and bushes, straw-added soil was laid. (Figure 15.a-b.). While the eaves with an average length of 50 cm were formed, rafters with a diameter of approximately 5 cm were added perpendicular to the rafters of approximately 10 cm in diameter. (Figure 15.c.). The earth flat roof keeps the interior tem-perature of the spaces in balance thanks to its heat storage capacity and lengthening the time-lag. Laying the middle parts of the soil floor higher than the edges creates a slope towards the edges. The slope created provides easy evacuation of rainfall. (Figure 15.d).

Figure 15. a. Earth flat roof layers **b.** The view of the rafters from inside the space **c.** The rafters that formed the eaves **d.** Top cover slope

4. CONCLUSION

Rural settlements contain examples of traditional buildings that are compatible with the climatic characteristics of their region. In this study, the design strategies adapted to the climate of the houses in Erimli Neighborhood of Sur District of Diyarbakır were evaluated. In-situ observations and examinations indicate that the buildings in the settlement are compatible with hot-dry climatic conditions. The adverse conditions of the hot-dry climate of the region, especially during the summer period, have been reduced by taking into account strategies compatible with the climate. It was concluded that the traditional dwellings in the Erimli Neighborhood settlement, which was chosen as the study area, were planned compatible with the climate and the negative effects of the hot-dry climate dominating the region were reduced with these planning features. In order to ensure the adaptation of the newly designed houses to the climate in the region, the climate-compatible design strategies applied in the examined traditional houses have the quality of being a resource. In this context, adobe local dwellings, which constitute examples of rural architecture in Diyarbakır's Erimli Neighborhood, should be preserved with their unique qualities.

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chapter 3

QUESTIONING THE USE OF TRAVERTINE AS A CONSTRUCTION MATERIAL IN HISTORICAL BUILDINGS WITHIN THE CONTEXT OF SUSTAINABLE ARCHITECTURE: THE CASE STUDY OF EVDIR HAN

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1. INTRODUCTION

Today, the reuse of historical buildings and their possibility for being handed down to the next generations are fundamental issues of the studies architectural preservation and sustainability. Considerable degree of deterioration may be observed in travertine used in historical buildings. Due to these corruptions the historical buildings collapse either partially or totally and they cannot be handed down to the next generations. General approach in restorations is completing the collapsed parts by the use of the original material. However restoration through original material should be questioned because of the problems of excessive deterioration observed in travertine.

Corruption in the stone sections of the historical buildings, especially in the monumental ones, is an important problem which has been observed for centuries. However along with the problems of the last century such as air pollution, traffic load, global warming, climatic change, deforestation and etc., (WWF, 2019) a significant rise of the degree of deterioration is observed regarding stone as a construction material used in historical buildings. Due to this reason, studies regarding the use, physical-chemical-mechanical properties, problems and solutions of preservation, ecological significance and sustainability of stone used in historical buildings have become much more frequent (Snethlage, 2011). Public and private organizations undertake studies and publish them in order to improve public consciousness as much as possible and globally renowned publishing companies disseminate the articles and books of researchers.1

This study focuses on the use of original material in accordance with contemporary theories and approaches of restoration. In this scope, the objective of this study is to determine the weak and strong qualities of travertine through the case study of Evdir Han, to identify problems and shed light on precautions significant for theoreticians and implementers during the use and restoration of historical buildings. On the other hand determination of deteriorations, risks and intervention methods regarding traditional materials necessitate interdisciplinary studies. For this reason, research and analyses within the framework of this study, which are leaded by a team of experts in architectural preservation, architecture and ecology, are assisted by experts in

[1]For instance see Science Direct (https://www.sciencedirect.com/science/article/pii/S0360132305005330), Springer Publications (https://www.springer.com/gp/book/9783642451546), ICOMOS (http://openarchive.icomos.org/832/1/ro18.pdf), İBB KUDEB (http://www.ibb.gov.tr/sites/kudeb/documents/icerik/kitabVI.pdf).

structural statics and a material laboratory. Results, which relate to different scientific fields, are derived through project designing, analysis of deterioration, statics, materials and ecology and thus the study intends to introduce an original contribution to the field.

2. EXPERIMENTAL DETAILS: MATERIAL VE METHOD

In this study, research and analysis are undertaken through a solid case study in order to question the use of travertine as a construction material in historical buildings. Evdir Han, which is a 800 year-old structure is chosen as a case study. Therefore the material of the study is determined as travertine and Evdir Han which was built by the use of this type of stone.

The restoration method implemented to the Evdir Han consists of four stages. In this context, firstly the architectural preservation projects of Evdir Han were prepared. The deterioration and static analyses of the structure were realized through the restoration projects. Material analyses were completed by taking samples out of different elements such as vaults, walls and arches. Finally ecological analysis was done.

In this way, the conditions for the use of travertine in a historical building was reviewed and the advantages and disadvantages of the use of travertine in restoration implementations were determined.

2.1. Travertine as a Construction Material

Since the prehistoric ages, stone has been amongst the most important and most valuable types of construction materials. Stone has been a symbol of "permanence" for the human beings since it is resistant, it has a long-life span and it can survive in different climatic conditions (Özgünel, 2009, page: 36). Its properties such as abundance in nature, capacity to be shaped and qualities of natural insulation have been important reasons for the selection of stone as a construction material. Contemporary research indicates that stone is an ecological and sustainable construction material because it is not harmful to human health and environment, it can breathe, it transmits air, it can be reused after the building in which it is used is collapsed, it does not leave any harmful wastes in nature (Khatip, 2016, page 286).

In its most basic definition, stone is a collection of minerals2. Stone can consist of one kind of mineral or it can also be composed of the collection of several kinds of minerals. Information regarding the origin of the stone can be gathered by analyzing the minerals in the content of the stone. Stone material is analyzed in three categories such as magmatic, sedimentary and metamorphic according to their geological formation and origins. These three main groups of stone are in a continuous cycle within which they are transformed into each other. Magmatic Stones are transformed into sedimentary and metamorphic stones; sedimentary Stones are transformed into magmatic and metamorphic Stones; metamorphic Stones are transformed into magmatic and sedimentary. Within themselves these groups of stones are transformed into structures of different features and they acquire different names (See Figure 1, URL 1).

Travertine, which is the focus of this study, is a sedimentary type of stone with chemical origin and it has been widely used as natural construction material. It is formed out of the sedimentations of water with calcium bicarbonate. Since plants with chlorophyll, which are in the formation process, take carbon dioxide melted within water for assimilation, sedimentation becomes faster and plants are covered with calcium carbonate. Among these stones, those which are more porous, light and containing herbal traces are

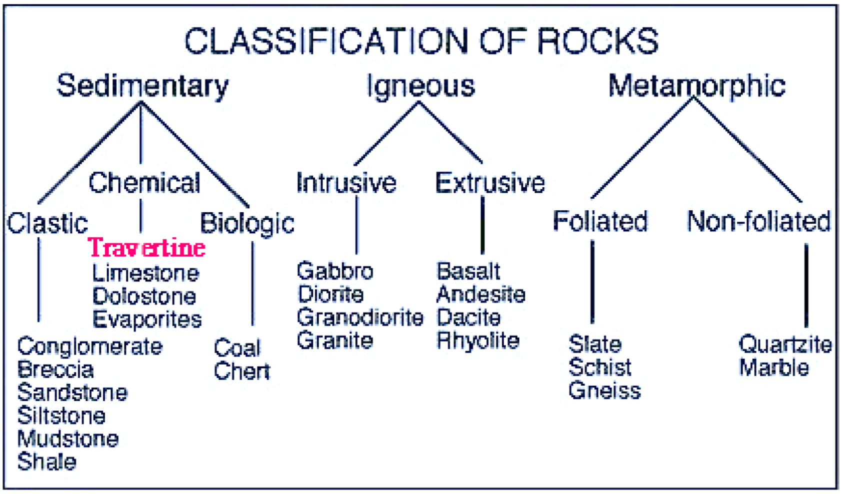

Figure 1. The classification of stone (URL 1).

[2]Mineral is a material consisting of inorganic chemical elements or chemical compounds whose properties do not change (MEB, 2013, page: 2).

called calcareous tuff, whereas those which are less porous and dense are called travertine (Küçükkaya, 2014, page:32).

Although travertine is porous it is a quite resistant and hard type of stone. Its quarry, processing and cutting are easy and it is abundant in nature (Küçükkaya, 2014, page: 32). It is resistant against heavy loads and climatic conditions. Due to these qualities it has been used very frequently for construction. On the other hand it is not resistant against fire. The reason for this is the fact that there is very little amount of water and soil within the content of travertine, in addition it contains so much air because of its porous structure. In case of fire it is burnt very fast and intensively (Vitruvius, 2005, page: 38).

Travertine is used as a construction material both in new and historical buildings. While it is mostly used as a cladding material in new buildings, in historical buildings it has been used for the construction of all structural elements. It has been widely used in elements such as walls, columns - piers, covering elements such as arches – vaults – domes and pitched roofs, floor coverings, windows – doors – hearths – niches. As in other types of Stones, the use of travertine in buildings is classified in four groups according to their kinds of processing: rubble stone, rough work masonry, fine work masonry and cut-stone (MEB, 2013b).

Since the ancient ages, stone has been an expensive construction material. Therefore it is not generally used in vernacular architecture. It is especially preferred in administrative and public buildings because of its strength and long life span. Travertine is also used generally in the context of such administrative ad public buildings (MEB, 2013b).

2.2. Evdir Han

Evdir Han is situated in the Western Mediterranean region of Turkey, within the province of Antalya, the county of Düzlerçamı and the district of Düzlerçamı. Its distance from the city center is 18 km (Figure 2). The building is a caravanserai located on the trade route connecting Antalya, an important port during the medieval age, to inner Anatolia. Evdir Han has been a part of the greater building projects of the Anatolian Seljuk State which envisioned to construct a web of caravanserais on the important trade routes of Anatolia (Karpuz,2001,page:79). As the single representative of the four iwan type plan organization reaching our days, the building is unique as a caravanserai without any completely closed space (Bektaş, 1999, page:58).

Figure 2. Turkey and Antalya on the World map and Evdir Han on the map of Antalya (DK, 2009).

According to its original inscription, Evdir Han was constructed during the reign of the Anatolian Seljuk Sultan Izzeddin Keykavus I (1211-1220). The architect is unknown. It has a rectangular plan with dimensions of approximately 68 m. x 54 m. It is prismatic building of 9m. height. After the process of excavation and cleaning, it is unfolded that the Project follows a plan typology with a central and symmetrical organization, open courtyard surrounded by two rows of porticos and for iwans. At the symmetrical axis of the southwestern façade there is an ornamented portal. There are two cisterns outside the building. The small one is located at the northwest while the large one is located on the southeast. There is a small toilet on the northern side of the southeastern cistern.

The southwestern and southeastern sections of Evdir Han were largely preserved. Whereas there are wall remains on the Northwestern and northeastern sections. It can be stated that nearly 65 % of the building could reach today (Figure 3 and 4, Archive of the Akdeniz University Faculty of Architecture (AUFA) Archive).

Figure 3. The aerial view of Evdir Han (AUFA Archive, 2016)

The sections of the building which could reach today are totally constructed by the use of travertine. The outer walls, with 146 cm thickness, were constructed by the use of case wall technique. The outer and inner faces of the outer walls are constructed using cut-stone, the inner sections were filled with rubble stone. The arches, of 90 cm. thickness, dividing the iwan and portico and piers with the sectional dimensions of 90 cm x 90 cm are constructed by cut stone. The platforms of the piers which define the borders of the spaces are also made up of cut-stone. The upper sections of the arches and the vaults are completed by using rubble stone. In some places, remains of travertine floor coverings are discovered (see Figure 5).

Evdir Han is a legally registered building considered as cultural heritage due to its significant architectural qualities. The building, which is 800 years

Figure 4. The southwestern façade of Evdir Han and the main portal (AUFA Archive, 2016)

Figure 5. The walls, arches and vaults of Evdir Han (AUFA Archive, 2016)

old, is constructed by the use of travertine. However, since its maintenance and restoration were not realized on time, nearly 35 % of the building had totally collapsed.

2.3. Method

In this study it is thought that stone should be analyzed in structural context because it is used in the structure and also it should be analyzed in ecological context since it is a natural material.

The study method implemented to the Evdir Han consists of four stages. In this context, firstly the architectural preservation projects of Evdir Han are prepared. The deterioration and static analyses of the structure were realized through the restoration projects. Material analyses were completed by taking samples out of different elements such as vaults, walls and arches. Finally, ecological analysis is done.

As a result of all researches the study aims to determine the advantages and disadvantages of using travertine during the restoration of historical buildings and new buildings located in regions with hot and humid climate. It is expected that this study provides guidance for further designs and renovations with respect to the use of travertine as construction material.

3. RESULTS AND DISCUSSION

Questioning the use of travertine in buildings requires the realization of some scientific experiments. Thus Project design, analyses of statics, deterioration, material and ecology have been undertaken through the case study of Evdir Han and travertine. In accordance with the results of these analyses it is aimed to determine the advantages and disadvantages of using travertine in buildings. Findings gathered were discussed within each section of analysis.

3.1 The Project Stage

The best way to get acquainted with a historical building is to prepare its architectural analytic survey drawings because in this process one is able to touch every detail of the structure by having a chance to discover all the details, even those which cannot be realized by anyone. For this reason, at first the analytic survey drawings of Evdir Han were prepared. Then, four different kinds of analysis, namely, the condition of originality, chronological change, identification of materials and condition of deterioration were realized by making drawings on these analytical survey. While preparing these drawings, all the measurements and conditions of change and deteriorations of today are documented. Meanwhile issues such as the reason for the selection of certain materials, the reasons for changes, the reasons for the deteriorations can be discussed. After identifications concerning the current situation of the building are completed, the next research question is about finding out how the building was when it was first built. The answers given to these questions are transformed into drawings by the architects during the restitution projects. After determining the original architecture of the building and its contemporary problems, the next research inquiry is concerned with how the problems of the building can be solved and how the building will be used. Decisions given at this stage are reflected to the restoration projects. All these drawings are explained by spate reports (Ahunbay, 2009, page:70-86).

Today the preparation of survey drawings is realized through advanced techniques and equipment of documentation rather than the traditional methods. These techniques and equipment enable more correct and precise documentation of the building. For this reason advanced techniques and tools of documentation were used during the process by which the projects of Evdir Han were prepared.

During the planimetric measurements of Evdir Han, Leica Builder 509 Total Station and Leica iCON gps 60 were used together. Forthe drawings of the elevations, the building was scanned through Faro Focus 3D laser Scanner equipment, and the cloud of points which was gathered were united and coloured by the use of Faro Scene 5.1 program. The plans, sections and elevations were prepared as twodimensional drawings by using the PointCap program and they were converted into dwg format. Very precise measurements were realized by these tools and the projects were completed. Canon 40D digital SLR with Canon EF-S 18-200 mm lenses were used for taking the photographs of the building, through the pictran software program and Autocad drawing program, the materials of elevations and the types of deterioration were implemented on the projects (Figures 6 and 7).

During the restoration Project of Evdir Han, the employer institution required that the structure would be transformed into its original architecture represented by its restitution project. This requirement means that the collapsed sections of the building would be completed by the use of travertine. According to the theories of restoration (Venedik Charter, Article 9), the restoration of historical building by using their original stone is a correct

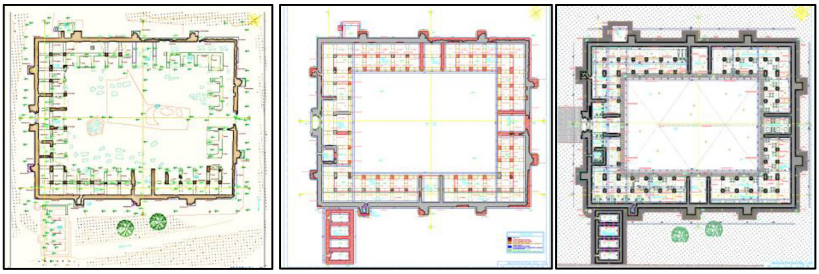

Figure 6. The survey – restitution – restoration plan drawings of Evdir Han (AUFA Archive, 2016)

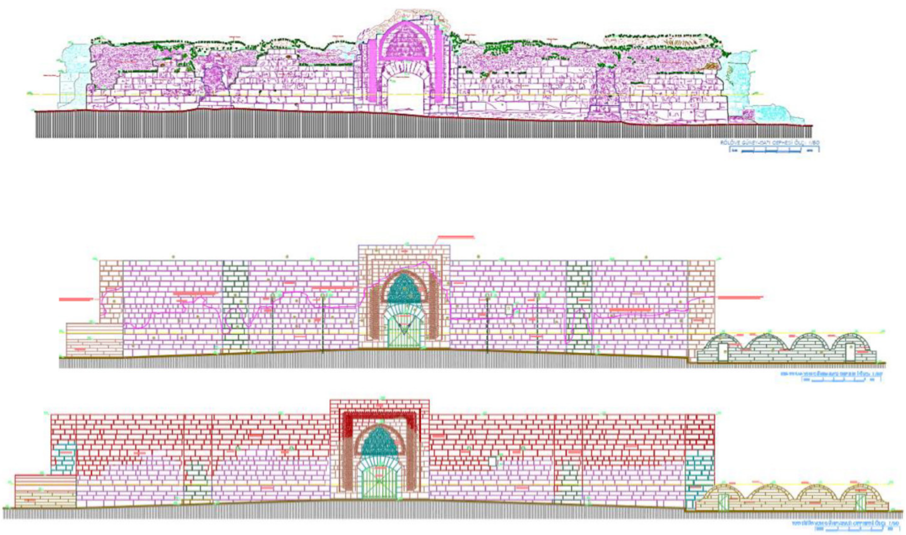

Figure 7. The survey – restitution – restoration entrance elevations of Evdir Han (AUFA Archive, 2016)

approach (ICOMOS TR, 1964). However, the important amount of material deteriorations observed in Evdir Han, raised the questioning of the use of travertine.

An important reason for deteriorations in historical buildings is wrong use of materials in the period of construction (Ahunbay, 2009, page 40). If it was a wrong decision to use travertine in Evdir Han is a separate discussion, on the other hand, it should not be forgotten that the building was constructed 800 years ago. However it should not be neglected that there are significant amount material deteriorations in the buildings which were constructed by using travertine. In this case, it is important to realize the analyses of deterioration and statics.

3.2. Deterioration and Static Analysis

At the second stage the deterioration and static analyses of the buildings were realized. These analyses indicate the weak and strong points of the building in terms of its structural system. Deterioration analyses were realized through observations and metric measurements on the building. Static analyses were realized through the restoration Project by the use of computerized static programs.

According to the deterioration analyses, widespread partial collapses and deformations were observed as regards the structural elements such as walls, arches and vaults. The deteriorations occurred due to mechanical effects and temporal and environmental circumstances. There has been a considerable degree of material loss within the stone masonry and mortar, cracks have occurred on stones and joints, disconnections are observed at the corners of perpendicularly connected elements such as walls, arches and transitory elements and deteriorations were documented due to plants and their roots. While the porous structure of travertine has provided living space for the natural flora, this situation has led to deteriorations due to herbal roots. (see Figure 8). There had been a rupture of approximately 5 cm between the portal on the axis-A and the surrounding wall. On the southeastern direction there is a problem of rupture along the portal. There are also ruptures between the vaults and the arches carrying them (İlki and Demir, 2017, page 8-11).

As regards stone used in structural elements, considerable amounts of material loss, cracks and crashes were detected. Temporal and environmental factors have played important roles during the formations of these deteriorations. Three different levels of attrition are observed regarding stone such as

Figure 8. Deteriorations of travertine due to flora (İlki and Demir, 2017)

shallow (0-5 cm), of medium depth (5cm – half of the depth of stone) and deep – critical level (half or the depth of stone or more) (see Figure 9, 10 and 11). Shallow deteriorations may only be negative in visual and aesthetic terms, they do not cause structural problems. However attritions of medium and deep level are important and dangerous deteriorations in structural terms.

Figure 9. Superficial deteriorations(İlki and Demir, 2017)

Figure 10. Medium-sized deteriorations (İlki and Demir, 2017)

Figure 11. Deep and significant deteriorations (İlki and Demir, 2017)

The static analysis has been conducted through the restoration.3 It is realized by the use of SAP2000 v18.2.0 structural analysis program based upon the model of finite elements (see Figure 12). The behavior and safety of the structure under the dead load of the structure (vertical loads) and seismic effects (lateral loads) are analyzed. During the analysis, the approach of macro modeling is followed and linear calculation approaches are accepted in terms of material and geometry.

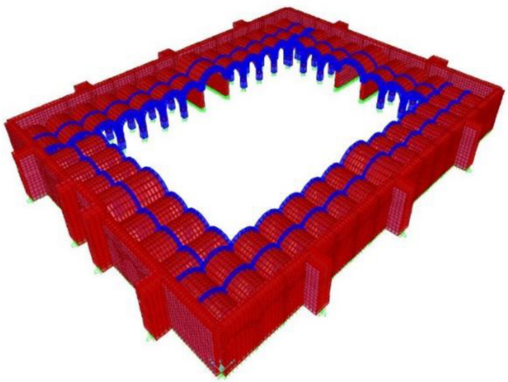

Figure 12. The finite elements model of the structure(İlkiand Demir,2017)

Table 1. The Analysis Of Tensions Occurring On Walls Due To Surfaces Within Walls

Wall	Maximum Compression Stress Level (MPa)	Maximum Shear Stress Level (MPa)	Compression Strength of Wall (MPa)	Shear Strength (MPa)
Southwest façade	0.25	0.20	1.12	0.20
Entrance iwan	0.60	0.30	1.12	0.34
Northwest façade	0.25	0.15	1.12	0.20
Northwest iwan	0.20	0.17	1.12	0.18
Northeast façade	0.25	0.18	1.12	0.20
Northeast iwan	0.25	0.20	1.12	0.20
Southeast façade	0.27	0.18	1.12	0.21
Southeast iwan	0.60	0.20	1.12	0.34

Reference:İlki and Demir, 2017

[3]We are indebted to Prof. Dr. Alper İLKİ and Dr. Cem DEMİR (İstanbul Technical University Faculty of Construction) for the studies of Static Report.

The stress levels resulting from the loads acting on the vertical bearing walls of the exterior walls and iwans are summarized in Table 1 for different stress types. While summarizing the stress levels, the stress types (compression, tensile, shear stresses) and stress directions (vertical, horizontal) that occur in the elements are taken into consideration. The building has been excluded from the current earthquake regulations as it has a historical nature. However, the 2017 Draft Earthquake Code was taken into account for reference values. The highest calculated value was taken into account in the stresses in the structural elements.

Through the analysis of tensions, it is concluded that the sections of the structural elements (walls, vaults, piers, arches, cisterns) previewed by the restoration project are sufficient.

Although deteriorations are detected in its structural elements, the fact that the sections of these elements are sufficient exhibits that there is no significant problem concerning the original structure and statics of the building. In this case, it becomes necessary to focus on travertine, which is the construction material, by considering the deteriorations of stone.

3.3. Material Analysis

As the third stage the material analyses of the building were made. Sample rubble stones were obtained from an arch and a vault. A sample of cut-stone is also obtained from an arch. Mineralogical, petrographic and chemical analyses of these stone samples were conducted. The definition of the outer appearance of stone has been made through macro analysis while detailed analysis of the mineral composition and texture is realized through polarizing microscope. The sections of samples were indicated on the plan of Evdir Han (See Figure 14).

According to the data of material analysis grey-green colored layers have been formed due to the deteriorations on the outer surface of the rubble stone sample. The inner surface of stone is yellow-beige. The sample of travertine is very porous and has a spongy texture. The cut-stone sample is a travertine piece which is also yellow-beige, banded and its voids are enlarged on the vertical direction (See Figure 15).

The rubble stone sample is generally transformed into cement through cement, and it is observed that it has some micritic sections. There is abundant amount of peloyit within sparitic cement. In addition, there are many large and small cavities together with sypherulitic calcite crystals. At the image A belonging to rubble stone, the representations are as follows: p: peloyit, k:

sparicalcite cement, b: cavity (double nikol); at the image B, s: sypherulitic calcite crystals (single nikol) (See Figure 16).

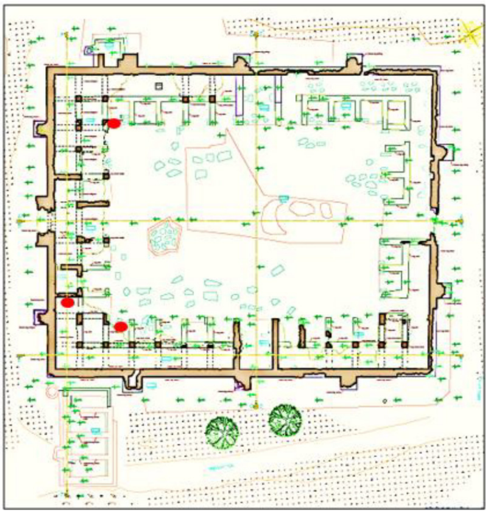

Figure 14. The sections of the stone samples indicated on the plan of Evdir Han (AUFA Archive, 2016)

Figure 15. General view of the rubble stone and cut stone samples (AUFA Archive, 2016)

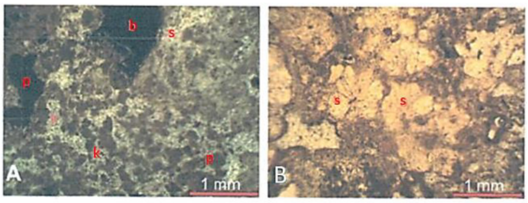

Figure 16. The images of rubble stone through polarizing microscope (AUFA Archive, 2016)

The cut-stone sample is also cemented by sparicalcite cement. There is abundant amount of peloyit inside the sparicalcite cement. There are micritic sections and secondary calcite formations due to recrystallization. The sections which were not recrystallized remained as cavities. Stone has a banded structure. Structures and fossils are observed as a result of microbially induced precipitation. At the image A belonging to cut-stone, representations are as follows: r: recrystallized calcit, b: cavity; the image B peloyids; the image C structures due to organisms; the image D f: fossil, r: recrystallization, b: cavity findings. Besides, all of the findings are double nicole (See Figure 17).

After the material analysis, it is understood the material of Evdir Han is travertine stone. Historical buildings are generally constructed by stone

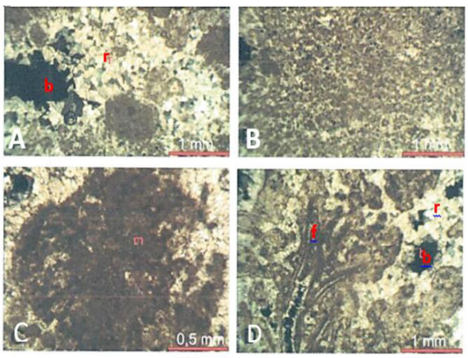

Figure 17. The images of cut stone through polarizing microscope (AUFA Archive, 2016)

Table 2. TS 11143 Standards and required values of travertine

Physical and Physico-Mechanical Properties	Travertine (Turkish Standards- 11143)	
Water absorption by weight (%) max	< 3	
Density (gr/cm^3)min	≥ 2,3	
CompressionStrength (kgf/cm^2)min	as structural material	≥ 480
	as cladding stone	≥ 300
Frost Resistance (%) max	as structural material	≤ 5
	as cladding stone	≤ 5
Abrassion Strength (cm^3/cm^2) max	as structural material	≤ 15
	as cladding stone	≤ 20
İmpact Strength (kg.cm/cm^3)	as structural material	≥ 6
	as cladding stone	≥ 4

Reference: Güneri, 2009, sa: 44 and Kılıç, 2017, sa: 10

Table 3. The results of the laboratory analyses of the Antalya travertines

Travertine Type	Water Absorptionby Weight (%)	Density(gr/cm³)	CompressionStrength (kgf/cm²)	Frost Resistance(%)	Abrassion Strength(cm³/cm²)	İmpactStrength(kg. cm/cm³)
Plant Textured	15,3	1,96	171	–	–	–
Spongy Textured	33,5	1,64	83	–	–	–
Massive Textured	5,66	**2,47**	214	–	–	–

Reference:İsmailov and others, 2005

Table 4. The results of the laboratory analyses of the Antalya travertines

Travertine Type	Water Absorption by Weight (%)	Density (gr/cm³)	Compression Strength (kgf/cm²)	Frost Resistance (%)	Abrassion Strength (cm³/cm²)	İmpact Strength (kg. cm/cm³)
Plant Textured	5,17	2,02	127	–	–	–
Spongy Textured	15,87	1,62	84	–	–	–
Massive Textured	2,34	2,35	223	–	–	–

Reference: Akçal, 2011

obtained from the closest quarries. It is thought that travertine of Evdir Han was quarried from the upper plate of the Döşemealtı region of Antalya (İnan, 1985). It is observed that this kind of stone had been used in many historical buildings in and around Antalya (Tayla, 2007, page: 62).

Travertine is abundant in Turkey and it is also exported. The travertine standards to be used as construction material in Turkey and abroad are determined according to the Turkish standards with TS 11143 code (See Table 2).

Travertine of Antalya is found in three main categories such as planted, spongy and massive. Laboratory tests conducted by two different researchers for these three categories are given in the tables below(See Table3 and 4).

In order to examine the use of Antalya travertine types in buildings, the results obtained from the laboratory analysis of Antalya travertine varieties were compared with the values required in TS standards.

When these values are compared, it is seen that the rate of *Water Absorption by Weight* of plant and sponge textured travertines of Antalya is much higher than TS Standards. For the massive textured travertine type, the situation is a bit complicated. While the value of the solid textured travertine was above the TS standard in the tests conducted by Ismailov and others, it was at an appropriate value in the tests of Akçal.The reason for this may be that massive travertines have different features in themselves.When stone absorbs too much water it becomes not resistant to frost and it breaks out in such cases. For this reason, before the massive travertine of Antalya is used as a building material, it is necessary to control the water absorption rate by weight.

In both analyzes, it is seen that only the values of massive textured Antalya travertines in terms of *Density* correspond to TS standards.However, the value of the plant and spongy typesare quite low. Density is directly proportional to the strength and load carrying capacity of a material. Low density value also indicates that the material has a porous structure (MEB, 2013a). Therefore, it can be said that Antalya massive type travertine can be used in the construction of the structural elements of the buildings, but other types should not be used.

When the *Compressive Strength* is examined, it is seen that all Antalya travertine types are not resistant to pressure and their values are far below the desired standards.Compression strength is an important mechanical property which determines the place of use for materials. Compressionstrength indicates the maximum vertical load bearable by the material. After the border value, the material fails (MEB, 2013a).According to the compressive strength values, all types of Antalya travertine are not resistant to vertical loads. Therefore, all types of Antalya travertine should not be used in load-bearing building elements.

In order for travertine stones to be used as a building material, TS 11143 Standard requires the values of "*Frost Resistance, Abrassion Strength and Impact Strength"* to be appropriate in addition to the above properties.The *Frost Resistance* property is an external factor that wears rocks a lot. The water that previously enters the pores of the rock, freezes by increasing its volume by ten percent when it reaches the freezing temperature.Thus, an internal pressure occurs in the rock and fragmentation begins.Especially temperature changes between -20°C and + 20°C may cause fractures depending on the physical properties of the rocks.Especially, marbles to be used outdoors are required to be resistant to frost (Arık, 2011).Abrasion, occurring on friction surfacesdefined as material loss. The material is partially or completely destroyed and becomes slippery. Abrasion is generally caused by living creatures and machines.It occurs on the roads and floors used.Sometimes it may cause corrosion in atmospheric and environmental factors.*Abrasion Strength* is a property that allows a material to withstand wear.Particular attention should be paid to the abrasion resistance of travertines to be used in ground and road pavements (Assoc. Prof Dr Metin Olgun Lecture Notes). The abrasion strength is directly proportional to the hardness of the stones. It is an important feature in determining the type of stone according to the place of use. It is possible to use stones with high abrasion strength as a load-bearing building element and floor covering (MEB, 2013a). *Impact Strength* is the ability of a material to absorb impact energy while resisting cracking or breaking.At the same time, it is defined as the resistance of the material under repeated dynamic loads acting suddenly.If the impact strength of the material is poor, cracks occur in the material at the moment of impact.In order for the buildings to have a long life, the impact strength of the material used is required to be high (Oltulu and Altun, 2018).

It is a very important deficiency that freeze, abrasion and impact strength tests have not been carried out in studies on Antalya travertines. In order to more accurately determine the places where Antalya travertines will be used in buildings, these three strength tests of all three types of travertine stones should be performed.

After the comparison of TS standards and the physical - mechanical properties of the Antalya travertine samples, it is found out that massive type of travertine can be used for interior space as a cladding material. The low value of compressive strength shows that it is not correct to use massive travertine in carrier elements.Freezing, abrasion and impact tests should be done to decide whether it can be used as a structure and outdoor material.

It is seen that the mass water absorption, unit volume weight and pressure values of plant and sponge-textured travertines are far from the standards.For this reason, it is a more correct approach to use plant and sponge textured travertines as cement and lime raw material and decoration material in productions that will not be exposed to carrier and external factors.

3.4. Ecological Analysis

Stone has frequently been chosen as a construction material due to its abundance in nature, its firmness, strength, long endurance, capacity to be shaped, strength against climatic conditions, natural insulation capacity etc. Besides, stone is an ecological material since it is obtained directly from nature, it can be recycled, it can be repaired and it leaves no poisonous wastes to nature. It has a good ecological performance in terms of embodied energy and embodied carbon. It is possible to preserve and hand down historical buildings constructed with stone if their maintenance and restoration are completed in the correct phase, and this is one of the most important objectives of sustainable architecture (Khatip, 2016).

Travertine is an ecological material because it is abundant in many regions of the globe, the transfer from quarries are short distanced and cheap, it is processed easily, it has natural insulation capacity, it can be reused in new buildings and etc. It can be accepted that Antalya travertine is also an ecological material because it also conforms to the abovementioned qualities and standards.

On the other hand, dust arising from the activities of the quarries has negative effects on human beings and flora. These air polluters are causes for damage to flora and agricultural land. Waste materials caused by quarries have harmful effects on flora, soil properties, water resources, agricultural lands and habitats of different organisms. In order to prevent such harmful effects, quarries should be placed on rocky territories without forests, in other words, they should be far from human settlements, forests, water resources.

4. CONCLUSIONS

Since the ancient ages, travertine has been used as a construction material. It has been used both in the manufacture of structural elements and as cladding materials in the historical buildings. However, today it is generally used as a cladding material. The most important reason is that reinforced concrete and other contemporary structural systems are preferred instead of traditional masonry structures. However its use in restoration implementations is inevitable since it has been the original structural material of many historical buildings.

However, while using travertine during restorations, implementers should be aware of its advantages and disadvantages in terms of deterioration and static properties, material and ecological qualities, and necessary precautions should be taken in case of disadvantages. It should be taken into consideration that, as in the case study of Evdir Han, the properties of travertine may change according to different regions. As it is seen in this case study, different travertine types within the same region may have quite different characteristics effecting their use as construction material. Every difference effects the physical, chemical and mechanical properties of stone. For this reason, detailed deterioration – static and ecological analyses should be completed before the use of travertine in buildings.

For instance, the analyses undertaken within the scope of this study have unfolded that the massive types of Antalya travertine can be used as cladding elements in interior spaces, whereas it is revealed that it is an incorrect approach to use plant and spongy type of Antalya travertine as structural and cladding material.

As it is observed in the case study of Evdir Han, due to temporal, structural and environmental factors, significant levels of structural problems may arise in the context of historical buildings which are totally built up of travertine. This condition makes it necessary to question the literature which qualifies travertine as resistant, stiff and able to bear loads. Another important point is that several plants or even trees may develop within the travertine masonry and these plants and trees cause considerable cracks on the walls. This is another important disadvantage of travertine buildings. Important abrassion problems have been observed in the travertine of Evdir Han, however abrassionstrength analyses could not be made within the scope of this study.

Precautions should be taken before using travertine because it is amaterial which may have static problems, erodible and plants may grow within it. Since the interventions should not conceal the original structure during the implementations of restoration, these precautions should be developed in laboratories as transparent jells or other materials which do not have dominant colours or dimensions.

On the other hand, the harmful environmental effects of the recently established quarries are widely known. In this respect, the dimensions of ecological loss / gain for humanity and environment should be considered carefully. Therefore, restricting the use of travertine in new buildings and confining its use in the restoration of historical buildings may be a correct approach.

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chapter 4

THE ANALYZING OF ARCHITECTURAL ORNAMENTS ON HISTORICAL ANTAKYA HOUSES, PAVILION DESIGN AS AN EXAMPLE OF THE RE-ORNAMENTATION*

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1. INTRODUCTION

More than a complex architectural element, an in-depth study, re-emergence, a social, cultural, and economic study of ornamentation will be discussed. Contrary to traditional understandings, ornamentation in contemporary architecture is loaded with new directions as it expands in the trivial realm of virtual reality through digital media. The ornamentation acts as a bridge connecting the building with the environment, connecting people with history and culture.

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Antakya, which has hosted many civilizations and cultures throughout history, has a long history. It has undergone big changes, yet continues to exist. The study aims to examine the ornamentation programs, which are one of the characteristics architectural features of historical Antakya houses to examine the ornamentation details, especially on stone as a result of this examination, and to discuss how a design idea can be put forward with a re-ornamental approach. To create a conceptual design pavilion in the light of the researches, and data available by examining the ornamentation programs of the traditional houses in Antakya. Accordingly, the residence to be examined in detail is the Fehim Pasha House. The aim is to shape the project design phases over the ornamentation detail selected by examining various ornamentation elements in the historical house.

To reach an artistic value, social pleasures and wishes, ornamentation was applied to the architectural product. Throughout the history of architecture, ornamentation has been applied as elements that embody emotions with aesthetic pursuits within the scope of the possibilities and techniques of the period, and it has been defined with its ornamental features (Aydın, 2009:5).

It can be said that since the beginning of the twenty-first century, ornamentation has strongly announced its return to the architectural scene (Picon, 2013:13). As a result of the return and a re-agenda of ornamentation in contemporary architecture, many architectural exhibitions on the subject were held in the last decade, special issues of magazines were published, and courses were opened at universities (Balık & Allmer, 2016:158). Even though the Vitruvian decor has ended in contemporary architectural practice, the ornament has never disappeared completely. In the last decade, ornamentation has re-emerged in a significant way (Picon, 2013:14). An ornament, as an ornamental item, is often described as an additive to decorate a superior, functional object (Bais, 2016:23). There can be a wide range of ornamentation from architectural details to urban texture. Digital, structural, symbolic aspects of contemporary architecture create an environment of an impression and an expression figuratively in ornamentation.

Traditional architecture and ornamentation depend on a combination of a lifestyle, religious beliefs, local climatic conditions, and availability of materials. Therefore, traditional buildings depend on the relationship between people and their environment, materials, ecological, social, and economic factors. Traditional architecture can also be differentiated according to the availability and type of materials in a particular region, local needs, items that reflect a local tradition or a culture. Building ornamentation has been done since people started quoting religious books using certain patterns, symbols, geometric shapes, and alphabets on the surfaces of architectural elements and other objects. These symbols and shapes were then used as the identity of people living in a particular environment, and as time went on, people began to make some changes in the ornamentation due to certain factors such as the change of existing materials, an international influence, cultural changes, and the advancement of technology. Although they look similar in some cases, the patterns can describe many cultures and regions by their physical characteristics.

Other influential factors include the materials used for ornamentation, tools used to create the forms, the patterns, and the method used for ornamentation. Geometric shapes and different colours have been added to the historical purposes of the ornamentation to make it look more attractive to the eye and give meaning to the ornamented object or architectural elements. The border between patterns and ornaments is blurred. Ornaments are a subset of patterns.

Local, contextual, and symbolic, it was losing its importance due to the standardization of details in architecture and globalization.

Unlike traditional concepts, ornamentation in contemporary architecture is loaded with new directions. It uses technology as a tool.

Using technology as a tool becomes a rationale for experimenting with an ornament, a form, a structure, and a surface in contemporary architecture.

A critical evaluation of the practice of art can contribute to opening new perspectives on ornamentation work. With the efficiency and technological advances of machines, and mass production, standardization has found its role in architecture (Bergeijk, 2014:151).

With the advancement of technology, the transition to mass production and the increase in machine usage, a simplicity in production, designers was able to create various designs more easily by moving from the point they wanted. So much so that if we simply examine today's pavilion designs, we can see that it is in its new form, in a front of a pavilion, on a completely different scale from traditional ornamentation details. Or how to use geometric forms by using parametric architecture will immediately catch our attention. The pavilion is a flexible architectural space that can be designed temporarily or permanently in functional and design meanings, can change its form or a function, inviting people to enter and spend time. Undoubtedly, simplicity and technological advances play an important role in our ability to create spaces that can accommodate such diverse structures.

The buildings can be viewed from different scales and distances as well as from different points of view, which reveals different decorative dimensions. The contemporary application of ornamentation proposes new directions such as structural ornamentation and digital ornamentation as it reinterprets normal practices of representing a culture, a function, a brand power and a context (Balık ve Allmer, 2016:167).

The city of Antakya, which has an extraordinarily rich and long history, is one of the settlements that have a cosmopolitan building culture as a result of various civilizations that dominate it and preserves its cultural heritage to a great extent. Today Antakya is the central district of Hatay province in southern Turkey. The city of Antakya, which has made a name for itself with its ancient mosaics, gained a different quality with the characteristic stonework, handwork, interior spaces, and woodwork examples on the facades of houses during the Ottoman period. Its cultural wealth has greatly affected art.

The city of Antakya, which is especially famous for its mosaics, is rich in culture, and art due to the stone workmanship that was a characteristic aspect of the houses in the Ottoman period.

There are examples of woodworking in the interiors and handcrafted ornamentation in the rooms (Tekin, 2011:19).

With this study, the ornamentation programs of Old Antakya houses were examined, and it was aimed to explain how they can be made functional in a new form for the city by drawing attention to the architectural ornamentation values.

The issue of how to design with lighter materials with a new material other than traditional materials is also emphasized based on locally used materials.

By revealing the transformation from traditional to contemporary in Antakya architecture, different ornamentation designed on the surfaces of the architectural elements of the buildings will be examined. A conceptual design pavilion will be created in the light of research and data obtained by examining the ornamentation programs of traditional houses in Antakya. Basing the building design in a tradition and giving a reference to it. Ultimately, the contemporary reinterpretation of a tradition will be a creative extension that brings it into the present through inspiration rather than a copy. It aims to create an aesthetically and functionally attractive space by creating an unforgettable cultural ideogram and try to use the design in a purely architectural dimension. Writing an endless story.

2. FINDINGS / DISCUSSION

The art of ornamentation, which has been linked to architecture since ancient times or can be handled independently, has provided many civilizations with the opportunity to introduce and express themselves. The ornament can be expressed in three dimensions as a two-dimensional art, obtained by using colours or carving surfaces using geometric shapes. There are some differences in architectural and architectural ornamentation according to the periods. It can be said that these differences stem from the material, cultural structure and economic situation of the region and the period. We can say that the architecture of Antakya consists of the common influence of the Ottoman period and Northern Syrian architecture. It is understood from the motifs that the ornamentation on the houses belong to the Ottoman period and continued with the effect of the Anatolian Seljuk period ornament program. This study aims to find answers to the questions asked about the transition of ornamentation from traditional to contemporary examples, and an innovative ornamentation approach. To examine the spaces suitable for contemporary architecture and to design a space suitable for the city of Antakya by using the opportunities brought by technology.

- What changes have been made between traditional and contemporary architectural ornamentation?
- What is a re-ornamentation, how can it be applied?
- If we have succeeded in making the ornament a reflection of our modern culture, can we consider bringing its role in a design to a different point?

In the study, where we want to see our future point with questions, we investigate and present how to design and analyze traditional ornamentation, and today's usage features according to the principles determined, from traditional architecture to contemporary architecture, based on the stonework of one of the dovecotes on the interior of the Fehim Pasha House one of the traditional Antakya houses.

The study assumes that architectural ornamentation acts as a bridge between the ages, that architectural ornamentation is not a crime, has a different meaning regarding a material, a cultural structure, and economic conditions, and is a manageable phenomenon. The ornament has become an art that speaks without the need for words while describing the periods it came and went through.

It was prepared based on the hypothesis that it is a flexible entity even if it is dressed in hard materials and that it can exist with a different richness without losing anything regarding the form, a material, and a displacement it is used.

The design project will be provided to take a shape without breaking the traditional shell line with contemporary architecture. An important architectural detail of Antakya houses will be created by depicting the inspired and ornamentation detail and motifs by emphasizing the stone ornaments on the dovecotes. It is based the form and ornamentation of the building on the tradition and refers to it, ultimately bringing it into the present as a creative extension through a contemporary reinterpretation of a tradition and an inspiration rather than a copy.

The method of the study consists of certification, analysis and evaluation processes. The development of the ornament is briefly explained. Information is given about ornamentation art related to architecture. Different techniques were used for this research analysis. Studies on history, traditional residential architecture, architectural ornamentation programs in general and in specific studies area; Existing literature such as journals, books, articles, and thesis studies were reviewed. The digital design process has begun by scanning the literature on the re-ornamentation approach, examining, and researching existing projects and making sketches for the new design and developing the design.

The design project was created by making 3D modelling a technical analysis and preparing a visual presentation.

For the designed architectural structure, AutoCAD 2020 and Fusion 360 3D CAD / CAM software was used in dimensions determined as a result of research and sketches.

In the literature research, the ornamental arts, and architectural ornamentation, the ornamentation programs in the historical process, its development, its position, and a place in the contemporary period have been examined. The re-ornamentation in architecture and architecture. The study was created considering verbal and written information.

3. HISTORICAL DEVELOPMENT, LOCATION, GEOGRAPHICAL FEATURES OF ANTAKYA

3.1. About the Region

It is known that products of a civilization reflect not only the image of the age they are in but the link between the pasts, and the future.

On the other hand, it also causes a displacement of human populations as a result of important events in history. They are civilization products that they produce to carry the subjective creative aspect of the product, not its object. In settled communities, the subjective side of this communication is established by successive generations.

The products of civilization do not appear by an accident but under certain conditions. These conditions either separate them or make them similar. Separates a Roman and an Egyptian is a country in which they live. It is labour that enables the production of civilization to mature and take a successful shape.

While examining the situation in the houses of the region, the ornamentation products, which are among the first art products, should evaluate the human resources and physical characteristics of the region as effective elements.

The first inhabitants of Antakya were a heterogeneous community of indigenous Syrians, Macedonians, Athenians, Cretans, Cypriots, Antigonia of the former residents, Argentines and Heraclitus, Jews, and retired soldiers. Antakya was both a trade and an entertainment city (Demir, 2016:16).

A period in the history of Antakya, which had an important place on the eastern border of the empire, ended with the beginning of the Arab invasions, which were known as the Eastern Queen, during the Roman Empire. Besides the Roman and Byzantine cultures, a new era has been created that will lead to the formation of the character of today's Islamic city, which is formed by blending the local features kneaded with Christianity with Islamic civilization.

It came under Ottoman rule in 1515. With the administrative regulations created after this date, it became a sanjak under the "State of Aleppo". The state of the city in the Ottoman Empire continued as a district until 1918.

With the Ankara, Treaty signed in 1921, and administrative autonomy was achieved, and after this date, it was occupied by the British and then by the French. Its existence continued as an independent "Hatay State" in 1937. In 1939, the independent, Hatay State Assembly, led by Tayfur Sökmen joined Turkey (Özdemir, 1994:120).

When the characteristic urban character of antiquity is examined, we see that the grid plans of cities are based on an introverted center, unlike modern cities. As a result of the changes that have taken a place over the centuries, the robust and symmetrical order has been disrupted, and a more complex and organic network has created a residential texture unique to Islamic cities (Yoldaş, 2014:50).

The Antakya settlement continues to exist today, and there are settlements where traces of the past can be seen, from the names of neighbourhoods and villages to the streets.

As for the city, which has been the subject of many travel books over time, in general; Since the cut stones used in the houses are of incredibly good workmanship, the houses have low floors, and the exterior appearance is neglected, but the interiors are very ornate and richly ornamented. The Asi River, the mansions around the river, and the walls surrounding the mountains are unique to the city, as they create a mysterious and powerful image. As a symbol of cultural wealth, it is often stated that everyone in the city lives together with peace and respect (Demir, 2016:302).

There is climate, land conditions, customs, and traditions, lifestyle and similar factors affecting housing construction in every region. Since Antakya has been under Syrian control, and French occupation for many years, it is seen that they are influenced by the cultures of these countries in their home typologies, materials, ornamentation, belongings, and social lives. Traditional Turkish and Syrian houses are similar in terms of housing shape. For this reason, it can be said that Antakya houses were formed as a result of the synthesis of these two cultures. The difference in status, such as the aristocratic class, artisans, and notables, which has been ongoing since ancient times, can also be seen in residential architecture and ornamentation programs. There are elegant, beautiful ornaments on wood, made by carving, painting, or joining. It enhances the appearance of the room and strengthens the effect of large houses and mansions belonging to the wealthy of Antakya, such as ceilings and closets, and wooden coatings.

As it was an important center in the past, it has hosted many civilizations and has shown continuity throughout its history. Antakya, with its cultural texture, historical, archaeological, and gastronomic features, is beyond being a mosaic city, it is a mixed city.

Another reason is probably the traces of people belonging to different cultures and religions in the city from past to present.

