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Editors

Assoc. Prof. Dr. Gülbin Çetinkale Demirkan

Assoc. Prof. Dr. Sertaç GÜNGÖR

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CHAPTER 1

TESSELLATION CONFIGURATIONS TRANSFORMING FROM ART TO STRUCTURAL DESIGN OF GRIDSHELL STRUCTURES

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1. INTRODUCTION

Artists and mathematicians have benefited from the tessellation method from the past to the present. Tessellations with a long history are based on the civilization of the Sumerians (Pickover, 2009). There are tessellations in the geometric decorations of the Alhambra Palace, one of the Islamic historical buildings (Bonner, 2017). In the historical process, many scientists have used this method. Artist and mathematician Maurits Cornelis Escher, mathematician Thomas Hull, and mathematician, computer scientist and artist David Huffman have also applied tessellation configurations to artworks. In Escher's works of art, symmetry, reflection and rotation parameters, which are the basic features of tessellation, are encountered (Figure 1). The tessellation method has also been strengthened with repetition, rhythm and harmony phenomena (Takva, 2021). In 1997, Thomas Hull created a modular origami model of tetrahedra. Tessellation configurations are used in this model. Today, many artists and mathematicians use the modular origami model to create tessellation configuration networks consisting of polyhedra (Wu, 2018). David Huffman is known for his origami tessellation configurations. He combined the tessellation method with the art of folding (Davis et al., 2013).

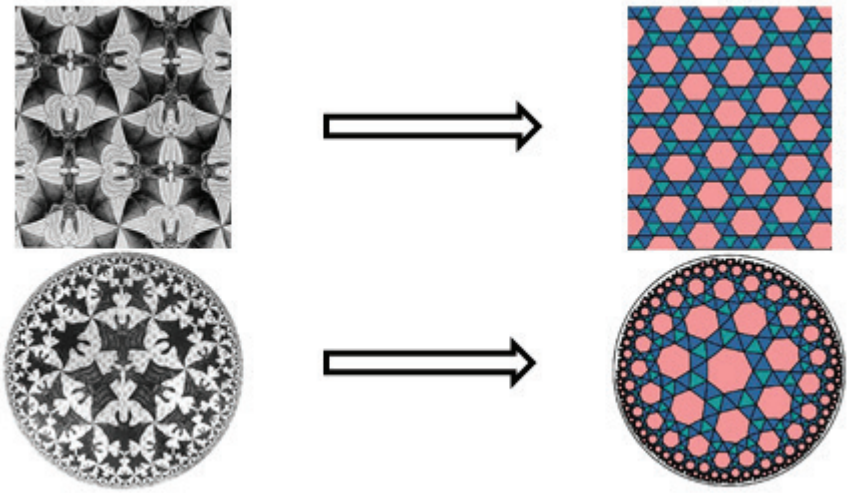

Figure 1. *The transformation of Escher's works from artwork to geometric objects in the Euclidean plane (Sazdanovic, 2012)*

The concept of tessellation is the method for arranging geometric shapes side by side with mathematical rules without overlapping or spacing between them (Huang et al., 2022). In the historical process, the tessellation method, which has survived for centuries and has survived to

this day, is used in the field of architecture as well as in science fields such as geometry, art and engineering (Takva and İlerisoy, 2021). In the architectural design process, examples are found in building elements such as walls, ceilings, flooring, landscape applications. There are also tessellation patterns in long-span architectural structures. The fractal tessellation method, which is one of the tessellation types, can be seen in dome structures, which are a type of gridshell structure with long-span, and regular/periodic tessellation method can be seen in geodesic domes (Figure 2).

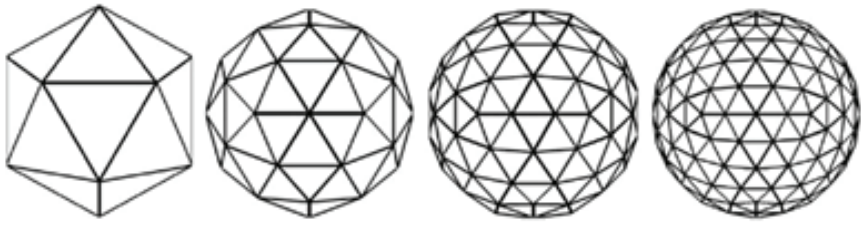

Figure 2. *Geodesic solids created with triangle geometry of different sizes (Wu and Takatsuka, 2006)*

Many systems have been used throughout history to pass long-spans. The shell structure is one of these systems. Shell structures are thin structures with curved surfaces that allow loads to transfer to the ground along with stress and pressure. These structures are three-dimensional curved surface systems in which the loads are effectively distributed and have a deep-rooted historical background. From the 1920s to the 1960s, the shell construction entered an innovative phase by designers such as Pier Luigi Nervi, Felix Candela and Heinz Isler (Leung, 2019). Shell systems are lightweight, long-span, easy-to-construct and cost-effective structures. It reduces carbon dioxide emissions with its fast construction process and creates a sustainable built environment. Since it is an advantageous system, architects and engineers have turned to shell structures (Elnagar, 2015). Since completely covering an area is not suitable for both cost and effective use of some space formations, new solutions have been sought for shell structures. In this direction, a gridshell system was developed from shell structures. While providing material savings and natural light in buildings, a structurally advantageous mechanism is created by reducing the weight of the building (Farshad, 2013). Gridshell structures are also shell structures that are in the process of development.

Gridshell structures are obtained by dividing a shell structure system into grids within the scope of passing a long-span. In a long-span structural system divided into grids, the depth/span ratio is also less. Gridshells can be designed in different curvature angles and in different geometric forms. The use of diagonal geometries also gives the structure rigidity and

versatile load transfer. Gridshell systems are lightweight structures consisting of rod networks and rigid fasteners that are resistant to axial tensile forces (Chilton and Tang, 2016). Gridshells, also called lattice shell structure, consist of a continuous surface, in contrast to thin-section reinforced concrete and masonry shells (Leung, 2019). Gridshells have high strength and are obtained from the double-curvature of the funicular geometry. Diagonal elements also provide extra strength in some cases (Elnagar, 2015). It is a suitable system for producing complex shape combinations because of its geometric rationality. They are structures with a wide design scale with their organic shapes, free surface design possibility, providing natural light and create column-free spaces. Frei Otto's works stand out in gridshell structures (Seifi et al., 2018). From this perspective, the use of advanced construction technologies is developing day by day and large areas without columns are increasing (Takva et al., 2022a).

Gridshell structures can be produced from many materials, such as reinforced concrete, steel, aluminum, bamboo, wood and composite. More rigid systems can be designed using nanotechnological materials (Ilerisoy and Takva, 2017). When each material is compared, it has advantages and disadvantages related to properties such as ductility, strength, weight, durability, economic and ecological cost, construction complexity and prefabricated production. The appropriate material selection should be made by looking at the gridshell system to be designed (Leung, 2019). Wood, a traditional building material, can create curved surfaces by providing structural rigidity as it is flexible and can be bent without breaking. However, very long-spans require high strength and deformation. Therefore, steel and composite materials are preferred (Tayeb et al., 2015). With the development of modular construction systems, convenience is provided in the installation and construction stages (Takva et al., 2022b). Developing sustainable and climate-sensitive designs in gridshell structures is also an important term of consideration for future generations (Takva et al., 2022c).

Gridshell structures provide different combinations of geometric shapes, resulting in various architectural designs and structural gains. A gridshell structure projected in geometrical order is easily produced through prefabricated production, and a long-span system is established with on-site construction. The integration of the geometrical formation into the structure can be achieved by the tessellation method. In the study, first, building samples were examined to understand the use of tessellation configurations in gridshell structures and the properties of the structures were presented.

2. TESSELLATIONS

Tessellation can be defined as a collection of shapes in a mathematical framework covering any surface. Tessellations, which enable two- and three-dimensional designs, are a set of patterns that are shaped as a sequence of geometric figures without overlapping or leaving any spaces between them (Lang, 2017). Tessellation patterns, which are encountered in areas such as wall decorations and floor coverings in ancient architecture, can be seen in many areas in modern art today (Wang and Wang, 2022). A geometric figure can be used to obtain tessellation configurations. However, in the figure used, the angle and edge connections are important for the continuity of the sequence. The tessellation module must complete 360 degrees in the arrays created with regular geometric shapes (Figure 3). Rhythmic tessellation configurations are created using regular polygons such as triangle, rectangle and hexagon (Choi et al., 2019).

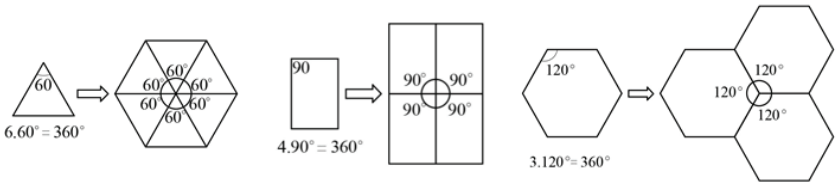

Figure 3. *Tessellation modules obtained with regular geometric shapes (by the authors)*

Tessellation configurations are produced because of duplication of tessellation modules created with basic geometric shapes (triangle, rectangle, hexagon, etc.) and these patterns can be applied to cover any surface (Jin et al., 2017). The duplication process is provided by the repetition method, which is also a basic principle of architectural design (Figure 4). Equilateral triangles and squares can be thought of as a parallel grid system, but not for hexagonal configurations. Hexagonal formations can be viewed as a diagonal grid system. Symmetrical and periodic tessellations can be derived by varying in triangular, rectangular and hexagonal geometric shapes (Lu and Steinhardt, 2007).