Antakya, a city of trade and entertainment since the past, welcomes many visitors with the liveliness of these cosmopolitan markets. Today, the traces that make up the cultural heritage of the city make themselves felt. Its historical, and cultural richness, its extreme food diversity depends on the city's functioning as a crossroads on the roads to the Middle East.

3.2. The physical Feature of the Region

Located at the eastern end of the Mediterranean climate zone, 22 km from the seaside, the city is approximately 80 m above sea level. It is between the Amanos Mountains in the north, and the Kel Mountain in the south, at the beginning of the Lower Asi Valley, in the northeast of Kel Mountain, on the slope of Habib Neccar Mountain at an altitude of 440 km.

Until recently, there was a lake known as Amik Lake in the Amik Plain, which is fed by Karasu and Afrin Stream, especially the Asi River. However, together with the lake, which is 16 km wide and 10 km long, and the swamps around the lake, the lake disappeared after a 310 km² part of the land dried up. The highly fertile soils obtained by the drying process that started in 1955 and completed in 1980, by the State Hydraulic Works were distributed to farmers and opened to agriculture (Demir, 2016:18).

The city of Antakya is located between the Asi River that divides the city of Antakya into two and the Habib Neccar mountain. Asi River is a geographical element that adds an identity to the historical texture. It served as a border separating the historical texture from the newly built area of Antakya.

Although Antakya is completely located in the geographical and climate zone of the Mediterranean region, its houses show a separate plan and a structure from the characteristic housing types of this region. It is possible to examine the houses of the Mediterranean region in a common plan. Two-storey houses, mostly made of stone, and the mudbrick, face south and west. There are almost no houses without a courtyard. The buildings are two floors, the halls are on the second floor. The lower floor serves as a warehouse and a cellar. The houses are covered with wooden roofs and tiles. The houses contain the plan of the houses with courtyards typical of Northern Syria and Anatolian Turkish houses together.

In ancient Antakya, the determining factors in the architectural character are that the houses have a planning scheme and some architectural features developed around a courtyard, the sense of privacy in the introverted lifestyle, the minimum relationship with the street and not perceived from the outside (Demir, 2016:311).

The architectural structure of the region has been on the same plane since Antiquity. The materials used reveal the character of the region. All kinds of traditional structures are mentioned in terms of ornamental motifs.

Ancient Antakya houses are typical examples of Roman Age house, a development of the Ancient Greek dwelling plan scheme and bearing its influence. This scheme carries an architectural expression that is closed to the outside but is generally introverted, where spaces take light and air from a space within the plan.

3.3. Traditional Antakya Houses Features

The houses are arranged in clusters along the streets, with common walls for defence, without leaving any space outside the street. All the independent houses have gardens. The facade in the form of a deaf courtyard wall towards the street is designed to hide the life inside. The only space on this wall is the arched door.

The courtyard, where most of the daily life passes, is accessed by a stone-paved door opening from the street. All similar houses have a courtyard layout and are shaded with citrus fruits to dampen the heat. The rooms are located on one, two or three sides of the courtyard and the doors open to the courtyard through arched windows and doors.

The small window chain above the main windows is unique examples of stonework. Additionally, the original form and ornate fountains placed between windows and doors are beautiful examples of stone carving art. The common building material of the houses in stone. There is a stone base on the courtyard floor. The upper floor is a mixture of wood and stone. The walls of the rooms are covered with built-in wardrobes, weights, and shelves that meet various requirements. These are good examples of woodworking. There are also houses with oil paintings. The part of the city where the old buildings are located preserves the architectural texture of the region, which is formed by the interaction of the Ottoman-Arab style, narrow streets, and stone pavement, the canal in the middle, houses, trees, and a lifestyle. The part of the new city which expands with the growth consists of buildings suitable for modern life and technology.

The most valuable rooms in terms of size and ornamentation are usually on the courtyard floor.

Houses with distinctive features in the old residential texture of Antakya is similar structures built in the same architectural style in terms of plan organizations and architectural elements (Demir, 2016:313).

In Antakya, windows are called 'taka'. In the windows with arched tops, two-winged window frames opening to the wall thickness is located on the courtyard side of the cavity. One or more of the spaces between the windows have grooves inside the stone wall structure, often referred to as the lantern space, to illuminate the courtyard.

Some rooms have a much smaller second window area in their windows.

These places, known as skylights in Turkish houses architecture, are called a dovecote in Antakya. The courtyard fronts on the dovecotes protected by plain glasswork and the covers on the room side are ornamented with rose carvings, each carved with different motifs (Demir, 2016:324).

There are elegant and beautiful ornaments made with craftsmanship and a traditional painting, carving or joints on wood in parts such as ceilings and cabinets, which are generally found in large houses and mansions of Antakya, which enriches the appearance of the room and strengthen its effect. The ottomans surrounding the room and the shelves that follow the upper floor of the windows are fixed elements that complement the room's architecture and ornamentation.

In the old Antakya houses, the ceilings of the rooms are high, these ceilings are obtained by plastering the laths that are frequently nailed on the laths or by laying the wooden boards of the lower surface in two-storey houses.

4. ORNAMENTS AND ORNAMENTATION PROGRAMS IN ANTAKYA

4.1. About Architectural Ornamentation

In architecture, ornamentation is used to create a more attractive part of the building, or an object by adding decorative details or features. The ornament is often carved from stone, wood, or precious metals, created with plaster or clay, or painted or printed on a surface as a pattern. In the historical process, aesthetics, ornamentation, a distinction, a symbolization, enrichment aesthetics emerged in a dimension identified with concepts and applied to the nature of the building to determine authenticity.

4.2. Etymological Definition of Ornament

The ornament is ultimately explained with different definitions that have the same meanings. Namely;

It is the word derived from "an ornament" in Old French and "Ornamnetum" in Latin (Online Etymology Dictionary, 2020: www.etymonline.com).

It is defined in English dictionaries as a useful accessory that gives elegance or beauty (Merriam Webster, 2020: merriam-webster.com).

It is something that is used or serves to make something look more attractive, often without a practical purpose (Oxford English Dictionary, 2020: www.oxfordlearnersdictionaries.com).

The act, a process, a technique, or art of ornamentation; is something used temporarily to celebrate a particularly special day or to mark a special day (American Heritage Dictionary, 2020: ahdictionary.com).

4.3. Definition of Ornament

It is to ornament the basic elements of the building with two- and three-dimensional shapes, patterns, and colours that their functions do not require, sometimes even to some extent.

It is an art created by the combination of ornamental motifs in a search of a certain form (Kuban, 2007:207).

The art of ornamentation has changed according to civilizations and ages and has become a form of introducing and expressing the personality of civilizations over time.

Ornament as an ornamental element is often described as an additive to an ornament a superior and functional object. Ornaments are the main sources of human visual cultures; hence, it is related to individual identity, and hence the identity of the community (McNicholas, 2006:5).

The ornament shows the historical, and cultural values of the society in a certain period of your time. It goes from an architectural communication to provides the identity of the building, and thus the whole community through an organized expression process (Bothireddy, 2007:5).

In architecture, ornamentation is used to create a more attractive part of the building or object by adding decorative details or features.

Since ornamentation is a process of adding elements to a work of art to reinforce its aesthetic features, and thus the depth and clarity of its symbolic results, it is used by every culture as an integral part of the artwork (Mitrache, 2012:567).

Ornament is produced by various individuals, architects, artists, and craftsmen.

In Egyptian art, ornamentation, which has a religious purpose in general, was replaced by the outward-looking tradition of architecture and ornamentation in the hands of the Mesopotamian people, who led an earthly lifestyle. The art of ornamentation, which developed greatly in the Greek, Roman, and Byzantine periods, enabled civilizations to express themselves with different architectural styles and forms in many parts of Europe in the Middle Ages.

Although influences from Antiquity, Sassanian and Central Asian art are seen in Islamic architecture and ornamentation, architecture, and ornamentation have found their style over time.

Throughout the history of architecture, ornamentation has been applied as elements that embody emotions through aesthetic pursuits within the scope of the possibilities, and techniques of the period. Period materials such as stone, brick, tile, ceramics, and glass were used for ornamentation, and ornamentation was obtained with the natural colour and structure characteristics of the material and the arrangements obtained by closing it later (Aydın, 2009:1).

4.4. Types of Ornaments

Depending on the architecture, ornamentation is seen in different ways. The ornament obtained using different materials.

For example, ornamentation can be provided while making walls with different colours, and patterns of building products such as stone, and brick. Another one is the ornaments made on the facade of the building later. Covering wall faces with different materials, a shaped plaster, wood, etc. Trying to beautify with is an example of the type that depends on the architecture and is made later.

In the mid-20th century, an ornamentation idea was formulated, called the structural ornaments inherent in the structure's function or materials. It is the ornamentation in architecture that must be derived directly from a function of the nature of the structures and used materials. Different understandings emerged from both the content and the formal structure of the ornaments; It is mostly based on religious-philosophical, symbolic, political thought and a worldview. Also, the notion that the shapes suggested for ornamentation has a certain value in various settings are often added (Mülayim, 2002:221).

Especially in geometric ornaments, the dialectic of the material in nature, the original structure of the material and the (functionalist) views based on the techniques (Mülayim) are determined.

Architectural ornamentation is also highly dependent on the building's building materials. Ornaments are created within the material in the processes of carving, inlaying, and chipping. Stone and wood are suitable materials. Thanks to the design, the structure of the material is delivered to different forms by various methods. Thus, the material becomes ornamented with a plastic effect.

In the prehistoric ornamental forms, the first objects that ornamentation appear are pottery (Ünsal, 1973: 229).

With the emergence of more advanced civilizations, ornaments based on natural beings or abstract geometric forms are seen in ancient Egypt, Mesopotamia, and the Mediterranean civilizations.

Some ornaments have the feature of being used both in a certain historical period and in certain parts of the building.

In Mesopotamian art, herbal, themed ornaments, lotus flower and opened daisy friezes are made of buttons and flowers with composite tiles and used for flooring. Another factor that affects architectural ornaments is the intellectual environment. They can find their forms in beliefs and objects ranging from polytheistic religions to Islam.

Architectural ornamentation finds an environment within the dimensions of the building, human and an existence. So, in general terms, such as the availability of the material used from the environment, the processing and usage possibilities of the material, the current world view in the social environment, the effect of the pre-civilization periods on the environment, the psychological and social structure of people.

4.5. History of Architectural Ornamentation

The abstract values that form the spirit of the space, such as the monuments that make up the memory of humanity, civil architectural structures, the rituals performed in these buildings and spaces, and special traditional productions, are the common starting point in shaping the future of societies. Ornament also plays an important role in showing the historical, and cultural values of a society. As a way of architectural communication, ornamentation provides an identity to the individual and therefore to society. The ornamentation shows the social status, talks about the differences between the people, and the class he belongs to. Additionally, to reveal the class difference, they also refer to the sectarian differences of multi-religious sects (Massey, 2013: 497).

Ancient Egyptian culture is probably the first to add pure ornamentation to its buildings. Ornamentation takes the shapes of the natural world in that climate, ornamenting the capitals of columns and walls with paintings of papyrus and palm trees. (Riegl, 1992: 218).

4.6. Ornaments and Samples in Old Antakya Houses

The main source of architectural ornamentation during the National Architecture period was the 15th and 16th century Ottoman architecture. It has been used to create a visual effect from traditional Ottoman architecture and surface ornamentation elements. Architectural ornamentation was used as the main tool in creating national consciousness and building elements were used for ornamentation purposes. In this period, the exterior facades were ornamented with tile and stone ornaments. Arch circles are areas where ornamental elements are widely used. Ornamentation in local architecture can be evaluated under the relations or creations of Central Asian, Ancient Anatolia, Roman, Byzantine, Seljuk and Ottoman civilizations (Tekin, 2000: 38).

The architecture of Antakya consists of the common influence of the Ottoman period and Northern Syrian architecture. It is understood from the motifs that the ornamentation on the houses belong to the Ottoman period and continued with the effect of the Anatolian Seljuk a period ornamentation program. The mastery of its ornaments in the structural use of the material also applies to its detailed application.

The better the material is used in the building, the better, plain, clean, and expressive the ornamentation will be.

4.7. Antakya Houses Ornamentation Features

A few houses from the 17th, 18th, and 19th centuries have survived. On the facades of the houses facing the courtyard, there are geometric ornaments (star, wheel of fortune, triangle, diamond) and floral motifs (palmette, Rumi, cloverleaf, curved branch) and animal depictions (bird and lion) in stone ornaments created with relief technique. There are also inscriptions and neo-classical decorations on the cartridges.

With the interior ornamentation of the houses and the 'Head Room', with floral ornaments, hand-work and geometric ceiling ornamentation made with applique lath technique; There are also examples of wood carving. Ornamentation programs in Antakya houses started in Istanbul in the 17th century and especially in Topkapı Palace in the 18th century (Tekin, 2011: 17).

The ornamentation in Damascus and Aleppo houses can be considered as a source of inspiration for the ornamentation in Antakya houses. Stone ornaments in Antakya houses are also found in Mardin and Urfa houses where Artuklu architecture reflects the Syrian tradition, and especially in rosettes and palmettes. The architectural presentations in the landscape surrounded by the trees seen in the pictures on the walls of Damascus houses, a small hive steamer, 3-4-5 eyed, triangular Ottoman bridges are also seen in the murals in Mustafa Kuseyri.

The handcrafted ornamentation in Antakya houses is like the motifs, and styles found in historical houses in Istanbul, Damascus, Aleppo, and Anatolian cities.

4.8. Ornement Motifs

Some motifs of the ornamentation are vegetal, geometric, and zoomorphic.

- Vegetal motifs consist of a flower, a leaf and fruit patterns. Examples are water lily, a papyrus, and palm leaves.
- Geometric motifs are the formation of abstract shapes that contain every shape from a point to a polygon.
- Zoomorphic motifs consist of abstract and tangible animal and human figures.

These motifs can be used in different combinations.

Motifs are present by default and can be found in structures intentionally or unintentionally. They can be seen as an experience by giving indications and sending messages to help users experience the architectural enclosure. This is the result of using modules or grids in the design.

Patterns are any item that is repeated in a specific order or a hierarchy. It can be expressed as an ornament or a functional element.

They describe many cultures and regions, although sometimes similar. It has taken various forms, shapes, and functions aesthetically or structurally.

The ornamental details used in traditional architecture can be seen on a certain surface and sometimes in the whole building. The use of ornamentation in contemporary architecture continued to be used in almost the same way, by changing the function, texture and material. Further explanations of the motifs that constitute the inspirational detail of our project, which was designed with innovative approaches from the Seljuk period to the present, will be given below.

5. RE-ORNAMENTATION

5.1. Re-ornamentation in Architecture

Historically speaking, the relationship between architecture and an ornament has taken quite an interesting course. It was revealed sometimes in the form of a mere expression and sometimes as a show of power. During its course of development, the concept of ornamentation has evolved from cave carvings to technical perfection and a photo mounting of new constructions (Sağlam, 2013:127).

Buildings can be viewed from different scales and distances, as well as from various points of view, which makes the reveal different ornamental dimensions. The contemporary application of an ornament proposes novel aspects, like a structural ornament, and a digital ornament, the maximum amount because it reinterprets the normal applications of representing a culture, a function, a brand, a power, and a context. It can be argued, one of the primary motives of applying an ornament in contemporary architecture is to attract public attention and to present a spectacle (Pietrzak, 2011:10).

Each successive style was a refinement and a transformation of a previous architectural language. The idea of creating a spectacle was important, so, it is worth interpreting the meaning of the term, something of a striking or impressive kind, something of remarkable nature, public performance, or a display especially on a large or lavish scale.

Ornament is on the lookout for a correct place for existence among or additionally to numerous diverse inputs like the effect of surface, materials, style, technology, location, construction, and mass. Nowadays, the art of ornament is moving in diverse directions, starting with its design to its production, more conceptually and abstractly as an evolutionary product of digital technologies.

Ornament declined at the start of the 20th century because it did not fit modernism's increasingly rationalizing perspective towards the planet. Adolf Loos also explained ornament as labour-intensive and as a waste of money, as the style would change whilst pure form did not.

Although ornamentation never completely disappeared from modern history, it did change significantly within a short period as artists and architects reacted against the status quo. The early era of the modern movement was concerned with the task of presenting the truth of materiality and proving how less could be more.

Ornamentation had transformed from an explicit device into an implied one, where its physical presence became embedded into the careful choice of a material or a celebration of details and joints. Ornament is a purely visual form, and because of this, it can be judged in aesthetic terms. Peter Collins argues the validity of sensing pleasure through the image of architecture. What is peculiar to architecture comes at the next stage, as it were: it is not the experience but the enjoyment that depends on it.

Thus, someone might say that the fundamental form of an architectural enjoyment is simply pleasured in the appearance of something and that the architect's task is to construct something which is both pleasing to look at and at the same time functional. Ornament is the finishing touch.

There is a danger in allowing too many memories to linger in the present time, one must be careful to distinguish the past and a present state. It is common for us to move between these two states when conjuring a memory. This is mental time travel between reality (the present) and history (the past). While it is perfectly normal to reflect on the past or recall moments from our youth, there is a dilemma when we desire to relive our memories in the present. This schizophrenic condition does not allow us to distinguish history and reality, and when interpreted architecturally, creates a scenario in which historic and contemporary architecture must be carefully assessed (Pietzrak, 2011:11).

Managed to abstract ornamentation into a reflection of our modern culture, then we should be able to reconsider its role in a design, as something more than an extra-budgetary expense. A re-ornamentation looks at how the building's ornament and character can be adapted to modern times without creating false illusions of mere reconstructions.

The rising mentality of efficiency that machinery brought to civilization would also not coincide with the labour-intensive mastery of an ornament. With the efficiency and the technological advancements of machinery and mass production, a standardization found its role in architecture (Bergeijk, 2013:153).

Following Aristotle, the first known architect to address the issue of theory and practice were Vitruvius. In the first two remarks from the first book of his seminal work, Ten Books on Architecture, Vitruvius (1914) asserts that an architect should have general knowledge on many fields since his mission is to control and organize the works of other artists. Knowledge, in Vitruvius' terms, involves both concept and practice, as a master architect should be equipped both theoretically and practically. Practice, during this context, means the manual application of a design from a drawing, whereas theory is the ability to demonstrate and explain design principles. The notion of being competent in both theoretical and practical aspects to lead to having absolute control of the craftwork (Balık ve Allmer, 2017:2).

The vernacular, the contextual and the symbolic were losing ground due to the standardization of detail in architecture and the globalization of style. In contrast to traditional conceptions, ornament in contemporary architecture is laden with new aspects, because it expands through the immaterial realm of a computer game using the digital medium. Accordingly, the current conception of ornament in terms of scale can vary from architectural detail to urban fabric. Moreover, ornament in contemporary architecture can be applied extrinsically or intrinsically to the building, ranging from being a graphic composition to a flat image, from a relief to a three-dimensional sculptural construction.

The contemporary age is bereft of a selected style, yet it is governed by the paradigm of digital technology, which enables the planning and production of intrinsic surface effects and dynamic ornaments. Using technology as a tool, ornament in contemporary architecture becomes a justification for experimenting with form, structure, and surface.

Antoine Picon (2013) In the book Ornament, the Politics of Architecture and Subjectivity the history of ornament and elaborates its contemporary conception. The characteristics of ornament in architectural history explore the limits of ornament in contemporary architecture. Picon asserts that ornament has lost its political and subjective aspects while symbolizing the social station of the client or bearing the private marks of the architect. The contemporary emergence of ornament in parallel with the new construction and manufacturing technologies, specifically CNC milling, laser-cutting, three-dimensional printing, and robotic layering.

In the edited book Pattern: Ornament, Structure and Behavior, Andrea Gleiniger and Georg Vrachliotis analyze pattern and ornament within the age of digital technology.

Along with four other theorists, Gleiniger and Vrachliotis (2009) argue that the new ornament, which emerges using digital technology, derives from pattern and pattern formation (Balık ve Allmer, 2016:162).

Dwelling on the topics of the algorithm, behavioural pattern, neuroscientific pattern, and musical pattern, the authors investigate global expansions of ornament in the digital age.

Technologies like 3D-printing, CNC milling, 3D-milling offer the possibility of change vis-a-vis ornament in practice. Unlike standardized machine mass-produced elements, these new technologies are capable of manufacturing ‘mass-customized elements.

During the design phase, these elements can be optimized by software to be ergonomically and economically designed and, relating to Loos, hence these designs would not become a waste of material or labour in their final state.

5.2. Ornamentation in Contemporary Architecture

The resulting innovative approaches, aesthetic values, the use of ornaments, patterns, lighting, and technical similarities to improve assembly and construction performance.

Parametric figuration is perhaps the most ambitious form of architectural articulation. To be effective, it must go beyond just visual effects (Schumacher, 2009: 34).

The pattern is the back pattern, one of the main incarnations of ornamentation: patterned colours, patterned materials, and assemblies (Levit, 2008: 8).

Ornaments in contemporary architecture contribute to image and commercial marketing. The dominance of images over architecture creates an existing culture. In the age of visual communication, these ornamentations attract the attention of the public in contemporary architecture (Balık and Allmer, 2016: 167).

With the latest technologies used, we can say that there is a significant return to classical ornaments.

6. THE CASE OF ANTAKYA HOUSE, AND DESIGN PROJECT SAMPLE WITH RE-ORNAMENTATION APPROACH

6.1. The Fehim Pasha House

According to the Hijri calendar in 1255 (According to the Gregorian calendar in 1830) A typical double-decked Antakya house with a courtyard built by Fehim Pasha (Nakib, 2012:131).

This house, located at number 62 on Kurtuluş Street, and served as the Malaria War Association. The house was restored by the Governorship of Antakya and allocated to the Chamber of Architects Antakya Branch as a working place (Tekin, 2011:20).

After entering the house from the street, there are kitchens and an office on the right side, a courtyard and two rooms on the left according to the entrance direction. According to the courtyard, the living room on the right is the Head Room of the house on the left. The courtyard is paved. A smooth cut stone was used on the exterior of the walls and the rubble stone was used on the inside. On the inner surface of both rooms, wooden materials are used in cabinets, shelves, room ceilings, window shutters, and window ceilings, Rectangular and square shapes were created with a wood carving in places on the wooden parts and the middle and edges of these were filled with chiselled ornaments.

6.1.1. Ornaments

The room to the right has no ornamental elements. It is seen that the window shutters, a ceiling and wooden coatings on the walls of the Head Room on the left have ornaments and intensely painted ornamentation in separate parts. Flower arrangements in a vase placed on tables. Fruit corners were preferred as an ornamental motif.

There are flower arrangements in various vases with leg and without a leg, double or single handles. Fruits and watermelon with a knife are seen on the plate between the parts. The inscription friezes on the entrance doors, cabinet doors and niches are one of the different aspects of this structure.

The stone ornamentation that is carved sequentially on the facade of the house is very rich. These carvings have more fine workmanship than other houses. There are nine dovecotes in front. There is a triangular pediment


Figure 6.1. Fehim Paşa House "Head Room" interior images (Z.E. Archive)



Figure 6.2. Interior images of Fehim Paşa House "ornamentation details" (Z.E. Archive)

covering the entire surface of the spaces at the bottom of the dovecotes. Between the two rooms, there is another space with ornamental detail called the lantern swap.

The first dovecote from the left was made in the form of an unadorned pointed arch. The second dovecote consists of a combination of eight palmettes circled. It is shaped like a star in the middle. In the third dovecote, there is a soft composition made of palmettes and greenery parchments. Rumi's ornament and epergne motifs are located on both sides of the lower part of this ornamentation. There is a composition consisting of a combination of star motifs on the fourth dovecote. It is surrounded by this ornament consisting of Rumi ornament from foliage scrolls and stylized flowers in relief technique. The fifth dovecote is above the lantern cavity. There is no triangular pediment at the bottom of this ornamentation. The ornament is created with Rumi ornament emerging from branches and stylized flower motifs. A palmette is placed on the top, framed differently from the others. In the thick border section, there are stylized flowers, palmettes, and leaves emerging from the Rumi branches on the bird swap. After this border section, the upper part is enclosed in a triangular frame to cover the entire ornament.

The ornamentation in the lantern swap space is arranged with a minaret balcony. The upper part of the lantern cavity consists of a combination of

Figure 6.3. Facade images facing the courtyard (Z.E. Archive)

diamond motifs and is in a triangle shape. The ornamentation on the sixth dovecote is made in polygonal style.

It is ornamented with star motifs. In the fountain to the left of the courtyard, eight-armed star, palmette and stylized flower motifs are placed on both sides of the round-arched section.

6.2. Projecting

Here, will be mentioned as suitable for the urban texture, and will bring a new breath with the development of ornamentation, motifs come together to form a composition researched, and analyzed the ornamentations in the old Antakya houses.

Palmet, the second dovecote from the left on the facade facing the courtyard in the Fehim Pasha House, is a circular composition composed of a star motif created by combining Rumi and its branches with detailed stonework. Based on this composition, a functional project with a different approach to re-ornamentation, a pavilion design project, which will become the new place

Figure 6.4. Dovecote images (Z.E. Archive)

of ornamentation in architecture, is presented. Project description and images will be seen in this section.

6.2.1. Project Description

An intention to creates a conceptual design pavilion. Basing the building form and ornamentation on a tradition and referring to it. Ultimately, the contemporary reinterpretation of a tradition is a creative extension of the present through inspiration rather than a copy. To create an unforgettable cultural ideogram, to create an aesthetically and functionally attractive space, and to

Figure 6.5. The 2nd dovecotes image on the facade facing the courtyard (Z.E. Archive)

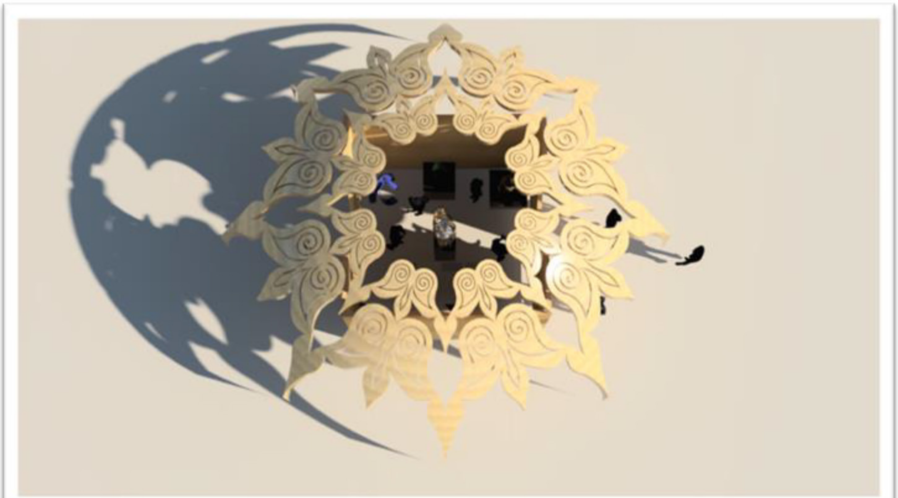

Figure 6.6. Design pavilion top view image (Designed by Z.E.)

try to use a design in a purely architectural dimension. To create a literary structure design that includes another story within a story by trying to write an endless story.

Designed as a single display area, the project was evaluated as a projective action of the geometric pattern created by the flower patterns from the top note.

Designed as a waiting and a meeting place, it is a common space for exhibitions, an exchange of ideas, and seeing an installation. This structure and a place (a city) will be the beginning of a dialogue, an agreement or a rejection. All these emotions are also the underlying emotions in all pursuits of an artistic expression. The building will be the center of creative artistic processes that will be closely associated with the public; with its new form of expression, it will stand against stereotypical architectural forms.

Giving a strong aesthetic message to those who come to the city from different places to attract visitors with the exhibition pavilion with this message, the ornamental motif in the Old Antakya Houses, which contains the old texture of the city and contains quotations, and the traces of the old houses, reconstructed in a modern form, It brings the beauty of its hidden old buildings with the clarity of life and every visitor. The building creates a different style motif in the traditional Antakya houses pattern taken from stone ornaments.

The motif used in the building form is the palmette motif carved on a round a cut stone, a traditional niche in the facade of the Fehim Pasha House, an old house to be used for a reinterpretation.

This motif has emerged in a round form of 8 palmettes by placing a palmette motif by forming a geometric circle and forming the octagonal star motif formed by the combination of twisted branches. Palmettes also contain the Rumi motif in them. The building aims to express itself with a single material. Inspired by the cut stone form of the convex form to be used, the natural light that will create during the day, by opening the motif patterns reflected in the exhibition enclosure will penetrate through the holes. The interior of the motif carved into the panels of the cube will be covered with plexiglass.

The material decided to be used in the construction of this structure is the Biocomposite Panel. We can give brief information about this material, and the construction of the structure as follows;

A Biocomposite panel is a special wood-based biocomposite board showing the architectural and structural potential of innovative building materials made from agricultural production waste. It is a type of coating that can be bent in both directions at a time. Lamination and shaping processes take place in a mould inside a vacuum press bag. It is laminated with CNC coating and 3D coating layers.

It is a material studied in the field of applications of bio-based materials and various approaches to sustainable architecture for the future. Natural fibres such as straw are waste that finds their second life as an architectural use material. The facades of the cube to be used as an exhibition area will consist of 12 flat panel pieces. These panels will be fitted by the screwing the parts. The convex structure form designed on a cube placed on a flat surface will also be calculated as 32 triangular plates. These triangular plates will be

Figure 6.7. Front view image of design pavilion (Designed by Z.E.)

Figure 6.8. Front view images of the design pavilion (Designed by Z.E.)

divided into two or three equal parts at specified intervals and will be joined by screwing method after the form is formed. The motif will be engraved on these plates with CNC.

7. CONCLUSION

With an innovative approach to ornamentation, the recorded turn of events, and the transition of Traditional Antakya structural ornamentation to contemporary engineering and ornaments used on the surfaces of the design components of the buildings was studied. Today, the innovative approach to ornamentation can approach different aspects as products that can be developed with digital technologies. Over time, the ornamentation was lost its importance and called a loss. But the ornament, which has always managed to preserve its pure form, continued to add various flavors to the senses with the same effect. The dramatically changing ornament is today a serious example of how it can be created from least to most. Ornamentation, which can vary from architectural detail to an urban texture, continues to be applied to contemporary architecture in another story, internally or externally. The research shows that the progress from traditional engineering to a contemporary design, the presentation of contemporary buildings innovation, a brand evaluation and an improvement of the detailed components found in Traditional Antakya Houses are followed. It seeks to be able to adapt ornamentation to our modern culture and re-ornamental its role in a design without a false illusion. While the ornamentation turns into a contemporary style in a traditional and traditional style, the surface and ornamentation of the city give the feeling of the period seen in Traditional Antakya Houses. The ornamentation programs in the usual spaces of Antakya are examined, and another initiative is structured by making verifiable and contemporary relationships. More work has to be done to find out how the idea of traditional ornamentation can be coordinated with contemporary ornamentation. The ornament has gained a model without specifying its symbolic significance. The components that make up the traditional ornamentation are the specific situation, the ease of use of the material, the social and public activities of the individuals. Once again, similar facts and contemporary and creative needs should be pursued.

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chapter 5

CONCEPT OF “AESTHETIC VALUE” LOST IN THE MODERN-DAY ANTHROPOCENE ERA AND LESSONS TO BE DERIVED FROM VERNACULAR NUBIAN ARCHITECTURE

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1. INTRODUCTION

Scientists state that the post-Quaternary, interglacial Holocene Age has ended and that we have entered the Anthropocene geological age as human activities shaped the earth. On the other hand, experts talk about the disfunctioning of human beings by moving from the industrial bourgeois era to the techno bourgeois era. One of the new functions of human beings should be aimed at preserving and sustaining the cultural and natural wealth for the future of our world entrusted to us. The geomorphologic structure of the earth is changing by increasing human interventions to the environment with industrialization and technological advances. Cultural riches are lost one after another, laying the groundwork for a larger uniform culture that feeds itself with industrial production, and the aesthetic values of many overlooked cultures continue to be lost. This situation also reveals that we should consider the importance of the concept of aesthetic value, which gradually reaches maturity with the consciousness that does not ignore the culture that is not its own, and respects the idea of diversity, as an answer to the question of how to use this information and to increase our level of knowledge about the consciousness of keeping our earth and cultural heritage alive.

It is known that dams built for development have many negative effects on the environment. An important part of the Nubian lands, where Nubian villages are located today, are under the waters of Nasser Lake formed by the Aswan High Dam established on the Nile. In this section, it is aimed to enlighten the importance of the struggle to survive the Nubian vernacular architecture, which is applied with the construction technique inherited from the ancient Nubia, with the displacement of the Nubians, who have a unique, privileged identity and language of today's modern age, different from Egypt, under the light of Nubian history.

"The risk in the modern world is to see the remains of this African civilization disappear before you know them," said Charles Bonnet, who excavated in the ancient Nubian city of Kerma. He emphasized the importance of understanding African origins, these complex states, kingdoms, traditions, architectural types and lifestyles in the Nubian lands (URL-1.

The most important of the cultural heritage of the Nubians is the adobe vault construction technique without the mold, which they applied without the need for any building specialist, and there is no community in the region that continued to apply this cost-effective technique other than the Nubians. For this reason, Nubian village houses with an aesthetic expression created by applying the adobe vault roof technique using local materials are also important.

With the construction of the dam in 1964, the lands of the Nubian people living in the region, along with their material and spiritual cultural heritage, were also flooded. With the displacement of the Nubians, a lesson must be learned from the damage to their identity formed by cultural evolution and social accumulation in the 70 years until today, as it represents the disappearance of cultural wealth in different parts of the world.

2. NUBIA AND HER IMPORTANCE

Nubia is the geographical region concentrated along the Nile, which is now divided by the border with Egypt and Sudan. The Nubian lands are important primarily because it is one of the first places that humanity has passed through in its long journey, starting from Africa and dispersing all over the world. Scientists say there is sufficient evidence that starting from the Neolithic period, ancient Nubia developed successive civilizations influenced by Africa, Arabia, the Sahara and Egypt. With the flooding of a significant part of the Nubian region, where the rock arts from the Neolithic period, mines, tombs, architectural monuments of different periods and villages of today, where their cultural heritage is kept alive by vernacular architecture, the cultural evolution and technical knowledge of people from the Neolithic period to the modern recent period also flooded. In other words, in addition to the benefits of the Aswan High Dam in Egypt, which was built for the purpose of controlling the Nile flood, agricultural irrigation and hydroelectric energy production, it has also had negative effects on today's Nile River geography, people and cultural heritage.

2.1. The Origin of the Name “Nubia”

Nubia is a name used in the Roman period. The origin of the name Nubian is unclear. Some associate it with nwb, which means gold in ancient Egypt, while others associate it with the term Noubades, the Greek name for people who moved to northern Nubia in the 4th century AD. (URL-2).

2.2. The Definition of Nubia Region

There are six narrow rocky gorges called cataracts through which granite rocks under the softer sandstone found in the upper layers of the Nile River rise to the water surface. (Figure 1) (URL 3). The geographical region on the banks of the Nile, divided into three as Lower Nubia, Upper Nubia and Southern Nubia, is defined by these cataracts. Lower Nubia is located in the south of present-day Egypt in the area between the first and second cataracts. Upper Nubia and Southern Nubia are located north of present-day Sudan, between the second cataracts of the Nile River and the sixth cataracts south of Khartoum, where the Blue and White Nile meet. (Figure 2) (El Hâkim, 1999). The lands of this region have hosted ethnic Nubians, who had unique cultural wealth and their own language, for thousands of years.

Figure 1. First Cataract (URL 1, 2020)

Figure 2 Map of Egypt and Nubia (URL 1, 2020)

2.3. The Language Used in Nubia

According to the extensive social and ethnographic research conducted by the Egyptian state and international scientists before the Aswan dam rose in the 1960s, it was seen that Nubia was divided into three different ethnic groups, each with their own language. The people of the Kanzi (plural Kanuz) region in the north spoke Fadika, the Hamitic language (Figure 3). The Arab (Mahas) region was in the middle, and its people spoke Arabic, as the name of the region suggests. The Mahas region extending to the south was joining the Nubia region of Adindan, on the border with Sudan, and the people there were speaking Matoki, a language of Hamitic origin (El Hakim, 1999).

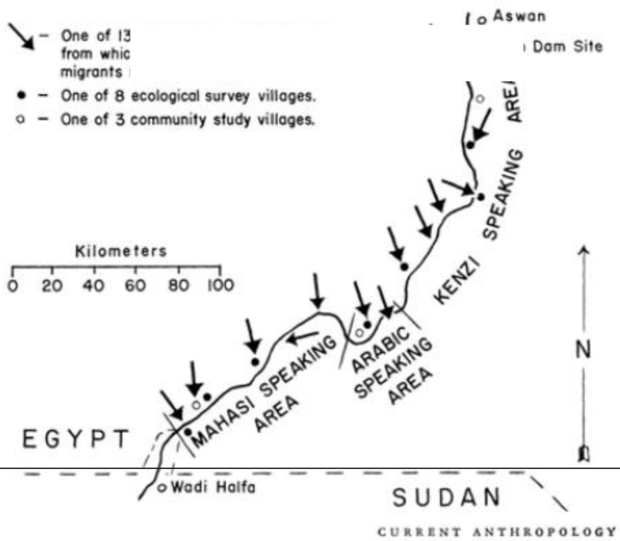

Figure 3 Distribution of Languages According to the Regions (URL 4, 2020)

3. A LOOK AT THE HISTORY OF NUBIA FROM PREHISTORIC TO TODAY

Nubia is the land of Africa's oldest kingdoms. The Nubians were known to be expert archers. The Egyptians referred to Nubia in their writings as "Ta-Seti" or "Land of Bows". Temples and royal pyramids, among the works left by their rulers, have survived to this day in places they built in Modern Egypt and Sudan (Firth, 1927).

In the north of the region, in Lower Nubia and Upper Egypt, cultural exchange and cooperation in times of peace when Nubia and Ancient Egypt intertwined, and mutual conquests in times of war. The emergence of socio-economic organizations coincides with the Early Period when the Egyptians made the pyramids around 3500 BC. with its rich gold resources, it was a gateway through which African riches such as ivory and ebony reached the Egyptian and Mediterranean civilizations.

Table 1 Historical Overview (Staatliches Museum, 2020)

Neolithic cultures	6000-3500 BC	
	4300-3000 BC	Prehistoric cultures
A-Group culture in Lower Nubia	3500-2800 BC	
	3000-2700 BC	Early Dynasty
	2700-2170 BC	Old Kingdom
C-Group culture in Lower Nubia	2300-1600 BC	
Kerma Kingdom in Upper Nubia	2500-1500 BC	
	2170-2040 BC	1. Interlude
	2040-1780 BC	Middle Kingdom
	1780-1550 BC	2. Interlude
Nubia under Egyptian Rule	1550-1070 BC	New Kingdom
	1070-750 BC	3. Interlude
Kushit Dynasty	1000-650 BC	
	750-656 BC	Kushit Dynasty in Egypt
Napata Kingdom	650-310 BC	Late Period
	332-30 BC	Ptolemaic Period
Meroe Kingdom	300 BC- 320 AD	
	30-395 BC	Roman Period
Late Meroitic Kingdoms	350-600 AD	
	395-600 AD	Byzantium Period
Christianism	540-580 AD	
Islamisation	Start of 642 AD	Islamisation

3.1. Prehistoric Neolithic Cultures and Rock Art (6000-3500 BC)

Around 5000 BC, in what is now called Nubia, due to changing climatic conditions, people from the Sahara joined the Neolithic revolution. They began to domesticate sheep, goats and cattle. Later, fishing and farming were added to the livestock and hunting, which took part in the social life and culture of this period. While advancing through the Nile valley in Nubia, they developed their skills in the art of pottery making (Staatliches Museum, 2020).

According to the researches of archaeologists, rock art is depicted in four main groups. Animals, domesticated animals, human figures, signs, symbols, various types of boots. They span from the prehistoric period to the second millennium AD. Rock art is an important source of information for the study of cultural and social development in the region, which has been experienced in the past. Over 5000 figures were documented at 954 rock art sites, and various stylistic and cultural horizons were distinguished as a result of the investigations. The first layers belong to the Sahara rock art tradition. Horizons originated from the cultures that developed in various periods in the Nile Valley and then took root in the development of the region. Rock art provides important resources in the past, in the field, for knowledge of cultural and social development. It provides information about the lives of ancient societ-ies and local prehistoric times in different periods of time. Rock art reflects the beliefs and priorities of the people living in the region, the landscape surrounding them, and the way they perceive the world (Figure 4). In rock art, hunters using bow and arrow depicted in the Neolithic Period were the pioneers of the Nubian archer culture in later times.

Figure 4 Aswan Museum Nubia Exhibition (Mert Ağar, 2018)

3.2. Land of the Pioneer Civilization: Nabta Playa

In the past, the Western Egyptian Desert was not arid. Some archaeologists believe that with the migration that took place in the years before the first pharaohs came to power due to changing climatic conditions, the people of Nabta Playa were the pioneering civilization of the first Nile periphery settle-ments that emerged in Sudan and Egypt thousands of years later. Although the Western Egyptian desert today is completely dry, the region was a savan-nah during the last glacial periods, dating from 130,000 to 70,000 years ago. Beginning around 10,000 BC, this region of the Nubian Desert received more rainfall and the formation of lakes began (URL 5, 2020).

Nabta Playa (Figure 5) was once a basin in the Nubian Desert, located about 100 kilometers from Abu-Simbel in southern Egypt. By 7,000 BC, one of the earliest periods of the Egyptian Neolithic Period, Nabta Playa had extremely large and organized settlements. The Nabta Playa people had aboveground and underground stone structures, villages designed with pre-planned arrangements, and deep wells that held water year-round. This complexity, expressed by different levels of authority in society, probably formed the basis of the structure of both the Neolithic community at Nabta Playa and the Kingdom of Ancient Egypt. The megaliths discovered at Nabta Playa are examples that appear to be one of the world's first astronomical devices, dating almost 2000 years before Stonehenge (Figure 6) (Schild and Wendorf, 2015).

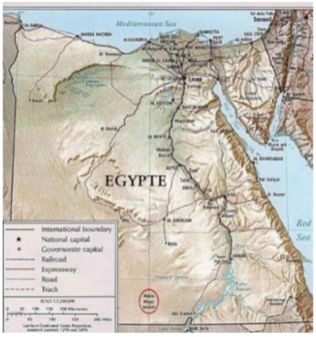

Figure 5 Location of Nabta Playa (URL 5, 2020)

Figure 6 The stone circle of Nabta Playa marks a summer solstice coinciding with the arrival of monsoons in the Sahara Desert thousands of years ago (URL 5,2020)

3.3. Cultures of Groups A, B and C

The second Nubian culture, called Group A, originated in Lower (Northern) Nubia. They were settled farmers. “Group A” was named by the American archaeologist George Andrew Reisner. He researched the origins of the Nubian civilization with the “Nubian Archaeological Research” that he conducted between 1907-1909. The A-Group had no writing and we still don’t know how these people called themselves (URL-6). The fertile farmland just south of the third cataract is known as the “Pre-Kerma” culture that emerged in Upper Nubia around 5000 BC. This culture began to decline in the early 28th century BC. The posterior culture is known as the B-Group. Most historians today believe that the B-Group is only the A-Group, but much poorer. Nubia was divided into a number of smaller kingdoms by the 6th dynasty of Egypt (Firth, C. M. 1927). Ceramic artifacts made by later people known as the C-Group, who lived in Lower Nubia (between 2300 and 1600 BC), are among the most beautiful works produced in Nubia. It is richly decorated and has very vibrant ornaments (Geuss, 1998).

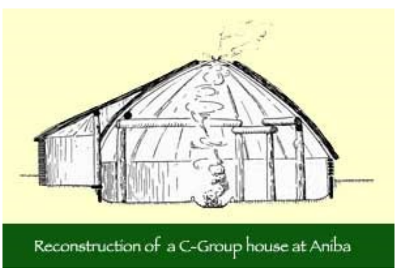

Figure 7 Reconstruction of a C-Group Aniba (URL-7, 2020)

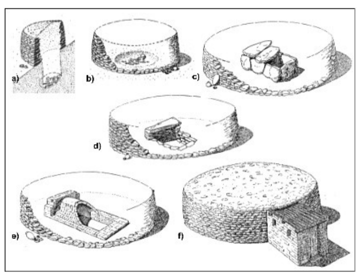

Figure 8 Typical C-Group house at superstructures, join with burial shafts (Hafsaas, 2006)

Group C has roots in Sub-Saharan African culture (Staatliches Museum, 2020). Small circular houses with stone foundations (Figure 7), tombs covered with circular stone mounds (Figure 8), elaborate engraved ceramics (Figure 9) are the characteristics Group C shared with previous Nubian Group A and Pre-Kerma cultures (URL-7).

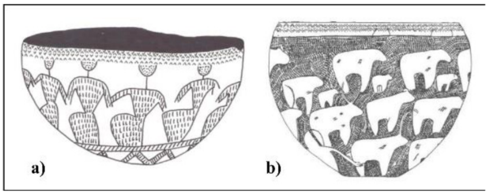

Figure 9 The dancing women and the cattle bowl from the burial in the cemetery in Adindan (Hafsaas,H. 2006)

But the importance of C-Group cattle depicted in tomb steles, pottery, figurines, and rock drawings also strongly correlated it with African cattle cultures that began in the Neolithic period and then spread to sub-Saharan Africa (URL-7). The C-Group culture has maintained its distinctive traditions for centuries. Later, it became less visible in archaeological remains because the Nubians adopted Egyptian styles during the Nubian invasion of the New Kingdom of Egypt (1550-1069 BC) (URL-7).

3.4. Period of Nubian Kingdom of Kush

Figure 10. Nubia and Kush (URL 2, 2020)

The Nubian lands also hosted the Kush Kingdom (Figure 10). In previous Egyptian writings, Nubia is mentioned as the land of Kush. Its people resided in the central parts of the Nile for millennia and hardly changed their traditional way of life until the Aswan Dam was built. In addition to agriculture and fishing, the Cushites, who continued the transportation of their goods up and down the Nile, developed powerful kingdoms. The first was centered in Kerma (2000-1650 BC), where the Nubian identity emerged, one of the oldest African civilizations in Sudan. Later kingdoms had capitals in Napata (800-270 BC) and Meroe (270 BC - 370 AD). Kerma is a Nubian term that can be roughly translated as “red mound”. In the archaeological field lies the history of Nubian from the Neolithic Period to the Meroitic Period. Thanks to the studies of the Swiss archaeologist Charles Bonnet, the Kerma Kingdom, which dominated most of the third cataracts for centuries and where the first monumental walls and adobe structures were located, was a large and inde-pendent urban complex. Kerma was a large urban center built around a large adobe temple called Deffufa (Figure 11), a unique structure in Nubian archi-tecture. The formation of a cultural tradition and a great cultural transforma-tion over time points to stability around Kerma. (Reisner, G. A. 1923). During the New Kingdom period (1532-1070 BC), the Egyptians destroyed the Kerma Kingdom and the Egyptian Empire expanded to the fourth cataract.

Figure 11 Deffufa (URL-8, 2020)

Figure 12 Ancient City of Kerma / Sudan (URL-8, 2020)

Opened in 2008, the Kerma Museum is located in front of West Deffufa in the Kerma archaeological site in the north of Sudan, and includes sections that focus on the Christian and Islamic history of the region, as well as many archaeological items belonging to the Kerma culture. The museum building was built inspired by the traditional adobe vaulted roof of Nubia (Figure 13) (Figure 14

Figure 13 adobe vault (URL-9)

Figure 14 Kerma Museum (URL-10)

Kush arts were inspired by the Egyptians, but were more of an African. The most striking of these were the Kush reliefs adorning the walls of palaces or pyramids. The Nubian Kings ruled Egypt as well as Nubia, ruling a mighty empire that stretched along the Nile Valley 2,500 years ago. Archaeologist Charles Bonnet and his team discovered seven monumental black granite statues inside a temple in the ancient city of Pnoubs, in Kerma, near the third cataract of the Nile (Figure 15). Statues of monarchs and other royals high-light the non-Egyptian alien origin of their vassals.

Figure 15 Statues of the Nubian Kings (URL 18,2020)

The Nubians built many small pyramids later in their history and used very complex burial systems to bury their kings. Many of them were in a style similar to the early Egyptian mastaba. In the following centuries, they became small pyramids with chapels and tombs under the ground. The most famous examples of Kush pyramids are in their capital Meroe, located in present-day Sudan (Figure 16). While the Kush pyramids are built on the catacombs, the Egyptian tombs are inside the pyramid. The people of Meroe were unique in many ways. They developed their own typeface. Nubia was very rich in gold. Meroitic metalworking was among the best in the world. Meroe was captured and destroyed by the Kingdom of Axum at the end of his ascension. Several states, including Nubia, arose on its former lands.

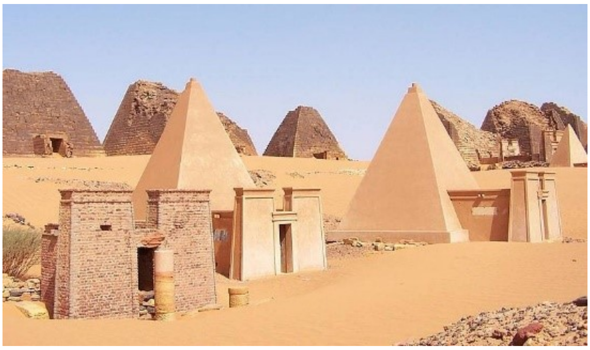

Figure 16. Meroe Pyramids (URL-3, 2020)

3.5. Periods of Christianity and Islam

The fall of the Kush, which has existed for more than a thousand years, accelerated with the invasion of the 4th Axum Kingdom AD, and witnessed the rise of the Christian kingdoms Nobatia, Makuria (Figure 17) and Alodia. With the fall of these kingdoms, the northern half of Nubia, which was conquered by the Ottomans in the 16th century, was divided by Egypt and the southern half by the Sennar Sultanate, and the Islamization and partial Arabization of the Nubian people was initiated. Nubia was reunited with the Egyptian Khedive in the 19th century. The Nubia region has been divided between Egypt and Sudan since 1956. The best church paintings that remain to this day are in the Faras Rivergate and Abd Al Qadir Churches (Staatliches Museum, 2020).

Figure 17 North Church Old Dongola (URL-11)

Figure 18 Islamic Grave Qubbas (URL-12)

The tombs for Islamic architecture were simple pits and their direction was facing Mecca (Figure 18). Some of the unique buildings were domes made of mud brick, tombs reserved for Muslim scholars.

4. ADOBE VAULT APPLIED WITH NUBIAN TECHNIQUE, A HERITAGE FROM THE ANCIENT PERIOD

The catenary curve is the inverted form of the curve in which the chain or cable we assume suspended from both ends is shaped only under its own weight. The catenary curve used in the adobe vault construction technique is currently used in Africa, many parts of the Mediterranean and some regions of Latin America.

The Nubian vault is a kind of curved surface that forms a vaulted structure. The adobe vault construction technique was rediscovered and revived by the Egyptian architect Hassan Fathy in the Nubian village of Abu al Riche. The feature of this technique is that it is applied using mud without the need for timber.

The city of Aswan in Upper Egypt is the center of ancient Nubian culture that brought the famous Nubian adobe vault to the world, built with mud brick and without formwork or other mechanical supports. It is an interesting tech-nique in which adobe bricks are lined up in a curve in slightly inclined rows. According to Hassan Fathy, it is the result of sophistication and technical inspiration. (El Wakil, 2012)

When the Aswan dam was raised for the second time in 1933, the Nubians rebuilt their new homes, a year before their existing homes were flooded. They built their villages, each made up of different houses that reflect their own identity, and were able to use their full creative potential. The reason why they cost in a short time and cheap is the adobe vault technique inherited from their ancestors for their roofs and the fact that they built their houses with their own resources.

The Nubian adobe vault technique, which originated historically in Nubia and is unknown in other parts of Africa, allows the construction of buildings with adobe vault roofs without the need for wooden scaffolding; Simple tools are used with local materials and require only basic technical competence. The binder mortar, approximately 1 cm thick, is silty, clayey soil from Nil, and the blocks used are adobe. Traditional Nubian technique requires a back wall to line up blocks (The Nubian Vault Association, 2015). The adobe vault is built in the form of an arch over the wall and thus rows

rows are laid vertically. The Aswan museum is designed with traditional Nubian architecture (Figure 19).

Figure 19 Aswan Museum (Mert Ağar, 2018)

4.1. The Oldest Adobe Vaulted Buildings in Nubia

The oldest mud-brick Nubian vaults in Luxor have been standing for over 3300 years (Figure 20). Excavations carried out by Walter Emery between 1929 and 1934 in the Kuban Fortress, just north of El Dakka, on the east bank of the Nile, found the oldest adobe structure in the Egyptian Nubia. This dwelling and granary with adobe vaults as roof cover dates from the 12th Dynasty (2115 BC), the time of the 2nd King Sesostris. (URL-13, 2020).

Figure 20 Adobe vaulted wheat granaries -Ramasseum (URL-15, 2020)

Later, in 1960/1961, mud-brick vaulted rooms with a width of 2.72 m were unearthed in the excavations carried out by the Cairo Museum in Aniba, a Nubian village, approximately 230 km south of Aswan. Pottery and vases found there indicate that the buildings belong to the second intermediate period (2000 BC). The sophisticated architectural example using the adobe vault was excavated in Nubia by Italian archaeologists in 1929 and 1934. The most interesting ones belong to the Byzantine-Christian period and are located near Adindan. An example of Nubian Christian architecture in the lower Nubian city of Faras is Faras Cathedral (Figure 21).

Figure 21 Faras Cathedral (URL-14, 2020)

The same team discovered monumental tombs in Nubia, where interesting conical domes cover the tombs one by one, on the plain of Gebel Adda, which dates back to 600 AD (Figure 22), (El Hakim, O. 1999).

Figure 22 A Muslim Cemetery (Huber R. 1963 to 1969)

5. THE EFFECTS OF THE ASWAN HIGH DAM ON THE NUBIAN TERRITORY

The first formation in the Nile valley took place between 1899 and 1902 by the English-built dam; the later high dam was seven kilometers up. This

30.5-meter-high dam, with the lake it created, raised the water level from 87 meters to 106 meters in the Nile valley, which stretches for 225 kilometers, permanently flooding the Kanuz region of Nubia. This first dam was then raised two more times; The first between 1907 and 1912, the second between 1929 and 1934, it reached a final height of 42 meters, increasing the water level to 121 meters in the valley (El Hakim, O. 1999). The foundation of the new high dam was laid on January 9, 1960. When the construction was completed 10 years later, the dam lake, which was named Nasser, was 320 kilometers in Egypt and 160 kilometers in Sudan, with the waters of the Nile, and it was recorded as the largest human-made lake at that time.

5.1. Anthropocene Effects in the Nubian Region Flooded by the Aswan High Dam

According to scientists, the reactions of our earth are an indication that we entered the Anthropocene geological period. Italian geologist Antonio Stoppani, in his book Geology Lessons published in three volumes in 1871-73, mentioned the increasing influence of humans on the world ecology and became the first scientist to use the concept of the human age for the last geological period. By using the term Anthropocene again in the 1980s, Eugene F. Stoermer succeeded in attracting the attention of scientists to this subject, and studies on the subject spread all over the world with the contributions of Crutzen (Sümer, 2020).

Dams have ecological, social, cultural and economic negative effects on the environment. The geomorphological structure of the earth that has occurred over millions of years is changed by dams. Since the agricultural areas, historical buildings and settlements were flooded by the dam built on the Nile, people living in the surrounding had to migrate. Shortly after the Aswan High Dam was put into operation, the soils on the delta side became arid, most of the marine fish species in the river mouth disappeared, and a parasitic infection called schistosomiasis began to be widely seen in humans. Because of the natural fertilization provided by alluviums, drought and serious yield decreases were experienced in agriculture. After this process, the delta soils were salted and barren due to the effect of sea water and severe evaporation. When river waters were blocked by the Aswan dam, both the oxygen flow and the transport of some organic matter that could be feed for fish were significantly reduced, which disrupted the balance and caused the extinction of some fish species. In the past, however, Nubian life revolved around the River Nile. The Nile provided water for drinking, cooking and washing as well as irrigation. Every year floods made agriculture possible. The flood not only brought abundant water but also replenished the soil along the banks of the river by accumulating the rich alluvial load it brought from above. Because of its benefits, the entire village was gathered by the river in ceremonies such as weddings, circumcisions, and harvest festivals, as homage to the Nile. The relationship and significance of ancient Nubia with the Nile was great.

5.2. Work on the Salvage of Nubian Monuments in Aswan High Dam Waters

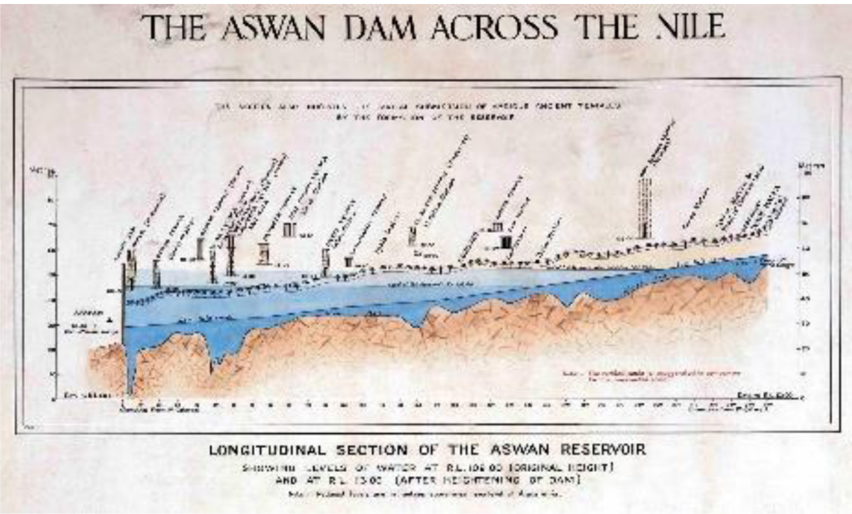

Figure 23 Aswan Dam and flooded monuments (URL-15, 2020)

The construction of the Aswan High Dam and the Nubian ancient ruins with the created Nasser Lake were submerged at a depth of about 50 meters from Aswan to the second cataract (Fig.23). In 1960, salvage excavations began with the International Campaign to Save the Monuments of Nubia (Fig.24). With the UNESCO campaign, hundreds of sites were excavated and thou-sands of artifacts were preserved, as well as large monumental architectural pieces were removed and relocated to safer places. The most famous are Philae Temple (Fig.25), (now located on Agilkia Island) and Abu Simbel temple (URL-6).

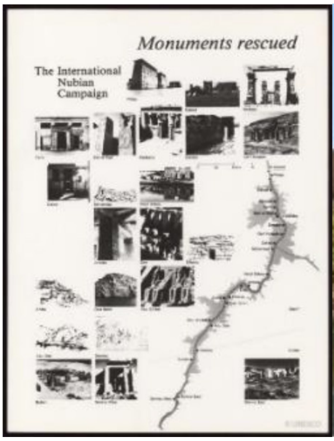

Figure 24 *Preserved monuments* (URL-16, 2021)

Figure 25 Philae (Mert Ağar, 2018)

When the High Dam was completed in 1971, the Lower Nubia region of approximately 5000 km2, stretching between the first cataract and the second cataract in Aswan, which has fertile soil, was flooded (El Hakim, 1999).

5.3. The Displacement and Dispossession of the Nubians

Most Nubians expressed their spiritual and physical attachment to their ances-tral lands, a strong sense of loss in the face of the sudden disappearance of their individual and collective legacies (El Hakim, O. 1999).

With the construction of the high dam in Aswan in June 1964 and the gradual flooding of the area, the last remaining part of the Nubian population left the area. Some of the almost fifty thousand Egyptian Nubians rebuilt their homes in higher places. The other part migrated to the land given to them (Abu El-Riche, Daraw and Kom Ombo) in the north of Aswan. At the same time, in Sudan, just over fifty thousand Sudanese Nubians migrated to Khashm El-Girba on the Atbarah River, about a thousand kilometers south of the border in Wadi Halfa.

In the 1960s, over a period of 70 years, with the construction of the High Dam in Aswan, sixty percent of Nubia was destroyed or made unfit for set-tlement. Date exports, which were the main source of income for all of Nubia before the Aswan Dam was built in 1902, declined in parallel with the flood-ing of palm groves with the successive rise of the dam. Almost nothing is left of Nubia’s agricultural capacity (El Hakim, 1999).

The inhabitants of the area had to farm on the small and scanty soils located higher up among the rocks. Most of the men rebuilding their homes a little higher went to work in the towns in the north to earn income for their families (El Hakim, O. 1999).

Until the third flood in 1963, the living vernacular architecture of Ancient Egypt, located in Nubian villages, was ignored by the whole world, apart from the difficulties experienced by the local people. Measurements were needed to make more detailed drawings of the regions named Kanuz, Arab (Mahas) and Nubi. The author of the book “Nubian Architecture” who undertook this was Omer El Hakim, who was an architecture student at the time at the American university in Cairo, and his brother, a social anthropology student. Before this region disappeared and was flooded, these two brothers traveled from village to village without a car at that time, preparing detailed drawings and sketches. While preparing the architectural drawings, they also recorded the social and cultural aspects of the region (El Hakim, 1999).

6. NUBIAN VERNACULAR ARCHITECTURE

The construction and completion process of buildings is in many ways more important to Nubian culture than their latest product. The old Nubian houses with adobe vaults, made with existing materials in the environment, are the manifestation and maintenance of a social environment based on interdependence, compatible with communal interaction (Fig.26). The collaborative effort, crucial to the creation of a Nubian village, not only strengthens social ties but also develops bonds of pride and mutual respect that are linked to a sense of belonging and community success (El Hakim, 1999).

Figure 26. Nubian village homes Gharb Soheil Asvan, (Mert Ağar, 2018)

6.1. Structure of the Village

Composed of neighborhoods called Nubu, villages in Nubia formed clustered lands by expanding towards the interior, following the natural slope of the land where the riverside was steep. Where the riverside was relatively flat, clusters in curved areas provided geography. (El Hakim, O. 1999). Throughout Nubia, on the east or west bank of the Nile, the main entrances to the houses faced the river. Village settlements were suitable for the topography.

6.2. Nubian Village Homes

The most distinctive feature of today's Nubian culture is the mudbrick vaulted roof village houses unique to Nubia, which is the last legacy from Ancient Nubia. Unprecedented village houses were large and spacious. It consisted of several large rooms built of adobe surrounding an open court (Fig.27).

The main entrance opened to a court with raised seating areas called mastaba. The rooms of the house were arranged along the far wall of the court, most notably the mandara or guest room with a separate entrance and adobe vaulted roof. Some living rooms, called tents or khaymas, were simply enclosed by a flat roof of palm branches. The interior and exterior plaster and wall decorations of adobe houses were made by women and children, espe-cially the entrances were decorated with bright and colorful patterns. Most importantly, the adobe vaulted ceiling of ancient Nubia was preferred. Air circulation was provided through small ventilation openings created at the high levels of the walls and the court, which served as a special piece of sky.

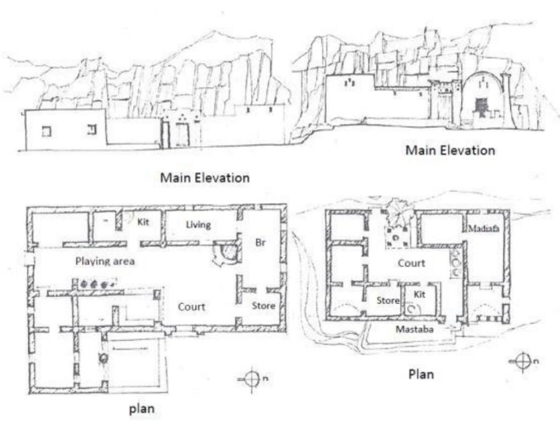

Figure 27 Nubian house plan (URL-17, 2020)

Entrance: Entrances were much decorated (Fig.28). Usually, the designs were inspired by nature. Nubians, inspired by the seasonal changes of the Nile each year, at their highly ornate and colorful gates, they used to regard the Nile as a symbol of respect for what it provided them (El Hakim, 1999).

Figure 28 Nubian house entrance Aswan Museum (Mert Ağar, 2018)

Setting of the House: The area around the house was used to enlarge the house. As the family grew, rooms and storage rooms were added, simply expanding in itself. The variety of use was striking. The plan types of the houses were developed according to the close social and economic relations of the family members (El Hakim, 1999).

Improved Air Circulation / Living Room and Khayma (Tent): Some living rooms had a high wall-to-wall opening above the door, or it was completely open to the court. In front of these rooms there was a khayma ("tent") covered with palm trunks and branches. Thanks to this improved air circulation, the place would be cool in the summer (El Hakim, 1999).

Mandara as the Symbol of Hospitality: The guest room (mandara) had a separate entrance, usually directly accessible, allowing guests freedom of movement, and was the only room in the house with windows opening to the outside. Mandara and hospitality were considered an important part of he home while still being a must for Nubians. The mandara, which was decorated with calligraphy and paintings, was usually covered with an adobe vault (El Hakim, 1999).

Wall Construction Methods: The method of building walls was different in the three regions of Nubia. In the south, where the Nile is wider and alluvial mud is abundant, a method known as the galos or tuff construction technique was dominant. The walls were usually of mudbrick and were half a dira (half arm length) thick. Thus, heat transfer was minimized.

Roofs: In the Mahas and Arab neighborhoods, roofs were built using split palm trunks and acacia wooden beams. Palm cane reeds and palm leaves covered the beams. In the Kanuz area, roofs were built as mudbrick vaults and domes (El Hakim, 1999).

Doors and Windows: In order to provide privacy in Mahas and Arab neigh-borhoods and to reduce the area exposed to the heat and glare of the sun, window openings were not created. In Kanuz, narrow slits were made on the walls on both sides of the village house entrance. The filigree cage workman-ship made of mud brick just below the roof in front of the door was remarkable (El Hakim, 1999).

External Rendering: Especially in the Kanuz and Arab regions, the houses were often whitewashed. The exteriors of the houses were plastered with a mixture of mud, clay and rock salt obtained from the neighboring hills. In the villages in the north of Nubia, the colors of the houses matched the ground and hills. Though they were barely visible from exactly a distance, the white-washed stripes above the wall were visible at 70 or 80 cm high following the horizon line. Interestingly twisting or zigzag white lines dominated the hill slope. Houses were plastered and decorated by women and children of the household (Fig.29). Bright, bold, colorful designs inside and out were created using dyes made from lime, ferrous and bauxite compounds available in the region (El Hakim, 1999).

Figure 29 Nubian village homes Aswan Museum (Mert Ağar, 2018)

Ventilation: Thanks to the court, fresh air was circulated, sunlight was allowed to enter the interior of the house, and the people of the house benefited from the sky. Very small window openings just below the adobe vaulted ceil-ings allowed the warm air to rise up and out of the rooms and let fresh air into the courtyard. (El Hakim, 1999).

Grain Storage: Dry basic grains were stored in large soil silos. In the autumn after harvest, grains such as millet, corn, barley were stored all year round in earthen silos mixed with handmade cylindrical corn stalk (Figure 30) in the courtyard set on a slight slope, avoiding moisture, on the floor of the courtyard. The dimensions of these silos could reach up to one meter in diameter and two meters in height. After being filled with grain, the upper part was covered with a mud disc and covered with mud mortar (El Hakim, 1999).

Figure 30 Mud built Silos (El Hakim, 1999).

Cooking and Kitchen: Food was prepared over an open fire using dried animal manure as fuel. The cooking pots were placed in the center, above the three-legged supported fire. Many kitchens had an oven. Since not every house had its own oven, it was jointly cooked once or twice a week. Food could be eaten anywhere in the home or in the courtyard, as there was no specific dining room. If there were any male guests to be entertained, food was served to them in the mandaras, due to religious traditions (El Hakim, 1999).

6.3. Differences Between Old and New Nubian Village Houses with Its Profound Impact on Nubians

Although only a small number of villages of the ancient Nubia survived, the difference between professional architects of the new Nubian regions planned by the Egyptian government with the rise of the waters of the Aswan high dam and the vernacular architecture of the Old Nubia had a profound impact on the identity-conscious Nubians at that time (El Hâkim, 1999).

The differences between new settlements and traditional Nubian settle-ments were great. After the High Dam was built, the Nubians who had to leave their place moved to their new village built by the Egyptian state in the north. These villages were built from different materials and with different types of plans. The urban fabric was designed without considering thoughts about privacy, family connections, or social divisions. There were differences between the traditional old Nubian village houses before relocation and the new state residences built afterwards (Bayoumi, 2016).

Old Nubian village houses provided shade, cut off the wind in winter, and were cool with their surroundings thanks to the narrow streets in summer. In the new Nubian village houses, because of the use of bricks instead of adobe, thermal comfort could not be achieved in the interior. The expansion and contraction of the roofing materials caused the wall materials to crack. Since the prevailing wind direction was not taken into account in the settlements of the houses, effective ventilation could not be provided and the temperature increased indoors in the summer.

There was no unemployment in the former Nubian villages. Economic, social and cultural life was stable. There was no shortage of food and water either. Nubian vernacular architecture had one loop, but the new one did not. There were poverty and social breakdowns that did not exist before. Environmental effects of residences that do not have thermal comfort caused local economic crises (Bayoumi, 2016).

The old Nubian village houses reflected the worldview and lifestyle of the Nubians. The state villages designed and built by professional architects reflected not the beliefs and social class of the Nubians, but a different world-view not respecting the ones of the displaced Nubians. This situation forced many changes in the Nubian lifestyle and daily life experience (Howeidy, 2017).

The new residential areas were very close to each other. The villages stretched for 320 km on the banks of the Nile at the time, and the new settlements were compacted to 50 km.

The design of the new villages created social problems with the identity of traditional Nubians due to their inability to connect with the Nile. Important ceremonies and rituals associated with the Nile were damaged due to the fact that the newly established areas were far from the river.

The patterns of the houses and the character of the new settlements had a direct impact on the Nubian community. In ancient Nubia, villages were organically built around large family units. The extended family, consisting of father, mother, unmarried children, married son and wife and grandchildren, was the central social unit where the strongest devotion was expected and was the foundation of the Nubian lifestyle with its holiness.

The new homes designed for nuclear family units were not suitable for extended family structures, but the state tended to ignore it. Moreover, the stereotypical planning of houses was due to administrative reasons and ease of construction. The rough allocation method in planning did not ensure the continuation of the old neighborhood, causing physical and social damage in the villages.

Houses in the new community were smaller and separated most of the community's older members. This has traditionally made it difficult to provide assistance to the elderly and their participation in the daily social life of the new community. The situation worsened when the government prohibited the transfer or sale of new houses. Cooperatives were established as a solution for the survival of the village. (El Hâkim, O. 1999).

7. RESULT AND DISCUSSION

Dams, depending on their location and size, can damage or even destroy not only the geomorphological structure of the earth and natural life, but also the cultural evolution and social accumulation of humans over thousands of years. For this reason, it is important to create alternative projects for development, energy production and irrigation by evaluating how it will affect the ecological nature, social and cultural life in the long term before deciding on the construction of the dam.

The Nubian lands are important in that it is one of the first places that humanity has passed in its long journey, starting from Africa and spreading all over the world. It is not only the cultural heritage of the Nubian lands, but the common cultural heritage of the whole world that has been formed over thousands of years has been submerged.

With the construction of the Aswan High Dam, which was the product of the Anthropocene age from 1902 to the 1970s, a significant part of the Nubian vernacular architecture has been submerged. The Nubians, with a population of half a million spread all over the world today, while they were around a hundred thousand when they were displaced, lose their memories that form their identity with their self-expression practices. Since the Nubians can no longer create their own living spaces with the technique inherited from their ancestors, they are unable to continue their traditions, and because cultural continuity cannot be achieved in settlements that are not suitable for their lifestyle, they lose their characteristics of being a unique society with a weakening sense of identity.

The social and cultural structures in their villages are very different from the past, as the adobe vault construction technique they used to construct their buildings became dysfunctional due to the change in the habits of using many local materials. Honorable Nubians, who have the ability to remember in the past, maintain their traditions and are known for their devotion to Nubia, are changing in their own country or anywhere in the world with different cultural and social structures.

The houses that were redesigned and built by the state-owned architects and the villages created in new places not inundated, unsuitable for their owners and without considering the local culture, never reflected the old Nubian identity. The Nubians have experienced difficult times culturally, socially and economically, with the loss of their aesthetic values passed down from generation to generation.

When we look at the historical process of residential areas in rural areas, we see that the cultural continuity has been achieved with the use of local materials, creative human mind, labor and cooperation. Nowadays, these cultural colors disappear one by one because we cannot protect them.

In order to sustain vernacular architecture, the decisions of the participating individuals who have a say in social activities are needed, and the resources of the geography they belong to are used for the necessary building materials. The situation in which identity is disregarded, the participation of the individual and consequently the society is not realized, and the profitability-oriented, mass-produced settlements that are imposed on the users cannot meet the demands that emerge as a loss of aesthetic value as the living spaces lose their authenticity by undergoing cultural and social changes.

The global aesthetic taste that has become the same today is offered and imposed on people. The use of local materials should be made attractive with creative ideas open to development and change, and local productions should be supported for the development of local people. It should be ensured that the aesthetic values of different cultures are at the forefront. Otherwise, even more economic difficulties will be experienced in our settlements created with industrial products, in our lives that have become the same. Many material and spiritual cultures have disappeared, ignoring rural communities and their values. However, by keeping the vernacular architecture alive, the cultural wealth in the world can be preserved. The organic bond we establish with our cultural heritage constitutes the source of our cultural wealth and makes our cultural history known, and enables us to be individuals with aesthetic value knowledge. When cultural development, change and progress steps are taken based on this basic principle, a weakening sense of identity is not experienced and it becomes easier to create conditions that will ensure cultural continuity with all its colors.

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chapter 6

ASSESSMENT OF TEXTILE ARCHITECTURE FROM A SUSTAINABILITY PERSPECTIVE

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1. INTRODUCTION

Urban areas are mosaics of diverse spatial patterns. Organisms built structures, and the physical environment interact. Flows and movements through the mosaic create a dynamic system. Built structures are a key to urban ecology. Architecture, housing, and transportation emphasize people–built structure interactions (Forman, 2014).

Being respectful of human beings and nature, and not damaging the habitat of living organisms form the foundational principle of sustainable and ecological architecture. Following this principle, enabling the minimum amount of energy consumption is discussed, starting with the planning stage and continuing during the construction, operation, and disposal stages of the building process.

The sustainable, ecological building design is harmless to nature, the environment, and human beings; pays attention to the relationship between human beings and nature by allowing climatic and topographic data to shape the building and starts with a planning approach that is intended for the productive use of resources. Implementations of this approach are executed in such a manner that will not disrupt nature's harmony. While buildings are environmentally friendly, durable, and economic, sustainable, ecological building design also incorporates a design-manufacture-use-recycle process during which user needs are well-considered.

When the structural and natural elements in the urban environment can be handled as a whole, within the frame of urban ecology, a positive sustainable balance between nature and human needs can be constructed (Forman, 2008).

The appropriate relationship between ecology and building can be realized by the following: minimizing the factors that cause environmental problems during the process of building design, construction, and use; energy conservation (gaining from the energy consumed and moving in the direction of benefiting from natural energy resources, such as wind, water and solar); and using materials that are compatible with the ecological balance.

2. ESSENTIAL CRITERIA FOR MATERIALS IN SUSTAINABLE AND ECOLOGICAL ARCHITECTURE

In architecture, there are many systems used in the assessment of environment-building relationships.

Sustainable and ecological properties of buildings are assessed under various categories via assessment systems such as the "Environmental Impact Assessment" (EIA) methods and "Life Cycle Assessment" methods which measure and assess the impact of buildings on the environment, BREEAM (BRE Environmental Assessment Method) certificate system, CASBEE (Comprehensive Assessment System for Building Environment Efficiency) and LEED (Leadership for Energy and Environmental Design) certificate systems.

It is observed that materials used in buildings have a significant impact on the rating systems of the aforementioned assessment methods.

In the BREEAM Assessment Method, assessments are executed according to the criteria defined under various performance categories. Projects earn credit points for each criterion they fulfill. As observed in Table 1, BREEAM Assessment Method is comprised of 10 categories; namely, energy, management, health and well-being, transport, water, materials, waste, land use and ecology, pollution, and innovation. Choices of sustainable and recyclable materials are included under the Materials category, in the section for assessing the reuse of building structure and façade and they cover twelve and a half percent of the total 110 possible credits.

Table 1. 2008 BREEAM, breakdown of percentage points for each category (Tönük et al., 2010: 296).

Categories	**New constructions, extensions, and major renovations, %**
Management	12
Health and well-being	15
Energy	19
Transport	8
Water	6
Materials	12.5
Waste	7.5
Land use and ecology	10
Pollution	10
Innovation	10

In CASBEE – Comprehensive Assessment System for Building Environment Efficiency, under the section titled "L-2 Resources and Materials" covered under the parent category "L (Built Environment Load)" recyclability of building materials are assessed and energy of production is calculated (Table 2).

Table 2. CASBEE - Hypothetical Boundaries (Tönük and Köksal, 2010:206

<table>
<tr><td rowspan="6">Building Environmental Efficiency – BEE</td><td rowspan="3">Q- Environmental Quality and Performance of the Building</td><td>Q1- Indoor Environment</td></tr>
<tr><td>Q2- Quality of Service</td></tr>
<tr><td>Q3- Outdoor Environment Quality on Site</td></tr>
<tr><td rowspan="3">L- Built Environment Load</td><td>L1-Energy</td></tr>
<tr><td>L2-Resources and Materials</td></tr>
<tr><td>L3-Offsite Environment</td></tr>
</table>

LEED (Leadership for Energy and Environmental Design) is a certificate system issued for buildings. For the certificate issued for new constructions and major restorations, "materials and resources credits" which are included under the title of LEED V3 rating system, cover 14 credits out of the 110 total credits. Table 3 shows the scope of the assessment criteria in LEED V3 rating system.

Table 3. Assessment categories and credits for LEED V3 rating system (Tönük and Düstegör, 2010:185).

LEED V 3 rating system credit categories	Credits
Sustainable sites	26 credits
Water efficiency	10 credits
Energy and atmosphere	35 credits
Materials & resources	14 credits
Indoor environmental quality	15 credits
Innovation in design	6 credits
Regional Priority Credits	4 credits

What is stated above as the essential criteria for ecological structuring also forms the basis of sustainable architecture. As observed in the contents of these conditions, materials used in building play a significantly effective role.

Materials gain importance as sustainable architecture actualizes its objectives with regards to finding architectural solutions that protect the environment and provide health and safety (Çelebi, 2003). The essential criteria for materials in ecological architecture include: the amount and embodied energy of the material used; reduction of waste generated by the material used; materials not having harmful oscillations, being reusable and recyclable.

According to Wærsted (2014), the use of textiles as building materials means that textiles are used in buildings in ways like how other materials are used, integrated with material components and systems. The various uses of textiles in architecture can be summarized as "Creation of New Kinds of Forms", "Regulation of Daylight", "Regulation of Sound", "Energy Efficiency" and "Lightness and Mobility".

In this study, assessment of fabric systems from a sustainable architectural perspective will be executed within the scope of the criteria published by Çelebi in her work titled "Environmental Discourse and Conceptual Framework for Sustainable Architecture." In this publication, Çelebi develops a conceptual framework intended to inspect sustainable architecture design with an approach that pays attention to designing and manufacturing sustainable buildings that create environmental consciousness and that can explain the building ecosystem. In this framework, "Protection of Resources", "Life Cycle Design (LCD)", and "Livable Design" are defined as the "Objectives of Sustainable Architecture."

The intents of the objective of “Protection of Resources” in sustainable architecture are to minimize the use of nonrenewable resources by protecting available resources during the stages of building design, implementation and use. Three main resources that need to be conserved are energy, water and materials. In sustainable building design, the intent is to reduce the input resources, to recycle or enable the reuse of output resources and to reduce environmental pollution by employing effective waste management during the process of resource flow (Çelebi, 2003).

Within the context of “Protection of Resources,” building site activities gain importance during the manufacturing and fabrication stage of the building. During the use and operation stage, the use of energy resources, the amount of energy consumed by heating, cooling, lighting and various equipment operations and the environmental impact thereof gain their importance.

With regards to criteria for building materials included in the objective of “Protection of Resources”, acquisition and design of materials, manufacture and lifetime thereof, whether these materials allow for reuse during the demolition stage, and the impact of the generated waste on the ecosystem are discussed (Çelebi, 2003).

The objective of “Life Cycle Design” in sustainable architecture is concerned with the process of the life cycle and environmental consequences of all architectural resources that are used in the construction of the artificial environment, from procurement to return to nature. It inspects the pre-building, building and post-building stages of the process and includes the impact of design, construction, operation and disposal of the building on the environment (Çelebi, 2003).

The objective of “Livable Design” in sustainable architecture incorporates a design approach in which the building is environmentally friendly; it does not harm the existing regional flora and fauna or destroy the ecological balance, and it is following the laws of the biology of the building. Besides, the intent of the objective of “Livable Design” is to create a built environment that sustains the physiological health, psychological well-being, comfort (thermal, acoustic, and visual comfort, etc.), safety and productivity of the building’s users. Assessment of textile architectural systems from a sustainability perspective will be reduced from the scale of the site down to the scale of materials, with the following titles and order thereof: “Livable Design”, “Life Cycle Design” and “Protection of Resources (Çelebi, 2003)”.

3. EVALUATIONOFTEXTILEARCHITECTURALSYSTEMS UNDER THE SCOPE OF "OBJECTIVES OF LIVABLE DESIGN"

It could be said that the forms of textile architectural systems can be constructed in accordance with the affordances of the existing terrain, compatible with the topography thereof (topographic compatibility.) Due to their structural features, these systems are often comprised of organic forms (Gezer, 2006). Dynamic curves and forms which are often dominated by fractal geometry compromise with the silhouette of nature and seamlessly integrate into the environment. Units comprising the form can be grouped in a way that will be compatible with the topography and they could be situated in sloping terrain without the need for excavation. Thus, the negative environmental impact created by the forms of textile architecture is removed.

The structures of this system could be compatibly constructed with the climatic and geomorphological structure of the region. Open, half-open and closed, or hybrid structures could be conceptualized and designed, both as structures and layers, according to the terrain and seasonal data.

Almost all case studies of fabric architecture are based on environmental concepts that seamlessly integrate with nature.

Textile architecture has a system that easily responds and adapts to functional changes. The portability of support elements brings freedom to space planning. Spaces could be rearranged according to changing conditions in order to adapt to the social, cultural and aesthetic needs of the building's users. For example, Eden Project - constructed with a half-transparent membrane (EFTE- ethylene tetrafluoroethylene) and hosting approximately 100 thousand plants belonging to 3 thousand and 500 different species - is an environmental structuring and a complex where cultural activities are organized (Figure 1). Designed to present a new way of thinking about life, this structure successfully brings together ecology, science, art and architecture. The project is designed with a concept that reminds one of how human beings are dependent on the existence of flora and trees, as a condition of a sustainable future. Eden Project also hosts many cultural and artistic activities. Furthermore, Eden Foundation, which was formed in the process, initiates various educational and creative development projects. With these projects, new employment opportunities were created for the Cronwall region, which had an unemployment rate of 75% before the development of these projects (URL 1).

Figure 1. Half-transparent canopy structure of the Eden Project(URL 1).

Eden Project, realized to create a live theatre performance of flora, hor-ticulture, agriculture and forestry of the world and to improve the economic and social structure of the region in addition to the development of its eco-logical structure, was implemented near St. Austell in Cornwall, located in southwest England. Designed to reside 15 meters underground, in an indenta-tion that does not have even soil (topsoil) surface, the locations for the Biomes were determined via Solar Modelling. Thus, maximum passive benefit from solar energy is achieved (URL 2).

A single sustainable skin to define space, washed with day lighting and harvesting rain water, was designed by FTL Design Engineering Studio for the Rosa Parks Transit Center in Detroit USA (Figure2). FTL developed a design approach that uses flowing canopies to create an active visual space and naturally day light space which challenges the conventional notion of roof where the PTFE membrane both hovers 50 ft in space, and in other areas brought to ground and to act as a giant water collector (URL 3).

Figure 2. The sustainable canopy system of Rosa Parks Transit Center in Detroit USA designed by FTL Design Engineering Studio (URL 3)

Designed by a research team led by Prof. Kristof Crolla at CUHK's School of Architecture, the ZCB Bamboo Pavilion, in Hong Kong promotes low-carbon living and construction, as well as to fully utilise the flexibility of bamboo (Figure 3). The project investigates how computational design tools can be strategically inserted into existing traditional construction methods to allow for a more engaging and innovative architectural outcome. The bamboo grid shell structure with a footprint of approximately 350 square metre and a seating capacity of 200 people is a flexible and environmental friendly material (URL 4, 5).

Figure 3. The ZCB Bamboo Pavilion, in Hong Kong (URL 4, 5).

4. ASSESSMENT OF TEXTILE ARCHITECTURAL SYSTEMS UNDER THE SCOPE OF "LIFE CYCLE DESIGN"

Within the framework of "Life Cycle Design", energy consumption is assessed for the whole life cycle of the material used in textile architectural systems; during the pre-building, building and post-building stages.

The amount of embodied energy in the structure is composed of four components, with a percentage breakdown as follows: manufacture and processing of the material (54%), transport (20%), construction activities (%10) and service / other fields (%16) (Yüksek and Esin, 2013).

If we examine the components comprising the structure system of the textile architectural systems within this context, the material covering the system in the structure is a membrane put together from various fibers. Membranes used in textile architecture include the group of textile products called "technical textiles", recently referred to as "architextiles". Technical textiles are defined as the textile materials and products manufactured for their technical and performance capabilities, rather than their aesthetic and decorative properties (Horrocks and Anand, 2003).

Fibers used in technical textiles can be diversified as modified versions of conventional fibers, mineral fibers (glass, carbon, ceramic and asbestos fibers), synthetic (artificial) fibers (polymer-based high modulus polypropylene, polyester, polyethylene, polyvinyl chloride, polyamides, aramids) and nanofibers.

Manufacture stages of fibers and coatings can vary. With the advancements in textile and coating technologies, manpower used in the manufacturing stages is gradually decreasing. In cases where the organic grain used, less energy is consumed in the acquisition of fibers. On the other hand, the artificial grain is less time-consuming and more economic. Waste is either not produced at all or the tiny amount of waste produced from manufacture to end-product stage is reusable.

With these fabric membranes, which are much faster and enable much less energy consumption in comparison with alternative building materials, very wide clearings can be constructed in the lightest possible way, minimizing the need for the support system components below. Establishing the static with tensile force, these fabric membranes require much less support components when compared to conventional building systems. The structure, constructed by a textile product in place of heavyweight concrete and steel, is highly durable given its lightweight. They are more resistant against external weather forces such as wind or snow. Organic grain fabric membranes usually weigh 600 gr/m2 and have a tear resistance of 3000 N/5 cm, and artificial grain fabric membranes usually weigh 700-1000 gr/m2 and have a tear resistance of 6000-10000 N/5 cm (Horrocks and Anand, 2003; Saçak, 2011). In these systems, some of the most commonly used fibers and relevant properties thereof are as follows:

Polytetrafluoroethylene: (Teflon-Hostaflon) (PTFE) is manufactured via polymerization of tetrafluoroethylene. PTFE chains in polytetrafluoroethylene, known as Teflon, are highly protected against external factors thanks to the existence of many voluminous fluorine atoms in the polymer structure. PTFE has a high density of 2, 2 g/cm3 and a high melting point of 400°C. It is insoluble and it disintegrates at about its melting point. These fibers are compatible with normal atmospheric conditions, durable against UV radiation and indifferent to humidity and chemicals. Their thermal stability is good, they are inflammable and could be used under temperatures of up to 300 °C (Saçak, 2002; Schweitzer, 1999).

Polypropylene (PP) is a polymer with low density (0,90 g/cm3). It does not hold moisture because it does not include high crystallite and polar groups.

Fibers made out of PP have high resistance and they display very good resistance in alkaline environments. The melting point of the material is 165°C and it retains its properties until temperatures of 100°C.

Due to their nature, fibers display resistance to many chemicals. However, they have a low resistance to impact. Since PP is affected by sun rays and oxygen, various precautions have to be taken to protect the material against ultraviolet rays and oxidation (Schweitzer, 1999; Ersoy,2001).

Glass fibers are inorganic fibers. Glass fibers have good fire and heat resistance and thermal insulation. They are not affected by microorganisms and can retain their dimensional stability.

Their density is high (2,5 g/cm3). Since they are not affected by moisture, fibers display the same mechanical properties in their wet and dry states. Glass fibers are composited with polymers, such as polypropylene, polyester, polybutylene terephthalate and polyamide, to produce composite products. With new technologies, glass grain that can be as small as 5 μm can homogeneously spread in clusters, without breaking apart (Saçak, 2002; Schweitzer, 1999; Ersoy, 2001; Gezer, 2009a; Gezer, 2010).

Carbon fibers are fibers that contain (at least) 90% carbon mass in their structures. Carbon fibers are light, fragile and chemically inert. Like glass fibers, carbon fibers are also commonly used as supplementary material in polymers. In performance tests, carbon supplemented thermoplastic resinous FRP composition reaches an elasticity module of 50 000 MPa and ultimate tensile stress of 300 MPa. This type of resin can withstand chemical environmental conditions and a temperature of 200 °C (Saçak, 2002; Schweitzer, 1999; Ersoy, 2001; Gezer, 2009a; Gezer, 2010).

Table 4 shows some of the life cycle phases of textiles and films used in architecture (the table is compiled by Monticelli and Zanelli, 2016 from different sources).

Coatings applied over the fabric are thin-film layers of polymeric material, which do not allow the permeation of water vapour but allow the penetration of liquid water. A typical coating, which is laminated over the fabric membrane in order to achieve mechanical power, is only about 10 mm thick. Polyethylene, polypropylene, polyamide, polytetrafluoroethylene, and polyvinyl chloride polymers belong to the thermoplastic group and can be reused via melting, without leaving any waste behind (Gezer, 2009a; Gezer, 2010).

Table 4. A comparison matrix of the existing environmental data and information of the life cycle phases of textiles and films used in architecture (Monticelli and Zanelli, 2016).

		Types of membranes			
		PES/PVC	Fiber Glass/PTFE	PTFE fabric	ETFE foil
Pre-use	EE (MJ/kg)	96/113,3	295	295	26/337,3
	EE (MJ/m2)	54/68	-	-	315 for a 5-layer cushion 326,2 for a 3-layer cushion
	GWP (CO2eq/kg)	4,6/6,13	-	-	89 170 for a 3-layer cushion
	GWP (CO2eq/m2)	2,2/4,1	-	-	137 for a 5-layer cushion
Use	Durability of material (yrs)	10-30	25	15 industry warranty 25+ expected lifespan	up to 50
	Life span of the construction system (yrs)	15			30, 25, 20
	Maintenance	Periodical and planned controls are needed to search possible damages to be as quick as possible repaired	Anti-adhesivity propriety, self-cleaning by rain. Periodical and planned controls are needed to search possible damages to be as quick as possible repaired	Anti-adhesivity propriety, self-cleaning by rain. Periodical and planned controls are needed to search possible damages to be as quick as possible repaired	Anti-adhesivity propriety, self-cleaning by rain. Inspection of the holes generated by birds Periodical and planned controls are needed: a. to verify the dirty deposition on the edges and on the frame alu profiles; b. To search possible damages to be as quick as possible repaired
End of life	Ongoing practices of life cycling	Composite material, non-homogeneous - Reuse and Recycling (down cycling)	Composite material, non-homogeneous - Recycling PTFE up cycling	Composite material, non-homogeneous - Recycling PTFE up cycling	Homogeneous material, dry assembled system, easy to be disassembled and separated - R down cycling

GWP: Global Warming Potential, EE: Entering Energy

The effect of sun reflection is higher in fabric membranes than in glass. One of the main advantages of fabric materials is that they have acceptable translucency levels and allow daylight illumination to be significantly reducedor eliminated. The reflectivity of some membrane materials such as Teflon coated fiberglass is about 70%. This feature is advantageous in hot climatic regions. The surfaces are not exposed to the sun as it reduces the heat gener-ation in the indoor area, but it expels the heat at night and thus reduces the artificial air conditioning load (Harvie, 1995).

These fibers are used in fabric membrane systems, in composite structures and together with various coatings. This achieves energy efficiency, even with very thin layers. For example, fabric membrane systems of National Space Center Museum, Bristol Wildscreen, Dynamic Earth (Figure 4 a-c), Younger Universe, Ministerial Entertainment and Recreation Center and Eden are constructed of layered, transparent PTFE material. In all applications, the use of PTFE increases the space volume and allows the entrance of a maximum amount of natural light into space. Holy Mosque's PTFE based umbrellas have a feature that significantly reflects the solar radiation. In Eden, lining the top of biomes with ETFE (Ethylene Tetra Fluoro Ethylene) folio increases energy efficiency to a maximum level.

Table 5. The solar optical properties of PVC coated polyester and PTFE coated glass samples (adapted from ElNokaly et al., 2002).

Type of Material	Diffused Transmittance (%)	Diffused Absorptance (%)	Diffused Reflectance (%)
Type 2 PVC coated polyester, gauge 0.7mm.	4,35	15,45	80,20
Type 3 is PVC coated polyester, gauge 0.85 mm,	3,81	17,97	78,22
Verseidag Indutex PTFE coated glass (new), gauge 0.75 mm,	5,33	24,75	69,92
Verseidag Indutex PTFE coated glass (weathered), gauge 0.75 mm.	78,00	15,00	7,00
Typical float glass surface 6mm gauge. Reflective glass surface 6 mm gauge	8,00	60,00	32,00

(a) (b) (c)

Figure 4. (a) National Space Center Museum (URL 6), (b) Bristol Wildscreen Hopkins Architects © (URL 7), (c) Dynamic Earth (URL 8),

ETFE's wide spectrum light transmittance allows for the maximum level of daylight that is vital for plant life. Having a weight equal to that of 1% of glass, being highly durable, recyclable and antistatic are other advantages of ETFE (URL 1).

Membrane comparisons according to translucency that was tested by the Birdair company are listed in Table 6. These scientific tests of solar properties have shown that PTFE fiberglass membranes reflect approximately 72-75 percent of the sun's radiated solar energy while allowing approximately 8 to 20 percent of natural daylight to permeate the membrane depending on the strength and thickness of the material.

Table 6. Membrane Comparisons according to Translucency (URL 9)

Property	PTFE Fiberglass	PVC	ETFE Film	ePTFE (High Translucency PTFE)
Translucenc y	10-18%	10-20%	Transparent	20-40%

Coated fabrics like translucent PTFE fiberglass and transparent films such as ETFE, are available in ranges from 10 to 40% and even more (URL 9).

For example, Switzerland's Montreux Garage's fabric membrane is a silicon coated textile supplemented with glass fiber (Figure 5). This half transparent fabric membrane allows for maximum transmission of sunlight. It is guaranteed for 25 years of use. The double layered glass grain textile with PTFE lining used in Burj Al Arab Hotel keeps the sun rays under control.

Figure 5. Montreux Garage (URL 10).

The double-layered glass fiber fabric membrane with PTFE lining of the Inland Revenue Center and "Grand Bigo" Port of Geneva, provides perfect insulation (Figure 6 a,b). Glass fiber increases the tensile strength of the fabric membrane and also allows sunlight to enter (it has a transparency of %13).

Figure 6. (a) Inland Revenue Center Hopkins Architects © (URL 11,12)

Figure 6. (b) “Grand Bigo” Port of Geneva (URL 13).

Among other applications of glass fiber fabric membranes with PTFE coating are Saint Nicholas Stadium and Schlumberger Cambridge Research Centre. Schlumberger Center in England is the first application of glass fiber fabric membrane with Teflon coating to a wide area. Building’s clearings are about 24 m and the total fabric membrane area is 8.046 m². 13% transparent fabric membrane allows for natural sunlight to penetrate into the deepest parts of the plan. The glass fiber fabric membrane with PTFE coating used in Haj Terminal of Jeddah reflects 70% of the heat from the sun and reflects the rays outwards all through the night, illuminating the space without the need for any other light source also due to its half-transparent nature.

Allianz Arena - Stadium’s fabric membrane, made out of double-layered half-transparent white EPDM (Ethylene Propylene Dien Monomer), is the world’s largest textile roof and it is only 0.22 mm thick. The material has the capacity to allow for the transmission of only 95% of sunlight. Since it receives natural light, the grass has no problem growing. This feature also supports the growth of natural vegetation.

Esslingen Airtecture Exhibition Hall in Germany is one of the special applications of inflated fabric membrane systems (Figure 7). All components comprising the structure of the double-layered pneumatic membrane are inflated. The building has 6m of internal height, 375m² of covered area and 2250 m³ of total volume. The total deadweight of the structure is only 7,5 kg/m². The building can withstand 50 kg/m² of snow load and 80 km/h of wind speed (Gezer, 2010; Pilar, 2005, Gezer, 2009b).

Figure 7. inflated fabric membrane systems of the Esslingen Airtecture Exhibition Hall (URL 14).

Applied to the surfaces of the north and south walls of the British Pavilion (Expo 92, Seville), the polyethylene textile surfaces with PVC coating provide extra protection from the sun, thereby dropping the temperature of the indoor environment. The fabric membrane system provides climatic comfort and shadowing indoors and maintains the desired lighting levels by allowing light transmission (Moore, 2004).

An example of a second skin façades design is the Gerontology Center, a spiral building in the south of Germany (Figure 8). This building has a shopping area on the ground floor and offices on the upper floors. The hori-zontal walkway, arranged outside the façade consisting of a standard post and rail system, is covered with a secondary membrane facade. With this mem-brane, it is protected from weather conditions and creates a thermal barrier. At the same time, thanks to this highly transparent "climate façade", which provides high visibility between the inside and outside, a naturally ventilated buffer is created in a controllable way. Constructed by Hightex Group as a prestressed facade, this ETFE membrane buffer creates an energy-saving intermediate temperature layer with a surface area of approximately 1550 m2 and is the first application of its kind in the world. Printing the transparent membrane with a silver dot fritting pattern serves as light scatter and sun protection. Additionally, the fluoropolymer-plastic ETFE which is used on this building has a range of outstanding properties (Cremers, 2011):

- Expected life is more than 20 years.
- ETFE membrane is flame retardant (B1) according to DIN 4102 and other international standards.
- ETFE membrane has a self-cleaning feature owing to its chemical composition and therefore can maintain its high translucency throughout its life.
- The material does not require maintenance.
- The translucency of the ETFE membrane is approximately 95% depending on the thickness of the foil. The scattered light rate is 12% and the direct light rate is 88%.
- ETFE membranes are 100% recyclable and extremely light (approximately 1/40 of glass).
- Two-dimensional patterns can be printed on the membrane to reduce solar radiation or achieve special designs while maintaining transparency.