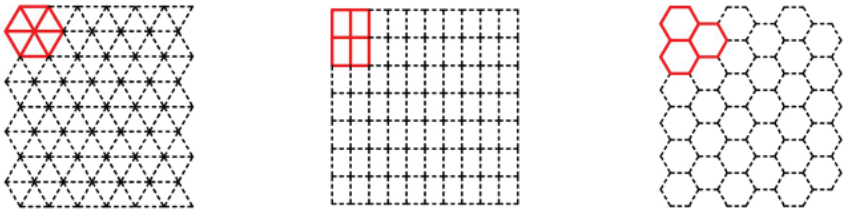

Figure 4. *Tessellation patterns obtained from tessellation modules (by the authors)*

Three basic rules must be met for the application of the tessellation method. Tessellations occur because of translation, reflection and rotation movements of a geometric form (Figure 5). Moving a geometric figure from one place to another in scale is called translation, taking its symmetry with respect to a certain line is called reflection, and changing direction by preserving its size according to a certain degree is called rotation (Değer and Değer, 2012). While one of these variations can be sufficient alone in the production of tessellation configurations, various patterns can be obtained using multiple combinations (Ždímalová, 2020).

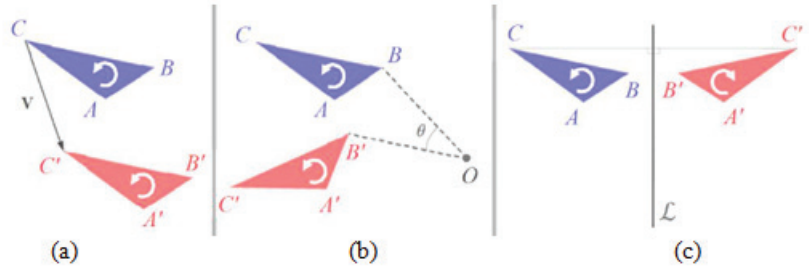

Figure 5. *(a) translation, (b) rotation and (c) reflection movements (Sareh and Chen, 2020)*

In addition to the application of the tessellation method with regular geometric shapes, editing can be performed using free-form, irregular geometric forms (Figure 6). While more stable and rigid configurations are obtained using regular tessellation, irregular free-form tessellation more flexible and variable patterns (Sotelo Calvillo, 2020). The use of a single geometrical shape is not essential for creating a pattern. The tessellations are also diversified using more than one geometric figure. The use of different geometric shapes also changes the mathematical expression of tessellation (Paulino and Gain, 2015).

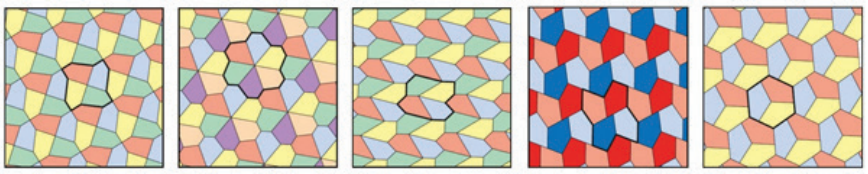

Figure 6. *Free geometric tessellation models (Fathauer, 2020)*

Tessellation patterns are derived from geometric shapes, and the number of sides of the geometric shape in each tessellation module provides the

mathematical expression of the tessellation configuration (Friedenberg, 2019). Putting a point in the middle of the tessellation module and writing the number of sides of the geometric form clockwise, respectively, numerically, creates the mathematical formula of that tessellation model (Gazi and Korkmaz, 2015). Tessellations formed with one regular polygon are called regular tessellations, and tessellations obtained with more than one regular polygon are called semi-regular tessellations. Since regular tessellation is produced from a single shape, the mathematical expression does not change within the tessellation configuration. Since there is more than one polygon in semi-regular tessellations, the mathematical formula may change at different points, but there is a possibility that it will not change. The mathematical expression is sought in tessellation modules that complete 360 degrees (Ross et al., 2020). The more the geometric shape diversity in the tessellation model, the greater the mathematical expression diversity (Figure 7).

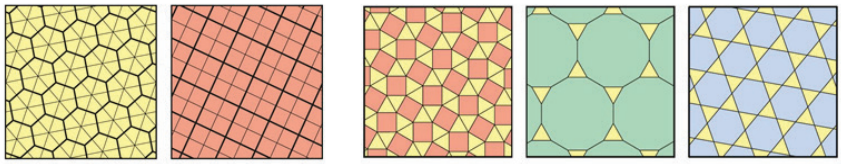

Figure 7. *(3.3.3.3.3.3) and (4.4.4.4) regular tessellations and (3.3.4.3.4), (3.12.12), (3.6.3.6) semi-regular tessellations (Fathauer, 2020)*

Not all regular polygons are suitable for tessellation patterns. Geometries such as regular pentagon, regular heptagon and regular octagon cannot form a regular tessellation by arranging them side by side (Figure 8). The reason for this is the deviation from 360 degrees as an angle, and the edges of geometric shapes cannot provide a regular sequence of tessellation. Tessellation patterns are derived from mathematical and geometric information. Some geometric forms alone cannot form patterns, but they can produce semi-regular or free-form tessellations with a polygon with a different number of sides completing 360 degrees (Akiyama et al., 2010).

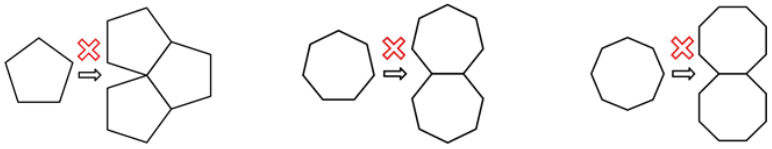

Figure 8. *Regular pentagon, regular heptagon and regular octagon geometric shapes in which the tessellation pattern is broken (by the authors)*

3. GRIDSHELL STRUCTURES ARE APPLIED WITH TESSELLATION CONFIGURATIONS

Regular spatial structures, such as shell and gridshell structures, derive their strength from their geometric shapes. Gridshell structures that can stand by support themselves also allow the use of different geometric shapes. Rectangular space is generally preferred in these structures. However, different combinations can be created according to the complexity of the geometrical shapes. Continuous gridshell alternatives can be developed by combining more than one geometric shape in the Euclidean plane (Rian et al., 2018). The gridshell building stock also varies with the use of structural elements such as steel, glass, aluminum, wood and composites (Douthe et al., 2010). In this section, the application of tessellation configurations, which are commonly seen in the branches of art and mathematics, in building examples in architecture is discussed. At this point, the geometry of gridshell structures, which are central to passing long-spans in architecture, has been examined.

3.1. Multihalle and Restaurant, Mannheim

It is one of the first and best known samples of wooden gridshell systems. the project started in 1971 and was opened in 1975 at the German Federal Garden Exhibition in Mannheim (Figure 9). The architect of the building is Carlfried Mutschler. It is a construction project approximately twenty times larger than the area of the largest span wooden gridshell structure ever built. In the early stages of the design, a scale model was made at Frei Otto's workshop Atelier Warmbronn determine the architectural form of the building. The double-layer gridshell is 50 centimeters apart in each grid direction and consists of interconnected vertical grids. The double-layer gridshell structure refers to the stacking of 4-layer wooden elements. The shell system has a surface area of 9500 square meters and a floor area of 7400 square meters. Ove Arup & Partners engineering firm was involved in the construction of the structure and physically simulated the structure with the network model (Tang et al., 2013). The double-layer wooden gridshell construction is reinforced with steel connecting networks to ensure cross-directional structural rigidity. The shell structure has a maximum span of 60 meters and a height of 20 meters (Sharma et al., 2015).

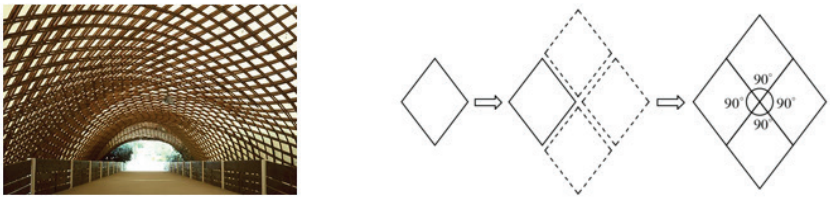

Figure 9. *Multihalle and Restaurant (Sharma et al., 2015) and tessellation module*

3.2. The Ephemeral Cathedral of Créteil, Paris

Créteil Cathedral was built in 2013 in Paris, France and is a free-form gridshell structure covering an area of 350 square meters (Figure 10). The building has a capacity of 500 people. It has features such as structural rigidity, fire safety, waterproofing and thermal comfort. Glass fiber reinforced polymer pipes (GFRP) with a diameter of 4.2 centimeters and a length of 2 kilometers are used in the gridshell system. The structural members are of different lengths and consist of composite pipes connected by steel sleeves. The structure was covered with a PVC cover system. The structure, built in the form of a free-form gridshell with composite material, has a spanning of 17 * 29 meters and a height of 7 meters (Du Peloux et al., 2016).