Figure 8. The second skin façade of the Centre for Gerontology, Germany Hightex © (URL 15)

The structure of fabric membrane systems is comprised of building components such as poles, support components, cables (tensile, edge cables), pole base, arch, frame and anchorage components. The material for these compo-nents is completely light steel. Steel material is recyclable. Almost no waste is produced during the construction site and application stages.

The system allows for convenient installation and replacement possibilities, as well as a very low maintenance cost due to its portability. Instead of conventional systems that require costly excavations, the foundation is comprised of shoes that transfer the load or anchored systems.

The foundation does not have to carry a lot of load; consequently, the volume of the foundation is smaller, and the weight is less (Moore, 2004, Soygeniş, 1999; Mollaert).

Membrane covers are especially preferred in building shell to minimize the use of materials. This material, which has an average perimeter of 1 mm and a weight of 1kg / m2, allows covering large areas as it does not put much load on the supporting structures. However, due to its low mass, it reacts extremely quickly to thermal factors such as temperature changes and solar radiation. Due to this structure, it cannot prevent temperature fluctuations like traditional heavy building materials. Its thermal properties are based on surface heat radiation transfer and optical absorption. The effects of the membrane on the thermal comfort of the space are various (Table X). The amount and direction of heat transmission through the fabric structure largely depends on indoor and outdoor temperatures, wind speed, U value, the thickness of the fabric, and whether it is a single or double membrane (Harvie, 1995).

The thermal and optical properties of a material distinguish its radiation behaviour in the thermal spectrum. Unlike most building materials commonly used in the construction industry, fabric membranes offer the advantage of translucency. The permeability of coated woven fabric membranes is typically between 0% and 25% or even higher. This allows a significant amount of solar radiation to penetrate the entire surface of the building, while the rest is absorbed or reflected by the membrane. The exact permeability values depend on the material used, the angle of incidence of the sun, and the wavelength of the radiation (Harvie, 1995).

5. ASSESSMENT OF TEXTILE ARCHITECTURAL SYSTEMS FROM "OBJECTIVE OF PROTECTION OF RESOURCES" PERSPECTIVE

Textile architectural systems introduce to the field of architecture, temporary foundations, collapsible structures, portable fabric membranes, and thus more possibility for movement. With this aspect, "flexible architecture" also concerns the subfield of architecture called "portable architecture." Energy consumption is reduced due to the low values of supported material weight and due to the convenience during installation, which is allowed by modular systems.

These systems are systems in tension, and they are different from masonry systems in terms of the support which the forms provide; they are dependent on the form of balance and the prestressing applied. Closed systems implemented as inflated systems are structures that are resistant to the air pressured form. The essential forms of these air pressured systems are spherical, and their fabric membrane surfaces are balanced by the difference between the internal and external air pressure. Namely, what holds the structure together is “air”. Surface tension is achieved by creating excess or lack of pressure between internal and external volume (Türkçü, 2003; Engel, 2004; Sungur, 2005).

In textile architectural systems, the system as a whole can be designed in compliance with energy conservation strategies.

In general, membrane structures react very quickly to external energy influences due to their low thermal mass. For this reason, they cause thermal losses in winter and overheating in summer. This means that additional heating and cooling equipment will be needed in spaces created or covered with a fabric membrane. However, since the textile membrane is an easy-to-shape material, it can also be designed to support thermal stabilization. Modular structure and curvature can be shaped according to thermal comfort (Elnokaly et al., 2002).

Nowadays efforts are being made to equip membrane shells with other properties or combinations of properties, such as providing thermal insulation, translucency, or combining with integrated photovoltaic (PV) systems. This effort not only provides many benefits but also requires combining many different materials and their properties into layered structures (Nanci Palla et al., 2018). In particular, the low thermal performance of membranes used in combination with PV systems can be turned into an advantage.

According to Cremers (2007), textile membranes can be used for very wide openings, allow the development of many different designs, and can protect from external factors such as sun, wind, rain, and snow. The development of high-performance membrane and foil materials based on fluoropolymers, for example, transparent foils made from a copolymer of ethylene and tetrafluoroethylene (ETFE), set a milestone for suitable materials for the building envelope. A lot of innovative research is being developed to adapt applicable solar technology to membrane systems by companies. This research is about solar energy gain control and heat protection, thermal insulation, acoustic and daylight improvement. The integration of fully integrated and flexible PV into a transparent membrane and pneumatic foil structures not only generate energy but also help to control solar energy gains.

For example, Eden Project has an active heating system that fine-tunes the indoor air quality of the biomes, supporting the natural passive system. In addition to this, air conditioning and water strategies are designed to reduce natural resource waste by studies of the measurement of liquid dynamics. For example, rainwater is transformed to moisterize indoor space and underground water leaks are used in irrigation. Also, by partnering with EGS Energy Company, the Project supports the geothermal power plant which requires a 25-million-dollar investment. Eden project's management aims to meet 10% of England's electricity by the wide geothermal energy reserves, waiting in the embodiment in Cornwall (URL 1).

The theme for Expo 2015 was chosen as "Feeding the Planet, Energy for Life". The German pavilion at the Exhibition Center in Milan, Italy, designed by Schmidhuber, clearly orients itself to this concept. The central design element of the pavilion are expressive membrane-covered shelters in the shape of sprouting plants: the "Idea Seedlings." Their construction and bionic design vocabulary are inspired by nature. The Idea Seedlings link the interior and exterior spaces, a blend of architecture and exhibition, and at the same time provide shade for visitors in the hot Italian summer. By integrating cutting-edge organic photovoltaic (OPV) technology, the seedlings become Solar Trees (Figure 9). The German Pavilion is the first large international archi-tecture project to use these innovative new products (URL 16).

Figure 9. The German pavilion and Solar Trees, Schmidhuber©(URL 16)

Architen Landrell Ltd., a company that works on tensile stress fabric membranes, has applied new technologies to layered sandwich systems, in order to provide insulation in fabric membrane systems. The company has been successful in reducing heat loss to a minimum (dependent on the indoor and external temperature difference.) The values are below reasonable values for England (U= 0.25 W/m2 C) (URL 17).

A low U-value is an indication of the low amount of heat energy transfer in the building. The company has achieved high-level heat insulation by using three membrane layers in large arched forms (surpassing 200 m clearing). Architen Landrell is also able to collect extremely high thermal values in its projects, due to the enveloping membrane which is constructed with sandwich system technologies. Furthermore, the inner lining also provides a neat appearance for the system.

Architen Landrell Ltd. also applied this system in the 1.000,000 m² dis-mountable theatre project in the millennium exhibition area in London, by improving the double-colored PTFE fabric in terms of acoustics. Acoustic issues were also resolved with the layered membrane system applied to IFAI Expo 2000 (URL 17).

Figure 10. Fabric membrane system of the Chatham Maritime Food Court Architen Landrell Ltd. © (URL 18).

Among energy-efficient building projects, in the Chatham Maritime Food Court project, Architen obtained an external membrane system by an external membrane insulated by Isowool, air spaces in between and an aluminium folio lined layered membrane system (Figure 10). Despite its three layers, this application is light and provides a neat internal appearance. The only down-side is the reduction in sunlight transmission (URL 17).

In studies investigating sustainable construction techniques in the devel-oping construction industry in South Africa, application possibilities of "architextiles" are being researched with a sustainable construction approach. Tensile stress membraned roof and façades, pneumatic systems and compat-ibility of manufacture of low-cost residency procedures with fabric perfor-mances are being investigated with experiments. The environmental (ecological, resources, geography, built environment), social (community, culture, politics) and economic (employment, wealth, finance, industry, infra-structure, consumer behaviour) criteria for these fabric membranes in terms of sustainability are being investigated (URL 19).

According to the Brazilian architecture firm - which researches building systems that require low-technology processes, utilize renewable natural resources, are eco-centered and recyclable or, have a high amount of recyclable components - states that for this region, fabric membrane systems are able to meet these features. Using fabric membrane systems in residential architecture, within sustainable parameters, are gaining importance (URL 19).

Further, microfibers that are lighter than other textile materials are being investigated in several studies (Gezer, 2012; Gezer and Merdan, 2010).

For example, as the first stadium structure to be a candidate for LEED Platinum certification, the roof cover of the Brasillia Stadium is covered with TiO_2 photovoltaic membrane and cleans the air by neutralizing nitrogen oxides that cause air pollution. By mounting 9120 PV panels on the circular membrane roof of the building, it has an annual energy generation capacity of 3,000 MWh (Gezer and Aksu, 2021).

Similarly, the TiOx coating used of the membrane on the Zentrum für Angewandte Energieforschung (ZAE) Bayern Building has a feature that can break down nitrogen oxides in the atmosphere with a photocatalytic effect and reduce surface pollution (Figure 11). This coating also helps to control daylight and indoor climate.

Figure 11. Fabric membrane roof of the ZAE Bayern Building. Lang Hugger Rampp GmbH Architects (URL 20).

The roof of the Dolce Vita Tejo mall is constructed by cushion membrane systems (Figure 12). Up to five different film types can be combined in a single cushion module to provide thermal comfort as well as a high level of daylight. Depending on the sky angle and the membrane level, daylight trans-mission is kept under control with different prints and the overheating inside is minimized. This is possible with a targeted sun protection system inside ETFE cushions. The surface of the sun-facing top layer consists of two layers each with an impression and is therefore almost opaque. The opposite surface of the sole is single-ply but double-printed. The north-facing surfaces of the middle layer and the upper and lower layers consist of a transparent ETFE film. Besides, the top surface has two-layer and has a partial Low-E coating on the underside of the second layer. Since the mall has a BREEAM certificate, natural light is of great importance in terms of comfort (Nanci Palla et al.

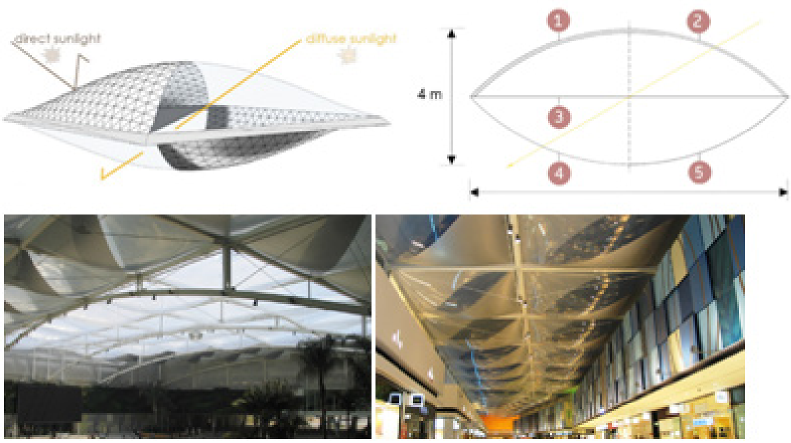

Figure 12. The day and night lighting effect of the Dolce Vita Tejo mall roof (Nanci Palla et al., 2018).

The use of fabric membrane systems in combination with wooden structures offers aesthetic and design options. In this sense, the enclosing shell structure of the Vitam' Parc Leisure Center in Neydens indoor pool, designed by the Spanish architectural practice L35 Arquitectos, consists of dou-ble-hinged frame arches made of glued laminated wood and additional arches between them (Figure 13). The wavy shell with an S-shaped ridge line is formed by the different seam heights of the arches and the different distances between the respective support pairs. Hose-like membrane cushions are attached to the outside along these arches. Owing to the transparency of the film, the carrier wooden structure can also be seen from the outside (Nanci Palla et al., 2018). As another wood constructed building, The Frankfurt Pavilion has around 500 square meters of floor space, 6.5 meters in height (Figure 14). With its self-supporting wooden structure and translucent mem-brane, this building is seen as the new landmark of the Frankfurt Book Fair (October 10-14, 2018) and is planned and implemented by the renowned architects Schneider + Schumacher (URL 21).

Figure 13. The Vitam' Parc Leisure Center in Neydens indoor pool enclosing shell, Seele © (URL 22).

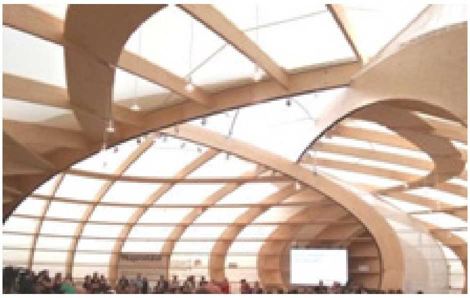

Figure 14. The wooden membrane construction of the "Frankfurt Pavillon". Kulturexpress © (URL 21).

Through its ability to cover wide openings, fabric membranes provide important advantages in the protection of architectural and historical places. The waterproof membrane covering an area of approximately 1700 square meters, allows the artifacts to be seen with its light-permeable feature (Figure 15) (İrepoğlu, 2019).

Figure 15. The waterproof membrane covering of the Göbeklitepe archaeological excavation site in Şanlıurfa,Turkey (URL 23, İrepoğlu,2019).

5. CONCLUSION

Textile architectural systems have the essential parameters of durability, utility and beauty, which are essential principles of architecture. Assessing these fabric membranes according to the criteria for sustainability, from the objective of “Livable Design”, these buildings have a design approach that is compatible with environmental and natural conditions and they can easily adapt to the topography of the environment. Textile architecture is compatible with the geography of its location; does not harm regional flora and fauna; does not disrupt ecological balance; and can be applied with a design approach that is in accordance with the laws of the biology of the building.

Furthermore, the building is able to create an environment that sustains the physiological and psychological health, comfort (thermal, acoustic and visual comfort, etc.) and security of its inhabitants. Buildings have a planning and structure system that easily responds and adapts to functional changes. The portability of support components provides freedom in space planning. Space can be rearranged to meet changing conditions based on the social, cultural and aesthetic needs of the building’s users.

Fabric membranes are non-toxic building materials. With technical textiles, ambience changes, such as dryness and wetness or hotness and coldness, can be balanced and appropriate lighting and air conditioning can be obtained. Thanks to their flexibility and collapsibility, the form of membrane systems can be modified extremely fast, depending on the conditions of sun and rain.

From the perspective of the objective of “Life Cycle Design”, fabric membrane systems do not harm the ecosystem during pre-building, building and post-building stages, during design, manufacture, operation and demolition stages. These membranes can be applied to clearings of up to 150m. This system provides the field of architecture with the possibility of movement with its temporary foundations, collapsible structures and portable membranes. This significantly reduces the energy consumption of the building during its technical implementation stage.

Energy consumption is reduced due to low values of supported material weight and due to the advantage, this brings as convenient installation during implementation. The total production energy of the material used is extremely low when compared with other systems. Therefore, less energy and natural resources are consumed. They are much lighter compared to conventional roofs. They allow for modular installation (material loss is reduced to a minimum.) They are easily implemented; therefore, they save time and reduce construction costs. It is quite easy to replace and repair them. Fabric membranes have extremely low energy consumption and emission values during all of the stages (energy used in processing and acquisition of its raw material, packaging, transport, manufacture, maintenance, repair and demolition.) It is not exposed to too much damage from the destructive effects of an earthquake, due to its flexibility and lightweight.

Mounting details can easily be resolved by multivariate adhesion methods or materials such as sealing strips. With appropriate finish methods, technical textiles can be simply manufactured with the desired high-performance properties.

Coating and lamination can be applied at the finish. With these applications, fabric membranes can be protected against UV rays and electrosmog. These membranes provide waterproofing and vapour permeability. They have high tear resistance. With special coatings, they can become resistant to fire and become secure. They can be manufactured in accordance with fire regulations.

Compared to conventional building materials, fabric membranes better resolve acoustic issues and are used for noise reduction in large areas. They absorb sound.They provide healthy indoor air quality, thanks to their high levels of degradation and inertness against chemicals.

From the perspective of the objective of “Protection of Resources”, it is possible to reduce the consumption of nonrenewable natural resources and to protect existing resources during design, application and use stages of fabric membrane systems. They allow for urban design and building design that aims for energy conservation.

Fabric membrane systems do not leave behind environmental waste during use, repair and renewal processes and they do not disrupt ecological balance. Applications have long lifetimes, such as 30-50 years.

With fabric membranes, the designer can tune the light to the level she desires. Natural lighting for the space is possible. Furthermore, since the material is as transparent as glass, it allows for maximum benefit from daylight. With the equipment placed between fibers, daylight is obtained during dark, or the sun’s energy is used with the intention to heat the building at night and for lighting. Since the air conditioning and heating systems of the buildings can be arranged as desired, energy consumption is low. High-level insulation could be achieved with layered systems. This reduces CO emissions. It is possible to reuse thermoplastic products with no waste. It is possible to reuse water, recollect rainwater and greywater at the building site.

In conclusion, when “textile architectural systems” are assessed from a sustainability perspective, according to the principles explained above, it could be said that these systems better comply with sustainability principles when compared to alternative building systems.

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chapter 7

DIGITAL FABRICATION SHIFT IN ARCHITECTURE

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1. INTRODUCTION

The transformations in architecture since the second half of the 20th century, go beyond just effecting the design tools&methods and necessitate re-questioning the role of the architectural profession in today's World. This new comprehensive process, which is named as *Digital Architecture*, is not only a change in representation mediums, but also directly affects the cognitive structure of design and design thinking. While architectural design tools and thought patterns evaluatecohiesively, studies are rapidly increasing about the construction of this new designs. These production methods, called *Digital Fabrication*, are effective in architectural processthrough all phases and in all scales. This research aims to understand this effects of Digital Fabrication in today's architecture proffession in different scales, techniques, tools and materials. The study starts with a brief history of machine tool evolution into *Computer Aided Manufacturing* (CAM) to understand the transformations in all aspects. Secondly, the first applications of *Digital Architecture* were explained to understand the very first impacts of this shift in design. Then selected projects are represented to underline the importance of the new techniques, tools and materials. In conclusion, further assumptions are made and potentials of digital fabrication are discussed, according to the current researches.

2. EVOLUTION OF MACHINE TOOLS INTO CAM: A BRIEF HISTORY

The Industrial Revolution was a result of James Watt's steam engine. When the engine become essential for more complex manufacturing of that time, the engine cylinders started to get problemmatic because of the handmade process. As a natural result of this problem machine tooling was born, to make production lines more precise. A machine tool is basicly a medium, in which the machines guides the toolpath. The first machine tool was John Wilkinson's boring machine (1775), thatproduces cylinders for steam engines (Weightman, 2007).Textile industry was known as the first use of modern production methods. Just before the revolution,BasileBouchon invented a way to control looms by using data encoded on paper tapes through a series of punched holes in 1725. Joseph Marie Jacquard strengthened and simplified Bouchon's concept by tying punched sturdier cards in sequence to automate the process in 1805 (Essinger, 2004). Punched cards developed through 1800's and their mechanical control turned into electromechanical system in 1896 with Herman Hollerith's Tabulating Machine Company.

With further developments thoruoghout 20th century, puched cards were used for data input and storage in computers and numerically controlled machines. *Numerical control* (NC) means using data in the form of letters, numbers, symbols, words, or a combination, to automate control of machining tools. In 1896, another groundbraking invention- *servo mechanism*- was created by H. Calendar. In time servos become the essential part of today's *computer numerical control* (CNC) machines to attain requredtolarences in automated machining process. CNC is, when precisely coded instructions are sent to a microprocessor in the control system of a machining tool, enabling an enhanced level of precision and consistency (Smid, 2008).

The attention on servomecanisms made MIT open a Servomechanism Laboratory, where another fundamental tool for Digital Fabrication was developed. From 1942 for 10 years many inventions made for Aircraft Industry (URL 1). In 1952, MIT demonstrated a 7-track punch tape system. In Scientific American's September 1952 issue, MIT's William Pease wrote a paper titled "An Automatic Machine Tool", in which he mentioned the first account of a milling machine that converts information on punched tape into a finished part (Pease, 1952).During that time, G-code, the most widely used NC programming language, was used to tell computerized machine tools how to make something. In 1956, *Automatically Programmed Tool* (APT) was created by Computer Applications Group atthe same laboratory to generate instructions for NC machines, which was the first steps of generating CNC machines. The MIT team introduced their first CNC machine development with a CNC-milled aluminum ashtray production in 1959. This research made The Air Force sign a contract about developing a "*Computer-Aided Design Project*." with MIT. The resulting system of this research was called, *Automated Engineering Design* (AED) (URL 1).The first commercial CAD system, Electronic Drafting Machine (EDM), was developed by ITEKin 1962. It was the first example of an end-to-end CAD/CNC production system and used to build production parts for a military transport aircraft (Weisberg, 2008).

One of the most influential computer program was designed for designers to draw basic primitives by using a light-pen for inputin 1963. Ivan Sutherland, a PhD candidate at MIT, submited his thesis titled "Sketchpad: A Man-Machine Graphical Communication System", describing the first graphical user interface. The program was capable ofmany typical CAD operations of today and differentiate from the earlier programs by it's interaction (Tedeschi&Andreani, 2014).

The effect of SketchPad created a rapid increase in computer programes for design during 1970's. One of the most important programe of that time, *Automated Drafting and Machining* (ADAM), was released in 1972 by Dr. Patrick J. Hanratty. ADAM was one of the first commercially available mechanical design packages. In 1976, Hanratty's laboratory MCS introduced AD-2000, a design and manufacturing system for computeras the first modeling software (URL -1) (Table 1).

1980's was the time when local area network systems emerged and microprocessors of computers dropped. In the second half of 80's large computer terminals are replaced by networked stations and personal computers became a daily life object (Weightman, 2007). It is no surprise that this rapid change also occured in development of CAD systems. Some of the programs released at that time can be listed as; Versa CAD (1980), 3D/Eye Inc. (1981), UniSolid (1981), CATIA Version (1982), AutoCAD (1982), CADplan (1982), BRAVO (1983), PseudoStation (1985), CADKEY (1985), ANVIL-5000 (1986), AutoSketch (1986), Shape Data Ltd. (1988), Strucad (1988), ArchiCAD (1989), in 1990's followed by Animator Pro (1990), ArcCAD (1991), 3D Studio (1991) and Visio Technical (1992) (URL 1).

Table 1. Important years and events in evolution of digital design and manufacturing until 1980.

Year	Development/Research/Inovation
1725	Data encoded punched holes
1775	Boring machine
1805	Punched cards in Jacquard loom
1896	Tabulating Machine Company Electric servomechanism
1924	IBM
1940	MIT Servomechanisms Laboratory
Mid 1950's	G-code
1956	Automatically Programmed Tool (APT)
1957	First CNC Machine Foundations of CAD
1958	A new era in manufacturing was born.
1950	CNC Aluminum Ashtray CAD Design Project starts.
1962	Electronic Drafting Machine Demonstration of an end-to-end system (CAD to CNC)
1963	Sketchpad
1965	Automated Engineering Desing
1971	ADAM (an interactive graphic design, drafting and manufacturing system in Fortran)
1974	Microcomputers
1976	AD-2000 (first modeling software)
1980	The era of personal computers begin.

As this shift was changing the whole understanding about design thinking, naturally the production technologies developed and started to look for alternative CNC systems during 1980's. In 1981 rapid prototyping was born, by two articles of Hideo Kodama, on three dimentional model fabrication (Kodama, 1981a, 1981b). Jean-Claude André, Alain le Méhautéand Olivier de Witte applied for stereolithography process patent in 1984 (Gibson & Jorge Bártolo, 2011).It was three weeks before Chuck Hull filed his own patent for stereolithography. Hull got the patent for "Apparatus for Production of Three-Dimensional Objects by Stereolithography" on March 11 1986. He defined stereolithography as "printing" thin layers of the ultraviolet curable material one on top of the other by the help of an advanced CAD/CAM software, which slices the computer model of the object into a large number of thin layers (Beaman, 1997). Same year, Carl Deckard started investigating a similar method to Hull's, which uses

uses powder materials, later to be known as Selective Laser Sintering (SLS) (Deckard, 1989). Scott Crumpcreated and patented Fused Deposition Modelling (FDM) the same year by automating the process by attaching it to a robotic XYZ gantry system (Crump, 1989) (Table 2).

Table 2. Important developments in evolution of digital design and manufacturing from 1980 until early 1990's.

Year	Development/Research/Inovation
1980	Versa CAD
1981	Rapid prototyping
1982	CATIA AutoCAD CADplan
1983	BRAVO
1985	PseudoStation CADKEY
1986	STL ANVIL-5000 AutoSketch
1988	Shape Data Ltd Strucad
1989	SLS FDM ArchiCAD
1990	Animator Pro
1991	ArcCAD 3D Studio
1992	Visio Technical (1992)

This very brief history of digital design and fabrication shows that nearly all of the inovations in this subject was made for engineering purposes. Therefore, architecture was adapted to these new techniques rather later than engineering.

3. DIGITAL AGE TRANSITION IN ARCHITETURE

Architecture is an effective communication of creative ideas through continuous dialogue of designing and making (Dunn, 2012).Drawing as the core activity of this process, become a more efficient and an easy task by using CAD in Architecture for nearly forty years. But this shift from traditional to digital did not reflect on the design of the buildings (Iwamoto, 2009). Drawing a project by using CAD with a traditional design thinking, can only be seen as a translation of analog logic into digital realm (Tedeschi&Andreani, 2014). This approach is an imitation of manual human design and is called "computerization", whereas, the real "computation" lets architects to search for "extreme, strange, and occasionally unpredictable situations" by the capacity and use of CAD (Terzidis, 2015), in design, form and construction.

First attempts for a digital design method was made long before the use of CAD in Architecture.Luigi Moretti, invented the definition for "Parametric Architecture" in 1939 and use the parametric design in his stadium models at the 1960 Twelfht Milan Triennial. According to his explanation for parametric architecture; the parameters become the code of the new architectural language and structure. These parameters and their interrelations must be expressed and supported by computational, logical and mathematical tools and techniques (Bucci&Mulazzani, 2000)Anohter traditional tectonic rejection example is Frei Otto's researches on form. Otto used physical models such as: soap films which found minimal surfaces, and suspended fabric which found compression-only vaults and branched structures to investigate architectural forms (Otto &Rasch, 1996).These searches emerged a new perspective in design thinking. The traditional form making approach of tectonics has shifted into form finding (Tedeschi&Andreani, 2014), even without proper CAD & CAM use in architecture.

Today, as designers realized that CAD programs could manage complexity beyond human capabilities, form-finding has becomean importantstrategy for shape determination.Now architects can design with a multi-parametric form-finding approach including geometry, dynamic forces, environment, social and any desired data. This new dialogue between form and process has led to new architectural tectonics. Kolarevic (2003a) list these tectonics as; topological, isomorphic animation, metamorphic, parametric, evolutionary, performative architectures and virtual environments. The variety of design processes affected the fabrication of architecture and its components as well.

Looking through it's history, digital fabrication was first used to make the physical models used in the restorations of Saint John the DivineCathedral and SagradaFamilia (Burry, 2003; Burry, Burry, &Faulí, 2001) for constructive decisions. (Kolarevic, 2003b). Frank Gehry's office began using CAD/CAM to develop and test the Disney Concert Hall's constructability in 1989. They adapted CATIA (Computer Aided Three Dimensional Interactive Application) to architecture, to model the exterior facade of the concert hall.

The digital model was send directly to digitally driven machines that essentially sculpted the physical production (Iwamoto, 2009).

Nowadays computers are used at every step of architectural design process for 2D drawings, 3D modelling, visualization, animation, fom finding, analyses, management and construction. Digital fabrication has narrowed the gap between representation and construction of an architectural design. The integration of CAD & CAM has created a new definition for design and production relations(Mitchell & McCullough,1995). This file to factory process (Dunn, 2012) will be discussed in the next chapters of this paper over selected examples, to explore the potentials and make further assumptions.

4. DIGITAL FABRICATION SHIFT IN ARCHITECTURE

Digital fabrication has a meaning referring to a production process by computer controlled machines (Gershenfeld et al., 2017). Although the definition sounds like, it is the last step of an architectural process, digital fabrication techniques are used for many purposes at different scales in architecture. According to the design, fabrication methods can differ. Most common digital fabrication procedures used in architecture are; additive procedures, subtractive procedures, formative procedures, joining procedures (Hauschild&Karzel, 2011) and robotic fabrication (Picon, 2014; Willmannet al, 2012, 2013, Güzelci, 2015, Güzelci&Güzelci 2018) (Table 3).

Table 3. Most used digital fabrication techniques in architecture.

Digital Fabrication Method	Tool Type
Additive	Stereolithography (STL) Selective Laser Sintering (SLS) Selective Laser Melting (SLM) 3 dimensional printing (3DP) Fused Deposition Modelling (FDM)
Subtractive	Lazer Cutter Jet Cutter Hot Wire Cutter Milling Routing
Formative	Bending Drilling
Joining	Welding
Robotic	Robot Arm Drone

Digital fabrication in architecture offers possibilities that were hard to apply in the past, not only for form but also for material, process-controland optimisationin construction. As the world is facing an ecological crisis and construction is one of the biggests contributors of it,with the help of these technologies, radical changes must be searchedfora more sustainable architecture.

Material processing is one of the most destructive environmental actors. Therefore, bio-materiality become a popular research subject for digital fabrication in architecture.*Pulp Faction* is a research on this subject, looking for an alternative material by utilising biological growth processes of fungallignocellulosic composites as passive engines for the transformation of renewable materials.The controlled growth of fungal mycelium within the printed material works as a binder of lignocellulosic biomass in post-extrusion (Goidea et al, 2020) (Figure 1).

Figure 1. Left. Substrate development prototype, here without fungus. The substrate was tested for extrudabilityas well as for the design material compatibility. Right. Column assemblage. design to fabrication (Burry et al, 2020).

Although the Project is a material research, it is believed that the large scaled implementation of such material, could reduce the ecologic impact of construction, by being environmentally safe and biodegradable without chem-ical process and non-renewable extraction. Also, the raw materials for such composites are low in cost and locally sourced (Goidea et al, 2020) (Figure 2).

Figure 2. Section of a column showing an assembly of the fungal-lignocellulosic components. Bonding between the segments is proposed to be achieved by extrusion of a connective tissue consisting of a modified version of the live pulp(Burry et al, 2020).

The MUD Frontier Project is another application focusing on inexpensive usage of free bio materials, such as local soil in construction by a robotic 3D printing set up. The mobile scara robotic 3D printer that was developed for the project, can print the local soils from the site and build structures larger than itself. Also the software application for 3D printing, is designedas an easy-to-use interace foreven novice users can quickly begin to create complex g-code to 3D print environments within minutes (San Fratello& Rael, 2020)(Figure 3).

Figure 3. Left. High alpine 3D printing with local soils. Right. The Lookout stair during construction(Burry et al, 2020).

'Sophisticated Buildings will be made of mud' was announced as the number one topic at thelist of *40 most important things one should know about the next 40 years* by the Smithsonian Magazine. The MUD Frontiers aims to see this prediction become a reality with further research(San Fratello& Rael, 2020).

Bio materiality is not the only way for ecological footprint reduction. Digital fabrication can be used as a construction tool that uses less amounts of existing materials used in construction, by optimised forms where they are needed, to create more sustainable designs. 3D concrete printing (3DCP) provides this opportunity with promising mouldless, no-waste constructions and shape customisation. Concrete Choreography is one of the projects searching for a new understanding on concrete with these aspects (Anton et al, 2020) (Figure 4).

Figure 4. Left. Fabrication set up. Photo. Axel Crettenand. Right. Transportation. loading the columns from ETH Zurich. Photo. Benjamin Hofer (Burry et al, 2020).

Nine different 2.7-meter-tall columns were fabricated in fiveweeks after four weeks of research. This project not only proves transformation in con-crete construction from an ecological and economical perspectivebut also changes the definition of concrete and designer. Concrete now is not an inert material but the part of the final production. Designer can make optimised decisions on elements for direct fabrication, without the drawings and proce-dures that will cause lots of time as we know today. Also, the high speed production of high detailed deigns creates a total shift in understanding about construction (Anton et al, 2020).

The changes in a total construction proces can only be understood in a real construction site. DFAB HOUSE was constructed to understand how can a complete habitable building be designed and built primarily using multiple digital fabrication processes(Graser et all, 2020) (Figure 5).

Figure 5. Left. Exterior view of completed DFAB HOUSE. Photo. Roman Keller. Right. Completed project lower level interface of Mesh Mould wall and Smart Slab (Burry et al, 2020).

Six new digital building technologies were combined for the construstion of design listed as; (1) the in-situ fabricator, (2) mesh mould, (3) smart dynamic casting, (4) smart slab, (5) spatial timber assemblies and (6) light-weight translucent façade. DFAB House is an important construction for digital fabrication in architecture which is embedding research to real practice (Graser et all, 2020) (Figure 6). The project raised questions about feasibility, cost-benefit of automation, new models of man-machine collaboration, optimized sustainability performance, new forms of collaboration, construction management, interdisciplinary work and inter-organisational knowledge in the process. Still, creation of a physical building showed digital fabrication to be an applicable concept for construction.

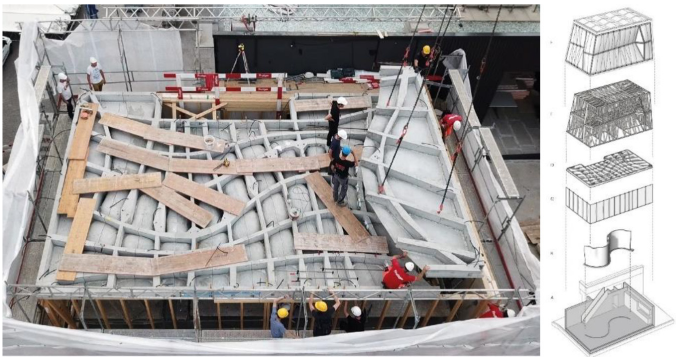

Figure 6. Left. Smart Slab during installation. Photo. digital building technologies, ETH Zurich / Andrei Jipa. Right. Innovation Objects in DFAB HOUSE, diagram. Image. NCCR Digital Fabrication / Konrad Graser (Burry et al, 2020).

Although digital fabrication refers to a file to fabrication process, Gerschenfeld proposes ‘digital fabrication’ as a process that compiles discrete building blocks. Retsin works on several timber assembly structures to search the possibilities of this discreeteness combining *Digital Materials*and *Programmable Matter* with the architectural field of *Prefabrication* and *Modularity*. In discrete a digital form, which isbased on versatile and accessible parts as digital data, offers a complex andopen-ended architecture (Retsin, 2019). This also creates a shift in relations between individuals, society and nature, in which predetermination is not required and responding for adaptation is the main design creteria(Kohler, 2016) (Figure 7).

Figure 7. Left. Gilles Retsin, Diamonds House, Belgium, 2015, Right. Gilles Retsin, Tallinn Architecture Biennale Pavilion, 2017 (Burry et al, 2020).

Similar to additive manufacturing, when the construction is discretised, it becomes integrated, continuous and organic. This method removes the gap between representation and construction completely by turning the digital design into assembled, and vice versa.Therefore, automation of construction increases and man power would become less required (Retsin, 2020) (Figure 8).

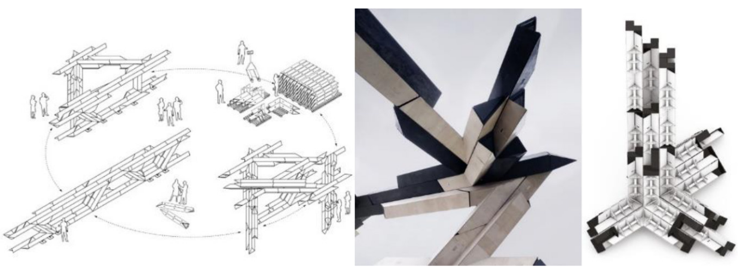

Figure 8. Left. Gilles Retsin, Tallinn Architecture Biennale Pavilion, 2017. Middle. Gilles Retsin, Tallinn Architecture Biennale Pavilion, 2017. Photo. NAARO. Right. Gilles Retsin, Real Virtuality, Royal Academy of Arts, 2019 (Burry et al, 2020).

Discrete Automation takes this one step further by enabling customisation and inassembly to adapt any new situation after assembly. It uses logics from automation in response to their contextualisation in society andin different scales. This is different to the previous understanding of digital designing with it's capability of 'customisation-infabrication' and'customisation-in-design' processes (Carpo, 2017).

Discrete Automation also considers computational and technological capac-ity of today/future and cost reduction.Selfsimilarity of building parts and repetition, shortens production lines, therefore the cost of the total production process. A Discrete design reduces the number of building parts in a typical building to a few parts of digital materials (Gershenfeld et al., 2015). This paradigm change in manufacturing and construction, reveals the innefficiency of current methods andenable the questioning of the material usein architec-tural design.

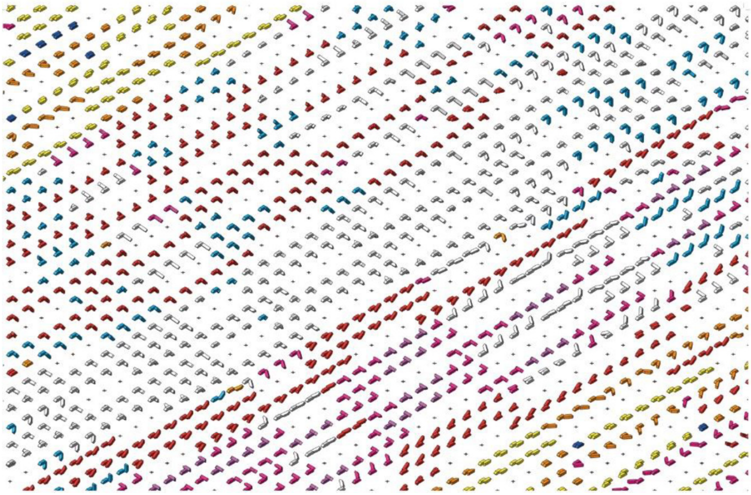

Figure 9. Generated combinations of discrete parts. Image. Ivo Tedbury, Semblr, Architecture MArch Unit 19/ Design Computation Lab, UCL, 2017 (Burry et al, 2020).

Automation functions in several ways in discrete. Digital fabrication technologies, can be used to produce the pieces of buildings or industrial robots can be used to assemble the pieces to their places. This way of using digital fabrication in construction needs an alternative framework for building assembly. Patternsof construction follow digitalassembly logics, allowing the parts to be changed, replaced or removed. *Discrete Automation* presents an ecology forproduction in which architectural labour and spatialpractices can be computed again and again without extending production chains. But,*Discrete Automation* does not project a non human labor where technologies inhabit all business.Therefore, thematerial arrangements must be re-articulated and tought to constructors. *DiscreteAutomation* seeks to take the first stepin devel-oping a more optimisticapproach to the new architectural production(Clay-pool, 2020) (Figure 10).

Figure 10. Automated assembly into a small house using mobile robots. Image. Ivo Tedbury, Semblr, Architecture MArch Unit 19/Design Computation Lab, UCL, 2017 (Burry et al, 2020).

Selected projects show that from material to building, digital fabrication has a great effect on today's architecture not only in construction phase but also in the description of all methods and professions in the whole process.

5. DISCUSSION

Architecture is a profession that informs and is informed from all of it's phases in different scales from two dimentional representations to construc-tion. Today, with the effect of technology, this mutual relation can be seen more than ever. What is concieved to be possible about design, form, tectonics, materials, manufacturing and construction is changing day by day (Iwomoto, 2009, Dunn 2012).

The brief history of digital architecture showed that when CAD replaced drawing by hand, buildings looked pretty much the same. This was just a replacement of a two dimentional representation with another in a different medium. The real shift occured in the theory of architectural design, with the boundary extending effect of three dimensional computer modeling and digital fabrication. The increase of computers and advanced modeling software has enabled architects to conceive and construct designs that would be very difficult to develop before. New tectonics came to life with new design methods allowing parametric and complex organizations to be generated and explored not only in design but also in construction. The inspiring possibilities offered by digital fabrication for architecture, as explained with examples in previous section, brings more questions to life about the future of architecture profession.

First question can be about education. Today, as we are facing a pandemic state, on-line education became a must instead of a need in circuculums. In most of the architecture faculties, CAD/CAM is still tought as a tool, that helps students to express their "traditional" ideas and designs in another medium. Based on the idea that the intellectual and instrumental digitisation process in architecture has created revolutionary changes, educational design studios should be fundamentally reconstructed as an important part of this revolution. Researches based on this assumption supports the idea that educational studios should be re-questioned in architecture, starting with general education systems. For example, Oxman (2008) emphasizes changing the studio setup away from a project-oriented structure intobanexperimental *Digital Design Studio*. He suggests conceptual titles such as; topology, mobius models, generative systems, parametric models, performative design, physical modelling and digital materialing. The educational character on which this approach is based, is built on the idea that the profile targeted by design education should be a designer-thinker (Oxman, 1999). Therefore, architects of tomorrow will have the ability to think and design in a "digital" way.

From the examined projects, the second question rises for the future of the "new" materials of this new digital architectures. These massive shifts in design processes have implications in material culture far beyond the discipline of architecture, at cross-disciplinary levels worldwide. It is crucial to understand the logic of geometric organization in relation with material properties in the digital medium because the material explorations would affect the whole fabrication process (Güzelci et al, 2017, 2016). The projects in this paper are examples of materialresearchs both for traditional and new materials. Today digital fabrication lets us to use the materials we are familiar with in spectacular ways. In addition to the Concrete Choreography in this paper, there are lots of researches continuing on searching the possibilities of using traditional materials with digital fabrication such as; BUGA Wood Pavilion, Urbach Tower, Textile Hybrid M1: La Tour de l'Architecte (URL 2), Augmented Bricklaying, ROB (URL 3)As we are facing an ecological crisis, alternative material searches keep increasing in digital fabrication, like we see in Pulp Faction. In addition to bio material developments such as; Silk Pavillion, Hybrid Living Fibres, Radiofungi (URL 4), there are also new researches continuing in new non-bio materials.Elytra Filament Pavilion, Cyber Physical Macro Material, MoRFES_01: Mobile Robotic Fabrication Eco-System (URL 2) are some of the examples that extend the material use both structural and construction wise.

According to World Economic Forum (2016) data, construction industry is one of the largest sectors in the world economy with 13% of global GDP representation and 7% of the world's population employment. It is also an industry with very low annual productivity increases, only 1% per year over the past 20 years. Less than 1% of revenues is invested in R&D. It is remarkably poor in comparison to other sectors (Barbosa et al., 2017). Also, only 0.2% of all robots worldwide are sold to the construction industry whereas 55% sold to the automotive industry (Executive Summary World Robotics, 2017). There are only a few examples where robots are predominantly/totally used in the construction of buildings (Claypool, 2020). Therefore, the third question is about the future of construction in digital fabrication. Compared to others, construction stillremains one of the most analogue industries. Digitisation in architectural production has largely remained in the virtual environment as design tool. Digital design enabled creating more procedural, flexibile, variabile, and interdependent formsutilising computational techniques (Carpo, 2012; 2017). But this ability was not translated to building practices directly. Therefore, the realisation of those designs, still dealing with challanges in production chains, manufacturing, assembling and labor. Although discrete automation suggests an easier way of production, construction still needs foundational changes for other types of digital fabrication. As we saw in The MUD Frontier Projectin-stu fabrication has great potential in digital fabrication of architecture. At the first days of pandemic, isolation cabins were printed with 3d printers in just a few hours. There are various examples in 3d printing such as;Mini-Castle (Andrey Rudenko), Urban Cabin (DUS Architects),Lewis Grand Hotel Extention (Lewis Yakich), AMIE (Department of Energy's Oak Ridge National Laboratory), Office of Future (Gensler), Rotor-shaped Residence (ApisCor), The BOD (COBOD), Yhnova House (University of Nantes & Nantes Digital Sciences Laboratory) etc (URL 4). Even space architecture searches alternative ways of 3DP in space with local materials (Leach 2014).

As it is clearly understood from all these examples, contemporary technologies must become an indispensable part of architectural practice, in order to make architecture to be a profession that has adapted to the present and could be easily adapted to the future like other technologies. Otherwise, when the last question,"What is the definition of the architectural profession?" emerge, answer will be given with a completely digitalized scenario, from professions of other than architecture. For this reason, it is inevitable to rebuild the profession with such a logic from its education, to its rules, materials and applications.

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chapter 8

INTEGRATING THE ALGORITHMIC TECTONICS TO THE DESIGN PROCESS WITH CAD/CAM: CHALLENGES AND OPPORTUNITIES

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1. INTRODUCTION

Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) is a widespread tool, medium, and partner for architecture students. While computer-aided design and manufacturing tools (CAD/CAM) and new technologies have become more accessible than in the recent past, many software and hardware have become open to public development and customization.

Due to the increasing advances in the development of CAD/CAM technologies, digital interfaces and toolsets which are commonly used for architectural representations and manufacturing have been changing in a short time. The pace of change is so rapid that the architecture students face many digital representations, modeling, and production interfaces throughout their undergraduate studies. Many of these digital interfaces are evolving and transforming until they graduate.

When students are introduced to a new digital design tool, it is observed that they spend all their effort on analyzing and understanding the tool. As a result, neither the students integrate the tool into their design processes, nor the tool provides feedback to the design process of the students. Due to the difficulties of integrating the new tool, methods, and approaches into the architectural design studio, using digital tools is mostly assumed as an independent ability. However, the ways of promoting creative approaches in the context of embedding digital design approaches in education are becoming a popular topic in architecture schools (Agirbas 2018; Agirbas 2019; Akin, 1990; Alaçam and Güzelci, 2017; Alaçam et al., 2019; Bacınoğlu and Alaçam, 2014; Benner and McArthur, 2019; De Vasconselos and Sperling, 2017; Dino, 2012; Duarte et al., 2012; Eilouti, 2007; Fricker et al., 2020; Karakoç, 2018; Mark et al., 2001; Oxman, 2008; Ünlü and Alaçam, 2021; Varinlioğlu et al., 2016a; Varinlioğlu et al., 2016b; Xavier et al., 2019; Zarzycki, 2013).

Some of the discussions about the CAD/ CAM in architectural education are as follows:

- Will the computer-aided design be considered as a separate course from project studios (Duarte et al., 2012)?
- Will there be an effort to integrate computer-aided design with traditional project studios (Duarte et al., 2012)?
- Will the problem-based learning approaches be addressed with CAD (Eilouti, 2007)?
- Will the paperless-digital studio replace traditional design studio (Norman, 2001)?
- How the requirements of professional practice and state-of-the-art technologies might be integrated into architecture curricula? (Duarte et al., 2012; Mark et al., 2001)?
- Can the design studio be associated with computer-aided manufacturing processes (Zarzycki, 2013)?

The potentialities of CAD/CAM, as Ahrens (2013) points out, are the data and information flows wherein and their continuous transformation into one another. When the use of a digital tool is integrated into the design process, the algorithmic logic that controls the data and information flows undoubtedly affect the architecture students' way of representing and producing the architectural models. Therefore, architecture students focus on the processing of information that constitutes the architectural form rather than the architectural form itself. In this sense, as Oxman (2006) underlines, rather than "form" as the final product, the term "formation" comes into prominence. In an environment where tools, interfaces, and representation techniques are continuously diversified, pedagogical methods and approaches for teaching digital modeling skills to architecture students by experiencing the formation process are a topic to be discussed.

In our teaching experience over a decade we observed that when students are introduced to a new design tool, students spend all their energy on studying, exercising, and understanding the tool instead of integrating the tool with their approach in the design process. In this situation, the design process cannot be approached from a critical point of view and students cannot evaluate their design processes (Bacınoğlu and Alaçam, 2014). Relatedly, "the outcome of the design process is not communicative with the environment and far away from the critical architectural discourse. There exists a lack of critical investigation about what they do, what they can do, and what has been done" (Bacınoğlu and Alaçam, 2014). Therefore, it becomes crucial for the instructors to reflect on the potential gaps between known and yet unknown in terms of toolsets, mindsets, and skillsets in the context of architectural education.

This study aims to answer the question of how architecture students can be encouraged to adopt algorithmic thinking by keeping students at a critical distance from CAD/CAM tools. In the previous studies, the researchers (Spuybroek, 2005; Symeonidou, 2016; Zarzycki, 2013) have been emphasizing the importance of the students' experimental and exploratory relationships with CAD/CAM technologies which are named as "analog computation" approaches in the literature, as well as introducing a conceptual framework that brings algorithmic explorations and physical explorations together in architecture education (Fricker et al., 2020).

For this purpose, instead of starting design students directly with predefined algorithms or CAD tools, a pedagogical model is proposed to teach algorithmic (computational) design logic and digital modeling approaches through physical experiments. The proposed model focuses on the observation and analysis of "formation" processes by the experiment setups prepared by students. The students are expected to relate the findings obtained from these experiments with the existing algorithms and develop new frameworks for the novel algorithmic approaches. In the analysis process which includes actions such as abstracting, diagramming, and listing the measurable and immeasurable entities, the whole-to-part (deductive) and part-to-whole (inductive) methods are used together. The analysis of the observed physical phenomena can extend the student's observation, analysis, and abstraction processes in analog environments with the help of existing digital algorithms. On the other hand, the students' processes of abstraction and algorithm development in analog medium support the interpretation and adaptation of digital algorithms.