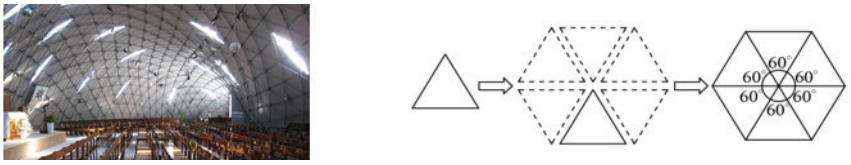

Figure 10. *The Ephemeral Cathedral of Créteil (Kotelnikova-Weiler et al., 2013) and tessellation module*

3.3. Centre Pompidou, Metz

The Center Pompidou was designed by Shigeru Ban. The building, which took 7 years to build, was opened for use in 2010. In the construction of the structure, initially large-sized glue-laminated elements were converted into the designed architectural form using a CNC milling machine. The roof structure is set on a hexagonal plan with a length of 52 meters and covers an area of approximately 7000 square meters. The span of the roof structure is around maximum 50 meters. The structure form consists of Kagome pattern geometry, which consists of hexagonal and triangular geometric shapes (Figure 11). The gridshell system has columns that reach the ground and are obtained from four inverted cone or funnel forms. The maximum height of the construction is approximately 36 meters and is supported by the core of the structure (Tang et al., 2013). Center Pompidou, consisting of a free-form, double-curvature wooden gridshell structure, is covered with a translucent PTFE membrane. The translucent membrane cover allows natural light to provide a bright environment (Chilton and Tang, 2016).

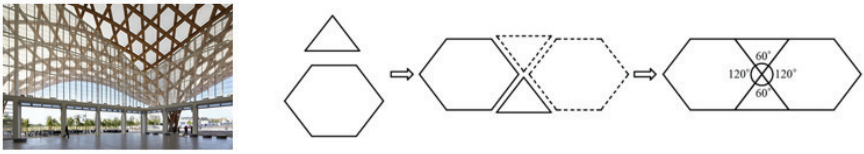

Figure 11. *Centre Pompidou (URL-1) and tessellation module*

3.4. Upper Trading Rows (GUM), Moscow

Vladimir Shukhov is an engineer who lived in Russia in the late 19th and early 20th centuries, who brought innovation to double curvature structural forms. Shukhov developed roof systems for light structures and mathematical analysis and produced steel and glass building materials for Moscow's famous buildings and roof systems for long-span lightweight structures. One of the most well-known samples among these structures is the Upper Trading Rows (GUM) gridshell structure, which was built with a barrel vault geometric form (English, 2005). In 1890, architects Aleksandr Pomerantsev and Shukhov achieved the three-section light barrel vault form by using multiple diagonal connections to minimize lateral displacements. The roof structure is made of more than 20,000 glass panes and a 14 meter diameter barrel vault is used (Figure 12). There are more than 50,000 metal partitions in the project (Leung, 2019).

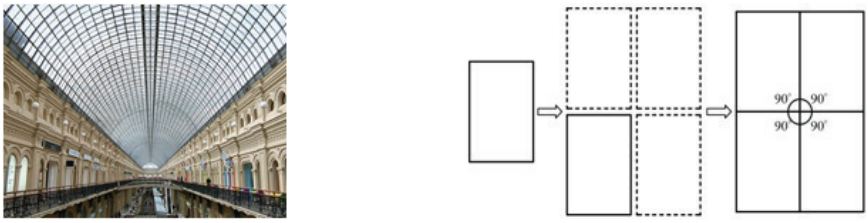

Figure 12. *Upper Trading Rows (GUM) (Leung, 2019) and tessellation module*

3.5. Toledo Gridshell, Naples

The Toledo gridshell construction was built in the courtyard of the University of Naples in 2012 on an area of 75 square meters. The gridshell structure was obtained from 156 square meters of flat grids using spruce wood. In this project, 626 knot points were consolidated with bolts at each connection point. With the Kangaroo program, the form of the gridshell system was determined through a special software. The shell system, which has a spanning of 10 meters and a grid spanning of 50 * 50 centimeters, is the product of an experimental study (Figure 13). The architectural consultants of the building are Bernardino D'Amico and Raffaele Stabile (Chilton and Tang, 2016).

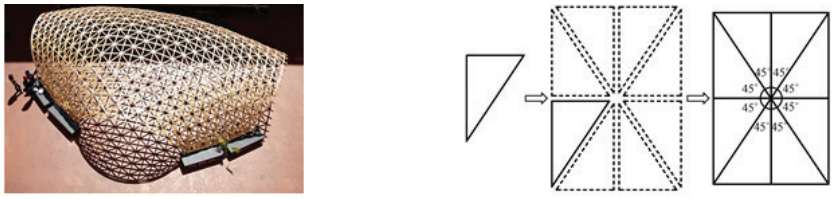

Figure 13. *Toledo Gridshell (Pone, 2017) and tessellation module*

3.6. Jewel Changi Airport, Singapore

Jewel Changi Airport is one of the innovative, ecological and sustainable gridshell system with long-spans. Designed by Safdie Architects and the construction of the airport was completed in 2019. The structure, which has an elliptical toroid shape, is approximately 200 meters long and 150 meters wide (Figure 14). It consists of a continuous gridshell configuration supported by 14 tree-like columns and annular beams. The waterfall spanning in the structure, which flows into the courtyard from a 40-meter-high central spanning called the Rain Vortex, makes the structure attractive. The construction is made of triangular panels made of steel and 9000 high-performance glass panels (Tahmasebinia et al., 2021). The roof structure has a single layer diagrid steel system of 33 rings (Liew, 2019).

Figure 14. *Jewel Changi Airport (Liew, 2019) and tessellation module*

3.7. Chadstone Shopping Centre, Melbourne

Located in Australia, Chadstone Shopping Center is a double-curvature freeform gridshell system using steel and glass materials covering 7,080 square meters. It receives sunlight efficiently with its free form and steel-glass structure. The span of the gridshell is up to 44 meters and rectangular geometric-shaped panels are included in the project (Figure 15). A total of 2645 rectangular panels were used. Maximum panel dimensions are 2.8*2.2 meters. Rectangular grids reduced the weight of structural steel and reduced the cost of cutting glass material. Special software for gridshell design has been developed by the British structural engineering company Atelier One. Additionally, the universities of Stuttgart and Bath took part in the project. For this project, a gridshell design method called PLATO was produced. (Chadwick et al., 2017). The structure reaches a height of 31 meters and is 260 meters long glass-steel roof combination.

Figure 15. *Chadstone Shopping Centre (URL-2) and tessellation module*

3.8. Canary Wharf Cross-rail, London

Designed by the architectural firm Foster + Partners, the structure consists of a 310-meter-long gridshell in vault geometry. There are 30 meters consoles at both ends. The roof structure was made of spruce wood using triangle tessellation, and the top cover system was ETFE material (Figure 16). The grid vault shell structure is 12 meters high and has a 30-metre diameter spanning. The wooden structure consists of 564 nodes. Rigidity is provided with steel connections at the node points. 777 ETFE variations are embedded in 302 different sized triangular panels. A flexible, computer-aided parametric design approach was adopted using software. Performance tests and structural analyses were conducted with the aid of algorithms (Chilton and Tang, 2016).

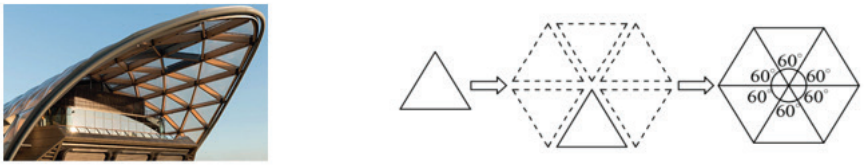

Figure 16. *Canary Wharf Cross-rail (Chilton and Tang, 2016) and tessellation module*

The eight gridshell structures with long-spans show differences in terms of tessellation patterns. Tessellation and structural variations were determined and tabulated by considering into account the characteristics of the structures (Table 1). Classification was made according to building location, building function, the year of completion of the building, panel shape, tessellation module, tessellation module formation, mathematical sequence, structure shape, structure materials, maximum structure height (meter) and maximum structure span (meter) parameters. When the structures are analyzed, it has been observed that the gridshell systems have made progress with the emergence of new innovations such as technology and material development. There has been an increase in the number of experimental studies recently because of the advantages of gridshells such as easy construction and low cost. It is striking that the structures built after 2000 were designed as more stable and rigid systems in the use of complex geometries and pass long-span compared to the gridshells built under 2000. Along with the developments in steel, glass and composite materials, these materials have started to be used in gridshell systems and traditional wooden building materials. When the sample structures are examined, it is seen that the gridshell systems are generally used in functions such as gathering places and meeting points.