The pedagogical model proposed within the scope of the study was tested in the Digital Architectural Design and Modeling course of which is conducted in the Architectural Design Computing Graduate Program at İstanbul Technical University between 2004-2020. In the scope of this study 2012-2013, 2014-2015, and 2016-2017 fall semesters of Digital Architectural Design and Modeling course and 2018-2019 fall semester course titled Special Topics in Architectural Design in the Architectural Design Graduate Program at İstanbul Technical University are examined. Within the scope of this study, the outcomes of the repeated course in different years were investigated and the general framework of different experiments from the many studies con-ducted in the course is presented.

2. THEORETICAL BACKGROUND AND RELATED CONCEPTS

2.1. From Static Towards Dynamic Understanding of Form

The term Digital Design is described as "a constructed relationship between information and forms of representation that support design in computational environments" (Sass and Oxman, 2006). Considering the relationship between information and the forms of representation, the generation of form in a digital environment becomes a dynamic performance. As Ahrens (2013) explains "the shift in the design process from creating static spaces to generating dynamic relationships based on performance and interaction" or Terzidis (2003) brings "modeling of the system of relationships rather than modeling the form itself" to the forefront. While the description of digital design is based mainly on the relations that form the whole by many academicians, digital models, in general, are classified as computer-aided design models

(CAD), formation models, generative models, performance-based models (Oxman, 2006; Oxman, 2017). Whereas, the terms, computer-aided design and computer-aided manufacturing (CAD/CAM), are approached in this study for the whole classes of digital models.

The shift from the concept of form, which is an object, to the concept of formation, which is an interaction between the internal forces and external conditions that constitutes an object, brings new quests to the theoretical and practical fields of architecture. Allen (1997) describes this situation as a transition from object to the field. The transition from a singular object to a dynamic field-object that interacts with its environment is a transformation that opens up “material improvisations” (Allen, 1997; Erten and Oral, 2019). Spuybroek (2005) claims that material improvisations are the geometric forms and formations that are derived from observed material behaviors. Moreover, Kolarevic (2005) asserts that the internal relations of an object that is put forward based on the machine’s internal logic also overlap internally and externally within the context of an architectural project. Relatedly, mathematical and logical models of design that can be represented through algorithms have the potential of enriching formation models. In that sense, an algorithm can be considered as a demystified part of internal and external relations of a given process, which is capable of constituting more complex representations and situations.

In addition to the epistemological crisis in representation and definitions, the concept of scale in CAD lost its conventional meaning because the microscopic and macroscopic scales are nested and become one. For instance, an intervention to the internal relations of matter at a microscopic level may cause a structural or behavioral effect when the matter is processed into a material. As Picon (2010) underlies the need for the explorative approaches, experimental practices, and new perspectives to research the matter, material, and form (Erten and Oral, 2019; Güzelci et al., 2017). This need reflects how the architectural curriculum addresses the subject of formation, scale, tectonic relations, and material.

Considering our previous studio experiences, the following problems often occur while presenting the CAD/CAM tools to the architectural students.

- Giving up the learning process due to the high cognitive load in the process of gaining new skills,
- Losing control of the digital model,
- Using CAD/CAM tools in the design process only for representation purposes,

- Unable to reflect the acquired modeling skill in a different architectural context,
- Unable to control the part-whole relationship in the digital model.

While CAD/CAM courses are taught discretely from design, the students continue to have difficulties in integrating design experience and digital modeling skills. Besides, it took a long time for the students to reflect on what they learned in CAD/CAM classes to the design studio. In the cases, where CAD/CAM skills are integrated within the design studios and as an extension of traditional design studios; both the ability to learn skills about new inter-faces and the expectation to deal with a design problem within integration with its contextual relations can create cognitive load on the students.

The diversity of the design products and repetitive development process of design may affect the architectural design studio performance negatively. As a result, often formally complex but immature design solutions are obtained. Furthermore, the use of CAD/CAM interfaces may be limited by representation, as to how digital counterparts of the representations occurring in the traditional design process are generated. In cases where the cognitive load is high, a common approach for students is to stop learning the digital tool and to avoid the exploration of the possibilities offered by the CAD / CAM interfaces.

2.2. Algorithms for Constructing Forms

Terzidis introduces a classification and conceptual framework for the form generation approaches in the context of computational design in his 2003 book titled "Expressive Form: Conceptual Approach to Computational Design". The terms proposed by Terzidis (2003) are listed below:

- Caricature Form
- Hybrid Form,
- Kinetic Form,
- (Un) folding Form,
- Warped Eye,
- Algorithmic Form.

The above-mentioned terms are related to the theoretical contribution of many pioneers including Peter Eisenman, Greg Lynn, William Mitchell, Marcos Novak, and John Frazer (Terzidis, 2003). Algorithmic Form among all, refers to the form which can be represented and generated through a finite number of rules, relations, and processes. In other words, the algorithmic form addresses computational procedures consisting of "deduction, induction, abstraction, generalization, and structured logic" (Terzidis, 2003). With Carpo's (2011) expression, algorithms refer to the new alphabet of today's architects.

The use of mathematical models and algorithmic modeling approaches enriches the design processes by providing a wide range of design alternatives that cannot be achieved with analog processes in a limited time. Apart from generating design alternatives, algorithmic modeling approaches can be also utilized in the various analysis, optimization, and evaluation processes. However, the complex algorithmic structure of many digital models causes students to lose awareness of their design process. Some of the challenges of employing algorithms in the design process without previous experience in coding as follows:

- Widely available algorithms are mostly well-structured. Therefore, it becomes difficult for students to adopt existing samples to an ill-defined design problem. As a result, the existing algorithms might dominate and limit students' design decisions.
- In a bottom-up algorithm development process, it is observed that architecture students can generate initial assumptions, rules, pseudocodes, and visual flowcharts. However, it might be difficult to translate algorithmic ways of representing design problems to the existing CAD/CAM software.
- Difficulties in perceiving the causalities between input-output and operation-result relations that use complex forms of datasets.
- Lack of a holistic understanding of the design process in the way algorithmic processes might require.

2.3. Algorithmic Tectonics

The digital representation, process, definition, and manipulation of form within the design process have caused a crisis in architecture according to many studies on digital theory. For instance, many architects still tend to approach CAD possibilities via assumptions of Cartesian space concerning the ontological crises of the digital age. A reflection of this ontological crisis reveals itself on the concept of scale. Digital tools allow designers to generate scale-free models of geometries. These models can be adapted to different contexts. Therefore, the concept of tectonic needs to be revisited in the digital age concerning the subject of transformability of scale. As Andersson and Kirkegaard (2006) unfold the contemporary discussions on "tectonic" in relation with “the theory of the inner structure of a work of art” and “the shaping and joining of form-elements to a unity” (Andersson and Kirkegaard, 2006). Moreover, Leach’s “digital tectonics” term suggests an engagement between the confronting terms such as digital and tectonic, virtual and concrete, abstract and tactile (Leach, 2004; Andersson and Kirkegaard, 2006) which provides a theoretical ground to discuss new possibilities of form.

According to Picon (2010), not only scale, which is the traditional dimension of architecture, and tectonics, that is structures conceived as space-defining are in a state of crisis, but also the presence of material in architecture is problematic. Thus, he urges the need for a new approach to the presence of material in architecture. Oxman (2006), on the other hand, claims that information is the new material of the designers and architects. In this sense, the content of information is important. Instead of designing by defining self-referential geometrical forms based solely on the internal relations of abstract geometry, there requires integrating the internal and implicit relations of material and matter into geometry during the design formation process.

Distinguishing wet grid and dry grid, Spuybroek (2005) addresses the integration of physics into geometry (physical into digital or material into abstract) while constructing a grid or any drawing at the process of design formation. In Spuybroek’s definition, the grid is a system that separates infrastructural movement from material structure. By the concept, dry grid, he points out the frozen conditions of the orthogonal grid because of its geometrical state of homogeneity relates to material, crystallized state of frozenness. For the wet grid, he points out the dynamic states of the structure. Spuybroek (2005) exemplifies wet grid with Frei Otto’s grid which is one in which movement is structurally absorbed and the geometry co-evolves with materiality.

Briefly, although the algorithmic tectonic term appears to refer to a set of abstract rules and relations results with a virtual form, it has strong connections with material and tools in the context of digital modeling. Algorithmic tectonics is related to algorithmic structures informed by or informing tectonic qualities of various design representations including but not limited to geometry, geometrical relations, parameters, rules, and operations. Algorithmic tectonics might manifest itself in the process or end-product of the design, while it can be considered as a part of a holistic system that depends on form, material, technique, and tool.

3. PEDAGOGICAL MODEL

Based on the findings of the literature study, the master course titled Architectural Design and Modeling has been selected as an experiment area. In this course, students are expected to develop their digital modeling and algorithmic (computational) thinking skills. The proposed educational model for students to develop these skills uses “digestible small contexts strategy” for analyzing, digital modeling, and algorithmically reconstructing physical experiments. In this chapter, after introducing “digestible small contexts strategy”, the two basic modules of the model are explained: one-to-many and many-to-many approaches.

The examined 14-weeks course covers 3 hours per week. In the first two weeks, the basics of CAD/CAM, parametric modeling, and scripting environment are introduced based on sample workflows. Over the next two weeks, the initial geometry (object or artifact) is given to the students to make the qualitative and quantitative analysis. In this phase, students use methods such as literature study, physical model making, 3D scanning, measuring, diagramming to decode and understand the given geometry. In the fifth and sixth weeks, students are asked to develop a generative model based on given geometry and a fabrication strategy to prototype new variations created by them. In this phase, students deal with abstract geometries in 2-dimensional and 3-dimensional digital environments, scaled prototypes in a physical environment, and their transformation to one another. Until the eighth week, students measure and model the given object, decode and re-model the representation of the initial object, transform the initial object’s representation and variations with an algorithmic model, and submit the documentation of the process as a mid-term.

In the ninth week, students start the second exercise which is structured with the many-to-many approach by the tutors. In the second assignment, each student chooses a physical or chemical phenomenon to observe. From the tenth to the fourteenth week, students are asked to decode the selected phenomenon algorithmically. Students also develop their notations (abstraction, diagram), algorithms, and parametric models to generate new phenomena. The course is concluded with the submission of a poster, video, and booklet to present the findings of the experiments.

3.1. Digestible Small Contexts Strategy

The term "digestible small contexts" refers to the contexts constituted of simple and abstract conceptual relationships. Describing a complex entity with simple relationships encouraging students to begin working (Bacınoğlu and Alaçam, 2014). By starting with simple relationships, we have intended to provide a dynamic layout for physical experiments where students can constitute new sets of relations on top of the previous ones.

Describing simple relationships and features can both lead to creative processes with unpredictable results and shift the focus of the student to the processes and stages of the process rather than the result. Therefore, relating the modeling tools and steps of algorithms becomes easier. The main data source of this research is the application of the pedagogical model of "digestible small contexts" for five semesters. In this model rather than teaching digital modeling with all complex relationships of architecture, we aimed to "learn algorithmic structures" as small parts with constraints.

3.2. One-to-Many Approach

The initial source of the one-to-many approach is static geometry. In each semester, tutors selected different contexts (initial/base geometry) to apply the one-to-many approach. The commonalities of the selected contexts are as follows:

- To be reproducible and codable.
- To have a measurable scale.
- To have different resolutions (tectonic relations) in different scales, when it is zoomed in and out.
- To have a complex geometry for challenging polygonal modeling and curved surface representations in different scales and details,

The students applied the one-to-many approach to the selected contexts which were a human face, a column capital, a muqarnas element, and a broken piece located in the faculty of architecture in the previous years. Phases of the one-to-many method are listed as:

- Measurement of an initial geometry that is present in the physical environment
- Developing individual notations with different measurement methods and tools
- Transferring the model into the digital environment
- Prototyping the digital model with digital fabrication tools

- Re-interpretation and re-structuring of the regenerated digital and physical model through tectonic analysis.

In the one-to-many approach, after measurement of an initial geometry, physical and digital modeling, the tectonic analysis of the physical and digital models, analog and digital representations of the tectonic relations, the interpretation, and variations of the analog and digital representation phases are repeated nonlinearly. In these phases, students switch between abstract geometries in 2-dimensional and 3-dimensional digital environments and scaled prototypes in the physical environment. Thus, the information that is used to define the tectonic relations in different forms of representation were reproduced iteratively.

Meanwhile, the contextual relationships of traditional architectural design approaches are avoided intentionally. Instead, the students' way of analyzing, interpreting, and decoding the tectonic relations of the initial context is preferred to build an ideocratic context. Correlating the self-experimented and explored relations with existing techniques of the digital modeling environment, learning algorithmic tectonics becomes more intuitive for the algorithmic modeling newcomers. The students' experimentation and exploration process with one-to-many approach covers six to eight weeks (24 to 32 hours).

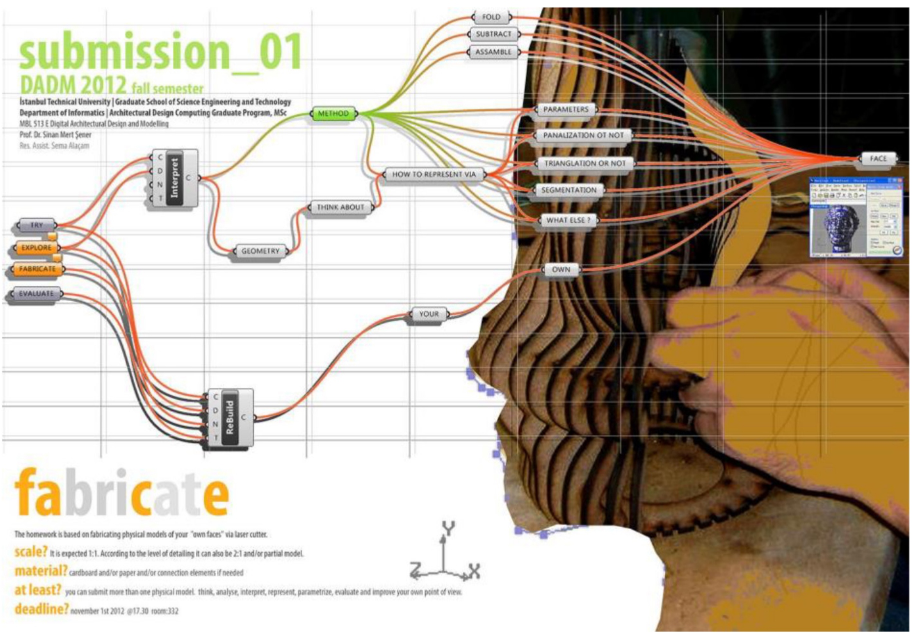

Figure 1. Handouts of the one-to-many exercise, 2012

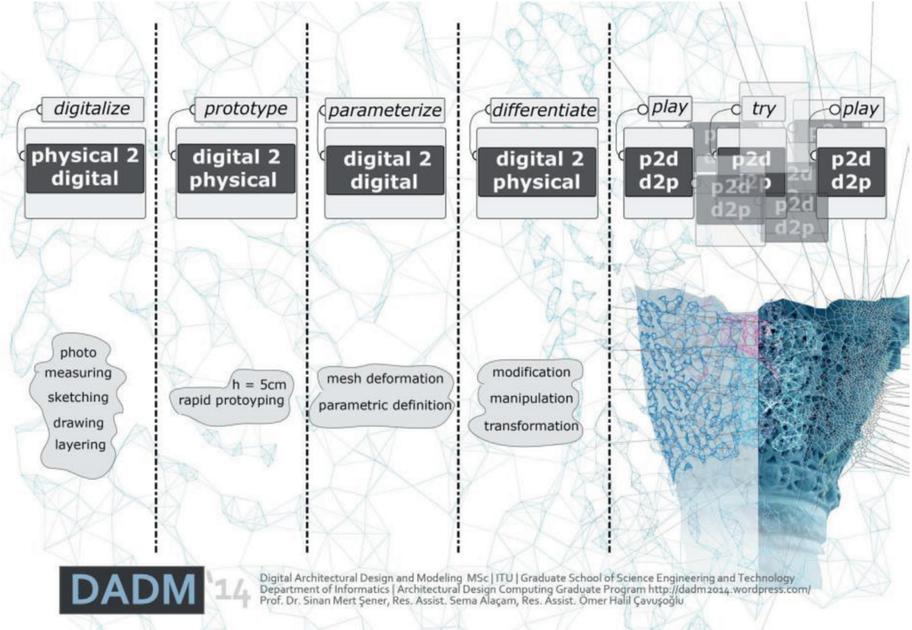

Figure 2. Handouts of the one-to-many exercise, 2014

One-to-many approach was tested in the 2012-2013 fall semester for the first time. Modeling and fabricating one's face was given as an assignment (Figure 1). The techniques, tools, and approaches were not clearly defined in the modeling process; however, laser cutters were given as a constraint for the fabrication process (Bacınoğlu and Alaçam, 2014). The assignment covered three steps: extraction of the surface data from the face, generating a 3-dimensional digital model, and implying a customized fabrication technique to the digital model to achieve a 1:1 scale prototype by using a laser cutter. In the first step, different methods were adopted by the students. To mention some of the methods implied in the first step:

- 3-dimensional scanning by using Kinect sensor,
- Using software that constitutes a 3-dimensional head model automatically by using 3 photos (one front view, 2 side photos),
- Using metal wires to measure curves on the face surface,
- Using aluminum foil to measure the surface geometry of their faces.

The digital models of the second step varied in terms of geometric definition (solid models, mesh models, surface model based on Nurbs), resolution, and precision. In the fabrication step, students were encouraged to explore different approaches to produce a 1:1 scale prototype. Some of the techniques adopted by students are waffle structure, slicing, triangulation, folding- unfolding. A student, Aren Semerci introduced an innovative novel technique, namely "angular waffle" (Figure 3). The angular waffle technique led to the generation of dynamic physical models that perform expand and shrink actions. This innovative contribution of angular waffle technique inspired further research framework (Alaçam and Çağdaş, 2014).

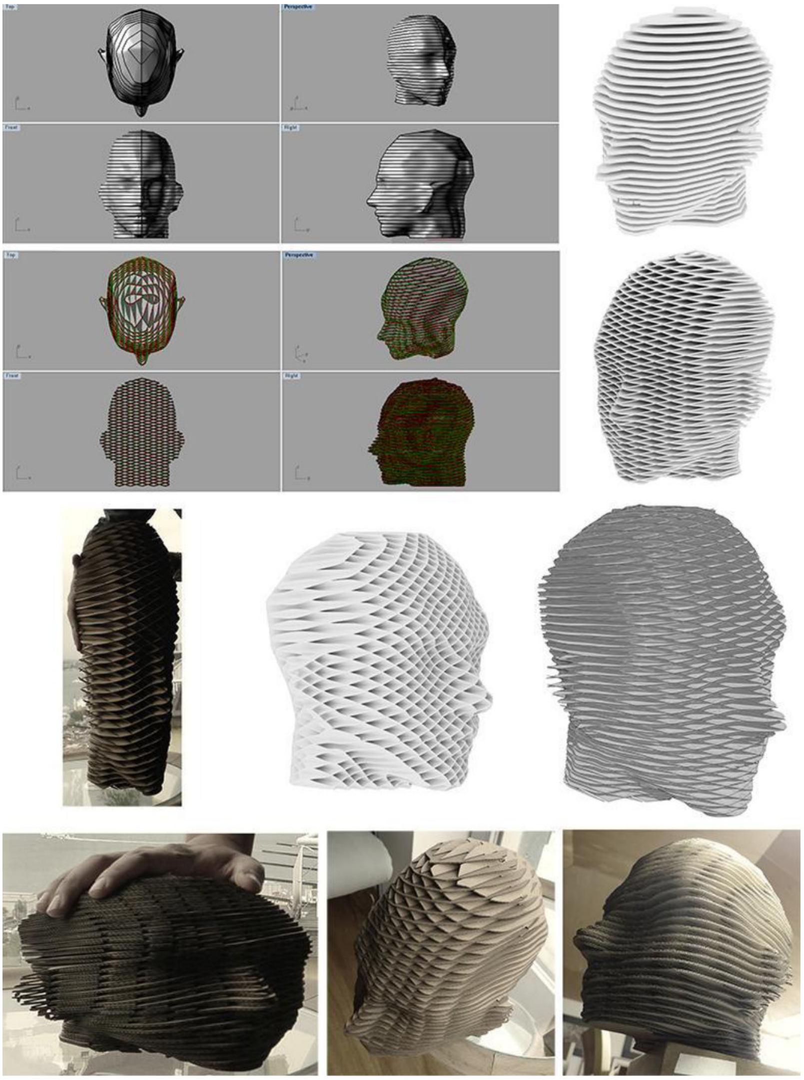

Figure 3. One-to-many approach to a face (Work by Aren Semerci)

Figure 4 illustrates how a student transfers the initial context (the geometry of a column capital) to the digital environment and experiences the shifts between physical and digital environments. In this example, first, the student transfers 2-dimensional data to a 3-dimensional modeling environment, secondly, the student uses basic operation such as planar subdivisions of geometry in the digital environment, then transfers 3-dimensional geometry to a 2-dimensional plane to be able to laser-cut it, and experiments with fold and cut operations after switches to the physical environment.

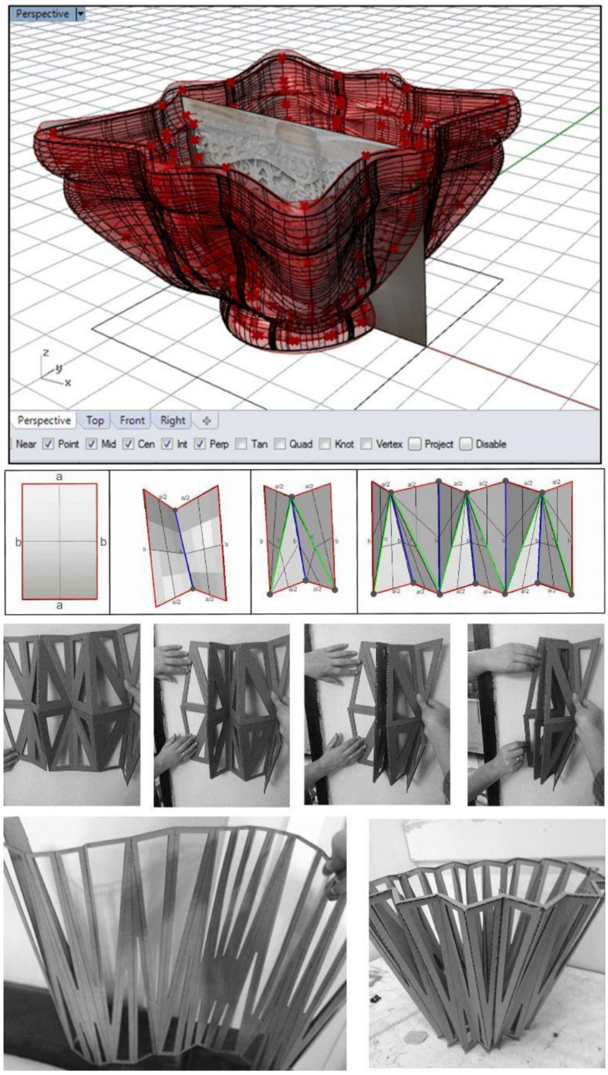

Figure 4. One-to-many approach to a column capital (Work by Gülce Kırdar)

Figure 5 depicts the transformation process of another initial context (the geometry of muqarnas surface). After redefining the geometry in the digital modeling environment, the student uses a new type of repetitive subdivision, Voronoi Tessellation, to generate a variation of the initial geometry. Then, the varied form is redefined as a single continuous surface by filling the Voronoi form with a simulated cloth through a cloth algorithm in Grasshopper environment. Last, the digital model is prototyped with wires, cloth, and plaster.

Figure 5. One-to-many approach to a muqarnas surface (Work by John Bogren)

3.3. Many-to-Many Approach

The initial context to start the physical experiments in the many-to-many approach is a physical or chemical phenomenon. The multifaceted characteristics of a physical or chemical phenomenon necessitate establishing more than one control parameter to understand them in their dynamic process.

The stages that form this approach are as follows:

- Explorative experiments: Selection of a dynamic process (motion-based approach, magnetism, particle behavior, fluid behavior-fluid dynamics, crystallization, etc.)
- Documentation: Taking a series of photographs depending on time, video recording, phenomenon-based framing, etc.
- Trial-Error: Repeat the same structured experiment multiple times
- Analysis: Presenting gained information from experiments, tectonic analysis of experiments (Obtaining information from visuals, photographs, or diagrams of phenomena)

In the many-to-many approach, students observe and explore the material behavior by changing the parameters of the material medium iteratively or by intervening with the material with the repetitive operations. Figure 6 illustrates the resultant algorithmic model of a student that is based on the particle behavior. The relations among the particles were defined by the student after recording, modeling, analyzing the geometric form of a ferrofluid composite at sequential time intervals.

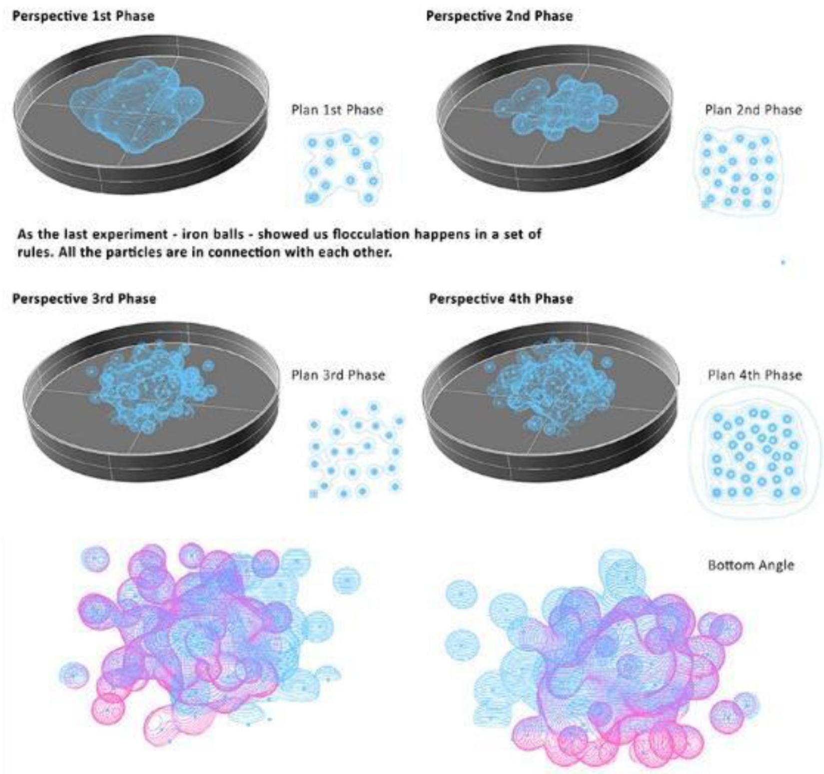

Figure 6. Many-to-many approach to the magnetism behavior (Work by Yiğitcan Ülkücü)

Figure 7 shows a student's in-progress diagramming of the diffusion of ink by zones (surfaces), paths (curves), and dots (points) which is captured at the four different levels of a water tank. In the beginning data capture method, variables and limitations of the experiment setup were unclear. After a series of trials, the students decided to collect data through video recording from the front view. The threshold conditions of the following situations were tested:

- Heating up or cooling down the water,
- Adding particles to the water such as salt or sugar.

Further to the experimentation process, image filters were applied to the video recording. Therefore, the number and value of the applied filters became a part of the experiment setup. After the diagramming process, the student shifted to algorithmic modeling through structuring the relations between particles (points) based on the generation of dots, curves, and surfaces.

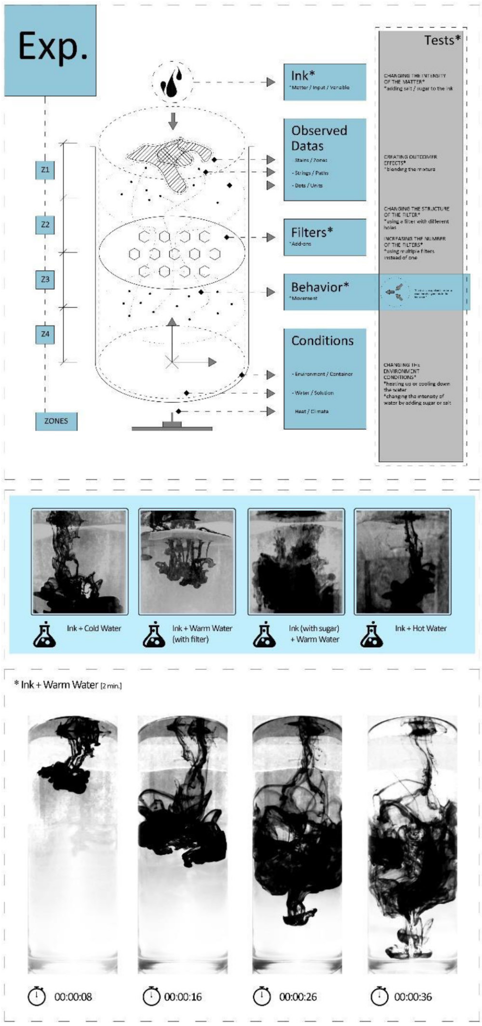

Figure 7. Many-to-many approach to the diffusion of ink in water (Work by Taylan Kılıç)

Experiences and observations of the Digital Architectural Design and Modelling Course in the Architectural Design Computing Graduation Program led us to test the many-to-many approach in other programs and courses as a sub-module. In the 2018-2019 fall semester, an elective master level course titled “Special Topics in Architectural Design” an assignment in which students were expected to observe a process of mixing as liquid diffused in another liquid was given. As different from the previous experiments, one of the students examined the permeability of the interface between the pouring liquid and the container liquid (Figure 8). The colorful liquid shown in Figure 8 is made of sugar and water. The viscosity of the caramelized sugar was changed through a heating-cooling loop and changing the intensity of the sugar. During the experimentation “narrow hole”, “low density”, “high density”, “wider hole”, “strain” parameters were examined.

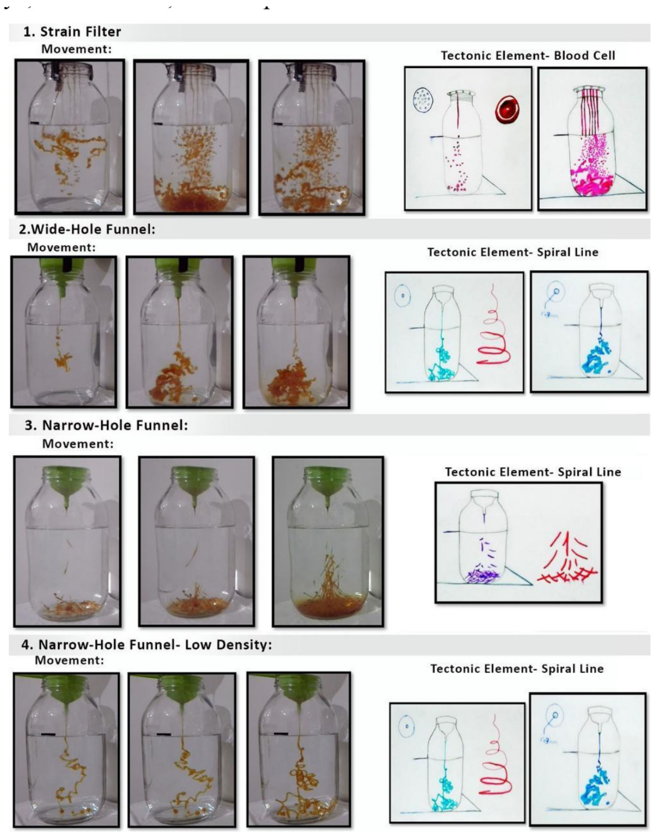

Figure 8. Many-to-many approach to the materialization of liquid in water (Work by Shadad Al-Samarraie)

One of the selected student work from the 2016-2017 fall semester of the Digital Architectural Design and Modelling course is shown in Figure 9. In this example, the student chose to analyze the formation of a curve as a common point for the whole experiment rather than focusing on one single material. However, the observation of a single phenomenon repetitively is complex enough for students to derive many properties and relations between parts (Figure 9).

The materials used in the experiment shown in Figure 9 are water, baby oil, food coloring, and Alka Seltzer, apart from the container and camera recording devices. One of the emergent behaviors observed by the student is that the oil and water are mixed regardless of the density of the materials. This finding led the student to conceptualize a particle-based algorithmic model for the simulation of the process. Moreover, the concept of polarity has been implemented and examined in the digital model.

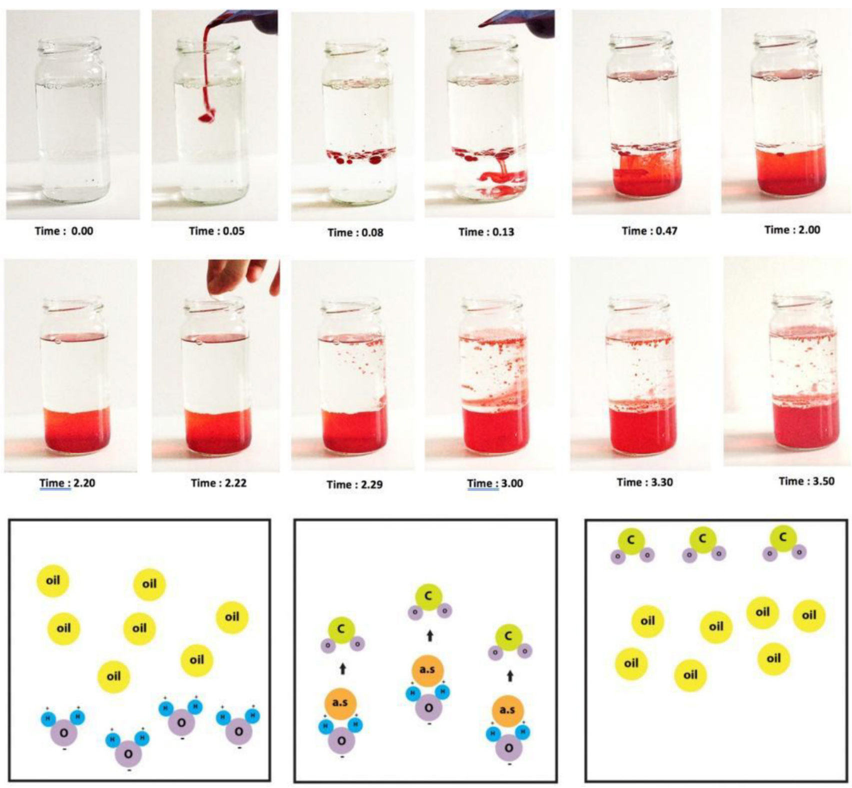

Figure 9. Many-to-many approach to the bubbling of material in water (Work by Begüm Moralıoğlu)

Another submission of the Digital Architectural Design and Modelling from the 2016-2017 fall semester is shown in Figure 10. Because of the com-plexity of a dynamic phenomenon, one or a couple of captured frozen frames of it reveals highly sophisticated geometries and tectonic relations. In the experiment illustrated in Figure 10, the student observed the bubble pattern on a glass surface as a result of vaporization and condensation. Then, the student developed an algorithm in Grasshopper to capture the emerged pattern on the glass.

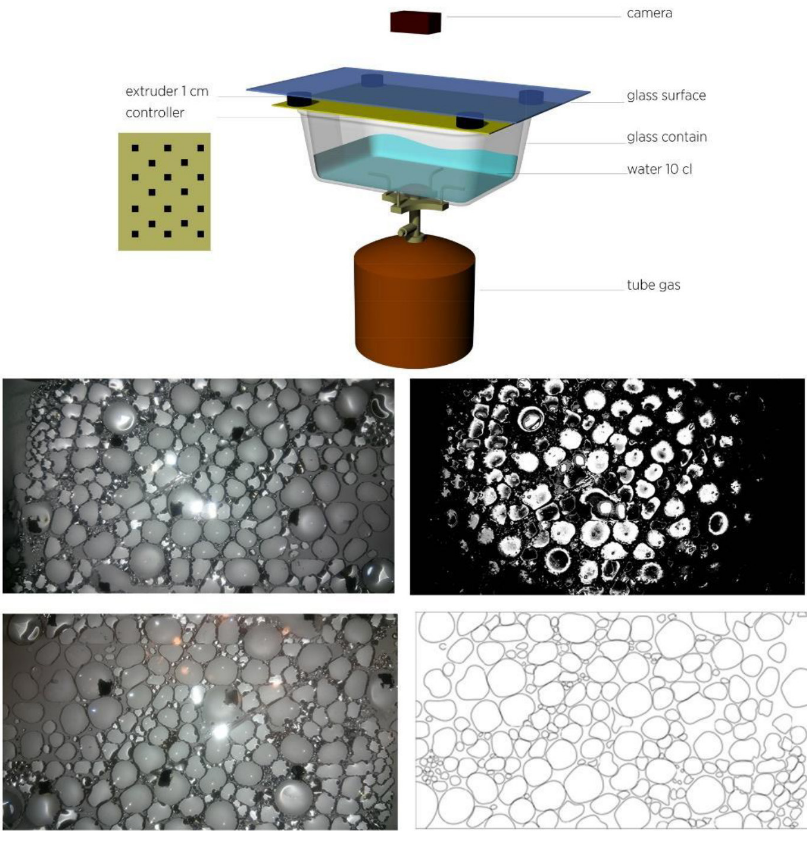

Figure 10. Many-to-many approach to the condensation (Work by Ahmet Onkaş)

In Figure 11, the student observed the growth and adaptation behavior of the crystalized sugar clusters. During these experiments, many parameters such as the temperature of the physical environment, gravity, amount of materials, and base form for the crystal growth are modified.

Some of the basic assumptions that the experiment in Figure 11 is founded on are listed below:

- Formation process of sugar crystals should be represented via a simple set of rules.
- Saturation of the liquid in the container might help to organize repetitive experiments.
- The shape of the container, saturation value, the initial shape, and the environment around the container are considered as variables.

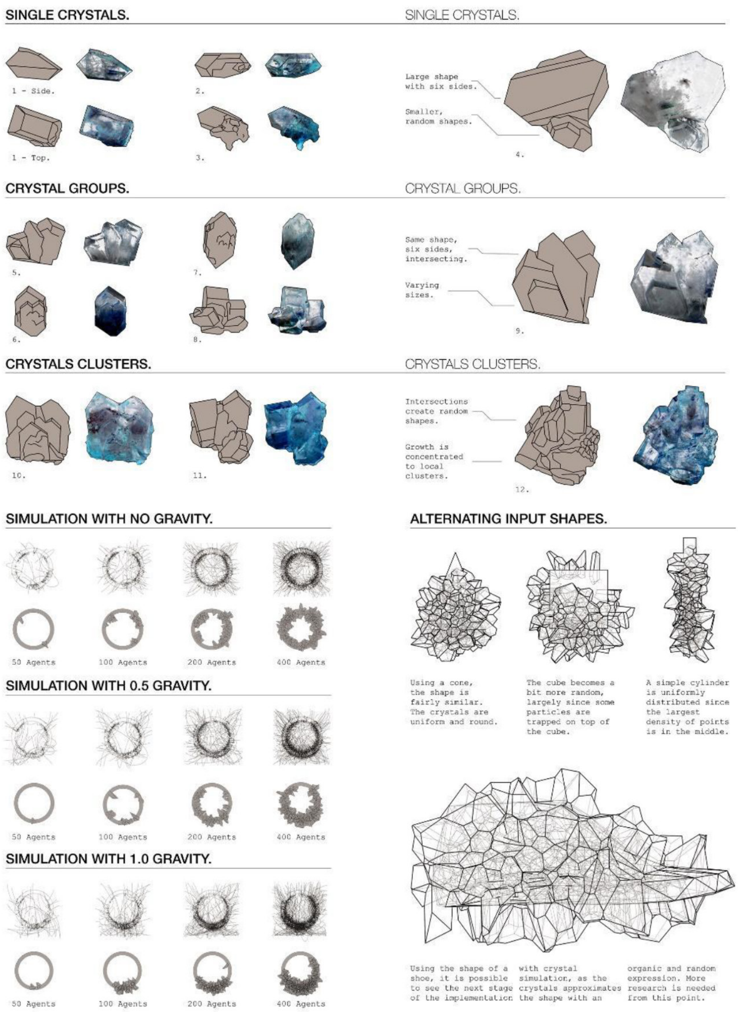

Figure 11. Many-to-many approach to the crystallization (Work by John Bogren)

The experiments illustrated in Figure 11 led to a series of findings that have been implemented to the digital model. One of them is shape classification based on the distinct features observed during experimentation. The student translated “random rotation” and “intersection of two shapes” rules to the digital model. Apart from merely boolean operations for the intersections and union of the shapes, inspired from the observation process the student also added a state of gravity to the digital (behavior and simulation) model.

The experiments illustrated in Figure 12 are focusing on the systematization of the form-finding process by fusing two or more materials. Wool particles, glue, the mixture of water and sugar syrup were used as material.

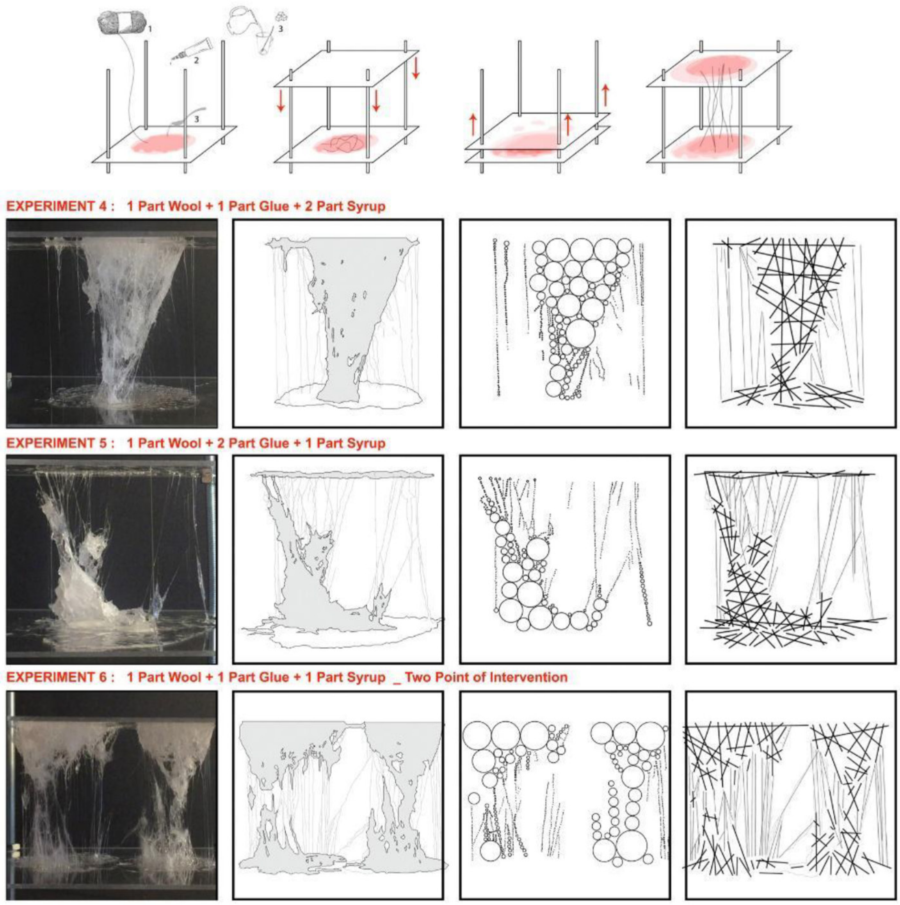

Figure 12. Many-to-many approach to the fusing behavior with liquid (Work by Duygu Kısacık and Sedanur Albayrak)

The amount of the abovementioned materials, the distance, and pressure between the two horizontal surfaces were used as independent variables. As a result of experiments, students have observed the emerged forms and topological relations. One of the findings is that in many examples, the diversity of the tectonic relations that are analyzed and proposed by the students have been influential in generating different digital modeling approaches. Therefore, it can be asserted that the effectiveness of the analysis/abstraction part has an impact on exploring divergent digital modeling processes. Relatedly, the more students repeat the experiments by changing the controlled parameters, the richer source for abstraction/digitization/analysis is provided. Therefore, the number of repeating experiments with minor differentiation is another important factor affecting the variety of outcomes.

3.4. Evaluation of the Experiments

It is seen that concrete outputs of student experiments were obtained from abstract diagrams. Conversely, the characteristics that are revealed from concrete outputs were explained with the abstract diagrams. The students mostly developed their graphic notations to explain the tectonic relations of the observed phenomenon. As seen in Figures 3 to 12, the diagrams, various graphic representations, and media outputs were key for the externalization of the students' process before the algorithmic modeling. In the experiments, seven experiments were selected among studies on magnetism, diffusion in liquid, materialization in liquid, fizzing in liquid, condensation, crystallization, and behavior after fusing with liquid.

The students are encouraged to focus on one phenomenon. The students have studied individually or in groups. For example, the students who have been examining the magnetism process (Table 1), selected the experiment setup, developed bottom-up notations, diagrams, specified parameters, and improved algorithms/workflows, and finally studied on top-down algorithms such as swarm behavior and metaball. Here the bottom-up term refers to generating algorithms based on an iterative abstraction and diagramming process. On the other hand, the top-down algorithm development process refers to the demystification of well-structured algorithms by changing parameters or components.

In real circumstances, the characteristics of the observed phenomena have been affected by a large number of parameters. In students' experiments, a maximum of five different materials are used, the medium where the material is located affects the experiment, and the intervention of the students directly differentiates the process and the final product (Table 1).

Table 1. The general structure of the experiments

Observed Phenomenon	**Materials Used in Experiment Setup**	**Parameters of the Experiment**	**Bottom-up (analysis, abstraction, algorithm development)**	**Top-down (usage and adaptation of existing algorithms)**
Magnetism	printer toner, motor oil, metal balls, oleic acid, magnets, ammonia	-amount of metal balls -ratios of used materials -coordinates of magnets	-polarization -milling	-swarm behavior -Metaball
Diffusion in Liquid	water, oil, ink	-density of liquid -temperature -time	-image-proces-sing based rotational geometry creation	-computational fluid dynamics
Materialization in Liquid	sulfuric acid, ammonia, solution, cotton, wool, shrink	-speed of shrink -height of shrink -viscosity		-dynamic ink diffusion -computational fluid dynamics -particle-based physics simulation
Fizzing in Liquid	water, oil, food coloring, effervescent antacid tablet	-ratios of used materials -amount of used materials -time		-cellular automata -PhysicsJS -computational fluid dynamics
Condensation	water, planar glass, heater	-temperature -time	-circle based analysis of bubbles	-voronoi
Crystallization	sugar, water, food coloring	-density of liquid -shape -temperature -time -gravity	-shape-based analysis -shape-based adaptation growth analysis	-voronoi, -agent-based behavior
Behavior after fusing with liquid	wool, glue, a mixture of water and sugar(syrup)	-ratios of used materials -amount of used materials	- node analysis -density analysis	-structural analysis - kangaroo -quelea

To avoid the cognitive load caused by a large number of factors, the students first analyzed the dynamic form of the object numerically, independent of the parameters. This analysis is mainly based on the properties of simple geometric elements (points, lines, circles) and the relationships between the elements. Subsequently, existing digital algorithms were interpreted and adapted to support and advance the analyzes. With the results of the experiment, the external factors affecting the dynamic formation of the object were determined and the internal relations that emerged were described.

4. CONCLUSION

The experiments to explore physical phenomena with digital modeling and analog computing methods allow students to handle the geometry not only as a single object but also in combination with its changing and transforming relationships. At the same time, the proposed approach has the potential to encounter various qualities and material behaviors other than the usual basic geometries. When the same behavior is observed, the representation of the focused characteristics and behaviors may be different for each student due to the geometry and algorithm used. Thus, instead of presenting the algorithmic modeling techniques to the students in sequential order, there is a chance of overlapping/intersecting/matching existing techniques with the relationships observed by the students.

After the experiments in both one-to-many and many-to-many modeling approaches, it was observed that instead of focusing on a single model, the students put effort into abstraction, digitization, revision, and development of the digital model. Therefore, it is concluded that there is not a single method or a single set of solutions for the digitization process. At the same time, after tectonic analysis and abstractions, it was seen that the students reconstructed the characteristics and qualifications related to the model by questioning them. Thus, each student has to develop their unique method and approach according to their own experiences and interests. In this context, the software used in representation and digitization processes is no longer the focus, and similar processes can be repeated in different software and platforms. As the research process involves the translation, re-representation, and transformation of information into different forms of knowledge, each student's discovery, research, and learning process is different. As a result, the range of modeling approaches is expanding, and unpredictable results are observed through creative processes.

While the proposed model affects all phases of the design process, it also provides the students with the ability to produce ideas, express, and model the process algorithmically. In this study, it is seen that the structured exercises namely digestible contexts have been helpful to students in constructing their relations and contexts. Besides, digestible small context strategy has also contributed to students' engaging the knowledge gained from their own experience as a result of the experimental studies and their design processes. As a result of the experiments, it is expected that the implicit knowledge learned by the students can be reorganized and used for the solution of different problems. It is also thought that the problems described as a result of observations and solving these problems by developing strategies can be a source of motivation for the students.

In the scope of this study, a pedagogical model and its implementation in different semesters are discussed. The pedagogical model has been focusing on empirical observation of the physical phenomenon. The implementation of the pedagogical model has been helpful to explore emergent relations and behavior of the observed matter. Therefore, the implementation of the pedagogical model has put forward a transdisciplinary approach through revisiting the knowledge of different fields such as mathematics, physics, computation, computer programming from a designerly point of view. At the same time, it can be considered as an attempt to engage the personal/subjective differences of the students and objective/observable information. It is asserted that providing situations to students in which they can learn from their own experiences will be more crucial for tomorrow's active learners.

Regarding the relationship between the Digital Architectural Design and Modeling course outcomes and the program outcomes (Url-01), it can be stated that there has been a shift from knowledge acquisition towards critical thinking skills, from problem-solving towards integrating creative and critical thinking with problem-solving skills. Before implementation of the proposed pedagogical model in the 2012-2013 fall semester the priorities of the course outcomes were focusing on (Url-01):

- Teaching expert-level theoretical and practical knowledge (Skill).
- Problem-solving (Skill).
- Developing and intensifying knowledge based upon the undergraduate level knowledge (Knowledge).
- Supporting students' gaining experience to carry out a specialistic study independently (Competence to work independently and take responsibility).

One decade-long teaching experiments has been influential on updating the prior outcomes of the Digital Architectural Design and Modeling course concerning the program outcomes as:

- Supporting students' ability to evaluate and use new information with a systematic approach (Skill).
- Supporting students' "ability to critically analyze, synthesize and evaluate the new and complex ideas" (Skill) (Url-01).
- Encourage students' "developing ideas and methods by making use of creative and critical thinking, problem-solving and decision making" (Learning Competence) (Url-01).

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chapter 9

EVALUATION OF VR APPLICATION (CSVR) DEVELOPED FOR INTERIOR ARCHITECTURE EDUCATION WITH THE SENCE OF PRESENCE SCALE

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1. INTRODUCTION

The rapid development of technology has accelerated the process of integrating technology into learning environments (Çakıroğlu, 2016). It is seen as a result of the current literature studies that the interior architecture education and training process is also affected by these technological developments and related new applications. As in all other professions, it is inevitable that the rapid change in technology will affect the revision and update processes in interior architecture education (Arabacıoğlu & Arabacıoğlu, 2013). Technologies such as 'Augmented Reality -AR', 'Mixed Reality' (MR) and

'Virtual Reality' (VR), which are at the focus of the study, are also It is considered as some of the new technological platforms.

VR technology enables users to experience a computer-generated virtual world at a level similar to that of physical reality by mentally abstracting from the physical space. Within the scope of the study, it was evaluated that VR technology can also be integrated into interior architecture education. It is thought that VR will help to convey the interior structure details, which are the components of the space and the components of the space, to interior architecture students more accurately, so that the students will better and quickly understand the aforementioned subjects. For these reasons, it has been evaluated that the need to integrate the VR system into the interior architecture education process has emerged.

1.1. Purpose and Scope of the Study

This study aims to propose a new teaching methodology by integrating VR technology, a new technological platform, into the interior architecture education process. In particular, it was thought that VR would offer a reinforcing alternative in subjects such as interior structure details, material, space and object scale that students sometimes have problems understanding. For this purpose, it is a virtual construction site for interior architecture education, such as' Gypsum Wall Animation ',' Drywall Wall Progressive Display ',' Exterior Sheathing ', Raised Floor', 'Laminate Flooring' and 'Suspended Ceiling'. A VR application teaching model named 'CSVR' with teaching levels was developed.

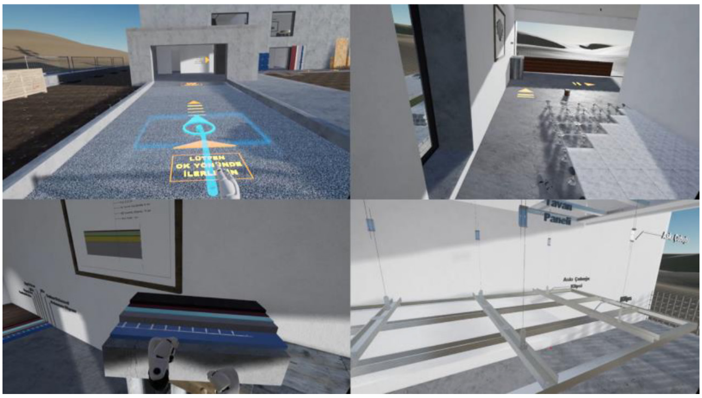

Figure 1.1 Images from parts of the CSVR application.

The research universe of the study has been determined as MSGSU Faculty of Architecture, Department of Interior Architecture, where interior architecture discipline education is given. The study sample, on the other hand, was limited to 80 of 135 students who took 'ICM 223, ICM 224, ICM 323, ICM 324, ICM 423 Interior Architecture Project Studio' (IMP) course in 2019-2020 Fall Semester of MSGSU Department of Interior Architecture. This number corresponds to 59.2% of the total number of students taking the project course. The IMP course is the basic course in which the student can use various interior structure details and considering that the transfer of these details in 3D and interactively by considering the general interior architecture design approaches is compatible with the system typology of VR, has been a factor in the selection of the students who have taken this course.

1.2. Method of Study

The construction site environment is modeled through the "Autodesk 3DS Max" program. The model was later transformed into an 'Immersive' VR application (CSVR) via 'Unreal Engine' (UE4)'Application Development Platform' (API). The teaching model suggested in the study is this newly developed application. During the experience of the application, the 'HTC Vive VR' has been tested using the virtual reality system. A quantitative research design was followed in order to measure the realism of the developed CSVR application and its ability to be integrated into interior architecture education.

In the research part of the study, 'Sence of Presence' (SOP) scale test was applied to the students who experienced the application of CSVR. The scale of presence was first developed by Witmer and Singer in 1998 to measure the 'sense of presence' or 'presence' of the user in a three-dimensional virtual environment. According to Witmer and Singer; The effectiveness of virtual environments is linked to the 'being there' feeling reported by the user. Witmer and Singer; They define it as the subjective experience of being in a mentally and sensually different environment even if the user is physically somewhere else (Witmer & Singer, 1998). In 2005, the researchers updated the structure of the SOP to a format consisting of four factors: Involvement, Sensory Fidelity, Adaptation / Immersive, Interface Quality. These factors are the question items that define each sub-factor. In the literature research, it is seen that the SOP scale was translated into different languages (Silva et al., 2016) and used in virtual reality research.

The SOP scale used in the study is the version of this four-factor scale translated into Turkish by Gökoğlu (2019). As a result of the analysis made by the researcher, it is seen that the 'Interaction' factor was added to the SOP scale and the 7-point Likert scale was converted to the 5-point Likert scale. After this arrangement, it was stated that the reliability validity of both the items and the factors on which the items were attached was ensured (Gökoğlu, 2019).

The sub-factors in the SOP test used in the study are Involvement, Sensory Fidelity, Adaptation / Immersive, Interface Quality and Interaction. The contents of the factors are given below:

- Involvement factor includes items for evaluating the situation that the user achieves as a result of consistently or meaningfully focusing on the relevant stimuli, activities or events.
- Sensory Fidelity, on the other hand, includes items related to the visual, auditory and tactile perception of the virtual reality scenario.
- Adaptation / Immersive factor includes the experience of the feeling of being surrounded / coiled and the flow-oriented items that stimulate this sense.
- Interface Quality factor includes items to evaluate the effect of visual and control interfaces in the virtual reality experience.
- Interaction refers to the evaluation of virtual reality glasses and motion controllers that help to interact with the virtual reality environment.

In their study, Youngblut and Huie stated that the assumption of a relationship between presence and task performance in virtual environments was supported, and they emphasized that there was a positive correlation between learning task procedures and presence (Youngblut & Huie, 2003). The STC test used in the study is a 5-point Likert scale consisting of 29 questions Likert (1932).

The Cronbach Alpha (α) reliability coefficient calculated for the overall SOP scale is .881. 2) Reliability coefficients calculated for sub-factors; It was found to be .787 for the involvement factor, .715 for the adaptation/immersive factor, .651 for the sensory fidelity factor, .554 for the interaction factor and .433 for the interface quality factor. High scores obtained from sub-factors indicate that the virtual environment is perceived in a more realistic structure, and the sense of presence presented by the environment is at a higher level.

In order to measure the level of presence of the VR application, the analysis of the data obtained from the SOP was made through the 'IBM SPSS' program. Frequency, descriptive analysis, T test and Anova test were applied to all demographics and data outputs obtained from the specified sample group and to sub-factors.

2. LITERATURE REVIEW

2.1. Virtual Reality VR

VR basically describes an environment in which the user mentally separates from the physical environment and dives into an artificial and three-dimensional environment, engages in various interactions such as being there, moving around, changing the location and properties of objects, and as a result of these interactions, receive sensory responses like in the real world (Mihelj et al. , 2014). According to Sherman and Craig, VR must contain five basic components to provide this environment; contributors, developers or designers, the virtual world are elements of immersion and interactivity. (Sherman & Craig, 2018). Virtual reality with all these components in mind; It should be characterized as an environment consisting of interactive computer simulations that perceive the participant's position and actions, transmit or increase feedback to one or more senses, and give the simulation a mental and physical immersion or a sense of presence (Sherman & Craig, 2018).

VR is not actually a new technology. It is a platform whose foundations were laid in the early years and began to be tested in the late 1960s with the early computer. Although some concept VR system designs emerged in the early 1990s, they did not become widespread enough to reach the end user.

When looking at the literature, it is seen that VR heads worn on the head are defined as 'HMD' (Head Mounted Diplay) (Huang, (2019); Mihelj, 2014). These devices refer to a head-worn headgear or goggles that, depending on the situation, have the potential to provide viewing of the outside world through its internal camera. In these devices, synthetic images are displayed on the screen inside the header or on a pair of screens for each eye.

What gives the user the feeling of being in the VR environment is the sense of reality provided by the equipment used. The graphical realism of synthetic 3D data, the image quality offered by the head-mounted audio-visual equipment, the tactile interface devices and position-orientation sensors used for interaction, and the availability of the physical space where all this experience takes place are factors that are directly related to providing a realistic experience to the user. The user's ability to live physically in a virtual environment produced depends on the correct manipulation of his perceptions.

Therefore, the more senses the user can be affected in a quality way, the more the user's sense of belonging in a virtual space will be.

2.2. Sence of Presence in VR Environment and Releated Works

The key to defining virtual reality in terms of human experience rather than technological hardware is the concept of sense of presence or presence. The concept of being present can be thought of as the experience of one's physical environment (Gibson, 1979). From this definition, it is understood that the sense of presence corresponds to the mental and physical 'immersion' of a person in an environment, that is, to 'feel that he is there'. Sense of presence is generally accepted as the key to VR. Although there is no common definition of the concept of being experienced through VR, there has been a consensus to describe it as a multicomponent structure. Some researchers (Barfield, et al., 1995; Lombard and Ditton 1997) have admitted that being is determined by two general categories of variables. These are defined as the characteristics of the media to which the user is exposed and the unique characteristics of the user.

In other studies discussing the concept of existence in the virtual environment; (Held & Durlach, 1992; Barfield, Sheridan, & Zeltzer, 1992; Heeter, 1992; Steuer, 1992) It has been seen that the factors that are thought to affect existence are listed as follows:

- Transmission of high resolution images to the participant in a way that does not make the presence of imaging devices noticeable,
- Consistency of the displayed environment in all sensory methods,
- Having the opportunity to react to the effects of the individual spontaneously (like in the real world), to navigate and interact with virtual objects in the environment,
- The behavior of the virtual body of the individual resembles his own body in terms of functionality and reacts appropriately to the movements of the head, eyes and limbs,
- The link between the individual's actions and the effects of those actions is simple enough for the individual to learn quickly.

In the literature, it has been observed that the realism level of the VR environment and learning have a close relationship with each other (Minocha & Reeves, 2010). In order for the virtual training to be effective, the participants must experience "being there". In other words, they must feel sensually and cognitively as if they exist in this artificial environment (Mantovani & Castelnuovo, 2003). From these expressions, it is concluded that the more the user feels as if he / she is actually present in the designed space, the more positive learning outcomes will change. In a way, it can be concluded that the realistic emotions and memories experienced by the student in the virtual space will make the learning more permanent in his mind. On the other hand, it is seen that there are some studies stating that the user's sense of presence in the virtual environment and learning have a positive relationship (Baos et al., 2005; Johnson & Levine, 2008; Monahan et al., 2008; De Leo et al., 2014; Freina and Ott, 2015; Peinl and Wirth 2019; Servotte et al., 2020). For example, in a study conducted by Servotte et al. (2020) with healthcare students studying in undergraduate and graduate programs, it was stated that the participants' sense of presence had a positive effect on educational outcomes, and the inclusion of more multidimensional tactile devices in the process showed that the sense of presence was positive. It was emphasized that it is predicted to be affected.

2.3. Application of the Study

Participating in the study is Studio Project I and Studio Project II level 2 grade student, Studio Project III and IV level 3 grade student, Studio Project V level 4 grade student. During this period, 135 students took the IMP course. The sample size of the study was determined as 80 people according to the 95% confidence interval. This number corresponds to 59% of the total universe. Generally, 95% value is used when defining the confidence interval. This value shows how confident we are when telling the results we obtained (Glantz, 2012). Tables containing demographic data of the sample are given in (Figure 2.1).

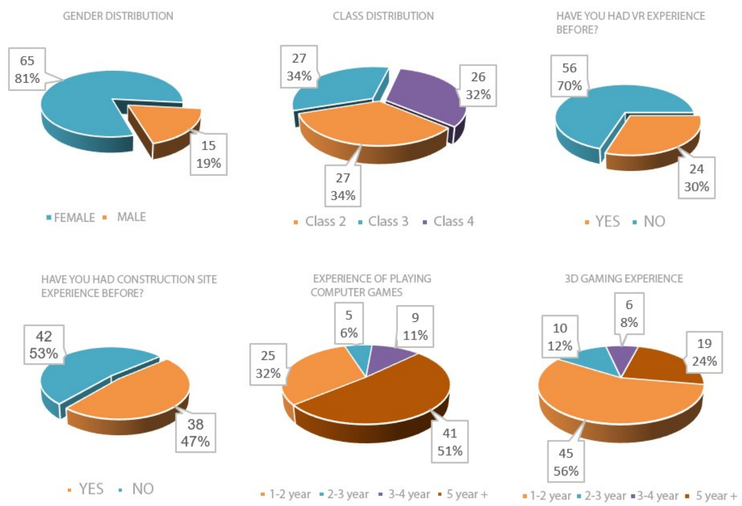

Figure 2.1. Graphics containing demographic information of the students partici-pating in the study (Tolga KILIÇ).

2.4. Application Experience

After the determination of the sample, the stage of experiencing the VR application started. VR experience was realized in MSGSU Interior Architecture Department, in the old computer workshop. The VR system was installed in this area and applied individually at the times determined after the meeting with the students. VR application was carried out in two sessions. In the first session, a 'Demo', ie preview session, was held for students to describe the VR system, learn to use the device and adapt to the virtual environment. After the demo application, the students were asked whether they learned to use the system or if they experienced any simulation or motion sickness (nausea, dizziness, etc.). Students who did not experience any problems were given a break for a while and started to experience the construction site VR application.

Figure 2.2 Students participating in the CSVR Application

2.5. Data Collecting

After the actual application, CSVR experience, students were made to fill the STC test. This test is a Likert-scale test in which the perceptual reality of the VR environment can be measured. The results of the test were analyzed through the SPSS program.

2.6. Application of the Sense of Presence Scale

After the CSVR Application experience, the 5-factor test developed by Gökoğlu, (2019) to measure the sense of presence in virtual reality environments was applied to the students. The SOP test was applied to determine how realistic the user found the virtual environment he experienced.

The RAC test has sub-factors such as 'Involvement', 'Sensory Fidelity', 'Interaction', 'Adaptation / Immersive' and 'Interface Quality'. The 'Cronbach Alpha' (α) reliability coefficient measurement was applied to these sub-factors and to the whole of the SOP test through the SPSS program (Cronbach, 1951). Internal reliability is a feature that a scale should have (Kılıç, 2016). The reliability coefficient value found in the Cronbach (α) coefficient (Table 2.1.) Found for the sub-factors of the scale is shown in (Table 2.2).

Table 2.1. Cronbach (α) values for sub-factors of the SOP scale.

Factors	α	Question Items	Number of Questions
Involvement	,787	(3, 4, 6, 7, 8, 10, 14, 16, 29)	9
Adaptation/Immersive	,715	(1, 20, 21, 24, 26, 27, 28)	7
Sensory Fidelity	,651	(5, 11, 15, 18, 25)	5
Interaction	,554	(2, 9, 12,13, 17)	5
Interface Quality	,433	(19, 22, 23)	3

The reliability of the scale is considered to be good if the Cronbach (α) coefficient is 0.7 and above (Kılıç, 2016). Values between 0.8 and 1.0 indicate high reliability (Özdamar, 2002). In addition, the low (α) value calculated can be attributed to the low number of items in the scale. When the calculated coefficient is above 0.9, it should be taken into consideration that there may be unnecessary questions in the scale (Cortina, 1993; Tavakol et al., 2011; Streiner, 2003).

Table 2.2. Cronbach (α) values for the overall SOP scale.

Test	α	Number of Questions
SOP Generally	,881	29

3. FINDINGS / ANALYSIS OF DATA

3.1. Analysis of Sence Of Presence Test

The responses to the scale of presence applied after the construction site CSVR application were statistically analyzed using the SPSS program. Analyzes were applied both to the overall SOP test and to sub-factors within the test. Based on this, both the general average of the answers given to the SOP test and the average scores of the answers given to the sub-factors were determined. The mean scores obtained from this analysis were evaluated in the context of determining how realistic the students found the CSVR application. As a result, it is thought that the realism level of the CSVR application developed will constitute an important criterion for the integration of VR into interior architecture education. High scores obtained from sub-factors of the SOP test indicate that the virtual environment experienced is perceived realistic and the user has a high sense of presence (Gökoğlu, 2019).

In the study, firstly, test responses were analyzed in order to determine the students' feelings of presence in the virtual environment with the SOP test. The answers given to the questions are positioned between 1 and 5 according to the 5-point Likert scale. Accordingly, the results obtained are classified as 1-'Highly Artificial', 2- 'Artificial', 3- 'Moderate' 4-'Realist', 5- 'Totally Realistic' (Figure 3.1).

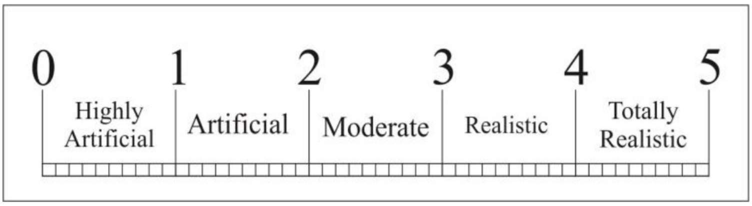

Figure 3.1. General sample score classification of the SOP test.

According to the frequency analysis applied to the whole test, the average of the answers given by 80 participants was determined as 4.29 out of 5. This indicates a general presence of 85.8% (Figure 3.2)

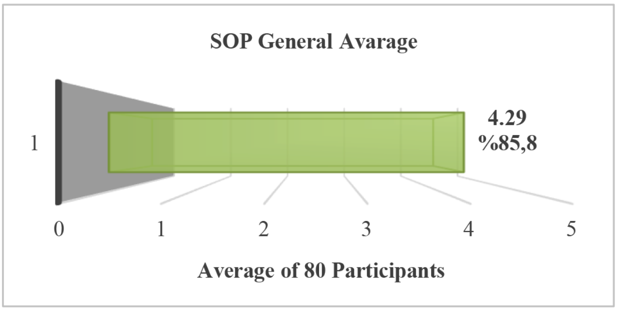

Figure 3.2. SOP General test mean table.

Participants' responses to sub-factors were also analyzed. According to the analysis of the answers given by the participants to each sub-factor in total; Interface Quality factor 4.2 (84%), Interaction factor 4.13 (82.6%), Sensory Fidelity factor 4.41 (88.2%), Adaptation /Immersive factor 4.3 (86.6%), The Involvement factor was determined as 4.33 (86.6%) (Figure 3.3).

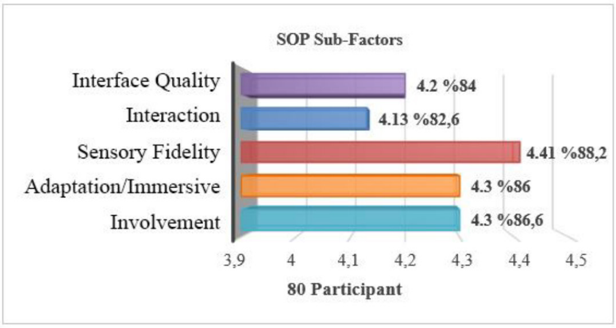

Figure 3.3. The overall mean table of the SOP sub-factors.

The average of the answers given by the participants to the sub-factors was determined as 4.28 (85.6%). This result gave almost the same result as the test performed on the whole test (Figure 3.4).

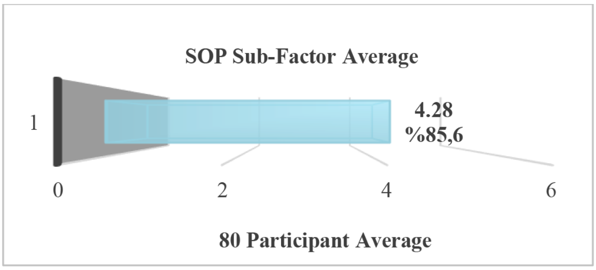

Figure 3.4. Table of the total mean of the SOP sub-factors.

In the VR experience, the responses of the participants to the presence test sub-factors were analyzed by separating the classes they were educated (Figure 3.5).

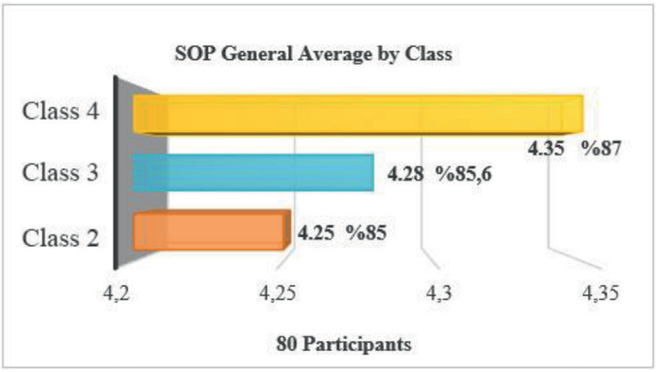

Figure 3.5. Class average table for STC participation sub-factor.

Generally obtained sense of presence data leads to the conclusion that students have a high sense of presence while experiencing the CSVR application. In addition to the frequency analysis, T test was applied to the entire test results in order to understand whether the perceived reality level in the CSVR environment had any relationship with using a VR system before.

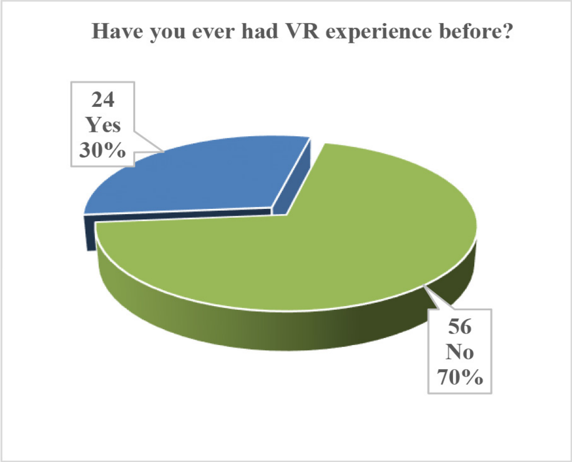

Figure 3.6. VR experience graph of the participants.

It is applied to determine whether there is a significant relationship between two items in the t test. For this, in studies, the 'p' significance value (significance value) obtained from the relationship between two items is compared with the ’alpha ‘value (Rosner, 2010). In studies, it is generally taken as alpha = 0.050. Alpha value is a rule that represents the value falling to 5% margin of error when analyzed at 95% confidence level in social sci-ences. If; If p <alpha, it appears that there is a relationship between items (Dawson & Trapp, 2004).

In the T test, it was examined whether there was any relationship between the general average obtained in the SOP test and the previous VR experience or not. The result obtained from the analysis was 0.091> 0.050, it was deter-mined that there was no significant relationship between these two items (Table 3.1). Accordingly, it can be stated that having used a VR system before is not related to the realism perception obtained in the VR environment.

Table 3.1. Table showing that there is no relationship between the SOP general perception of reality and VR experience.

Have you ever used virtual reality glasses / systems before?		Answers	SOP Average	Standard deviation	**Significance Value (p)**
SOP Generally	Yes	24	4,3994	,39577	0.091
	No	56	4,2482	,34760	

On the other hand, T-test was applied to the general average obtained from the SOP test and whether the students were present at the real construc-tion site or not (Figure 3.7) in order to determine the relationship between the perception of reality they felt in VR environment.

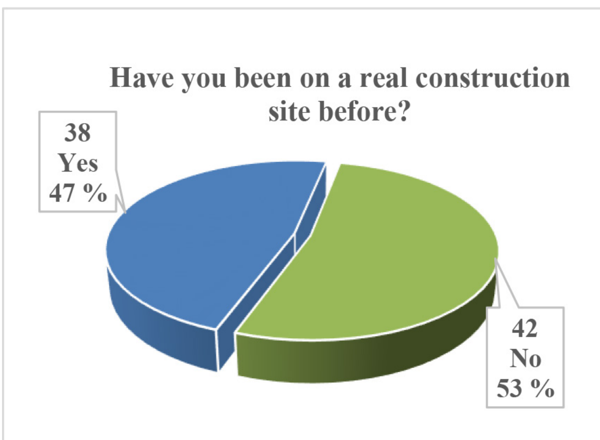

Figure 3.7. Real site experience graph of the participants.

However, here the result is 0.511> 0.050. According to this result, there is no significant relationship between these two items. Therefore, having been in a real construction site before is not related to the perception of reality obtained from the VR environment (Table 3.2).

Table 3.2. The table showing that there is no correlation between the SOP general reality perception and being on a real construction site.

Have you ever been in a real construction site environment?		Answers	SOP Average	Standard deviation	**Significance Value (p)**
SOP Generally	Yes	38	4,3221	,36601	0.511
	No	42	4,2677	,37012	

In the study, in order to find the answer to the question '*Is there any relationship between gender differences and the perception of reality in VR?*', The SOP general average and gender items were analyzed. As a result of the analysis, the significance value was found to be 0.276> 0.050. According to this result, it was revealed that there was no significant relationship between these two items (Table 3.3). From this point of view, it can be interpreted that having a different gender is not related to the perception of reality in VR environment.

Table 3.3. The table showing that there is no relationship between the general reality perception and gender n the SOP.

Gender		Answers	SOP Average	Standard deviation	**Significance Value (p)**
SOP Generally	Yes	65	4,3151	,37278	0.276
	No	15	4,2000	,33564	

Whether interaction devices such as VR glasses and motion controls used in the CSVR application have a relationship with the quality of the reality perception obtained from the virtual environment was examined by correla-tion analysis. Correlation analysis examines whether there is a relationship between two or more variables, and if there is a relationship, its negative or positive aspect and strength.The correlation coefficient (r) is the measure of the relationship between two variables and varies between -1 and +1. The following definitions are made for the strength of the correlation coefficient: 0.00 - 0.25 Very weak relationship 0.26 - 0.49 Weak relationship 0.50 - 0.69 Medium relationship 0.70 - 0.89 High relationship 0.90 - 1.0 It means very high relationhip (Köse, 2008).

As a result of the analysis, it was seen that there is a positive correlation of 0.813 between interaction devices and the sense of presence (Table 3.4). This relationship indicates a strong relationship between 0.70 and 0.89. Therefore, based on this result, it has been concluded that "*If the quality of the glasses and tactile devices used in the experience of the VR environment is increased, the presence of the user from the virtual environment and there-fore the sense of reality will increase*."

Table 3.4. The table showing the positive relationship between the overall mean scores of the SOP and the interaction sub-factor.

CORRELATION		INTERACTION	SOP GENERALLY
Etkileşim	Correlation	1	,813**
	Importance (Sig.2)		,000
	Participant	80	80
SOP Generally	Correaliton	,813**	1
	Importance (Sig.2)	,000	
	Participant	80	80

In order to understand whether there is a significant difference between the realism perceptions obtained from the VR environment of different grade levels, the "Anova Test" was applied to the 2nd, 3rd and 4th grade student groups and the SOP general scoring averages. 0.451> 0.050P value in the test result indicated that different class levels did not correlate with the sense of presence in the VR environment (Table 3.5).

Table 3.5. The table showing that there is no relation between the overall mean scores of SOP and the grade levels

Class	Class Population	SOPAverages	Standart Deviation	**Significance Value (p)**
Two	27	4,2388	,33744	0.451
Three	27	4,2797	,38426	
Four	26	4,3647	,38027	
Total	80	4,2935	,36686	

.

On the other hand, it has been determined that the three-dimensional game playing time is related to the interaction sub-factor score averages from the SOP (Table 3.6). 0.008 <0.050. Here, it was observed that the average interac-tion of the subjects who played 3D games for 1-2 years was lower (3.9), and the students who had experience of playing 3D games for 5 + years (4.4) were higher. Therefore, it can be concluded that 'students with more 3D gaming experience have more interaction performance in virtual environment and more success in using devices.'

Table 3.6. The table expressing the relationship between the SOP interaction sub-factor and the duration of 3D game play.

3D Game Play Time	Answers	Interaction Point Average	Standart Deviation	**Significance Value (p)**
1-2 years	45	3,9956	,50360	0.008
2-3 years	10	4,0400	,65184	
3-4 years	6	4,3000	,24495	
5 years+	19	4,4421	,33051	
Total	80	4,1300	,50526	

4. CONCLUSION

When the data obtained from the SOP test were evaluated, the average value that the students gave to the general sense of presence of the application was calculated as 4.29 out of 5. This means that proportionally, students have a sense of presence in VR application of 85.8%. From this point of view, it was understood that the students evaluated the application as having a high level of realism between "*Realistic*" and '*Totally Realistic*' points.

On the other hand, it was analyzed whether the students' being at different grade levels had a relationship with the sense of reality they felt in the CSVR environment, and it was observed that the responses of different classes to the SOP sub-factors were close to each other, so it was determined that there was no significant difference between the classroom levels and whether the construction site VR application was perceived realistically. . In addition, Anova test was applied to these class differences and felt realism variables. With the value obtained as a result of the test, it has been verified that the classroom levels do not have a relationship with the realism level obtained from the VR environment.

In addition, '*Does using a virtual reality system before have an impact on evaluating the CSVR application*? An analysis was made to find the answer to the question. This analysis was conducted to see if the quality of a previous VR experience compared to the current VR experience. However, it has been revealed that whether the students have used the VR system before or not has any relationship or effect on the evaluation of the CSVR application.

At the same time, '*Is there a link between the perceived reality level in the Construction Site VR app with a previous presence at a real construction site*? An analysis was made to find the answer to the question. The reason for conducting this analysis was to find out whether a comparison was made between the previous real experience and the current virtual experience. As a result of the analysis, it was seen that there was no significant relationship between the students' having seen or not seen a real construction site before and their evaluation of the realism of the CSVR application.

These two tests revealed that the information or experiences that the students brought from their previous VR experiences or real construction site experiences did not affect the result in their evaluation of the VR application, and the level of realism obtained was related to the unique structure of the application.

In addition, it was observed in the study that having a different gender was not related to the perception of realism obtained from this practice. However, it should be underlined that the gender distribution in the study is not homogeneous and this result should be confirmed by a more homogeneous gender distribution repeatedly.

In the study, a correlation analysis was made between the answers given to the interaction sub-factor and the overall average scores obtained from the construction site VR application. As a result of this correlation analysis, it has been determined that there is a positive relationship between the presence level felt in the CSVR application and the interaction. Within the framework of this result, it was seen that the increase in the quality of the feedback level (resolution, touch, feeling, etc.) provided by the glasses and controller devices used in the VR application to the user will positively increase the level of reality that the user feels in the virtual environment.

Finally, Anova test was applied to the answers given to the interaction factor and to the three-dimensional game time of the students in order to measure whether the three-dimensional game playing time had a relationship with the interaction devices used in the VR environment, and the data obtained showed that there was a relationship between these two variables. In the light of this analysis, it was found that students who played three-dimensional games for 5 years or more, and those who had 1-2 years of experience, used interaction devices more successfully, had more difficulty.

When the data obtained from all this SOP test are evaluated;

It was understood that the CSVR application created a perception of reality similar to that of a real construction site in general, students were able to examine the interior building elements as if they were in a real construction site and adopted the virtual environment in terms of realism.

However, it has been observed that there are some problems in the use of the system. These were read as getting used to the devices, experiencing anxiety due to fear of hitting the physical environment, and some movement functions causing problems in software.

On the other hand, in this study conducted with the participation of 2nd, 3rd and 4th grade students, it was understood that there was no class level difference in the perception of the CSVR application. Therefore, it is predicted that the integration to be realized can be designed with common content for all three classes based on the proposed model. For example, it is thought that all students who take the project course from a VR course with similar content will benefit equally.

In addition, it was observed that there was a relationship between students' experience of playing three-dimensional games and their better use of controllers in the VR system. When the subject is handled in this context, although there is a prejudice in the minds that all students play games and will be familiar with the virtual environment, while ensuring the adaptation of the model, it is necessary to consider the students who have little or no experience in this subject, and to create an environment of readiness for this. It was thought to be necessary.

The data obtained from the interaction factor has been determined that the feedback quality of tactile devices such as glasses and controllers significantly affects the quality of the VR experience, and improvements in these devices or devices that provide sensory feedback to the user will also positively affect the experience.

On the other hand, data supporting the SOP data were obtained from the interviews with the students after the study. In this context, it was concluded that the majority of the students found the CSVR application realistic and the impression was that they were actually on a construction site. It was understood that the students who felt as if they were there, disconnected from the physical reality and adapted to the virtual construction site environment.

With the help of the VR system, it is determined by the students' comments that the possibilities of seeing the details and components closely in three dimensions in the interior structure sections as in reality, to be able to observe all the stages of construction together with the stages, to '*examine some assembly details, for example, to the screw*' makes the interior structure detail parts extremely realistic and instructive. has been.

Although the first impressions of the students about learning the interior structure details are very positive, the subject of teaching is thought to be a subject that needs to be measured for a longer period of time. Whether there is a change in the outcomes of the lessons related to VR integration to a specified course curriculum should be measured by supporting with longer studies.

Almost all of the students stated that the details in the interior structure parts they experienced through VR were catchy and they learned the details they saw more easily and quickly than classical methods. The students stated the reasons for this, seeing the stages of making the detail, examining the three-dimensional models and explaining the detailed explanation of the instructor. However, the persistence of information is also an issue that requires long-term measurements and tests. Therefore, although it is inferred that these comments of the students have positive results for the use of VR in interior architecture education and that integration can be achieved, it should be underlined that new studies should be carried out on the permanence of information.

In the light of the data obtained as a result;

The use of virtual reality technology in interior architecture education as a teaching tool in teaching interior building details such as gypsum walls, suspended ceilings, and flooring is thought to have a positive effect. It was concluded that the integration of the VR model proposed in the study into the interior architecture education process can be achieved provided that the difficulties encountered during the study, the demands and complaints of the students are eliminated.

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chapter 10

ENERGY EFFICIENCY IN CROSS LAMINATED TIMBER (CLT) BUILDINGS

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1. INTRODUCTION

Worldwide energy consumption has been increasing very fast depending on population growth, industrialization, competing demand for buildings, and technological developments. Despite advancing technology, use of renewable energy resources in buildings (solar power, wind energy, etc.) is insufficient, and the most part of energy consumed for the purpose of heating, cooling, and electric still has been derived from fossil fuel such as natural gas and coal.

The production and consumption of electricity accounted for one third of the building energy use in 2019. Beside this, fossil fuel usage increased by 0,7% from 2010 to 2019. Carbon emissions “CO2” induced by buildings reached all-time high in 2019 (Abergel and Delmastro, 2020). Energy efficiency in buildings has to be taken into consideration not only for equipment which requires heating, cooling, and electricity usage but also all building materials. Concordantly, demand for ecological and sustainable building materials which can be derived from renewable resources has gradually increased in recent years. Practicing native materials in architecture and incorporating them into sustainable development processes have resulted in a significant increase in energy conservation (Korjenic, 2011). Decreasing energy consumption and fossil fuel quantity in buildings according to the needs also reduces quantity of C02 and S02 which are released into the atmosphere. Instructions prepared for building energy performance suggest that buildings be designed in such a way as to decrease energy amount required for operating system and that more precautions taken in order to enhance energy performance in existing buildings (Papadopoulos and Giama, 2007).

Building materials selection, heat insulation applications and environmental performances of these materials allow for analysis of energy efficiency and construction costs. Type and thickness of insulating materials can be changed even in early design stage. For selection of construction materials and elements, a great variety of criteria such as thermal and physical characteristics, environment, energy, and cost are evaluated based on an integrative approach (Anastaselos et al., 2009). Moreover, another prominent one of sustainability precautions to decrease carbon footprint, energy use, and greenhouse gas emissions in buildings is the use of insulating materials (Rakhshan et al., 2013). Application methods, thickness, and types of the materials are determinative factors for their performance (Papadopoulos, 2005). Wood is one of high-performance insulation materials. It is possible to generate insulation panels consisting of particles with several types and dimensions by using wooden materials (Viot et al., 2015).

At the first part of the study, structural-physical-environmental-economic characteristics, use-application styles in buildings, insulating properties, earthquake resistance, advantages-disadvantages, etc. of the material Cross Laminated Timber (CLT) is examined thoroughly, and some CLT building samples in Turkey and the world are shown. The second part focuses on a comparative evaluation of energy performance in a sample building that is assumed to be erected in a mild humid climate region by using CLT materials and different traditional building materials.

2. CROSS LAMINATED TIMBER (CLT)

The most important building material used in architectural sectors is wooden materials. Mechanical properties such as weight, resistance, density, structural characteristics, insulating properties, and also high thermal characteristics play a significant role in using wooden construction materials (Breyer et al., 1999).

Today, having been built by using engineering wooden materials (Glulam Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), Laminated Strand Lumber (LSL), Cross Laminated Timber (CLT), high-rise structures covering large spans are drawing more attention. These materials have been used in numerous fields such as bridges, coach stations, education facilities, sport halls, industrial buildings and dwellings other than single-story wooden structures (Rowell, 2012). CLT was developed in Switzerland in the early 1990s, and took its today form in 1996 in Austria because of industry-academy cooperation. In 2000s, building with CLT gained speed. Austria, Sweden, Switzerland, Norway and the United Kingdom are prominent countries in using CLT for dwellings, education facilities, etc.

Among the advantages of CLT materials are to make undersized pieces of saw timber into oversized building materials, to be eco-friendly, to shorten construction period, to be lighter in proportion to concrete and steel materials, to provide convenience in building process due to prefabrication, to have a high load capacity, to be made from solid wood, to have a high fire-resistance, to have a good heat insulation, to allow for flexibility in architectural design (Crosslam, n.d.; KHL, 2019). Together with its advantages, there are also some usage restrictions for the material. For instance, finished panel designs before starting site works, a properly founded base for panel applications, and face veneer or coating in order to provide weather-resistant building envelope are required (Greenspec, n.d.).

2.1. Structural Properties and Installation

CLT is a wooden construction product with 3, 5, 7, 9 or more layers as a result of gluing and pressing solid wooden panels together in a way that fiber directions are perpendicular to each other. CLT consists of minimum 3 layers that are glued together and the layer thickness changes depending on structural requirements. The layers are fastened by using nature friendly glue containing formaldehyde not less than 1% of the product (Stora Enso, 2017). For cross-laminated timber materials produced with commercial purpose, some techni-cal properties taking place in literature are given in Table 1.

Table 1. Some Technical Properties of CLT Material (Greenspec, n.d.)

Thermal conductivity: 0.13 W/mK
Density: 480–500 kg/m (spruce)
Compressive strength: 2.7 N/mm (perpendicular to grain of boards) 24–30 N/mm (parallel to grain of boards)
Bending strength: 24 N/mm (parallel to grain of boards)
Elastic modulus: 370 N/mm (perpendicular to grain of boards) 12,000 N/mm (parallel to grain of boards)

Combined wooden panels as in Figure 1 is defined as dovetail connection (joint). In this joint system, a dovetail made from wooden or steel material is added to CLT wall panels and the walls are combined. Among the most remarkable advantages of the joint type used both to produce CLT panels and to fasten wall panels are having a high resistant to disintegration, allowing for a fast and easy montage, and being flexible, versatile and affordable (Sustainable Construction Services, n.d.).

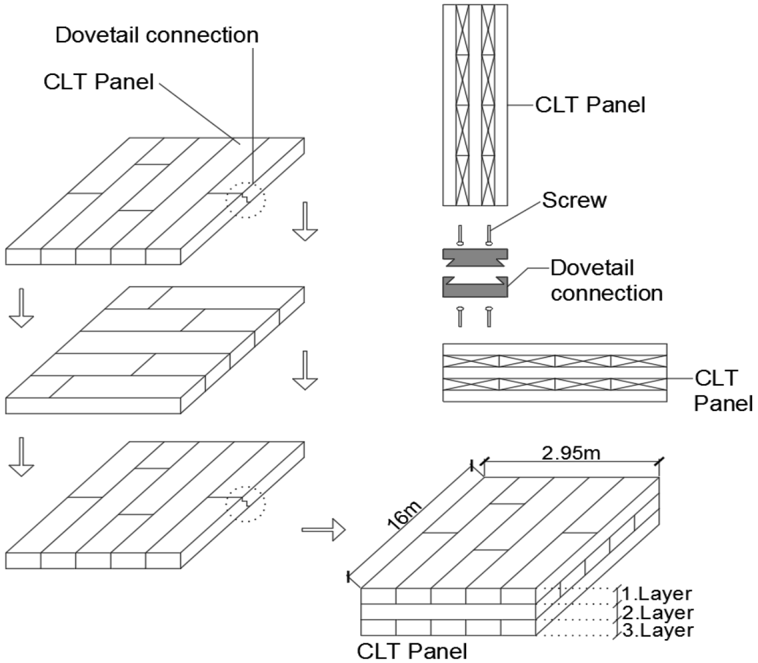


Fig. 1. Connection system in CLT assemblies (Stora Enso, 2017; Sustainable Construction Services, n.d.)

Due to being a prefabricated material, construction time of CLT is quite short. CLT panels can cover a 7 to 7,5mt span without an extra bearing element and can be produced by 20m-length through end to end joint (finger joint) upon request (Wood Solutions, 2014) (Figure 2). Furthermore, CLT panels compose a system with a higher shear strength which is structurally stronger and lighter when compared to concrete and steel material (Crosslam, n.d.).

Fig. 2. Finger joint system between CLT panels (Cree Buildings, 2015; Crosslam, n.d.)

CLT panels can be used for roof, wall, and floors in buildings. Figure 3 shows detail drawing of alternative layers that could be used for roof, wall, and floor mounting in a building. These details were obtained from different sources and rearranged.

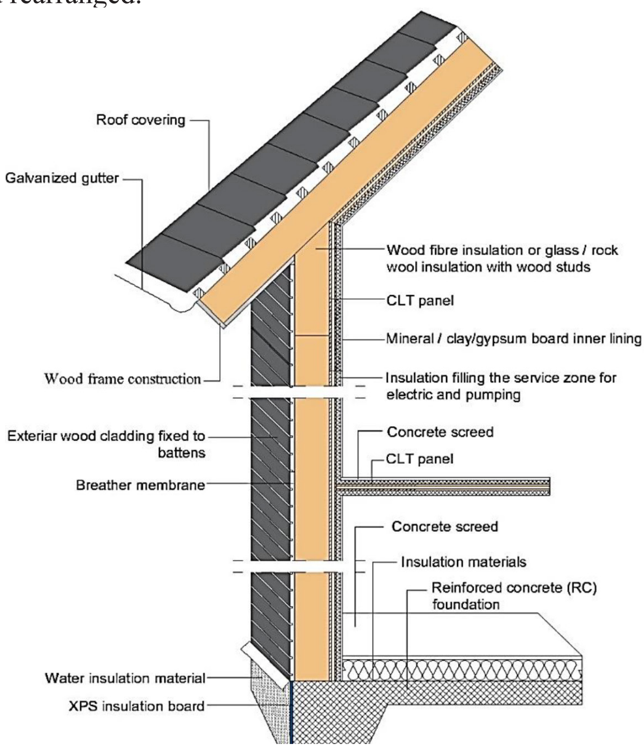


Fig. 3. Roof, wall and floor application details of CLT panels

CLT panels are transported to the construction site after being manufactured. The panels which are numbered according to the installation plan are moved to a proper place with the help of cranes. The panels, thereafter, are fastened by means of predetermined junction sections, screws, and bolts. The wall panels that are lifted up with the help of cranes considering the number coding system are placed and fixed on the prebuilt base of the building by means of fixing sections (Wood Solutions, 2014; Crosslam, n.d.). Due to being prefabricated, CLT structures reduce the risk that design problems arise. CLT panels are cut in compliance with installation projects at CNC countertop, and electricity wiring and water system are installed.

Wooden products are a good preference for most green building projects including both construction and renewal (Crosslam, n.d.). The total cost of buildings erected by using CLT materials is less by 0.9 -1.3% than the cost of traditional reinforced concrete buildings (Jayalath et al., 2020). During the installation stage, CLT buildings provide savings on cost and time when compared to concrete buildings (Ceccotti, 2010; Kayakıran and Kishalı, 2019; Van De Kuilen et al. 2011).

2.2. Fire Performance

Wooden buildings are the structures more resistant to fire than the steel ones. Because of leading to fast heat dissipation, steel allows fire to spread around rapidly. While steel material becoming substantially soft after fire causes a building to collapse, wood materials char equally at a speed of 1mm/min in case of fire, and thus create a carbon later which prevents fire from going on (Crosslam, n.d.). CLT panels with 30, 60, 90-min fire endurance period can be produced. CLT composition can put up resistance to massive fire during 120 minutes without sacrificing the structural system of the building. The main reason is that the mass ratio is high (Greenspec, n.d.; Crosslam, n.d.). In spite of the fact that CLT materials do not need to be covered with various materials on the purpose of putting up resistance to fire, the laws concerning fire regulations require that they be covered with fire-resistance sheets (Henek et al., 2017).

2.3. Earthquake Performance

Wood is a light material resistant to tensile and strain. Wood is lighter 15 times than steel, 5 times than reinforced concrete (Turer, 2006). Tensile-resistance wood material can cover large spans (Kuban, 1992). Wood changing shapes when force is applied resumes its original shape when force is removed (Alih and Vafaei, 2019). Due to being light, wood reduces lateral pressure (horizontal force) (Avlar, 2002).

CLT panel is a material that is light, flexible, earthquake-resistant, and has high value of the rigidity and bearing capacity. That is the reason why it is a building material often preferred in earthquake-prone regions. That build-ings are light reduces the risk of collapsing (Stora Enso, n.d.; Tobriner, 2000). Owing to the durability and dimensional stability, CLT panels develop very good resistance to lateral load. When compared to other materials, CLT struc-tures can be repaired more easily, safely and faster when they are damaged because of earthquake (Crosslam, n.d.). Problems arising during an earth-quake are usually caused by junction breakages (Mohammad et.al, 2013).

2.4. Heat Insulation Performance

Of wood materials, energy consumption and thermal characteristic are better in proportion to those of concrete and steel. According to the declarations by American Wood Council (AWC), the insulating value of coniferous wooden materials is roughly one third of that of fiberglass insulation with the same thickness. The same value is higher 3 times than that of concrete material and approximately 400 times than steel material (Canada Wood, 1995). However, energy consumption is 1,7 times higher at reinforced concrete structures and 2,4 times at steel structures than wooden ones (Tokyay, 2017). Heat conduc-tivity of wood material is low (Table 2), which makes it suitable for both heat and sound insulation (Upton, et al., 2008).

Table 2. Thermal Conductivity Of Some Materials (TS 825, 2008)

Material	Density (kg/m3)	Conductivity (W/m.K)
Concrete	2400	1,93
Brickwork	1700	0,77
Reinforced Concrete (RC)	2300	2,5
Gypsum	1200	0,43
Timber (softwood, plywood, chipboard)	500	0,13

Through the method of adhesive bonding which is employed for CLT panel production, high-grade impermeability is procured throughout panels. Moreover, CLT panels have high specific heat capacity, which can considerably reduce heating and cooling costs and also enhance indoor comfort by creating sort of thermal mass action. In order that a building with CLT materials has a high energy performance, extra insulation on the building envelope is required (Cross Timber Systems, n.d.).

At wooden buildings, heat insulation is carried out generally on exterior surfaces. Conducted in Chang, et al. (2019), a study indicates that exterior-insulated CLT walls have lower thermal bridges. External insulation allows for the continuity of insulating layer around structures. However, insulating layer is interrupted at wall-floor or wall-ceiling junctions in internal insulation applications. In order to enhance building energy performance and decrease thermal bridges, the continuity of insulation is so important. Beside this, external insulation reduces expansion in walls by protecting CLT panel against external climate conditions (Greenspec, n.d.).