Table 1. *Arrangement of structures according to tessellation and structure variables (by the authors)*

	Multihalle and Restaurant	The Ephemeral Cathedral of Créteil	Centre Pompidou	Upper Trading Rows (GUM)	Toledo Gridshell	Jewel Changi Airport	Chadstone Shopping Centre	Canary Wharf Cross-rail
Building function	Social, cultural	Religious	Social, cultural	Trading, symbolical	Thesis work	Trading, transport	Trading	Trading, transport
Year of completion of the building	1975	2013	2010	1893	2012	2019	2016	2014
Panel shape	Diamond	Triangle	Triangle, hexagon	Rectangle	Triangle	Triangle	Rectangle	Triangle
Tessellation module								
Tessellation module formation	translation	rotation, reflection	translation reflection	translation	rotation, reflection	rotation, reflection	translation	rotation, reflection
Mathematical sequence	4.4.4.4	3.3.3.3.3.3	3.6.3.6	4.4.4.4	3.3.3.3.3.3. 3.3	3.3.3.3.3.3	4.4.4.4	3.3.3.3.3.3
Structure shape	Four layered dome	Double curved freeform	Double curved freeform	Barrel vault gridshell	Self-shaping gridshell	Semi-inverted toroidal dome	Double curved freeform	Barrel vault gridshell
Structure materials	Timber (western hemlock), PVC membrane	Glass fiber reinforced polymer tubes (GFRP), PVC coated fabric	Glued-laminated timber, PTFE membrane	Steel, glass	Timber (spruce)	Steel, glass	Steel, glass	Timber (spruce), ETFE membrane
Maximum structure height (meter)	20 m	7 m	36 m	Not found	Not found	37 m	31 m	12 m
Maximum structure span (meter)	60 m	29 m	50 m	14 m	10 m	200 m	44 m	30 m

4. CONCLUSION

Tessellations, which have an important place in art, are seen in the fields of architecture as well as geometry and mathematics. It can also be used to coat surfaces by creating patterns. These surfaces can be seen on the facades and roofs, as well as in the plans of the buildings and the load-bearing elements. Because of the development of structural systems with innovative and advanced construction techniques, lightweight structures have emerged. The progress of structural elements, such as steel, has accelerated the transition from a solid-body structure to hollow-body structures. In hollow body systems, geometric calculations and formal parameters play a role. In this study, the geometric features of gridshell structures, which are hollow body systems, are emphasized. It is the field of architecture and engineering that progresses based on long-span buildings, developed technological building elements, innovations in the construction process, costs, and demographic conditions. Gridshell systems are also preferred structures for long-span structures, which are advantageous in terms of saving materials, testing innovative building elements, and easy assembly and installation. Geometric shapes are the elements that enable the formation of grid systems and are integrated into the structure by making aesthetic and static evaluations.

In this study, it is aimed to explain the tessellation method produced with geometric shapes and to examine it in gridshell systems. Firstly, the method of tessellation seen in the branches of art was emphasized. After introducing the features of the method, information about long-span gridshell structures is given. Then, the gridshell structures are presented with examples and the tessellation modules are shown. All samples were grouped by looking at their tessellation and structural properties and inferences were made. A better understanding of the tessellation method and its use in gridshell structures from a structural perspective are analyzed. As a result, it has been determined that geometric shapes are effective in building structures in the context of design.

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CHAPTER 2

INVESTIGATION OF WOOD-BASED INTERIOR MATERIALS IN TERMS OF ECOLOGICAL DAMAGES

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Introduction

In spite of the fact that the concept of ecology has been around for quite some time, in recent years it has emerged as one of the most intriguing and highly contested topics in the world. Over the past several years, both scientists and members of the general public have been devoting a greater amount of attention to this matter. This is as a result of factors such as the increasing pollution of the environment, the extinction of some species of living creatures, the increase in average temperature around the globe, and the fast destruction of natural regions. This action is being taken as a response to the increasing environmental pollution, the extinction of certain living beings, the rise in the average temperature of the earth, and the rapid deterioration of natural areas. Ecological disaster is one of the most pressing problems of our day, particularly for the children and grandchildren who will be the next generation after ours to face the world.

People typically have the mentality that the natural environment and the man-made environment, which was created by humans, should be able to coexist harmoniously at every stage, beginning with the origin and continuing through production, use, and finally assimilation and destruction in the biosphere. This concept originates from the fact that individuals created the artificial world in which they live. The word "artificial environment" may be used to refer to a broad variety of locations, ranging from enormous cities to small hamlets, structures, and huts. These are all examples of man-made environments.

Because of the negative impact, they have on one's health and the frequency with which they are found as pollutants within the home, aldehydes, notable formaldehyde, are considered to be among the most significant types of indoor pollutants (Dallinga et al., 2010). Ureaformaldehyde is the least complicated and the pollutant that is found inside the most commonly. It is also the aldehyde that has received the most attention. Formaldehyde is a volatile molecule that is readily polymerized, combustible, and colorless (Pepper & Carrington, 2009; Ye et al., 2017). It may be found in the environment either naturally or as a byproduct of human activity (for example, in exhaust gases, pollutants, and cigarettes). Research conducted at home reveals that it may be found in significant quantities. In a study that was carried out in houses in urban and rural areas of Ankara, it was discovered that the levels of formaldehyde in the living rooms and kitchens of the houses were higher than the allowable level. Additionally, the level of formaldehyde was found to be statistically significantly higher, which was associated with symptoms such as tearing, running nose, and dry throat in the residents of the houses. Figure 1 shows the relative contributions of potential sources of indoor volatile organic compounds in apartments for the first year.

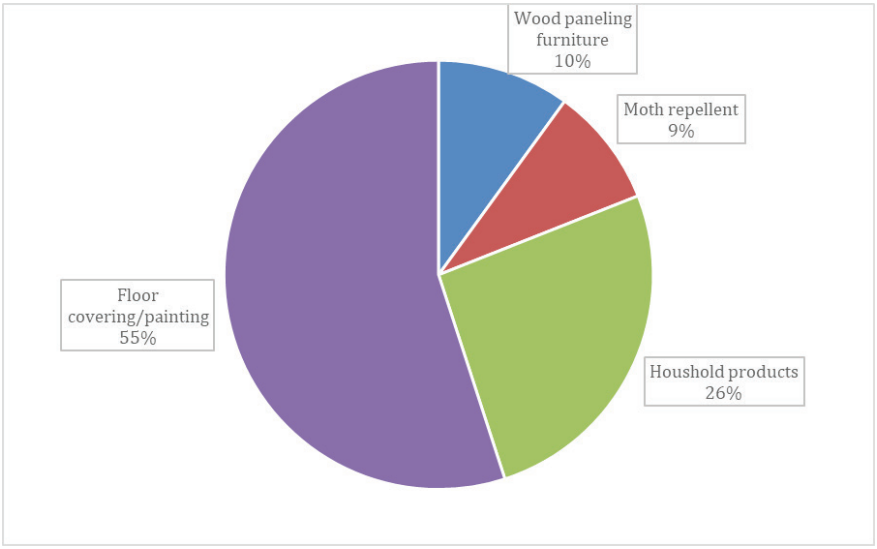

Figure 1. For the first year, the relative contributions of possible sources of volatile organic compounds in apartments (Shin & Jo, 2014)

Formaldehyde and acetaldehyde, which can be found in cigarette smoke, furniture, carpets, and heating and cooling systems, can be found in the air inside. It is often employed as a preservative in paints and coatings, as a component of gums and adhesives to provide permanent shape to flooring and drapes, etc., and in the manufacturing of furniture, either formaldehyde itself or its compounds created with other chemicals are utilized (Seguel et al., 2016). The use of plywood with adhesives that include urea and formaldehyde resin, as well as goods that use these types of adhesives, are common sources of formaldehyde in houses. Products made from plywood that are suitable for use inside and around the house include:

- Particleboard (under floors, shelves, cabinets, and furniture)

- Hardwood paneling (decorative wall coverings, furniture, and cabinets)

- Coatings made of medium-density fiberboard (also known as MDF) used for drawer doors, cabinets, and furniture.

Wood is typically thought of as being useful, beautiful, and economical. Because wood is often thought of as being warmer, friendlier, nicer, and more relaxing, it can also be used in interior spaces because of psychological expectations and preconceptions (Jiménez et al., 2016). A study was done to find out how well wood-based materials used in interior spaces fit in with nature from the time they are made to the time they are thrown away. The study also looked at how designer choices affect the natural environment.

This study looked at the interiors of buildings, which are the most important part of the artificial environment, as well as the wood and wood-based products used for both furniture and finishing materials. The focus of this study is how wood is used in interiors since wood is the most important part of an artificial environment. Additionally, an examination will be carried out to determine the effects that the decisions that designers make have on the natural environment.

Wood Flooring Materials

Solid or layered flooring can be crafted out of wood and other materials derived from wood. Wood can be used alone or in combination with other materials. When their power is enhanced, they will be able to be utilized in a number of situations, including houses, hotels, companies, and other types of commercial facilities, among other places. It enjoys widespread popularity and is put to use in a variety of settings, both inside and outside the house. The modifications that take place in these materials, which are frequently used by designers in their designs because they evoke a natural and warm feeling, as well as the risks that the chemicals that they carry in their bodies or that are loaded later pose to human health are the subject of current research. Designers frequently use these materials because they evoke a natural and warm feeling. These materials give off an earthy and welcoming vibe, which is why designers want to work with them. It is not obvious how they may pose a threat to human health, particularly with regard to the contamination of the air in confined spaces that do not have sufficient ventilation.

Massive Panel

The thickness of solid panels is from 2.2 to 2.6 millimeters, while their length is 4 meters and their breadth ranges from 6 to 10 centimeters. Additionally, solid panels are created exclusively from natural materials. They go through a variety of stages, such as drying, slicing, mixing, and packing, as part of the production procedure. During the drying process, the ovens are brought up to the appropriate temperature and the wood is allowed to lose any leftover moisture while the ovens continue to heat. It is generally known that the purpose of these processes is to render the material unusable, and this goal is achieved through their execution. Because the impregnation ingredient dissolves in water and the inert wood material cannot be recycled, conventional impregnation with biocides is not used in many countries in Europe and the United States of America (USA). This is because conventional impregnation is considered to be an outdated method. In modern times, the impregnation procedure has been replaced with heat treatments as the method of choice for preventing material from functioning as it should. It is necessary to do this in order to stop the substance from functioning properly.