2.5. Environmental Properties

When an approach to reducing environmental effects and climatic changes is brought, utilization of wooden materials instead of such materials as concrete whose consumption of energy and Cis high is a good solution. It is known that wooden structures lead to less C emissions during their life cycles when compared to the systems based on concrete, steel or brick (Upton, et al., 2008). Due to having a key feature of carbon sequestration, wooden materials can store 28,5 tons of carbon dioxide which a 216 square- meter house produces and which is equal to the quantity of carbon dioxide that a car exhales for 7 years (Tokyay, 2017). Utilization of CLT for structures contributes to the preservation of biological diversity, forest ecosystems, and soil-water resources, and reducing greenhouse gas effects caused by carbon emission (Crosslam, n.d.).

3. CLT BUILDINGS

Around the world in recent years, CLT buildings serving many different purposes but generally as dwelling houses have been built. In this section of the study, CLT building samples, the designs of which are done, in the country and abroad are shown.

3.1. Kea Boumanstraat

The house built between the years of 2012 and 2013 in Amsterdam, the capital of the Netherlands was designed to serve as a 240-square-meter and 3-storey plus basement home for a family of 4. In order to shorten the construction time and maintain the sustainability, the house was built by using CLT panels. Beside this, it was designed to be an energy efficient house with features such as solar panels on the roof and a tank in the garden to store rain water for reuse (Meesvisser, n.d.).

Fig. 4. Kea Boumanstraat building (Meesvisser, n.d.)

3.2. Lct One

The 18-storey building, which was built between the years of 2015 and 2017 in Vancouver, belongs to the University of British Colombia, and has gained the title of the tallest wooden building in the world, is 53 meters in height and provides 404 students with the spaces for accommodation, education, and recreation. The building was erected on a concrete basement by using a 17-storey solid wood system with 5-layer CLT panels. Owing to the wood system utilized for the building, 1753 metric ton of carbon dioxide was stored and 679 metric ton production of greenhouse gas emission was prevented (Build Up, 2013; Cree Buildings, n.d.)

Fig. 5. Lct One building (Gayle, 2012)

3.3. Ubc Brock Commons

The office building with an 8-storey modular and hybrid (CLT-concrete) structural system was built between the years of 2011 and 2012 in Dornbirn, Austria. For the flooring of the building with 27-meter height, 13-meter width, and 24-meter length, a wood-concrete composite rib unit was developed. For the building, a good heat insulation level was provided and the thermal transmittance (U) for the main external walls and the roof was calculated respec-tively 0,12 W / (m^2 K) and 0,07 W / (m^2 K) (Naturally Wood, n.d.; UBC Sustainability, n.d.; Think Wood, n.d.).

Fig. 6. Ubc Brock Commons building (UBC Sustainability, n.d.)

3.4. Minneapolis T3

The office building was a solid wood building with LEED Gold certificate, constructed in 2016 in the USA. The 7-storey building has a 20500-square-me-ter construction site. For the columns, walls, and floors of the building, 3600-square-meter wooden materials (CLT) were used. During the physical life, the building that was once the biggest CLT building of the North America continent was assumed to store 3200 tons of carbon (MGA A Katerra Design Partner, n.d.; Arch Daily, n.d.; Bilgiç, 2017).

Fig. 7. MINNEAPOLIS T3 building (MGA A Katerra Design Partner, n.d.; Arch Daily, n.d.)

3.5. The Tree (Treet)

Fig. 8. Treet building (Urban Next, n.d.)

The 14-storey dwelling house with 52,8-meter height, which was built between the years 2015 and 2017 in Bergen, Norway, has a 7140-square-meter con-struction site. For the construction, CLT and Glulam were used. Beside this, each flat was provided with its own self-balancing ventilation system by using an 80% - efficient heat recovery ventilation system (Urban Next, n.d.; Abrahamsen and Malo, 2014).

3.6. Grand Ottoman Hotel

The building serving as a hotel is located on the riverside of Yeşilırmak in Amasya, Turkiye. The 2-storey project, the walls and floors of which CLT was used for, has a 1000-square-meter construction site was built by the firm, ASMAZ Ahşap Karkas Yapılar (Wood-Frame Buildings).

Fig. 9. Grand Ottoman hotel (Asmaz, n.d.)

4. BUILDING COMPONENT AND CASE ANALYSIS

The CLT building design and its characteristics were explained in detail at the first part of the study. As for this section, the data of the sample building, the energy simulation of which was made were shared here. In order to make a comparative energy efficiency evaluation and thermal analysis of the sample building which was made from CLT and other construction materials, DesignBuilder Simulation program was used. Such descriptions as the con-struction materials, thermal zones, heating-cooling system, spaces, and cli-matic data of the sample building were made (Figure 10).

The scope of the study was bounded by Istanbul located in mild humid climate region (Turkey, 2nd degree-day region). Of Istanbul, the climatic data based on long term averages are seen in Table 3 (Turkish State Meteorological Service (n.d.).

ISTANBUL	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. Temp.	22.4	24.6	29.3	33.6	36.4	40.2	41.5	40.5	39.6	34.2	27.8	25.5
Min. Temp.	-13.9	-16.1	-11.1	-2.0	1.4	7.1	10.5	10.2	6.0	2.2	-7.2	-11.5
Average Temp.	5.8	5.5	7.3	11.2	15.7	20.5	22.9	23.4	19.9	15.8	11.0	7.8
Average Max. Temp.	8.5	8.7	11.0	15.5	20.1	25.0	26.9	27.2	23.8	19.2	14.2	10.4
Average Min. Temp.	3.5	2.9	4.4	7.8	12.2	16.7	19.7	20.4	16.8	13.2	8.5	5.5
Average Rainy Days	15.2	13.2	11.7	8.9	6.6	4.7	3.0	3.4	5.5	9.0	11.2	14.5

Table 3. Long-term Average Temperature Data in Istanbul (1929-2019)

The building modelled as part of the study is a one-story rectangular structure having a usable area of 80 m2 with the dimensions of 8m by 10m. The modelled building contains a lounge, a kitchen, bedrooms, a circulation area, and a bathroom (Figure 10). A hipped roof and standard double-glazed wooden windows were selected for the building.

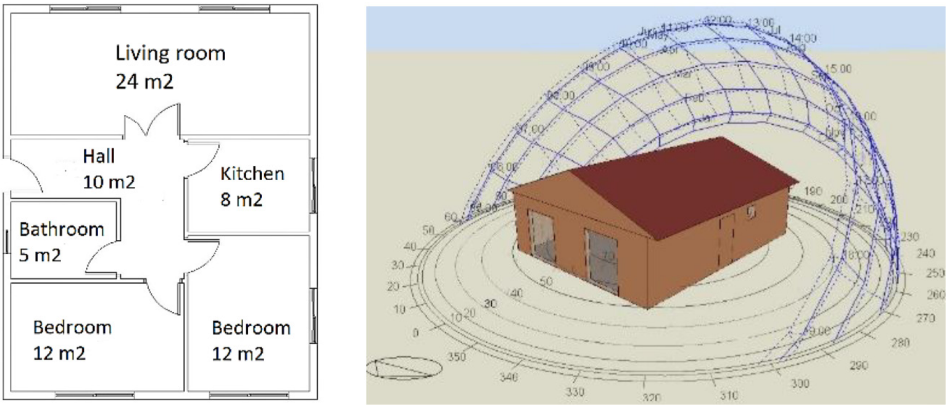
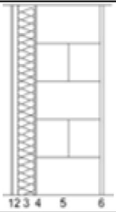
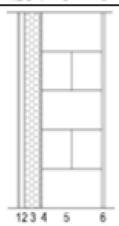
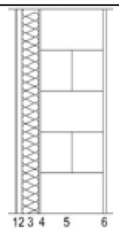
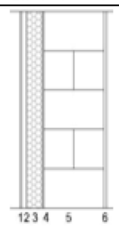
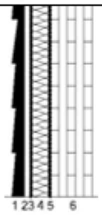
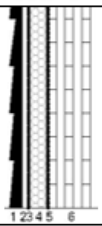


Fig. 10. Floor plan and 3D rendering of model building

Among the alternative options for the walls were brick, gas concrete, and CLT that are commonly preferred. The options were based on the U values of exterior walls determined for the second climate zone in conjunction with the TS 825 standard. Sections that are commonly practiced in today's house designs were generated, and the same thickness and type of insulation were selected (as 5cm and Rock wool, EPS) for all the options. For the CLT walls, the panel thickness was 10cm (the most-preferred one in practices). Of the materials shaping the alternative wall layers, the technical specifications are given in Table 4.

Table 4. Thermophysical Properties of Wall Materials (TSE 825, 2008)

WALL LAYERS		No	d (m)	Materials	λ W/mK	P Kg/m^3	c J/(kg.K)	U (W/ m^2K)
BRICK WALL (Rock wool)		1	0,005	Gypsum plaster	0,16	600	1000	0,442
		2	0,015	Cement mortar plaster	0,42	840	1200	
		3	0,05	Rock wool	0,038	40	840	
		4	0,005	Cement mortar plaster	0,42	840	1200	
		5	0,19	Brick	0,30	1000	840	
		6	0,01	Cement rendering	0,42	840	1200	
BRICK WALL (EPS)		1	0,005	Gypsum plaster	0,16	600	1000	0,456
		2	0,015	Cement mortar plaster	0,42	840	1200	
		3	0,05	EPS	0,40	16	1400	
		4	0,005	Cement mortar plaster	0,42	840	1200	
		5	0,19	Brick	0,30	1000	840	
		6	0,01	Cement mortar plaster	0,42	840	1200	
GAS CONCRETE BLOCK WALL (Rock wool)		1	0,005	Gypsum plaster	0,16	600	1000	0,413
		2	0,015	Cement mortar plaster	0,42	840	1200	
		3	0,05	Rock Wool	0,038	40	840	
		4	0,005	Cement mortar plaster	0,42	840	1200	
		5	0,19	Gas concrete	0,24	750	1000	
		6	0,01	Cement mortar plaster	0,42	840	1200	
GAS CONCRETE BLOCK WALL (EPS)		1	0,005	Gypsum plaster	0,16	600	1000	0,425
		2	0,015	Cement mortar plaster	0,42	840	1200	
		3	0,05	EPS	0,40	16	1400	
		4	0,005	Cement mortar plaster	0,42	840	1200	
		5	0,19	Gas concrete	0,24	750	1000	
		6	0,01	Cement mortar plaster	0,42	840	1200	
CLT WALL (Rock wool)		1	0,03	Wood cladding	0,13	700	1200	0,381
		2	0,015	Air gap	-	-	-	
		3	0,0001	Vapour retarder	2,3	130	2300	
		4	0,05	Rock Wool	0,038	40	840	
		5	0,0001	Water insulation material	0,23	1,3	1000	
		6	0,10	CLT	0,13	500	1300	
CLT WALL (EPS)		1	0,03	Wood cladding	0,13	700	1200	0,391
		2	0,015	Air gap	-	-	-	
		3	0,0001	Vapour retarder	2,3	130	2300	
		4	0,05	EPS	0,40	16	1400	
		5	0,0001	Water İnsulation material	0,23	1,3	1000	
		6	0,10	CLT	0,13	500	1300	

The U-values and thickness of wall sections vary according to the formation and application detail of section. For the model, the value of infiltration occurring from external environment to indoor is established as 0.8 ach-1. The user profile identifies a single-child family of three people. It was assumed that the period during when the family stayed in the house was between 08.00 and 17:00 on weekdays and whole day at weekends. The heating-cooling values determined for the usage of building and spaces are shown in Table 5. Spaces, the heating-cooling requirement of which was similar were modelled as they were a single thermal zone while creating a thermal zoning. In the examined dwelling house, natural gas central heating boiler system for heating and air conditioner and natural ventilation for cooling was included in the program.

Table 5. Heating-Cooling Setpoint Temperatures

Heating (°C)	19	Cooling (°C)	25
Heating set back (°C)	15	Cooling set back (°C)	28

4.1. Heating - Cooling Loads of Building

Within the scope of the study, total heating and cooling load calculation for each of wall samples was performed by month and year through the DesignBuilder program using the climatic data of Istanbul as base. The results obtained from the model were used to compare all other scenarios (brick wall with rock wool / EPS (BW-R, BW-E), gas concrete block wall with rock wool / EPS (GSW-R, GSW-E), CLT wall with rock wool / EPS (CLT-R, CLT-E). In Figure 11 and 12, the heating and cooling load values for different scenarios of the model building in summer and winter are given.

According to the simulation results, the annual energy consumption by the heating load is 2912.21 kWh for the scenario 1 (BW-R), 2872.22 kWh for the scenario 2 (BW-E), 2845.65 kWh for the scenario 3 (GSW-R), 2872.223 kWh for the scenario 4 (GSW-E), 2714.737 kWh for the scenario 5 (CLT-R), and 2734.28 kWh for the scenario 6 (CLT-E). When comparing all the sce-narios with each other, we see that the scenario 5 (CLT-R) related to the rock wool-insulated CLT building delivered the best performance in terms of the heating load. The scenario 5 provided energy saving respectively by 7 % and 5 % when compared to the rock wool-insulated brick wall and the rock wool-insulated gas concrete wall. All the results are associated with the thermal conductivity and specific heat values of construction and insulation materials. The CLT walls presenting the effect of massive thermal mass enhance build-ing energy performance provided that they are insulated with materials suit-able for the climate region where they are

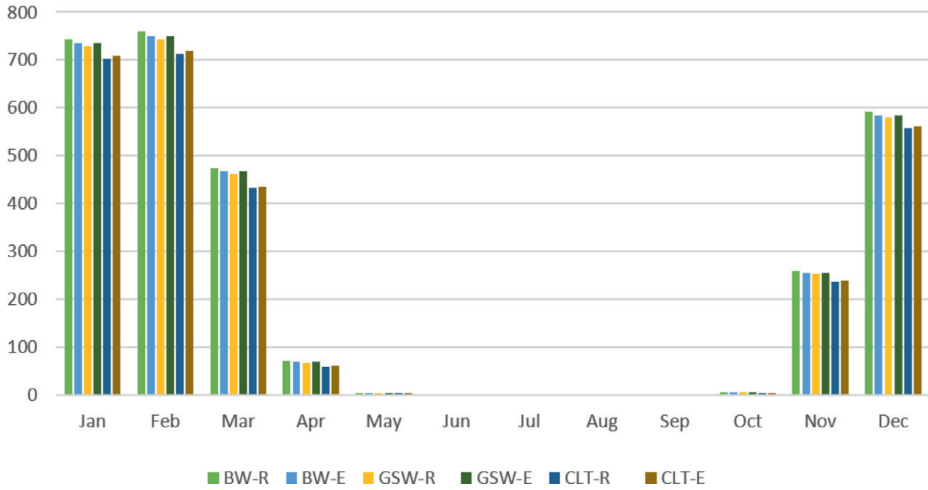


Fig. 11. Heating loads for different wall scenarios

According to the simulation results, the annual energy consumption by the cooling load is 229.6 kWh for the scenario 1 (BW-R), 229.9 kWh for the scenario 2 (BW-E), 228.5 kWh for the scenario 3 (GSW-R), 228.7 kWh for the scenario 4 (GSW-E), 262.2 kWh for the scenario 5 (CLT-R), and 263.2 kWh for the scenario 6 (CLT-E). When comparing all the scenarios with each other, we see that the scenario 5 (CLT-R) related to the rock wool-insulated CLT building delivered the least performance in terms of the heating load. The scenarios for the insulated gas concrete walls and brick walls revealed approximate values in terms of the cooling load of the model building. That CLT walls have the characteristic of high air tightness and provide insufficient natural ventilation due to their compacted formation affect cooling load per-formance negatively in the summer months.

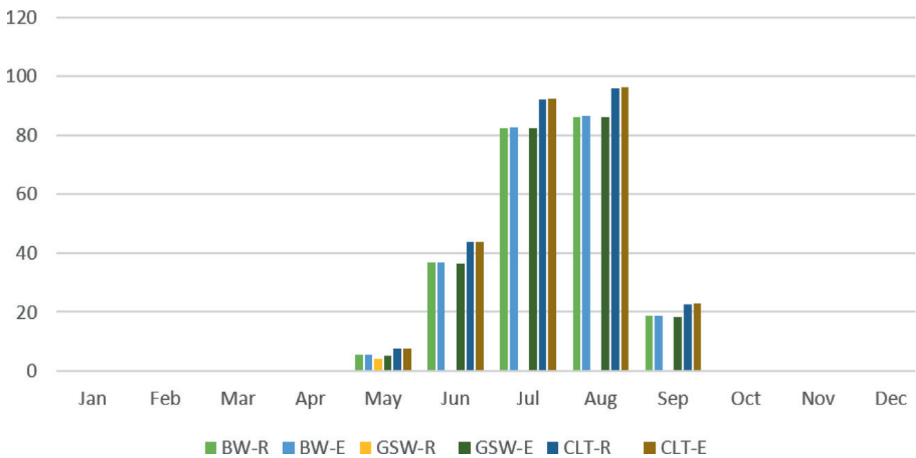


Fig. 12. Cooling loads for different wall scenarios

5. CONCLUSIONS

Low-energy building designs which have been recently constructed through passive systems in architecture sector as a solution to climate change and global environment problems by using renewable energy sources and ecological building materials have been drawing attention. In this regard, CLT, a new generation wood product, has been commonly used in construction sector around the world due to having many advantages that will make a great contribution to sustainable design. Load-bearing (being able to cover large spans) and non-load bearing construction elements can be made of CLT materials which can be used for low, medium, and high-rise buildings (taller than 8-storey). Beside this, CLT panels can be easily integrated with steel, reinforced concrete and other wood-frame systems.

As part of the study, energy efficiency of a representative building which had been constructed by using CLT was evaluated by comparing with other construction materials. Consequently, when compared to the walls which were built with other construction materials (brick, gas concrete, etc.), the insulated CLT panel walls were seen to have enhanced the energy efficiency of the building and had positive impacts on the heating load. That CLT has a high-density formation (massive timber) and very low air tightness increases energy efficiency by creating sort of the thermal mass effect. However, thermal mass effect and air tightness generate adverse effect in terms of cooling loads. The data of cooling load related to the CLT building, the simulation of which was made for the study, also corroborates the aforesaid situation. In their studies, Glass (2013) and Khavari et al. (2016) indicate that the cooling load was high in the CLT buildings which they had analyzed but the peak cooling load lower than that of the reference building was required. Moreover, the thickness of CLT panels is inversely proportional to the U-value but directly to the thermal performance, which also allows for the lower thickness of insulation. According to a general evaluation of CLT energy performance; climatic zone where a building is located, building usage purpose, size, CLT panel properties, heating-cooling-ventilating type, and indoor thermal load are the parameters which are the points to take into consideration in order to provide low energy consumption.

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chapter 11

EFFECT OF GREEN WALL SYSTEMS ON BUILDING HEATING AND COOLING LOADS IN SUSTAINABLE DESIGN

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1. INTRODUCTION

The socio-economic changes that accompanied industrialization in almost all countries of the world brought about the phenomenon of urbanization and increasing population problems with advances in technology and health. The rising standard of living of the population in urban areas has also triggered spatial preferences in terms of small square meters, functional and vertical structuring.

These changing and diversifying spatial demands have set in motion the rapid degradation of the natural environment and led to the consideration of issues such as air quality and consumption of energy resources. According to the United Nations Environment Program, 40% of resources, 40% of energy and 25% of water are consumed by the building sector worldwide, and 33% of greenhouse gas emissions are reported to be responsible (UNEP & SBCI, 2013). The increased indoor comfort conditions with urbanization and modernization have led to serious energy consumption values with the developing technologies of smart building systems and building materials industry. Looking at the average values of final energy consumption in European countries since 2004, the construction sector accounts for 30% of total energy, the non-residential sector for 12% and the construction industry for 2% (Itard and Meijer, 2008). Important issues such as urban heat island, pollution, ecological destruction, deterioration of air and water quality, danger in the consumption of limited natural resources and energy conservation require important solutions from sustainable architectural principles. Green walls, one of today's trending topics, have gained prominence due to their ability to solve the above problems.

Therefore, the need for a design that prevents the waste of natural resources and supports energy conservation by protecting the ecology is increasing day by day. Referring to the researches considering sustainability based on the concept of sustainable architecture understanding is one of the current trending topics. Three basic elements, such as the most favorable use of available resources, life cycle continuity, and transmission to other generations, are important for sustainable architectural understanding, as well as increasing space and human comfort in design (Çığan and Tokman, 2019: 34). Sustainable architectural principles continue to bring forth new systems and materials that are a solution to the natural environment and today's energy problems by utilizing resources of the important elements that support them. Green walls, as one of them, and the benefits they provide, form the basis of the study.

This study answers the question of how a green wall can change the energy performance of a building and affect the heating and cooling energy demand. To evaluate and compare the performance of green wall applications, a traditional insulated brick wall is also used as an example. To understand and demonstrate whether green wall applications are effective, the energy load calculations were performed for a residential building example. The energy loads of the sample building were calculated for five different locations (Antalya, Muğla, Konya, Sivas and Erzurum) from five different degree day zone regions of Turkey, which were determined in TS 825 Thermal Insulation Regulations in Buildings Standard (TS 825). In the study, the heating and cooling demand of the building samples were calculated using CARRIER Hourly Analysis Program (HAP), and the thermophysical properties of the building components were taken from TS 825.

2. SUSTAINABILITY AND SUSTAINABLE ARCHITECTURE

With industrialization, the world's ecological balance began to deteriorate in the late 1960s, and energy problems became increasingly visible. In this process, humanity faced important global problems, such as depletion of natural resources, excessive increase in population, decrease in water resources, air pollution, proliferation of chemicals / heavy metals in nature (Gleeson and Low, 2000: 4-6). Protection of natural and structural environmental balance has been sought. Changing and evolving technologies have highlighted the need for more qualified, livable and environmentally friendly solutions. The concept of sustainability, put forward and accepted by all disciplines, has emerged as a key concept aimed at protecting future generations of societies.

With the "Common Future Report" published in 1987 by the United Nations Commission on Environment and Development (WCED, 1987, sustainability has become a global agenda issue. According to the report, the concept is based on the principle of meeting present needs through the use of existing resources without compromising the needs of future generations (Bourdeau, 1999: 355 An ecological worldview has gained worldwide acceptance (Keleş,1998: 112)Sustainability is also expressed as the use of natural resources and environmental values through rational methods without allowing waste, as well as the ability to sustain both its existence and that of the environment (Meadowcroft, 1997: 168. With this value, the multidisciplinary concept based on environmental, economic and social components (Kohler, 1999: 311 has found a place as an important design key for architecture. As the building sector is responsible for energy consumption issues as well as the degradation of the natural environment and air quality, environmentally friendly building techniques and the search for materials should be accepted as a real necessity (Vardy and MacDougall, 2007. In the Sustainable Development Report, published by the United Nations Environment and Development Commission, it was emphasized that solutions should be created by considering the regulations necessary for sustainable development along with the idea of economic development growth (Bourdeau, 1999: 355. Sustainable architectural principles such as integrating the natural and built environment, utilizing natural daylight and ventilation opportunities, increasing indoor comfort, and supporting issues such as minimal energy consumption were accepted along with their expanded applications.

Sustainable architecture is also known as solar architecture or green architecture, where the purpose of sustainable architecture is not only to use solar energy according to the geographical data, but also to reduce the consumption of natural resources and fossil fuels. The main goal of this architectural application field is to reduce the impact of the built environment on the ecological system, to support the efficient use of resources, and to ensure the recycling of waste without polluting the environment (Sev, 2009; Yetkin, 2019: 72). The sustainability criteria of buildings include important features such as minimal energy consumption (Kumar etc, 2016: 587), the ability to produce energy self-sufficiently, and having technologies that contribute to the environment when needed (Kayıhan and Tönük, 2008: 140; Özorhon, 2013: 1475).

It is possible to call buildings that meet these criteria sustainable architectural structures (Tavşan and Yanılmaz, 2019: 363). Sustainable structures, aim to ensure the health and comfort of the user and to protect the existence of natural resources during both the construction and use phases, as well as to produce waste in such a way that natural resources are not endangered and nature is not harmed even after destruction (Geçer etc., 2019: 333). Nowadays, *sustainable, ecological, green, environmentally friendly, smart and high performance building design concept* exists as a new trend with the main goal of protecting the rights of future generations without wasting today's energy resources and guiding designs with an architectural understanding that respects nature.

There are many strategies and technologies in sustainable architecture, such as reducing environmental impact and increasing the quality of indoor comfort. Some of the important ones are use of natural landscape, use of sunlight heat, natural ventilation and improvement of indoor air quality, effective energy use, use of renewable energy, construction waste management, water conservation, waste management and estimation of operating costs (Mclennan, 2004). The use of green walls, which is considered as one of the sustainable architectural systems and a solution to today's pollution and waste management problems, is considered capable of achieving energy savings of up to 60% (Joshi etc., 2018: 6). This architectural understanding is the argument of social well-being and sustainable development with its aim of maximizing human comfort with effective design, supporting ecology and natural resources (Yudelson, 2008: 242), and saving construction, building operation and maintenance costs.

3. THE USAGE AND BENEFITS OF GREEN WALLS IN SUSTAINABLE ARCHITECTURE

Ecologically supportive design began in the 1970s with the oil crises and a design approach that minimized environmentally damaging impacts by integrating with living processes in the use of resources. Sustainable green design is also known as (Dias, 2015: 147) green buildings that support sustainable architecture and ecology, create structures that are sensitive to the ecosystem by supporting the use of renewable energy resources and natural materials, with reference to consumption as much as the needs in the building site survey and ecological environmental assessment, taking into account the environment and human health (Erdede and Bektaş, 2014: 2).

Green walls that support urban biodiversity play an important role in improving the urban environment (Lundholm, 2006: 88; Francis and Lorimer, 2011: 1431). Green walls support urban ecology in the sense that they allow the use of vegetation without taking up space on the streets in an urban context. In addition, green wall systems (Manso and Castro-Gomes, 2015: 864), which contribute to urban stormwater management, also contribute significantly to improving air quality (Paug and others, 2012: 7696; Rahman etc., 2011: 209). In cities where green walls are commonly used, they have been recognized to contribute to many issues such as performance in reducing temperature (Santamouris, 2014: 684) and assisting in reducing the urban heat island effect (Alexandri and Jones, 2008: 482; Gago etc., 2013: 751). Contributing to urban esthetics and acoustics, green walls with their complementary visual and physical elements offer important opportunities for sustainable development in the social and economic spheres, as illustrated in Figure 1.

The cost of a building is generally referred to as three major economic components, such as the initial investment cost, the occupancy cost, and the disposal cost upon disposal (Güzelkokar and Gelisen, 2019: 79). In this system, which considers all components of the building production process, the construction and utilization techniques and costs are considered as important parameters. Therefore, by supporting the relationship between ecology and materials, which are the reference principles of sustainable architecture understanding, the use of green roofs and green walls is an important design parameter. These design and application systems contribute to the urban skyline and natural environment with their visual and esthetic qualities, as well as indoor comfort and building operating costs with energy efficiency.

Figure 1. A green wall pattern changes the face of the urban environment (URL-1).

At the scale of the building, green walls that contribute to its sustainable performance are often used as a passive design solution (Perez et al., 2011: 4856). It plays an important role in terms of indoor comfort in buildings, as a complementary insulation system to improve the climate in winter (Bass, 2007: 3). It also benefits from vegetation cover on the façade surface as a supplementary insulation layer in both summer and winter. (Koyama etc., 2013: 96). Green wall systems are important façade protection especially in summer as they provide shade by covering and protecting the building surface (Cheng et al., 2010: 1780; Stec et al., 2005: 421), at the same timethey effectively protect the building surface from rainwater. While the system prevents rainwater from entering the building surface, it reuses the collected rainwater in a recyclable way in the life cycle of the green wall (Loh, 2008: 4). Moreover, with the moisture level it supports, it contributes to indoor comfort by reducing the heating value of building surfaces through the evaporative cooling effect on facades (Perez et al., 2011: 4856).

With the effect of building facades increasing heat loss or gain through air movement, green walls are nowadays pioneers for effective energy efficiency. Moreover, green walls can be said to increase urban biodiversity, support energy efficiency and ecology, improve air quality, reduce noise pollution, and bring health and well-being to the city and its users. This building material, which is also recognized by well-known certification systems such as LEED and BREEAM worldwide, is now accepted to support awareness and is one of the many basic criteria of sustainability to support ecology (Erten et al., 2009: 16).

Based on the above benefits, the advantages that are related to the heating and cooling energy demand of the building and the heat transfer through the walls with a green wall system to be built on vertical surfaces in an urban area form the application part that will be explained in the next section of this study.

4. APPLICATION STUDY

In this study, the effect of green walls on building energy (heating-cooling) loads has been revealed with an application study. The study area was created according to different degree day zones determined in TS 825. In this context, five different cities from different zones; Antalya for the 1st degree day zone, Muğla for the 2nd degree day zone, Konya for the 3rd degree day zone, Sivas for the 4th degree day zone and Erzurum for the 5th degree day zone were selected. The geographical features taken into account in the calculations of these selected cities are given in Table 1.

The monthly averages of solar radiation and minimum and maximum ambient temperatures used in the calculations are given in the graphs for each province in Figure 2.

4.1.1. Case Study

A building example was designed to perform a comparative performance analysis of green walls and brick walls under the same conditions for different climate zones. The designed building example is single story and has a gross area of 54 m^2. It consists of an entrance, living room, bathroom and bedrooms. The floor plan of the house and its location in the field according to the directions are as shown in Figure 3. All four facades of the house with a terrace roof are related to the external environment, although it has no blind facade, and the ground floor is in the form of a floor sitting on the ground. 3D images of the building are shown in Figure 4.

Table 1. Climate zones and certain data for selected cities

Location	Antalya	Mugla	Konya	Sivas	Erzurum
Degree-Day Zone	1st	2nd	3rd	4th	5th
Latitude	36º 53'	37º 12'	37º 52'	39º 45'	39º 55'
Longitude	30º 42'	28º 21'	32º 30'	37º 01'	41º 16'
Elevation	43 m	103 m	1024 m	1285 m	1893 m

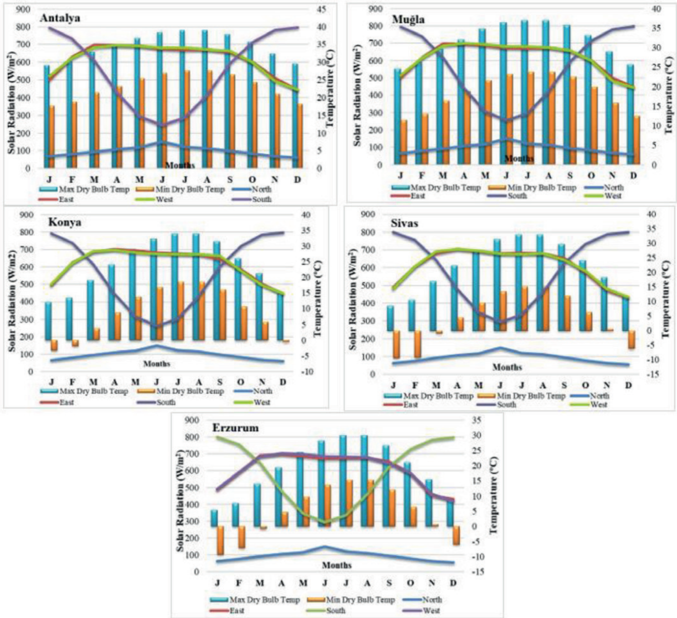

Figure 2. Climatic data for the selected cities

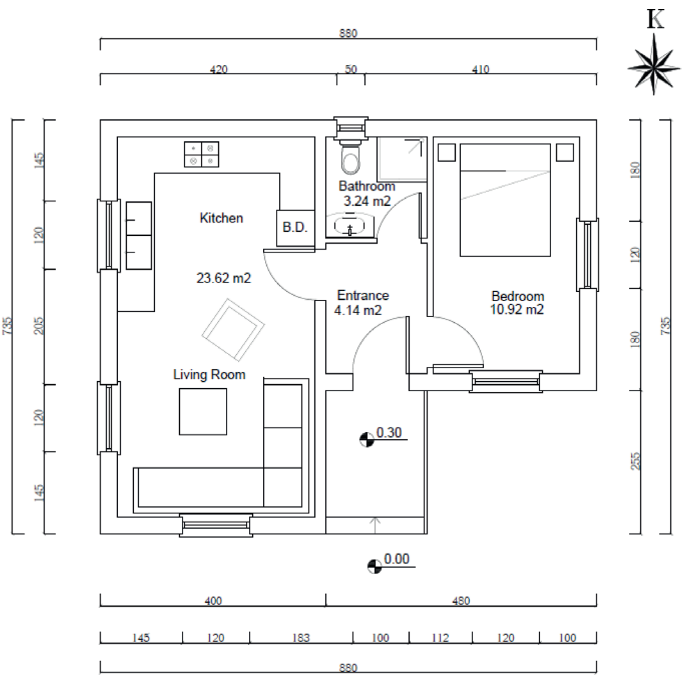

Figure 3. Sample residential building plan

Figure 4. 3D models of the sample building

It is assumed that all exterior walls of the sample residential building were thermally insulated with 4 cm XPS and plastered on both sides with 29 cm thick brick material. For another alternative, where only the west wall of the building is a green wall and the other walls remain brick, the climate data of the cities selected from 5 different climate zones and the heating and cooling loads of the building were calculated. The green wall pattern adopted in the study is shown in Figure 5.

The properties of building components and heat transfer coefficients (W/m^2K) used in the calculations are given in Table 2.

4.2. Hourly Analysis Program (HAP)

The Hourly Analysis Program (HAP) is a validated computer program developed by Carrier to help engineers design building HVAC systems. It is approved by the US Green Building Council LEED rating system for heating load calculations and energy modeling. The software works in two stages. First, it designs a system by estimating building loads and then determines energy costs by calculating energy consumption. This capability of schematic design and detailed cost estimation is useful for many building rating systems such as LEED. HAP uses the ASHRAE (American Society of Heating,

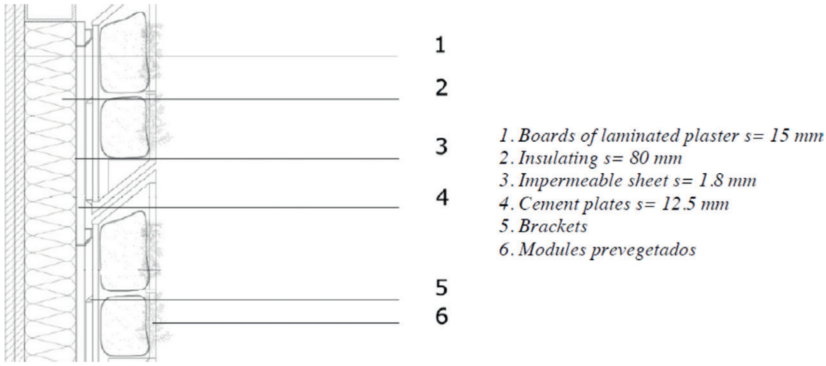

Figure 5. Green Wall Section(Nori et al, 2013. 2)

Table 2. Properties of building components and heat transfer coefficients

Building Component	Heat Transfer Coefficient W/(m^{2}K)
Brick Wall (29 cm)	0.395
Brick Wall (10 cm)	1.854
Green Wall	0.120
Flat Roof	0.326
Floor	0.33
Door (Steel)	4.00
Door (Wooden)	2.40
Window	2.40

Refrigerating and Air-Conditioning Engineers) transfer method to calculate building loads with detailed simulation techniques of 8760 hours (one year) per hour for energy analysis. The simple and clear interface of the program, shown in Figure 6, ensures that it is widely used worldwide.

HAP estimates the design of cooling and heating loads for various building types to determine the required sizes of HVAC system components. As a result, the program provides the necessary information for equipment selection and identification. HAP uses its database of weather and climate conditions, which includes nearly 500 cities around the world. It is also flexible enough to allow input of external climate and environmental data for different locations.

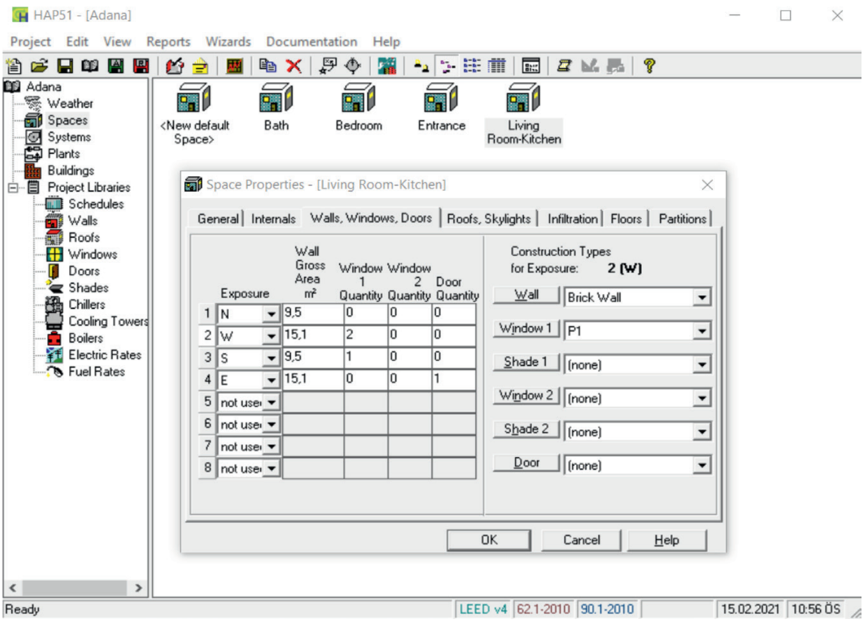

Figure 6. The user interface of HAP program

5. FINDINGS AND EVALUATION

In this section, the effects of green walls on the heating and cooling loads of buildings in different climates in Turkey were investigated in comparison with the example covered brick walls. To see the performance of green walls in different climatic zones, five different cities from different degree day zones in Turkey are considered. The effect of green walls on the energy demand of the building has been evaluated by comparing with the results of the sample designed with brick walls. It is assumed that the green wall is located on the west side of the living space. The heating and cooling energy demand of the building is calculated for five different cities representing different degree day zones. A split air handler is used for the heating and cooling calculations of the building example. The results for heating and cooling energy are shown in Figure 7 and 8, respectively.

Looking at the total heating energy demand of the building examples, it is found that the highest demand is in Erzurum where the winter months are harsh and the temperature values are lower throughout the year than in other climatic regions. In Erzurum, where the heating energy demand is 8355 W, this value is 55.3% higher than Antalya, 39.44% higher than Muğla, 18.14% higher than Konya and 4.28% higher than Sivas. In direct relation to the thermal transmittance (U) values of the walls, it can be seen that the applications with green walls on the western façade vary in heating energy depending on the climatic region during the year and are on average 3.3% more beneficial than the brick wall patterns in terms of energy consumption. Considering that the building sample has a small wall area and the area of green wall application is limited, as the wall areas in the city center and high-rise buildings will be much more, and the benefits that can be achieved with green wall systems will be correspondingly larger.

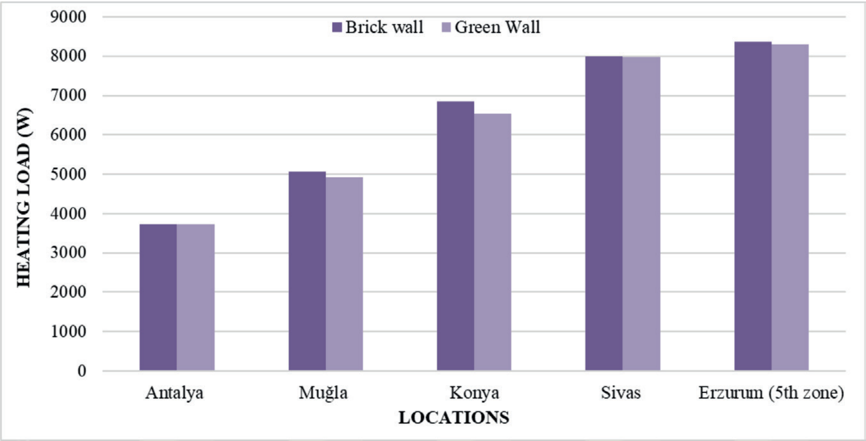

Figure 7. Heating energy requirements of the building samples for different climate zones

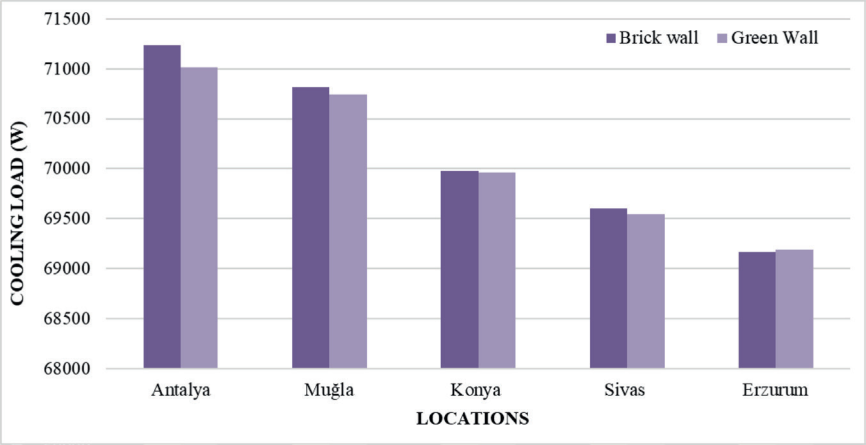

Figure 8. Cooling energy requirements of the building samples for different climate zones

Looking at cooling loads, it is seen that the highest cooling load is reached in Antalya, which is located in a hot climatic region. In cooling load calculations of the whole building, it is difficult to evaluate only the effect of the wall because the internal loads of the occupants, lighting and other electrical equipment have much higher values than the loads caused by walls and windows. To see the effect of the wall more accurately, the thermal loads of the living room where the green wall application is built will give a more realistic assessment.The assumed green wall accounts for 31% of the total wall area of the living room.The heating and cooling energy requirements of the space in question for brick and green wall constructions are shown in Figures 9 and 10.

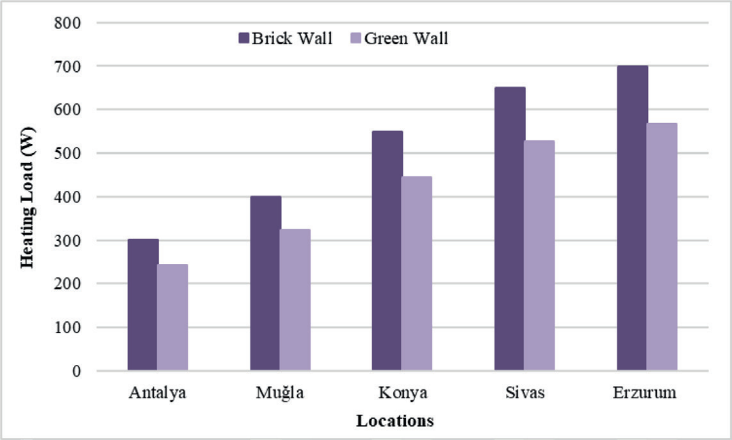

Figure 9. Heating energy requirement of the living room

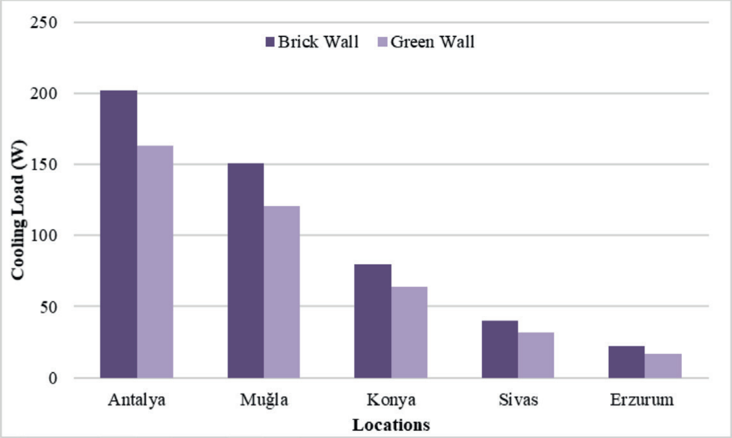

Figure 10. Heating energy requirement of the living room

Looking at the figures in detail, it can be seen that the green wall applications offer an average advantage of 19% in heating energy demand for each climate zone. Considering the cooling loads, this ratio is 19% for Antalya, 20% for both Muğla, Konya and Sivas and finally 23% for Erzurum.

The heating and cooling energy demand resulting from heat transfer from the wall surface, which is 12m2 except for the windows where the application is made, is shown in Table 3. With the application of the green wall, it was found that the heat transition through the wall in Antalya decreased by 29%. This rate is 60% for Muğla, 84% for Konya, 88% for Sivas and 95.8% for Erzurum. In terms of cooling energy, the advantage that can be achieved in Antalya, Muğla and Konya is about 66%, while it is calculated as 76% in Sivas and 50% in Erzurum (Table 3).

It is also well known in the literature that the ability to control heat gains and losses contributes to both improved indoor comfort and low heating and cooling energy consumption in green wall studies (Alexandri and Jones, 2008: 491). In accordance with the literature, it is one of the findings that green walls reduce heat loss from buildings in cold climates due to their low heat transfer coefficients, as well as reduce heat transfer from walls that cause unwanted overheating in hot and temperate regions. In this sense, it has been confirmed that it is an alternative method to improve indoor comfort conditions in both hot temperate and cold climates and avoid environmental damage due to low energy consumption.

6. RESULTS

The changing lifestyle with modern times has also changed the understanding of space or the demands of individuals. The changed demands have created the causes of many difficult problems, such as rapid consumption of natural resources, air quality, and energy problems. The understanding of

Table 3. Heating and cooling energy requirements of different walls for different locations

Locations	Antalya		Muğla		Konya		Sivas		Erzurum	
	Brick	Green Wall	Brick	Green Wall	Brick	Green Wall	Brick	Green Wall	Brick	Green Wall
Heating Energy Requirement (W)	82	25	110	34	150	46	178	55	191	59
Cooling Energy Requirement (W)	58	19	44	14	24	9	21	5	8	4

consumption that developed in the late twentieth century with the understanding of the value of sustainability is replaced by less consumption of natural resources and the rights of future generations. *A sustainable understanding of architecture* was created. This understanding of architecture paved the way for many new construction systems and materials. Thus, architectural systems were introduced to reduce construction costs and transform buildings into energy-efficient structures, with manufacturing systems that have low energy consumption instead of wall systems that have high energy consumption.

The study's analysis to demonstrate the benefits of using green walls, one of the sustainable architectural design principles, was based on a simulation conducted using Carrier's proprietary program HAP. Buildings Standard The simulations were conducted for the building patterns adopted in Antalya, Muğla, Konya, Sivas and Erzurum, five cities from five different degree day regions identified in TS 825 Thermal Insulation Rules. The heating and cooling energy demand and the amount of heat transfer from the wall element towards the west of the living room of the building sample were determined for different scenarios formed with brick and green wall applications in each city.

As a result of the analysis and measurements carried out in the study, the following points were found in relation to green walls, which are one of the sustainable architectural systems:

- Thanks to the use of green walls in the building design, the heating, cooling loads of the buildings are reduced,
- Depending on the climate zone, it is found that the use of green walls results in a minimum of 29% and a maximum of 95.8% energy savings in heating and a minimum of 50% and a maximum of 76% energy savings in cooling.
- Green walls allow for more cost effective heating, ventilation and air condi-tioning systems in almost all climates.
- Green wall systems support the provision of indoor comfort in different climate zones and the realization of comfort conditions at significantly lower costs, especially by reducing energy loads and costs.
- With their water collection property, especially in places with heavy rainfall, it is evident that green walls will contribute to the drainage of excess water generated by rainfall.
- It has been observed that the benefit in reducing the cooling energy demand of buildings in hot climatic regions is almost double as compared to heating energy.

- However, the green wall system is also effective in cold climates provided that the green wall system can be supported to live in harsh climatic condi-tions. The benefits in saving heating energy savings will be almost 96% as it was calculated for Erzurum city in 5th degree day zone of Turkey.

It should also be noted that the benefits of using green walls, which are accepted as the new original design system of sustainable architectural under-standing, are not only low energy consumption. The natural ecology and landscape, which cannot be provided horizontally due to dense development in cities, support them vertically without taking up space, which makes them accepted as an original building element. In addition to contributing to the natural landscape and esthetics of the city, it also makes an important contri-bution to the health of urban users and air quality in the city. Green walls designed with this innovative sustainable approach are also an important parameter for sustainable development. In terms of urbanization; the contribu-tion of green walls to the landscape in the state of belonging to the region/place, the particular insulation details in the orientation and detailing of the building and the support they provide to urban hydrology, air quality and natural environment are very important. When the green walls are at the building scale; their support for structural form, their contribution to indoor comfort, energy conservation and efficiency, thus sustainability and sustain-able development are quite noteworthy.

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chapter 12

FACADE DAMAGES THAT MAY CAUSE / AFFECT BUILDING COST ITEMS

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1. INTRODUCTION

Although we have technical capabilities and knowledge in the construction industry, to build healthy buildings with adequate user needs is a major challenge. As it is known, the life of a building is a whole from design to construction, until the end of its useful life, and the efficiency, comfort, longevity, economic viability and appearance of a building can be affected by decisions and actions taken at any time in the history of a building project, from its initial conception to its final demolition. A mistake that can be made for many reasons in any of the design, construction, usage and maintenance phases that make up the life of the building directly affects the building and causes various undesirable building damages. These damages make the structure difficult to use, require major maintenance and repair from time to time, and also negatively affect the appearance. Building defects and failures cannot be avoided in the lifecycle of a building, even if everything improves properly during the construction phases. All buildings begin to deteriorate from the moment they are completed and from that moment they begin to need maintenance. However, in order to extend the life of a building, its functions should be preserved until destruction and demolition. Increasing the efficiency of the building is possible by constructing healthy buildings and maintaining current standards until its destruction. With an effective maintenance system to be applied to all subsystems of the building, natural damage should be prevented. However, it is observed that care is frequently neglected and effective care practices are rarely applied. This leads to lower environmental standards and the need to solve technical and managerial problems.