During the slicing phase, the tree is cut down to the dimensions at which it will work the least, cuts are made in the direction of fiber lengths, and smoother images are obtained by removing places with color and texture differences, such as knots. During this phase, the tree is also sliced in the direction of fiber lengths. During this stage of the process, the tree is also shrunk down to the dimensions at which it will function the least effectively. After being trimmed to the appropriate proportions for the lath, the side-to-side and longitudinal joints are fastened using a type of glue referred to as polyvinyl acetate (PVA). The primary component of PVA is a combination of carbon and hydrogen, which is used in the manufacturing process. It has a structure that does not dissolve in water, turns brittle when the temperature is low, and turns liquid when the temperature is high. There is not a shred of evidence to suggest that this substance is in any way hazardous to human beings (Aksakal et al., 2005). As a result of the fact that PVA is composed of molecules that are susceptible to melting, it is not advisable to utilize this chemical in settings where the temperature is very high.

Since natural wood is used to make this material, the loss of trees that happens when trees are cut down in areas that don't grow back in an organized way has a big effect on the animals that live there (Hart, 2011). In addition, it is necessary for us to be aware of the type of energy resources, whether renewable or nonrenewable, that are utilized in the functioning of the machines that are utilized in the production process. In the designs that are going to be built utilizing solid panels, the selections that the designer makes are going to be very essential. This substance, which poses the least risk to human health when it is used, will hurt both people and the environment if it is used without planning. This is something that should be taken into consideration.

Parquet

All of the tongue-and-groove parquets come from the same tree and are referred to by their solid parquet name. They are produced using the same methods as solid panels, however, they differ from solid panels in that they are thinner, shorter, and joined using tongue and groove rather than traditional methods. The width of solid parquet ranges from 3 to 5 centimeters, the length ranges from 20 to 35 centimeters, and the thickness is 16 millimeters. The manufacturing stage for solid parquet is quite similar to the manufacturing stage for solid panels; the main difference is that longitudinal joints are not formed. Following the installation of the solid parquets, the surface of the upper parts is sanded, the cracks and gaps inside are filled with parquet paste, the surface is varnished with cellulosic filler varnish to make the surface smooth, and finally, parquet polish is used to polish it as the final process; this procedure is known as the "scrape process." It's common knowledge that the scraping process is the last step

in the intervention sequence and that it helps both the durability and the appearance of the repair.

The cellulose-based varnish that is used in the scraping process is a form of natural varnish that is derived from plants and does not have any adverse impact on the health of humans (Aksakal et al., 2005). It has been shown that cellulose-based varnish can come straight from nature, which is good for health. In addition to this, it is the designer's obligation to build solid parquet entirely from trees, much like solid panels do. Laminated parquets are a type of flooring that is usually made by laminating three different layers together.

1. Top layer in polished hardwood
2. Middle layer
3. Top layer

In laminated parquets, the primary design is created by the first layer, which is typically between 3 and 4 millimeters thick. The rest of the tree layers in the lower parts of the parquet are called filler because they are not as valuable as the top layers. In the bottom and higher layers, the direction of the fibers runs parallel to the long side, whereas in the intermediate layer, the fiber direction runs parallel to the short side. By doing things in this manner, the working rate of the material is slashed significantly. varying thicknesses of 10, 14, and 20 millimeters. PVA glue is used to hold the layers together, and it is scraped in the same way that solid parquet is. The widths may reach up to 15, 20, and 25 centimeters, and the lengths can reach up to 200 and 250 centimeters. Because of how PVA glue works, this part shouldn't be used in places where the temperature is very high.

Laminate parquets use less wood than solid parquets, so fewer trees are needed to make them (Yeang, 2008). From this point of view, it's important for designers to do research on where the product came from. They are floor-covering materials that are formed by combining different materials in layers under high temperatures and pressure.

1. Protective, transparent layer
2. Decor layer
3. Medium or high-density fiberboard layer
4. Compensation layer

It is composed of four distinct layers in total. The lowest layer, called the "balance layer," can be made of plastic, paper, or melamine. Its job is to keep the floor from making moisture and to make sure that the parquet is installed evenly. the second layer This layer is the primary water-resist-

ant carrier layer, and it may be made from either medium-density fiberboard (MDF) or high-density fiberboard (HDF). MDF and HDF are both produced by the same process, which involves compressing wood fibers together with an adhesive and resin. The ornamental layer is the layer that gives the parquet the appearance of a natural tree design. This layer is also known as the top layer. This layer is basically a photograph and is generated by compressing many paper layers with melamine resin. This process creates the layer. True colors and mother-of-pearl paint give this layer a deep design and a real picture. It is made by putting melamine, formaldehyde, and urea formaldehyde on these patterned sheets and baking them until they are dry. This process creates the base for the next layer. Figure 2 shows layers of a parquet.

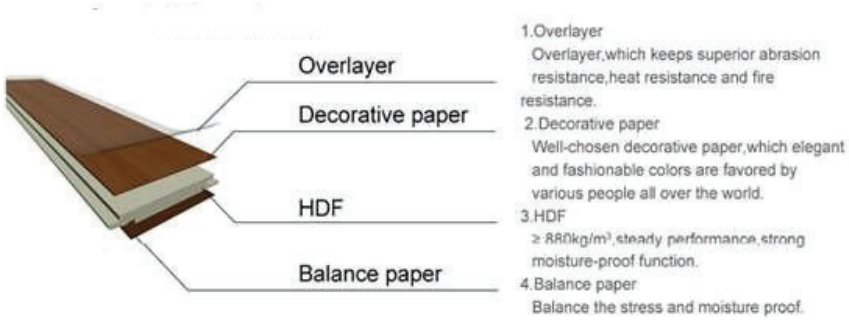

Figure 2. Parquet layers (URL 1)

Melamine, formaldehyde, and urea formaldehyde, which are all known as volatile organic compounds (VOC), are utilized in the role of a resin in both the MDF and HDF layers, as well as the décor layer (Salthammer & Uhde, 2009). Some of the volatile organic compounds, like formaldehyde, are released into the atmosphere even when the temperature is at room temperature, and when the temperature rises, the density of these compounds in the atmosphere also rises. For instance, if the temperature goes from 230 degrees Celsius to 400 degrees Celsius, there would be 5.2 times as much formaldehyde in the air (Pepper & Carrington, 2009). These compounds, which are present in laminate flooring and are frequently used as flooring materials in interior spaces, are released into the environment in proportion to the temperature of the environment. Laminate flooring is widely utilized as a flooring material in interior spaces.

Formaldehyde is a poisonous chemical that has no smell and no color. It is very dangerous to human health. It also has a very pungent and offensive stench. Studies have revealed that VOCs, particularly formaldehyde and urea formaldehyde, have highly harmful effects on the respiratory tract as well as

the central nervous system and that they can potentially cause cancer. It is especially harmful to babies and children because it causes developmental abnormalities (Aksakal et al., 2005). E1 is the name given to the regulation that requires member states of the European Union to restrict the quantity of free formaldehyde between 3 and 8 mg per 100 grams of the plate. The fact that this number is higher in E2 points to an unfavorable condition; furthermore, it is possible that these values will reach 2 mg/100 g in the future. It is hoped that it may be brought down to the value of E0, which is the plate. The formaldehyde that is present in the wood itself is what is meant by the term "E0" (Sivrikaya, 2008). According to studies, there is significant work to be done in order to meet the natural criteria of wood.

These compounds have a significant positive impact on the air quality inside buildings, which are often sealed up and devoid of ventilation, particularly during the colder months when it is important to minimize heat loss. As the frequency and duration of people being in such environments increases, disorders such as Sick Building Syndrome (illness without infection caused by indoor breathing) and Boring Building Syndrome (different psychological effects caused by breathing in environments) are observed (Gou & Siu-Yu Lau, 2012). Sick Building Syndrome is the illness of a person who is not infected as a result of indoor breathing. No matter if we are aware of it or not, these substances hurt us in our everyday lives.

There is a layer that is resistant to abrasion that is located on the top protective layer of laminate flooring. This layer is a coating that is made from transparent aluminum oxide. Depending on the trends in consumer preferences, this layer can have a low or high gloss. Additionally, it stops any moisture from getting into the parquet where it is installed. It is clear that this layer is an important part of making the parquet flooring last as long as possible.

Furniture

The vast majority of the time, individual pieces of furniture are constructed from solid wood or panels that are based on wood. Lacquers and varnishes, stains, resin-impregnated papers, overlays, and high-pressure laminates are some of the several types of finishes that are used to cover its exterior. Lacquers and varnishes are two examples of these types of finishes. The bulk of these coatings, somewhere in their chemical structure, include terpenes, aromatic hydrocarbons, or aldehydes, and as a result, they produce a wide variety of volatile organic molecules (VOCs). Lacquer is a common substance that is used in coatings, and it has the ability to enhance the color of the wood's natural grain while also increasing the smoothness and shine of the surface, the feel of the surface texture, and the three-dimensional character of the wood (Ulker et al., 2021). The surface

of the wood can also be made smoother and shiner with lacquer. There are many different kinds of lacquers, but the ones that emit esters, alcohol compounds, and aromatic hydrocarbons include aqueous lacquers and polyurethane (PU) lacquers. Other types of lacquer also exist. However, ultraviolet (UV)-curable lacquer does not release any esters or other compounds, and it is particularly efficient in suppressing the development of aldehydes, alcohols, and ketones. UV-curable lacquer is cured by exposure to ultraviolet light. Figure 3 shows an example of an interior made up of wooden-based furniture and covering.

Figure 3. An example of an interior made up of wooden-based furniture (URL 2)

Products that are used for finishing, such as solvents, emulsions, and chemicals in aerosol form, are produced with the intention of increasing the overall quality of the finished product as well as extending the product's usable life. When wood composite panels like particleboard, medium-density fiberboard (MDF), and oriented strand boards (OSB) are used to make the units, certain coatings, such as overlays, are also used on the surface of the units. In many cases, these coatings are able to lower the amount of volatile organic compound emissions that are created by the substrate.

Toluene, xylene, benzene, and styrene are the primary components that are often found in emulsion-type and solvent-type finishes, respective-

ly (Guo & Murray, 2001). In the production of styrene and styrene acrylic, ethylbenzene and p-dichlorobenzene are employed as intermediates. Carboxylate styrene-butadiene polymers are another type of coating that may be applied to wood substrates (Alimardani & Abbassi-sourki, 2014). Some of these chemicals are put to use as solvent-cleaning agents in the furniture business so that stains may be removed from the surface and so that the surface can be prepared for further treatments like painting or the application of conversion coatings (Baghdady & Schug, 2018). As a consequence of the species, the moisture content is another well-known critical characteristic that influences both the overall coating quality and the service life of the coating. A previous study found that a lower moisture content of a unit resulted in increased VOC emissions such as aldehydes and methanol, while a higher moisture content resulted in more terpene emissions. This was found to be the case when comparing a lower moisture content to a higher moisture content.

Ways to Mitigate the Effects

The usage of synthetic construction materials is frequently linked to the high levels of volatile organic compound concentrations found within. Eliminating the primary sources of VOC emissions inside a building is among the most efficient methods for controlling VOC concentrations (Shin & Jo, 2014). In most cases, determining the source of an emission requires an understanding of both the chemical composition and the intensity of the emission source. A well-known method to qualitatively characterize the chemical composition of volatile organic compound (VOC) emissions from building materials are known as static headspace analysis (Guo et al., 2003). Within a closed container, individual measurements of the materials are taken. In order to determine the makeup of the substance chemical makeup, a gas chromatograph/mass spectrometer (GC/MS) is used to examine air samples that have been obtained from the inside of the container (Han et al., 2011). On the other hand, headspace analysis was unable to determine either the emission strength of the materials or their decay rate.

The emission factors for VOC and emission profiles as a function of time can be obtained by monitoring in a dynamic environmental chamber (Wallace et al., 1987). As a result, quantifiable information on the source strength and variation characteristics of building materials may be acquired. The long-term decay rates. In addition, the measurements of indoor VOCs taken at various stages of building construction may prove useful in elucidating the local chemical composition of building materials and the pattern of their deterioration (Kim et al., 2006). Therefore, it is essential to do research into the behaviors of focus throughout this time period. However, the process of constructing the interior was not given much consideration during the process of measuring or modeling the in-

door VOC levels. Measurements of volatile organic compounds taken during the building stage were also taken rarely.

Conclusion

Within the scope of this study, the natural or man-made materials, chemicals, and parts that go into making wood-based indoor flooring products were looked at, as well as the stages of their creation. The results were looked at from an ecological point of view, and their effects on both people and nature were thought about and debated. The use of solid boards and solid parquet flooring, as it turns out, is relatively good for human health; nevertheless, in the long term, there is a huge risk of chopping down more trees if it is done unexpectedly. This is because of the use of solid boards. On the other hand, it has been found that laminate flooring is very bad for people's health, whereas using natural materials is much less dangerous. If you want to lessen the amount of pollution in your home's air and make it more comfortable, use materials that produce less pollution. There are several different methods of measurement that may be used to determine the composition of the air found inside. Particularly important is having enough ventilation inside. Checking the documentation that is associated with the manufacturing of the floor covering material that is going to be utilized, as well as researching the potential risks that it poses to human health, are both important steps. To make sure that future generations will inherit a world that can be lived in, it is important that materials for wood-based interior flooring are made that are not only good for the environment but also safe for people's health.

Synthetic building materials are often associated with high volatile organic compound concentrations. Eliminating building VOC sources is one of the most effective ways to reduce VOC levels. Emission sources are usually identified by their chemical composition and intensity. Static headspace measurement is a popular approach for qualitatively characterizing volatile organic compound (VOC) emissions from building materials. Materials are measured in a sealed container. A gas chromatograph/mass spectrometer (GC/MS) analyzes container air samples to identify the substance's chemical composition. Headspace study could not establish the emission strength or decay rate of materials. A dynamic environmental chamber can measure VOC emission components and profiles over time. Thus, construction material source strength and variation may be quantified. Long-term deterioration. Indoor VOC measurements collected during building construction may also reveal the local chemical composition of building components and their decay trend. Thus, attention habits must be studied throughout this time. During VOC measurement and modeling, the interior construction process was ignored. VOC measurements during construction were unusual.

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CHAPTER 3

PLANTS AS ITEM OF IDENTITY IN CITIES

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INTRODUCTION

Cities are overpopulated settlements at the highest level of vital activities in direct proportion to their economic and social structure (Belge 2018). In parallel with the increase in population, cities that move away from naturalness day by day in order to meet the housing and job opportunities are organized with planning and design decisions that are not based on an ecological basis. The quality of life of people is adversely affected in the unplanned urbanization caused by the imbalance of living and non-living interactions (Ekici and Sarıbaş 2006). In this intense interaction, cities form the basis for many aesthetic, functional, ecological and social studies. Within these studies, the subject of urban identity is frequently discussed in the context of the perception of cities and the memorability of cities.

Cities are areas of life that change and develop over long periods of time, where the needs for settlement, housing, work and recreation are met (Korkut et al. 2017). In this formation process of cities, their relationship with their environment ensures the development of values belonging to the city over time and these values give the city an identity (İlgar 2008). In addition, historical elements, flora and fauna, water resources, cultural elements, topographic features are the most important factors that give cities identity (Güneroğlu and Bekar, 2017). Depending on these factors, the retention of urban identity depends on people's mental perception. As a matter of fact, cities may have different characteristics such as dense construction, rich historical texture, geographical and geological characteristics, depending on the principles of establishment and development. Parallel to these features, it can also be mentioned with sectors such as industrial city, tourism city, trade city, which have a large share in the city's economy. In addition to all these identities, the density of green texture and green areas, being unique to the region can determine the perceptibility and memorability of the city (Karagüler and Korgavuş, 2014).

Cities contain green areas that reflect the ecological and historical structure in relation to their environment. Especially architectural structures and open green spaces are important components that ensure the integrity of cities. Urban open green spaces as vegetative surfaces outside of dense structural surfaces are public spaces that enable people's social and physical activities and positively affect their psychological state (Çorbacı et al. 2020; Tarakçı Eren and Var 2016). Plants play an important role in the evaluation of green spaces that contribute to the image of the city. Plants are an integral element of our daily life. In order to create more comfortable outdoor spaces, it is necessary to consciously use plants suitable for the design purpose and ecological conditions (Ekici and Sarıbaş 2006).

Apart from being a source of food since the existence of human be-

ings, plants make them the most important living material in the outdoors, as they provide shelter, medicine, equipment making, improving air quality, addressing human psychology and making positive contributions to the environment (Güneroğlu et al. 2018). Plants that create functional and aesthetic spaces also play a role in softening the structural elements such as stones, walls and flooring in the urban landscape. Over time, plants transform solid looks into nature and give designs the concept of time, which is 4 dimensions (Eroğlu et al. 2005: Kahveci 2021).

In both urban and rural landscapes, plants, especially trees, have been the primary materials for people throughout history, civilizations have planted the trees they brought from miles away in their living spaces. Information about the care and contribution of the trees they planted has been revealed. Today, developed cities are characterized by the types and numbers of trees, and plant inventories are made by maintaining and repairing these trees (Yılmaz and Irmak 2004). Plants perform functions such as cleaning the air, providing climate, wind and erosion control, creating a pollen source, taking nature into the city by making wildlife a part of the city, and making a positive contribution to the aesthetics and image of the city (Tülek and Mirici 2019; Güneroğlu and Pulatkan, 2021; Sarı, 2021). Considering that natural plants can adapt more easily to urban environments, it is inevitable that they provide all these features easily.

Natural plant species gain importance with the social, cultural and natural factors of the cities in which they are located (Kaya Şahin et al., 2020). For this reason, trees are one of the most important plant elements as an identity element in cities. Trees used in urban green areas increase the perceptibility of the city together with structural elements with their size, form, color, texture and linear features. In the urban landscapes of many countries in the world such as Japan, Canada, Italy and Turkey, there are different tree species as an identity element. In this study, tree species used in urban areas of different countries with both their cultural value and aesthetic and functional properties were investigated. The remarkable features of these trees as an identity element in the countries where they are located are emphasized.