The aim of this study is to emphasize the importance of facade damages that make the use of buildings difficult and increase their total cost. These damages cause a great need for maintenance and repair, as a natural consequence of this, a large amount of money is spent due to this need and has a negative impact on people. The scope of the study is limited to mention the cost items caused by facade damages in the total cost of a building. Quantifying the effect of facade damage on the total cost of the building can be considered in ongoing studies. This study is based on observations from a field study in Istanbul, where hypothetical deductive system was used under the counseling of Toydemir N. In the light of these issues, this study will be discussed under the following subheadings;

2. Building Facade Damages Literature Review

Facades are considered essential elements of buildings as they affect the appearance, structural safety and insulation of the buildings and also act as an external shield against air and pollution (Chew, 2010). However, constant exposure to bad environmental conditions over its long life brings aging faster than other building components (Lee, 2018). This situation manifests itself in various types of defects on the building facade over time (Das and Chew, 2011). If defects in the building facade are ignored, they can lead to shortened life, damaged facade appearance and increased maintenance costs (Guo et al., 2020). It is ideal to avoid any defects that would cause damage during the design or construction phases, but this is usually not possible (Kim et al., 2010). For this reason, damage needs to be monitored actively and responded quickly during the maintenance phase (Love and Smith, 2016).

It is accepted that the value of the buildings gradually decreases due to the aesthetic, functional and structural deterioration caused by the damages on the building facades. In response to these deteriorations, the value of buildings can be restored through maintenance and restoration (Lee et al., 2016). It is necessary to determine the factors that affect the damages on the building facades and to examine the relationship between factors and defects.

These factors can be classified as environmental factors, site conditions, building properties, materials and building facade elements. Data related to these factors can be collected from field books, weather information, map etc., but it is not easy to determine information on facade elements. This is because there is a wide variety of facade elements and a variety of sizes and shapes for each element. Additionally, these elements are complex and collecting data takes a lot of time and effort. The analysis object is existing building facades through various maintenance operations. However, it is better to minimize the depreciation on maintenance (Lee et al., 2016).

Damages on the building facade are the main factors that cause the building to decrease in value and depreciation expense. On this subject, Brimblecombe and Grossi (2005) analyzed the color and pollution of the stone as well as the exterior of the building, Lourenço, et al. (2006) determined the relationship between building shape and material, indoor temperature and moisture related damage. Hong (2011) suggested using a management plan to prevent damages during the construction phase and to recognize the main content. Silva, et al. (2011) estimated the average lifetime of buildings using a life expectancy model with stone surfaces. Neto and Brito (2012) analyzed the relationship with other factors related to stone material damage. Hebert, et al. (2012) examined the causes of internal and external damages. In addition, various depth studies were carried out on the damages (Lee et al., 2016).

It is thought that this study will contribute to the literature in terms of drawing attention to the generally neglected building use value and cost and pointing to the possibility of faulty decisions made during the design phase and mistakes done in the construction phase causing unforeseen costs that will continue throughout the lifecycle of the building and it is expected to contribute to the construction sector by drawing attention to the importance of factors affecting the costs of renovation or reconstruction resulting from facade damages.

Factors Affecting Building Facades

There are various types of defects in buildings, and each defect type appears in an irregular pattern (Liu et al., 2019, Macarulla et al., 2015, Panand Thomas, 2015, Cha et al., 2017).

We can classify the factors affecting building facades as follows;

- Meteorological Factors Affecting Building Facades
- Mechanical Factors Affecting Building Facades
- Chemical Factors Affecting Building Facades

- Biological Factors Affecting Building Facades (Tüz, 1996)

2.1. Meteorological Factors Affecting Building Facades

Under the title of meteorological factors affecting building facades, the subtitles of rainfall, solar radiation and wind are examined.

2.1.1. Rainfall (Water, Snow, Rain, Hail)

Rainfall is encountered in different ways like snow, rain, hail. The physical and mechanical effects of each on the building facades are different. For example, snowfall plays a role in shaping building roofs as a result of its mechanical effect. In regions and countries with abundant rainfall and especially snowfall, building roofs are designed very steep. The purpose of making the roof steep is to remove the snow from the roof s and thus to get rid of the load it will put on the roof construction. This situation has resulted in local architecture in different regions and countries.

With its solid, liquid and gaseous states, water is the primary factor requiring protection. Depending on the nature of the facade material used, water causes conditions such as drying, swelling, frost, fungus, blooming, corrosion, etc. (Addleson, 1972). Color difference resulting from fade damage caused by discoloration of water-moisture-induced paint on the building facade and careless maintenance of capillary water absorption damage can be seen at Figure 1.

Figure 1. Color Difference Resulting From Fade Damage (Dal and Yılmaz, 2015).

2.1.2. Solar Radiation (Heat, Infrared and Ultraviolet Rays)

Rays such as ultraviolet and infrared in sunlight cause visible damage on building facades. Ultraviolet rays lighten material color. It also causes damage to the materials. The heating effect of the light called infrared is high. This overheating causes the material to expand. Damage to the facade cladding with expansion can be prevented with various design solutions (Kafescioğlu, 1984).

2.1.3. Wind (Air Movements)

The wind spreads dust, smoke, sand and causes them to accumulate in the recessed, nook corners of the building surfaces, and the pressure it exerts causes the water coming from any way to enter the surface through various cracks and the drift of the particles falling as a result of the surface erosion. It also gives a horizontal velocity component to the rain, which theoretically has to descend vertically on the surface, causing it to hit the building surfaces, enter through various holes and cracks, wet the wall, and grow cracks. Penetration of rainwater into the wall causes various chemical and physical damage within the wall. For this reason, the direction, speed and changes of the prevailing winds are important in building design. When only a certain surface of the building is exposed to rain over a long period of the year due to the prevailing wind, the choice of materials and facade construction for these and other surfaces are important (Figure 2).

2.2. Mechanical Factors Affecting Building Facades

Geological effects, mechanical abrasions, sand, dust and water effects can be discussed under the title of mechanical factors effecting building facades.

2.2.1. Geological Effects

Geological effects are effects that result from unknown earth crust movements, which precisely doesn't known when, where, and how severe they occur. These events are earthquakes (Figure 3), landslides, volcanic events, floods and tsunamis.

In the investigations made after an earthquake, it is seen that the damage to the buildings is generally caused by the following reasons;

- Damages caused by static acceleration.
- Damages caused by different building foundation settlements
- Damages caused by structural vibrations

Figure 2. Wind Effect on the Facade Covering (URL-1).

Figure 3. Earthquake Effect on the Masonry facade, California (URL-2).

2.2.2. Mechanical Abrasions (Sand, Water, etc.)

Mechanical damage to the facades as a result of hitting, impact, friction. It can be examined as sand and dust and water (Zaim, 1985).

2.2.2.1. Sand and Dust

The big factor here is the wind and the abrasive grains that are driven by it. The rate of abrasion of materials such as sand that causes mechanical abrasion is proportional to the wind speed. Sand particles blown by strong wind hit the building surfaces and erode the surfaces.

2.2.2.2. Water

Another cause of damage is the abrasion of grained materials dragged with water. The contact of rainwater falling with strong winds is harder and its penetration into the wall is faster.

2.3. Chemical Factors

The destructive effects of atmospheric pollution spread over a wide area when combined with rainwater and cause corrosion, erosion and weathering on the surface materials of the structures. In addition, various harmful gases and dust, sand etc. carried by the polluted atmosphere. Solid particles accumulate on building surfaces with the help of wind and form a dirty layer. Gases (SO2, H2SO4, etc.), which are the main factors affecting building facades, will be discussed below.

Under general conditions, components of the air cannot cause atmospheric pollution. Other substances such as sulfur oxide, chlorine and fluorine compounds and salts (salt of the sea) make up the components of the contaminated atmosphere. Even in a highly polluted atmosphere, the proportion of pollutants remains low, but the strength of pollutants cannot be predicted when combined with water. The reasons for the air pollution seen especially in our big cities today are generally; Irregularity of housing, lack and insufficiency of infrastructure, unplanned, unscheduled, uncontrolled development of urbanization, almost intertwining of industrial units with residential areas, lack of green space and afforestation system. The biggest cause of air pollution is the burning of various fuels and can be examined under the following headings (Tüz, 1996). Gases (SO2, H2SO4, etc.), which are the main factors affecting building facades, will be discussed below.

2.3.1. Smoke

Smoke is the visible product of defective fuel combustion. Due to their adhesive properties, smoke particles stick to the surface and eventually form sooty layers. In addition to distorting the appearance, the sooty layers are hygroscopic and have a fairly large water holding capacity.

2.3.2. SulfurDioxide

S0 2 is found in sulfuric acid in the air. It is also formed as a result of the burning of fuels such as sulfur dioxide, coke, coal, fuel oil and has a corrosive action.

2.3.3. CarbonMonoxide

It is formed by the burning of petroleum products. The density of carbon monoxide is high, especially on busy streets with a lot of motor vehicles. Carbon monoxide accumulates on building surfaces and creates black stains that are difficult to clean.

2.3.4. AirPollution

With various harmful gases and dust, sand etc. carried by the polluted atmosphere solid particles accumulate on building surfaces with the help of wind and form a dirty layer.

2.3.5. IndustrialFactors

Although the burning of various fuels is generally accepted as the main source of contamination, industrial sources such as;

- Paint particles and solvent odors
- Gases resulting from chemical studies, SO2, sulfurizedhydrogen, carbonbisulfite, nitrogenoxide, etc.
- The dispersion of sand and dust in large quantities as a result of industrial processes,

Contribute significantly to regional pollution.

Also fire can cause serious damage to building facades. Burning can be defined burning as the chemical reaction between substance and flammable gas at a certain temperature. High temperature and toxic gases resulting from this reaction can cause, death of people and loss of or carbonization facade elements (Figure 4), (Toydemir, 2007).

Figure 4. Fire Effect on the Facade, Keşan (URL-3).

2.4. Biological Factors Affecting Building Facades

Under the title of biological factors affecting building facades, the subtitles of living organisms, and plants are examined.

2.4.1. Living Organisms (Birds, Animals)

The greatest damage birds cause to building facades is contaminating surfaces with their faeces. This causes faeces to accumulate in certain parts of buildings and chemically damage facades. People also play a big role in the formation of facade damage. Unconscious and out of function use damages facades. Lack of necessary periodic maintenance is also one of the factors that shorten the life of the building.

2.4.2. Plants (Tree, Grass, etc.)

Plant seeds that are thrown with flying pollen or dust soil find a place for themselves on the facades and grow there. Over time, some buildings have roofs covered by trees and completely grasscovered facades. Although these facades are found beautiful by most people, they have great damage to the structure.

While examining the factors affecting building facades, besides the environmental factors listed above, human influence in various roles such as user, designer, engineer or builder (wrong material selection, neglect and lack of maintenance, construction and detailing mistakes, lack of control and vandalism) should not be ignored either (Figure 5), (Coşgun, et al, 2002).

Facade elements that lose their strength can lead to collapse and may be lifethreatening for users (Belson, 2008). For example at Bank of America Building New York, with the falling of glasses from the facade due to the deformation in the facade carrier people passing by, were injured many times (Figure 6).

Figure 5. Fall in Facade Cladding Due to Mounting Mistake (Mayuk and Avlar, 2014)

Figure 6. Bank of America Building- Fall in Facade Cladding - New York (URL-4).

3. BUILDING COST

Construction is an economic activity. The total cost of the construction, which starts with the conception phase for the building and ends with the end of the usage phase, is named the building cost (Yaman and Taş, 2007: 74).

Building cost consists of project design, construction, use (operation, maintenance and repair) and demolition costs starting from the conception stage (Figure 7).

Factors affecting the cost are the factors that occur during the usage phase due to usage, maintenance, renovation, change of building function.

The definitions that should be known about the total cost of the building are as follows;

Building total cost; is the sum of initial investment cost and usage cost (Total cost= Initial investment cost + usage cost).

Initial investment cost; It is the cost from the first decision made for the construction until the building started to use.

Usage cost; is the cost from the first use of a building to its last use. It includes the expenses made for the building to fulfill its performance throughout its life (Maintenance-Reconstruction, Operation, and Renovation). Factors affecting the cost are the factors that occur during the usage phase due to usage, maintenance, renovation, change of building function.

Maintenance cost; is the reconstruction required for the building to maintain its life-long performance,

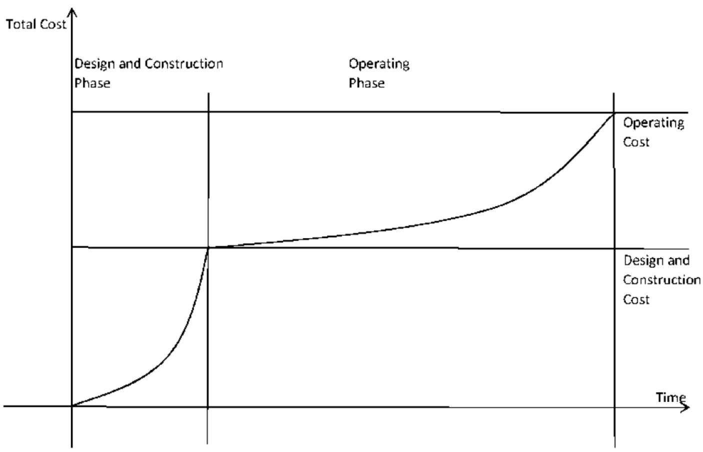

Figure 7. Building Cost

Renovation is; the renewal of end-of-life elements in order to maintain the performance of the building throughout its life.

Operation; includes building cleaning, heating and cooling, waste water, clean water, electricity costs, operation of technical systems, open area costs, employee expenses, etc.

As seen in the Figure 8, operation and maintenance cost is a large percentage of the total lifecycle cost (50%-80%). It is important to minimize damages, which are the main causes of building usage costs.

The Whole Lifecycle Cost is summarized in Figure 9;

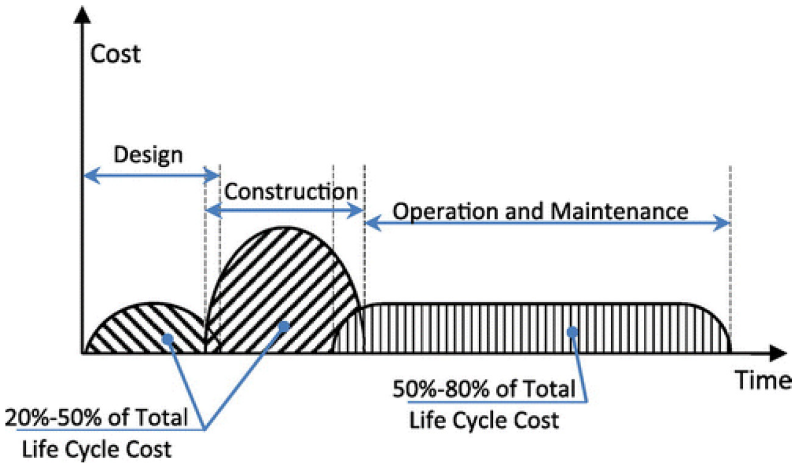

Figure 8. Lifecycle Costing Profile (Bull, 2003)

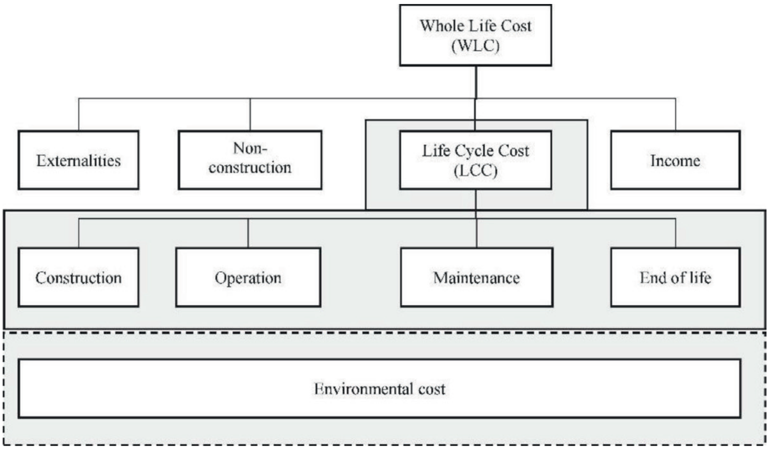

Figure 9: Whole - Lifecycle Cost (BSI, 2008)

The points to be considered during the maintenance / repair phase are:

- Determining the estimated dates of deterioration in the building and whether they meet the conditions and conditions in the building technical specification
- Lifetime of each building element in the building,
- Renewal cost of each architectural element during its lifetime
- The cost of the loss of use caused by the deterioration and wear of the architectural element,
- Costs associated with maintenance and reconstruction management (BSI, 2008).

More than one application is possible, especially when the life of the building is longer than the life of the building material. With the expiration of the first application, the first applied building material must be disassembled from the structure, removed by disassembly before reapplication (BSI, 2008).

4. COST ITEMS THAT FACADE DAMAGES MAY CAUSE / AFFECT

In the field study conducted in Istanbul under the consultancy of Toydemir N., the damages caused by various reasons (design, application, use and maintenance) on more than a hundred building facades were tried to be explained. Based on the observations in this field study, an inspection was made based on the analysis of the causes of facade damage.After taking more than a hundred photos of buildings and examine them carefully, it is understood that building's facade problems are generally because of four reasons. They are:

- Design related damages (Wrong detailing and choosing wrong materials while designing),
- Application related damages (Applying the right design decisions wrong),
- Design and application related damages,
- Damages due to lack of maintenance and repair (Wrong using of the building and not caring periodically) (Tüz, 1996).

In this study, it is emphasized that the life cycle cost items of a building can be associated with the façade damage reasons listed above.

Costs associated with the maintenance / reconstruction of a building after damage generally consist of costs related to building materials, equipment or machinery costs, foreign labor and subcontracting costs, and transportation, insurance, construction site equipment, administrative unit, etc. (Ocakcı, 2007).

When the national and international literature on building construction costs is reviewed, the study conducted by Al-Haram and Horner (2002), which examines life cycle costs, draws attention. In their research, the authors evaluated the design costs, operating costs, maintenance and repair costs of the building and the destruction costs at the end of the economic life of the building, as the life cycle cost of a building. Similarly, Minami's (2004) survey of the life cycle cost of a post office building in Japan; emphasizes that total cost means the sum of; maintenance, repair, reinforcement costs incurred the lifecycle of the building, operating costs and demolition costs incurred at the end of its economic life. In one of the studies examining quality costs in construction projects, Hall and Tomkins (2001) evaluated the construction cost elements of a building: preliminary costs, demolition costs, foundation and infrastructure costs, carcass, exterior, finishing works, mechanical and electrical installation, roof, external works and they determined as completion costs. In another study, Newton and Christian (2006) assesses the quality of construction both during the construction phase of the building and throughout its economic life, maintenance / repair, improvement, operation, etc. and determined that especially the design quality has a significant influ-ence on the maintenance / repair and improvement costs of the building.

In the light of the above information and previous studies; it is observed that the damages on the facades of the building increase building usage cost in a way that we could not predict at the beginning.

5. CONCLUSIONS

The construction sector is one of the leading sectors of the national economy, especially in recent years, providing mobility also among the most important sectors in economy. Building construction is an economic activity and every decision we make has an economic consequence. It is known that damages on building facades increase the cost of building use in a way that we cannot predict at the beginning. In addition to the external factors that will cause damage to the building facades listed in the study, the building facades are damaged due to improper design, inappropriate material selection, wrong application, workmanship mistakes, faulty in material production, and possible mistakes in material supply. The effect of these damages on the cost items that constitute the usage cost is very high. In these situations that require maintenance, as well as the apparent cost the building brings to its users, it also brings loss of prestige, time, rent and value. The environment is also harmed due to the cost items that will occur from the beginning during maintenance of the buildings. In some cases, it is seen that there are situations such as the fall of the facade material, and that lawsuits are filed against third parties for damages. It is important to make correct and timely decisions in all production processes of the building in order to prevent all these losses before they occur. Mistakes should be minimized by establishing more than one inspection system where supervisory and implementing teams are selected separately while the all phases of the design, construction and use of the building.

In the pre-use stages of the building, while selecting of building materials, it is important to calculate costs throughout the life of the building, not just its technical characteristics and price.Therefore, with this study, to draw attention to the importance of determining the renovation or reconstruction costs caused by building facade damages in the construction sector, which is one of the crucial points of the economy, and the factors that affect these costs is important. Also, the factors that will affect the costs can be investigated by examining the construction activities in more detail and benefit / cost analysis can be emphasized not only in terms of costs, but also by taking into account the social costs and returns of practices such as recycling of residues generated as a result of construction activities. Sustainability and green building concepts should also be taken into account in cost / benefit analysis for maintenance / rebuilding of a building after damage. This subject is also closely related to ensuring sustainability and reducing environmental pollution.

In addition to the cost items listed above, the cost of facade renovation can be examined in terms of benefits such as saving material by protecting the primary structure, preserving the architectural identity, revealing the hidden value of the building at a higher speed and more efficient use of energy. A thoroughly renovated facade can increase the energy efficiency potential of the building by 50% or more and determine the level of renewable energy use. As supported by various studies, if energy efficiency is not ignored during renovation, it is obvious that the cost of building renovation will contribute positively to the subsequent use cost of the building.

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chapter 13

SPATIAL LEARNING THROUGH LANDMARKS

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1. INTRODUCTION

To understand the interaction between individuals and the built environment, relevant attributes, and filtering mechanisms of how individuals perceive the built environment and act within this environment should be investigated. According to Golledge and Stimson (1997), the main psychological variables intervening between an environment and human behavior are a combination of cognitive and emotional attitudes, values, emotions, perception and cognition, and learning. Moreover, these variables are connected to each other and take place within people's social and cultural networks. Spatial learning of a new route in an unfamiliar environment needs spatial decision-making processes, and in these processes, people use landmarks.

Saliency of a landmark depends on the nature of the landmark, and its uniqueness. Therefore, saliency of a landmark may change. Today, people depend on their navigation devices and smart phones for navigation and wayfinding. The importance and popularity of information and communication technologies is undeniable. What happens when individuals do not have an Internet connection or lose their smart phones? In several studies, the effects of landmarks on spatial learning in a virtual environment has beeninvestigated (Steck & Mallot, 2000; Sturz & Bodily, 2010; Nys, Gyselinck, Orriols & Hickmann, 2015). Gramann et al. (2017) explored whether customized navigation directions support incidental spatial knowledge acquisition in a virtual driving environment. An examination of the literature shows that there are several studies focusing on comparing spatial learning from maps and navigation in the real world.Thorndyke and Hayes-Roth's study (1982), which is prepared for The Office of Naval Research, is one of the earliest studies in this research field. They investigate differences in spatial knowledge acquired from maps and navigation. Richardson, Montello and Hegarty'sstudy (1999) compares spatial knowledge acquisition from a map, from direct experience and by traversing through a virtual version of the building. Hirtle's study (2000) examines four case studies, such as you-are-here maps, information kiosks, an information browser in a virtual environment, and web-based browser for a library locator system. However, there is a lack of research focusing on cognitive aspects of landmarks such as which landmarks are more difficult to recall, or how navigation assistance systems affect an individual's spatial cognitive skills such as attention, perception, memory, learning and reasoning in the built environment. Therefore, the goal of the current study is to formulate a model to predict recollection of landmarks as a function of their saliency and the cognitive awareness levels of participants while navigating in the built environment. To that end, an experimental studydesigned by Wielens, Cenani, Kemperman and Borgers (2011) is used to investigate how navigation assistance systems influence the relationship between saliency of a landmark and the cognitive awareness of an individual. Gender-specific differences in the recollection of landmarks are expected to be found. Based on existing studies such as Sholl et al., 2000, Saucier et al., 2002, and Choi et al., 2006, it is assumed that female participants would be better at landmark recollection tasks. In addition, it is expectedthat there will be a difference in therecollection of landmarks between thepaper map group and thenavigation device group. Finally, it is expected to observe salient landmarks are recalled easier than other landmarks, since it is argued that there is a correlation between saliency of a landmark and cognitive awareness of an individual.

The remainder of this chapter is structured as follows: The following section reviews the literature on spatial learning. This is followed by a section describingthe proposed model of landmark recollection. The next sections present the experimental studyand results. Finally, the last section discusses the main findings and draws some conclusions.

2. SPATIAL LEARNING AND LANDMARKS

The literature on spatial learning is comprehensive. Studies on how individuals gain spatial knowledge and develop cognitive maps of the built environment have a long history (Evans, 1980; Richardson, Montello, & Hegarty, 1999; Gärling & Golledge, 2000; Tverksy, 2000; Ishikawa & Montello, 2006; Wang, Mou and Sun, 2014). Thorndyke (1980) stated that at the first (the lowest) level, individuals simply know a set of landmarks. They learn significant locations or objects such as an interesting façade or a sculpture. Landmarks are detected early in the learning process and can easily be remembered. If landmarks have any significance for individuals, it is easier for individuals to make assumptions as they construct their first mental map. At the second level, Thorndyke emphasizes that individuals are still not capable of connecting landmarks; however, they are able to point out landmark's direction relative to their positions. At the third level, individuals can memorize the sequence of locations. These sequences are still separated in their minds, but now they know several route alternatives. However, they are still unable to build new routes between different locations which belong to different groups. Finally, at the highest level, individuals succeed to develop a comprehensive representation of their environment. At this level, individuals can associate different locations and routes, and are able to develop a mental network representation of the city.

Golledge (1999) indicates that individuals' learning strategies in an unfamiliar environment are based on exploration according to some rules or heuristics, such as acquisition of a-priori knowledge about this environment from maps, sketches, verbal descriptions, or photographs. Peopleusually exhibit differences in their ability to recall different landmarks.A landmark plays animportant role in navigation. It helps us to identifya route and recalllearned routes. Anything can be a landmark, howeverit should be unique and easy to remember, so that it stands out as a reference point. Heth, Cornell and Alberts (1997) state that landmarks are essential for navigation for being unforgettable reference points that are selected along a route. They also indicate that landmarks mayhelpa person to determine spatial interactions between objects and routes, which consecutively make possible the development of a cognitive map of an area.

A landmark can be defined as an object or a feature of a city that is easily seen and recognized from a distance. A landmark can help individuals to be certain of their whereabouts. Lynch (1960) indicates that "a landmark is not necessarily a large object; it may be a doorknob as well as a dome". Here, he points to the subjectivity of landmarks. Furthermore, landmarks must be visible;therefore, the location of a landmark is important. Lynch (1960) characterizes landmarks as external point references which may differ in size. He defines singularity and saliency as the importantcharacteristics of landmarks. According to him, singularity is connected to a clear shape; a landmark should create a contrast with its background and has a well-known location. In summary, buildings with distinct forms, buildings on decision-points and easily recognizable buildings due to their use types (e.g., hospitals, schools, military, or religious buildings, etc.) are expected to be noticed and recalled easily. If powerful cognitive reinforcements such as historical or personal associations are attached to an object, that object's importance as a landmark increase. Dependent on these attributes, it is argued that a landmark may differ in terms of its saliency.

The role of landmarks in navigation has been investigated in several studies (Sorrows & Hirtle, 1999; Klippel & Winter, 2005; Gramann, Hoepner and Karrer-Gauss, 2017). Landmarks help individuals to identify their current positions in the built environment. Additionally, landmarks can indicate changes of direction, such as turning points or intersections. Landmarks can be used to maintain a course. If individuals do not use navigation devices or maps to navigate in an unfamiliar environment, they use landmarks to remember the route for their next trip. The most important feature of navigating in an unfamiliar environment is to maintain the spatial orientation. This means that an individual should be able to pinpoint his/her location relative to existing landmarks. Spatial orientation is the process of founding a link between spatial perception and spatial knowledge that is stored in one's cognitive map or spatial knowledge acquired from a regular map (Peruch & Lapin, 1993). However, if an individual is familiar with the environment, then (s)he does not need landmarks for navigation, (s)he uses his/her cognitive map. Therefore, navigating in a familiar environment is rather easier than navigating in an unfamiliar environment.

3. THE MODEL

In this study, a model that predicts the probability that an individual recall a landmark as a function of two parameters is formulated: saliency of a landmark and the cognitive awareness level of an individual while navigating in the built environment. As stated before, a landmark plays an important role in wayfinding as well as in spatial knowledge acquisition. An individual (e.g., tourist, newcomer) who has insufficientinformation will need landmarks, given landmarks' importance for wayfinding and navigation. However, not all landmarks are equally distinctive (Cenani, 2013). Therefore, this study's purpose is to estimate a parameter for saliency that captures such discrimination. In principle, this parameter can be linked to explanatory variables such as the degree of uniqueness and the type of the landmark. For example, a hospital may be a less unique landmark than a palace. If a landmark is unique, the probability of recalling it will be high, and therefore the saliency will be high too.

Based on the discussed literature, it is assumed that the probability of an individual to recall a landmark is a function of (i) the saliency of a landmark, and (ii) the cognitive awareness of the individual. All other things being equal, the probability of an individual recollecting a particular landmark will increase with an increasing saliency of a landmark. Similarly, the probability will, ceteris paribus, increase with increasing awareness of an individual. Let δ denotes the saliency of a landmark j, and θ denotes the cognitive awareness of the individual i. It is assumed then that the probability of the individual i, recalling a landmark j is given by the following equation:

$$P_{ij} = \frac{\exp(\theta_i - \delta_j)}{1 + \exp(\theta_i - \delta_j)}$$

Please note that the structure of this equation is identical to the Rasch (1960) model originally introduced for measurement of certain attainment tests and intelligence tests in physiological and educational research (Kaiser & Keller, 2001; Evans et al., 2007).Also,the Rasch model has beenused in healthcare and marketing research (McHorney & Monahan, 2004; Salzberger & Sinkovics, 2006). The Rasch model can be applied to any type of discrete data for measuring a quantitative attribute. In the present study, the Rasch model is adapted into a cognitive task, to analyze the connection between the saliency of a landmark and the cognitive awareness of an individual while using a paper map or anavigation device.

4. METHOD

The experimental studywas originally designed and conducted in the context of a study by Wielens et al. (2011) and Wielens (2011). The details of this studycan be found in Cenani et al. (2017). Two circular routes (Route-A and Route-B) were chosen in Eindhoven, the Netherlands (see Figure 1). Both routes had similar features such as same number of turns (10 turns), length (1.6 km) and land-use type (mostly residential buildings along with several commercial buildings). Each participant walked one of the two predetermined routes, either with a paper map or anavigation device, during daytime. All participants were tested individually. Before the study, they were asked a series of questions to guaranteeminimumfamiliarity with these locations.

4.1. Participants

Forty male and 20 female undergraduate students from the Department of the Built Environment, Eindhoven University of Technology participated in this study. They received partial course credit for their participation. The mean age of participants was 21.1 years (SD = 3.99). Twenty male and ten female participantswere assigned to Route-A, and the other 30 participants were assigned to Route-B. Fifteen participants from each study location used the given navigation device and the rest of the participants performed the same task with a paper map.

4.2. Task and Apparatus

The navigation device used for the experimental studywas NAVIGON 2510 Explorer. The main reason of choosing this device was the pedestrian oriented navigation features. For example, the map was automatically oriented to the direction of the individual. This was an important feature because it eliminated the need of orienting the map. It was assumed that navigating in the built environment would be less time consuming, making a cartographic mistake would be minimal and the most important of it all, the need for landmarks to navigate in an unfamiliar environment would be less in navigation device users than paper map users. Therefore, it wasexpected that there would be a difference in the landmark recollection results between paper map users and navigation device users.

The participants used the navigation device in pedestrian mode. The route was uploaded before the field study. To restrict the visibility of the study area, the map on the screen was locked, so they could not zoom-in or zoom-out. Furthermore, all features of the device except for the names of the streets, the route and the North direction were turned off.

Figure 1. Tools Used in the Experimental Study. Navigon 2510 Explorer and A-4 Size Paper Maps

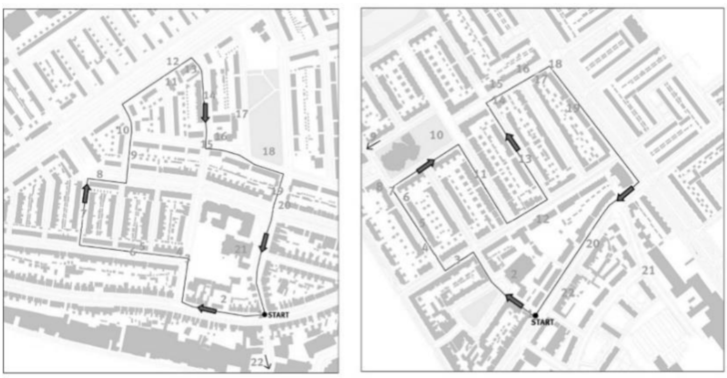

Figure 2. Landmarks (Green Numbers) on Route-A (Left) and Route-B (Right)

Paper map groups were given a printed map that was taken from www.maps.google.com. The route, the North direction and the street names were visible on the map, but information about landmarks, tagswereremoved. The tools used in the experimental studycan be seen in Figure 1. Figure 2 shows the locations of the landmarks (green numbers) and start/end point on both routes. Arrows indicate the direction of the route.

After the field study, 24 randomly numbered and placed cards containing photographs of landmarks of two test areas were given to the participants at the lab. They were asked if they recall these landmarks. Participants received a point for correct answers and received none for incorrect answers. If participants could not answer the question, it was assumed that they did not recall the landmark; therefore, they did not receive any points for unanswered questions.

4.3. Software

ConstructMap is used for the analyses. This software is chosen, because it provides a method for estimating respondent proficiency from assessment data and it also provides advanced interpretation of respondents' knowledge and behavior than test theory or item response theory (IRT) approaches (Kennedy, 2005).This software produces awareness estimates using expected a-posteriori (EAP), maximum likelihood (MLE), or plausible values (DPV) estimation algorithms. Kennedy (2005) indicates that the software produces these estimates using a multidimensional polytomous extension to the Rasch model known as the Multidimensional Random Coefficients Multinomial Logit (MRCML) Model (Adams, Wilson & Wang, 1997). Kennedy (2005) specifies that the EAP method provides a Bayesian analysis of observed events and it is a Bayesian estimation procedure using both the participants' scores and the distribution of the participants. In this study, the EAP method and the Monte Carlo method of integration are chosen for the analyses.

5. RESULTS

5.1. Saliency of a landmark

Based on the saliencyvalues calculated by *ConstructMap*, the comparison of two routes in terms of saliency of landmarks is shown in Figure 3. Please keep in mind that a higher (positive) value indicates a landmark with low saliency. According to this graph, L14 (house) on Route-A and L19 (house) on Route-B are the least salient landmarks, whereas L1 (church) on Route-A and L2 (playground) on Route-B are the most salient landmarks.

According to the findings, church and playground are more salient landmarks than rest of the landmarks. Since these landmarks create a contrast with their background and are easy to recall due to their architectural functions, these landmarks are the most salient landmarks in the landmark recollection task. These results are in line with initial expectations.

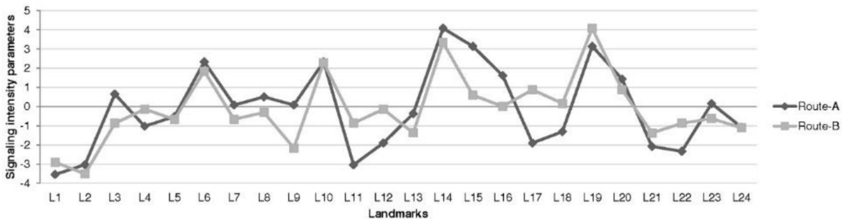

Figure 3. The Comparison of Saliency of Landmarks on Route-A & Route-B

5.2. Cognitive Awareness of an Individual

In this study, cognitive awareness represents the landmark-based spatial knowledge of an individual. Cognitive awareness of participants of Route-A and Route-B are shown in Table 1 and Table 2. Given that there are 24 landmarks in total in the landmark recollection task, the maximum score that can be achieved by a participant is 24. In the tables, a raw score represents the total number of the recollected landmarks by a participant. The next column indicates a participant's awareness estimate, and the last column shows the standard error for that estimate. Additionally, variance of the estimates (EAP Variance), the standard error of the mean value (SE of the Mean), the (given) model variance, and the marginal maximum likelihood (MML) reliability index are displayed at the bottom of each table.

As can be seen from Table 1, participant ID-4 (male) recalled 20 out of 24 landmarks; therefore, he achieved the highest score within his group. On the other hand, participant ID-26 (female) recalled 10 out of 24 landmarks; so, she achieved the lowest score in her group. In Table 2, participant ID-55 (male) achieved the highest score within his group, and participant ID-33 (male) and participant ID-49 (male) achieved the lowest scores in their groups. According to Table 1 and Table 2, male participants achieved the highest scores in their groups. The findings indicate that male superiority is observed in landmark recollection task. Surprisingly, these results are not matching with the initial assumption. It isassumedthat female participants would be better at landmark recollection task than male participants. Therefore, further statistical tests were conducted to confirm the significance of these results. In Table 3, independent samples test results (on number of correct answers) indicate that there is no significant gender difference for Route-A (Sig.: .659) and Route-B (Sig.: .290).

Table 1. Cognitive Awareness of Participants (Route-A)

Participant ID	Gender	Navigational aid	Raw score (max. score=24)	Est.	Std. Err.
1	M	map	13	0.31	0.26
2	M	map	12	0.24	0.26
3	M	map	13	0.31	0.26
4 [a]	M	map	20	0.79	0.26
5	F	map	15	0.45	0.26
6	F	map	15	0.45	0.26
7	F	map	16	0.52	0.25
8	M	map	12	0.24	0.26
9	F	map	14	0.38	0.26
10	M	map	15	0.45	0.26
11	F	map	12	0.24	0.26
12	M	map	17	0.58	0.25
13	M	map	13	0.31	0.26
14	M	map	15	0.45	0.26
15	M	map	15	0.45	0.26
16	M	nav. device	14	0.38	0.26
17	M	nav. device	14	0.38	0.26
18	M	nav. device	15	0.45	0.26
19	F	nav. device	15	0.45	0.26
20	F	nav. device	14	0.38	0.26
21	F	nav. device	14	0.38	0.26
22	F	nav. device	14	0.38	0.26
23	M	nav. device	17	0.58	0.25
24	M	nav. device	11	0.17	0.27
25	M	nav. device	15	0.45	0.26
26 [b]	F	nav. device	10	0.09	0.27
27	M	nav. device	16	0.52	0.25
28	M	nav. device	13	0.31	0.26
29	M	nav. device	13	0.31	0.26
30	M	nav. device	12	0.24	0.26
		Average	14	0.39	0.26
		Average EAP	0.39		
		EAP Variance	0.01		
		SE of the Mean	0.02		
		Model Variance	0.09		
		MML (EAP/PV)	0.21		

[a] Participant ID-4 is male and achieved the highest score.
[b] Participant ID-26 is female and achieved the lowest score.

Table 2. Cognitive Awareness of Participants (Route-B)

Participant ID	Gender	Navigational aid	Raw score (max. score=24)	Est.	Std. Err.
31	F	map	11	0.13	0.36
32	F	map	18	1.08	0.36
33 [b]	M	map	9	-0.11	0.36
34	M	map	15	0.68	0.37
35	M	map	17	0.95	0.36
36	M	map	15	0.68	0.37
37	M	map	18	1.08	0.36
38	F	map	17	0.95	0.36
39	M	map	10	0.00	0.35
40	M	map	14	0.54	0.37
41	M	map	16	0.81	0.36
42	M	map	18	1.08	0.36
43	F	map	17	0.95	0.36
44	F	map	15	0.68	0.37
45	M	map	16	0.81	0.36
46	M	nav. device	16	0.81	0.36
47	M	nav. device	13	0.40	0.37
48	F	nav. device	16	0.81	0.36
49 [b]	M	nav. device	9	-0.11	0.36
50	M	nav. device	18	1.08	0.36
51	F	nav. device	17	0.95	0.36
52	M	nav. device	14	0.54	0.37
53	M	nav. device	12	0.26	0.36
54	F	nav. device	17	0.95	0.36
55 [a]	M	nav. device	19	1.21	0.36
56	F	nav. device	14	0.54	0.37
57	M	nav. device	17	0.95	0.36
58	M	nav. device	17	0.95	0.36
59	M	nav. device	14	0.54	0.37
60	F	nav. device	18	1.08	0.36
		Average	15	0.71	0.36
		Average EAP	0.71		
		EAP Variance	0.13		
		SE of the Mean	0.06		
		Model Variance	0.26		
		MML (EAP/PV)	0.51		

[a] Participant ID-55 is male and achieved the highest score.
[b] Participants ID-33 and ID-49 are male and achieved the lowest scores.

Table 3. Results of the T-Tests

Group Statistics

			N	Mean	Std. Deviation	Std. Error Mean
1	Route-A	female	10	13.90	1.729	.547
		male	20	14.25	2.149	.481
2	Route-A	nav. device	15	13.80	1.821	.470
		map	15	14.47	2.167	.559
3	Route-B	female	10	16.00	2.160	.683
		male	20	14.85	2.996	.670
4	Route-B	nav. device	15	15.40	2.694	.696
		map	15	15.07	2.915	.753
5	Route-A & Route-B	route A	30	14.13	1.995	.364
		route B	30	15.23	2.763	.504

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	T	Df	Sig. tailed)	(2-Mean Difference	Std. Error Difference	Lower	Upper
1	Equal variances assumed	1.098	.304	-.447	28	.659	-.350	.784	-1.955	1.255
	Equal variances not assumed			-.481	22.046	.635	-.350	.728	-1.859	1.159
2	Equal variances assumed	.423	.521	-.912	28	.369	-.667	.731	-2.164	.830
	Equal variances not assumed			-.912	27.192	.370	-.667	.731	-2.166	.832
3	Equal variances assumed	1.542	.225	1.078	28	.290	1.150	1.067	-1.036	3.336
	Equal variances not assumed			1.202	24.084	.241	1.150	.957	-.824	3.124
4	Equal variances assumed	.000	.988	.325	28	.747	.333	1.025	-1.766	2.432
	Equal variances not assumed			.325	27.828	.747	.333	1.025	-1.766	2.433
5	Equal variances assumed	3.579	.064	-1.768	58	.082	-1.100	.622	-2.346	.146
	Equal variances not assumed			-1.768	52.783	.083	-1.100	.622	-2.348	.148

5.3. Frequency Distributions

Figure 4 and Figure 5 show the frequency distributions of participants' awareness values on 24 landmarks on both routes. Figure 4 illustrates the frequency distributions of the participants' awareness values filtered by gender, and Figure 5 shows the frequency distributions of the participants' awareness values filtered by the type of the navigational aid. In these figures, three ordered levels are used to define the logit ranges for each category: high (0.6 and more), medium (0.5-0.4), and low (0.3 and less).

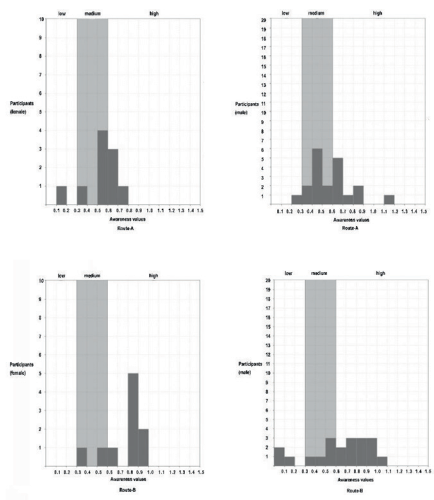

Figure 4. Frequency Distributions of Participants' Awareness Values (Filter. Gender)

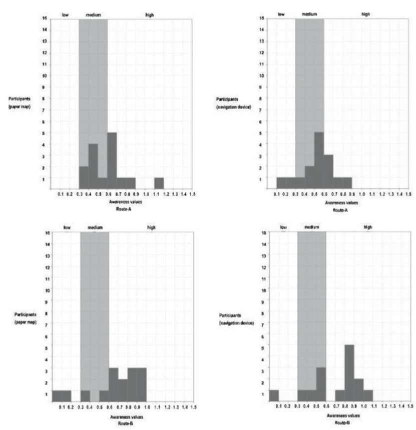

Figure 5. Frequency Distributions of Participants' Awareness Values (Filter. Navigational Aid)

Figure 4 shows that the number of male participants (*n*=9) with high awareness values is higherthan the number of female participants (*n*=4) with high awareness values forRoute-A. The number of male participants (*n*=12) with high awareness values is also higherthan the number of female participants (*n*=8) with high awareness values for Route-B. Similarly, in Figure 5, the number of paper map group's participants (*n*=8) with high awareness values is higherthan the number of navigation device group's participants (*n*=5) with high awareness values forRoute-A. The number of paper map group's participants (*n*=11) with high awareness values is also higherthan the number of navigation device group's participants (*n*=9) with high awareness values forRoute-B.

To summarize, based on these distribution graphs, contrary to the expectation, the number of male participants with high awareness values is higher than the number of female participants on both routes.Furthermore, the number of paper map group's participants with high awareness values is higherthan the number of navigation device group's participants forboth routes. The latter finding is in line with the expectation. However, as shown in Table 3, according to the independent samples test results, no significant navigational aid difference is found for Route-A (Sig.: .369) or Route-B (Sig.: .747). Having said that, of course these results hold for the current sample size; enlarging the sample and re-running the tests may lead to significant differences in the results.

6. DISCUSSION AND CONCLUSIONS

This study investigates the development of spatial learning through landmarks in an unfamiliar environment. The study focuses on how young adults (n = 60) identify and recall landmarks in visual-spatial tasks after walking a route. In this study, the Rasch model (1960) is used in a testthat includes visual-spatial tasks. The model is used to predict recognition of landmarks as a function of landmarks' saliency and the cognitive awareness levels of individuals while navigating in the built environment. To that end, an experimental study is designedto investigate how navigational aids (i.e., paper map and navigation device) influence the relation between saliency of a landmark and the cognitive awareness of individuals.

Two unexpected findings emerged from this study. First, in the landmark recollection task, male participants scored higher than female participants.

This means that male participants recalled more landmarks than female participants. However, various studies (Sholl et al., 2000; Saucier et al., 2002; Choi et al., 2006) have shown that men are more likely to use survey perspectives (e.g., cardinal directions and distances) in giving and following wayfinding directions, while women are more likely to use route perspectives (e.g., landmarks), and moreover, based on these studies, females use a landmark-biased strategy. If using landmarks for giving and following wayfinding directions is linked to the cognitive ability of recollection of landmarks then, one can assume that women would excel inthe landmark recollection task, given that existing studies indicate that women tend to pay more attention to landmarks. Therefore, it was expected that female participants would recollect landmarks to a greater extent. However, the findings showed that male participants are more successful than female participants inthe landmark recollection task (see Table 1 and Table 2). This result can be explained by gender-specific differences in cognitive skills. Although further study is required to gain a complete understanding of the spatial cognitive processes of individuals, the findings indicate that there may be some cognitive differences between spatial perception and recollection of landmarks among men and women.

A second unexpected finding that emerged from this study isthat contrary to the initial expectations, no significant difference can be found between the use of the paper map and the electronic navigation device (see Table 3). These findings can be caused by the small sample size, therefore; a larger sample size may give different results.

Furthermore, the results revealed that church (L1) and playground (L2) are the most recollected landmarks on both routes (Figure 3). In other words, these landmarks are the most salient landmarks of Route-A and Route-B. Lynch (1960) indicates that the singularity of a landmark is linked to a distinct form, contrast with nearby elements, and spatial prominence. If the singularity has an impact on saliency, a landmark such as a church is easy to recollect, due to its distinct form/architecture and spatial prominence. Similarly, a playground contrasts with nearby elements, makes it a salient object. In brief, this finding is consistent with the initial expectation.

It should be indicated that the sample contained undergraduate students who were very receptive to use information and communication technologies in their daily lives; therefore, in the future, a diverse socioeconomic and demographic sample will be included in the study. Finally, it is worth noting that the approach used in this paper can be improved by inclusion of more challenging cognitive tasks such as returning to the starting point without any navigational aid.

It is a fact that the use of electronic navigation devices is rapidly increasing. Moreover, most of the individuals do not pay attention to their surroundings while using a navigation device.As a result of using navigation devices, people do not learn the route they useand theirsurroundings. As discussed in this paper, landmarks and the level of cognitive awareness can be different from one individual to another; therefore, it may be better to consider these aspects while designing an intelligent navigation system. Intelligent navigation systems could include advices to support spatial learning and nurture spatial cognitive abilities. Today, with the help of advanced deep learning algorithms, it is possible to design intelligent navigation systems that learn users' interests, habits and improve their spatial knowledge acquisition. These navigation systems could advice users to plan their daily activities. For example, because of the rush-hour traffic or a traffic accident, the navigation systemmay suggest doing the grocery shopping first and then picking up the kid from the daycare. By receiving real-time information from systems such as travel, weather, or traffic systems, the advices about daily schedules might be modified. The quality of life of the users can be enhanced by the development of such advanced intelligent navigation systems.

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