Plants with Identity Elements in Japan

Naturalness is at the forefront of Japanese culture garden understanding. Generally, in gardens where evergreen plants dominate, the color effect is achieved by the coloring of the flowers of the plants in the spring and the leaves in the autumn (Polat and Öztürk Kurtaslan, 2011). When evaluated from this point of view, especially *Ginkgo biloba* L., *Prunus serrulata* 'Kiku Shidare' (Sakura) and *Acer palmatum* 'Atropurpurea' species attract attention with their intense use in urban green areas of the country. *Ginkgo*

biloba L. is a plant that stands out with its aesthetic feature in landscape studies with its form, autumn coloring and different leaf structure similar to elephant ears. Especially in autumn, the appearances that appear with the yellowing of the leaves are quite effective. In addition to being a natural species, it is a plant with high cultural value for the country. Due to its healing properties and very old history it is considered a sacred tree. It is used extensively in sacred areas. It is used solitarily in urban green areas, as well as in urban parks in groups and in road and street landscapes in the form of linear compositions (Figure 1). With these features, they draw attention as important identity components in Japanese cities.

Figure 1. Gingko biloba L. usage areas (1:URL-1, 2:URL-2, 3:URL-3)

There are more than 200 taxa of *Prunus* sp in Japan, and the flowers of these taxa are called Sakura. Flowers of Prunus sp taxa that do not bear fruit are expressed as Sakura. *Prunus* sp taxa, which have a great importance in Japanese culture, are also one of the national symbols of Japan. Sakuras represent the sudden and short lives of samurai with the possibility that they may die while fighting. Expressing beauty and life, these trees create effective landscapes with their colorful flowers in spring. The flowers, which bloom before they become leaves, are flamboyant, white, pink in color and fall from the trees without drying and fading (Çınar Altınçekiç, 2016). These plants, which symbolize death and rebirth, are used extensively in the planting of urban areas such as coasts, streets and parks (Figure 2). During the flowering periods of the plants in the spring season,

they organize sakura festivals that represent the resumption of life in the city. These festivals attract tourists from many parts of the world. Considering all these features, it is seen that these plants are an important urban identity element for Japan.

Figure 2. Prunus serrulata Lindl. usage areas (1:URL-4, 2:URL-5, 3:URL-6)

Just as they celebrate the blossoming of trees with festivals, the falling of leaves of trees has a similar importance for the Japanese. In Japan, there is a traditional activity of watching the trees fall in autumn and finding the most beautiful red leaf among the fallen leaves. In addition, these leaves, which reflect many shades of yellow, orange, brown and red, are an indispensable element of traditional clothes. For these reasons, it is inevitable to see maples, which have a cultural significance for the Japanese, in urban areas such as parks, gardens, streets and temples. Especially *Acer palmatum* Thunb is one of the most important components of Japanese garden designs with its red leaves and wide crown (Demirbaş, 1997). Not only the forms of the leaves and the reddening of the leaves, but also the calligraphic structure of the branches after the leaves have fallen, display effective appearances. With these features, they are used as an accent element in parks, streets and waterfronts both in solitary and group form (Figure 3). *Acer palmatum* Thunb also draws attention as an important identity element of Japanese cities due to its cultural value and being a natural plant.

Figure 3. Acer palmatum Thunb usage areas (1: URL-7, 2: URL-8, 3:URL-9)

Plants with Identity Elements in Turkey

Naturalness and the depiction of paradise are at the forefront in the understanding of garden in Turkish culture. The color effect in the designs is especially provided by flowering ground cover or bush-sized plants. As trees, species that attract attention with their size and form are preferred. From this point of view, *Platanus orientalis* L. and *Tilia* sp. L. types are in the foreground. *Platanus orientalis* L. is an important solitary plant used in herbal designs with its form and magnificent size. It is a natural species in Turkey and is culturally valuable as a symbol of longevity. These trees, which have the ability to create spaces on their own, attract attention as elements that carry the traces of the past for Turkish people. They are also used as indispensable elements of parks and road landscapes as a group (Figure 4). When evaluated with these features, they draw attention as an element of urban identity in Turkey.

Figure 4. Platanus sp. usage areas (1:URL-10, 2:URL-11, 3:URL-12)

Linden trees, like plane trees, are among the natural species in Turkey. They are among the most used species in herbal designs with their forms, autumn colors, and floral beauties. Linden trees, which are culturally important plants due to the healing properties of their flowers, are mostly used in urban designs, parks and street plantings (Figure 5). These species, which are also suitable for pruning, are also evaluated in espalier applications. With all these features, they are also at the forefront as an identity element.

Figure 5. Tilia sp. usage areas (1:Güneroğlu 2021, 2:URL-13, 3:URL-14)

Plants with Identity Elements in India

In Indian culture gardens, trees are considered religiously and culturally sacred. Indians deified plants and venerated them. Evergreen and majestic trees form the main elements of the gardens. *Ficus benghalensis* L. and *Ficus religiosa* L. draw attention as both culturally valuable and magnificent trees in the country. *Ficus benghalensis* L. is a tree, also known as a single-trunk forest. It is a symbol of immortality and is an important part of Indian legends. It is forbidden to damage and cut the tree, which has a single trunk and wide crown (Güneroğlu et al., 2018). For this reason, they are used solitarily in urban areas as well as in parks and streets (Figure 6). With all these features, the country is of great importance as an element of urban identity.

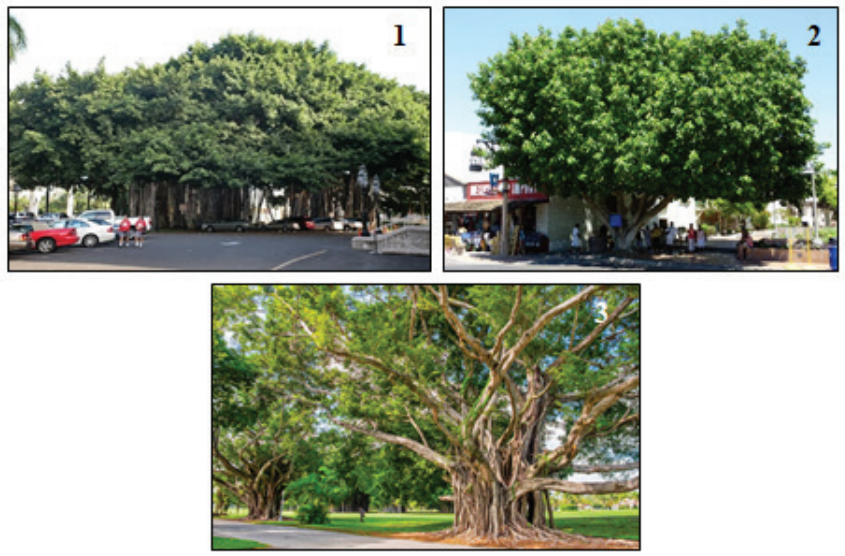

Figure 6. Ficus benghalensis L. usage areas (1:URL-15, 2:URL-16, 3:URL-17)

Ficus religiosa L., a symbol of happiness, peace and luck, is a sacred tree like *Ficus benghalensis*. With the use of this plant species in bonsai, it is also possible to grow it at home. Consideration has been given to the use of these evergreen and broad-shaped trees in roads, parks and sacred spaces within the urban green spaces of India (Figure 7). *Ficus religiosa* L. also draws attention as an important identity element in Indian cities due to all these features and being a natural species.

Figure 7. Ficus religiosa L. usage areas (1:URL-18, 2:URL-19, 3:URL-20)

Plants with Identity Elements in Italy

Unity, integrity and splendor are at the forefront in the understanding of garden in Italian culture. Tall evergreen trees stand out as vertical linear design elements along with the columns that are often seen in Italian gardens. With these features, *Pinus pinea* L. trees are widely used in parks, streets and gardens as the symbol of Italian coastal cities (Figure 8). *Pinus pinea* L. trees, which draw attention as an important identity element especially in the city of Rome, have been the most encountered species, constituting 16.4% of the total registered trees (Biocca et al., 2021). Functionality is at the forefront in the use of stone pines in the history of the city. The pine has been preferred as a shade element with its leaves and wide crown at all times of the year. Today, it still exists in Roman historical areas and maintains its importance as an important character element of the city (Resuloğlu, 2019).

Figure 8. Pinus pinea L. usage areas (1:Güneroğlu 2021, 2:URL-21, 3:URL-22)

Olea europaea L. is one of the important plant species for the country, both symbolically and as a nutritional element (Costantini and Barbetti, 2008). Olive trees are striking elements in herbal designs with their evergreen and silvery gray leaves. In addition, due to their form features and being resistant to pruning, they are considered as accent elements in designs. In the urban areas of Italy, olive trees are frequently encountered with these features. It is used as a street decoration in narrow streets in cities, in repeated rows in flower pots. They are used as a group in parks and gardens. They are also used as a group in parks and gardens. In addition to these, they are evaluated in residential gardens with the aim of both obtaining food and creating space (Figure 9). For these reasons, olive trees also have the potential to be an identity element for the country.

Figure 8. Olea europaea L. usage areas (1:URL-23, 2:URL-24, 3:URL-25)

Plants with Identity Elements in Argentina

In the green space planning of Argentina, the influences of Italy, then France and Spain are seen. In urban green areas, grass surfaces and tall, umbrella-shaped trees that stand out with their flower beauty attract attention (Faggi and Ignatieva, 2009). The most important of these tree species growing naturally in the country are *Tabebuia impetiginosa* (Mart. ex DC.) Standl. and *Jacaranda mimosifolia* D.Don. The use of Tabebuia impetiginosa in parks, residential gardens and streets is prominent in urban areas (Figure 9). It is considered the most beautiful of the city trees (Carol et al. 2008). The intense pink flowers exhibit impressive views. It creates an emphasis effect by using it as a solitary, especially in spaces. With all these features, the country has an important place as an identity element.

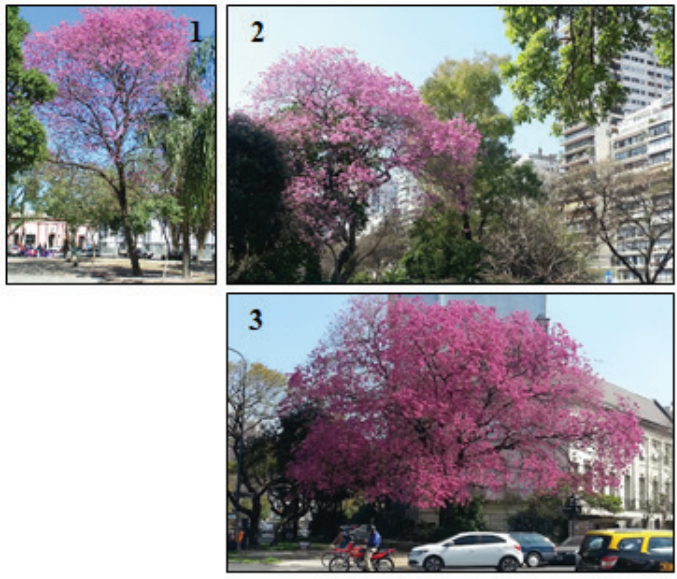

Figure 9. Tabebuia impetiginosa (Mart. ex DC.) Standl. usage areas (1:URL-26, 2-3:URL-27)

Jacaranda mimosifolia D.Don is one of the most important green elements that complement the structural elements of the city of Buenos Aires. It is used extensively on roads and parks with its purple-colored flowers (Figure 10). For these reasons, *Jacaranda mimosifolia* D.Don trees also have the potential to be an identity element for the country.

Figure 10. Jacaranda mimosifolia D.Don usage areas (1:URL-28, 2:URL-29, 3:URL-30)

CONCLUSION AND RECOMMENDATIONS

Technological developments and modern living conditions cause cultural values to decrease day by day. Likewise, cities change, develop and tend to resemble each other over time. At this stage, attention should be paid to the use of natural plants in urban areas, considering both ecological, economic and cultural factors.

In this study, it is seen that in many countries around the world, importance is given to the use of natural species in urban green areas with their cultural value. It is noteworthy that some countries support these values for tourism purposes and host tourists from many parts of the world by organizing festivals and provide economic gain. It has been determined that tree species with philosophical, historical and healing value also attract attention and value in urban areas as an important identity element.

However, it is seen that exotic species that are easily produced and easily supplied are used in plant designs made in urban areas in many cities today. When evaluated from this point of view, importance should be given to the use of plants, especially as elements that distinguish cities from each other. For the selection of plant species to be used in the planning and design studies, first of all, inventory studies should be carried out on natural plant species suitable for the physical and climatic characteristics of the region where the city is located. Production of natural plant species should be supported and endangered species should be protected. Access to natural plant species should be provided in the designs to be made and the use of natural species in urban areas should be encouraged. Particular attention should be paid to the use of plant species with identity value, especially in the avenue and road afforestation, where the usage density is high, and the awareness of the existence of these elements should be increased among the local and foreign city users.

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CHAPTER 4

CARBON-LANDSCAPE RELATIONSHIP IN URBAN OPEN GREEN AREAS

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1.INTRODUCTION

With the increasing world population, consumption demands, fossil fuel uses, industrialization, urbanization, globalization and new developments in technology are beginning to occur. With new developments, human demands and needs on natural systems and resources are beginning to diversify proportionally. While keeping up with the new developments in the environment and the world we live in, this sometimes leaves us with positive results and sometimes negative results. Considering the negative results, it can be seen that it causes multifaceted destruction and deterioration in the physical dimension (Gül et al., 2015). In the event that this situation cannot be prevented, it is predicted that it will bring about different negative consequences in the future. Climate change is the most important of these negative consequences.

Climate change is closely related to all countries in terms of sustainable development and the continuation of the ecosystem. Climate is one of the most important factors affecting the life styles on earth. And it expresses the average weather events of elements such as precipitation, humidity, temperature and wind of a region (Jackson, 2018). Changes occur as a result of the effects of natural and human factors on the climate system. These changes are defined as climate change (IPCC, 2007). Climate change is known to have an impact on the earth's water cycle first. It causes fluctuations in the water cycle, causing extreme water events to occur. In addition, it has effects in many areas on a global and regional scale. These; agriculture, forest and vegetation, clean water resources, sea level, energy, human health and biodiversity (Akalın, 2014; Bayramoğlu & Seyhan, 2019).

From the past to the present, it has become the center of attraction for large population movements as the production, trade, education and culture focus of the cities. With the increase in population, solid fuel consumption and energy use have increased. In other words, the amount of pollutants released into the atmosphere with urbanization has also increased. In this case, the air in cities needs to be cleaned. Urban open green areas come to the fore here. Because urban open green areas play an important role in the production of clean air, that is, oxygen, and in the retention of carbon dioxide released into the atmosphere (Durkaya & Varol, 2016; Gül et al., 2016).

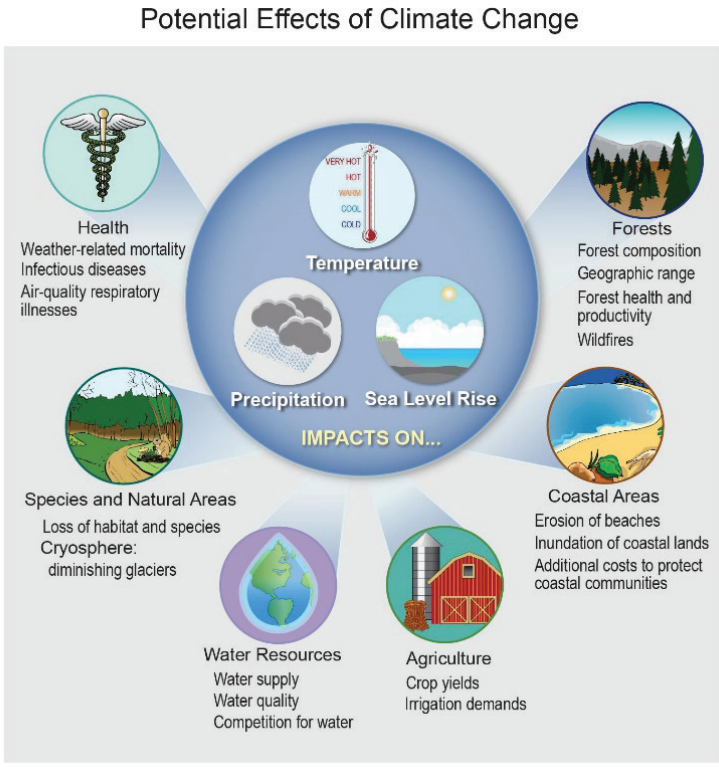

Figure 1. Climate Change (Url-1, 2022)

In recent years, climate change has been changing atmospheric carbon levels in urban areas as a result of increasing urbanization and intensifying global warming effects. In this direction, various studies have been started by city planners and researchers. One of them is the planning of open green spaces in cities. (Choudhury et al., 2020). Because open green spaces are the most important carbon sinks in terms of holding 76-78% of the organic carbon in the terrestrial ecosystem, and they contribute significantly to reducing the negative impact of global warming and protecting the climate at the regional and global level.

Plants in urban open green areas have the capacity to capture CO2 through photosynthesis. For this reason, it is considered as the most important sink areas by storing and holding carbon in plant biomass and underground. Today, anthropogenic carbon dioxide (CO2) emissions have increased significantly as a result of the increasing intensification of vehicle traffic with rapid urbanization. The role of urban road trees in reducing CO2 emissions from cities is not fully known. Scientific research is needed to better understand the current and future roles of urban trees in carbon storage and sequestration (Gül, Topay & Özaltın, 2009; Fares et al., 2017).

2. URBAN OPEN GREEN AREAS FUNCTIONS

Urban open green areas have an important role in balancing the human-nature relationship, which is deteriorated for various reasons in cities, and in improving living conditions in the city. At this point, many developed countries see the number and characteristics of the green areas they have as an indicator of their quality of life and civilization. In this direction, urban spaces that are suitable for people's needs and lives are trying to plan and design. Urban open green areas are one of these efforts. They are physical spaces that provide important contributions to a city in terms of ecological, economic, socio-cultural, psychological and aesthetic. In particular, it regulates the urban micro-climate, integrates it with nature, provides active and passive recreation, enables equipment related to entertainment, determines the mass-space balance spatially, etc. It plays an important role in the creation of urban life quality with its features (Gül & Küçük, 2001; Eraslan et al., 2014). They are areas consisting of living (such as trees, shrubs, ground covers, grass) and non-living (such as roads, water elements, urban furniture) elements such as forests, groves, parks of various functions and sizes, cemeteries, refuge areas, building gardens, which serve functions such as recreation, landscape and hydrology (Pamay, 1978). It helps to clean the air, protect water and soil, balance the natural and urban environment, reduce anxiety and stress in people, and improve physical and mental health in people (Anguruni & Narayanan, 2017). The functions that open green areas provide to the city; economic function, ecological function, social and cultural function, physical function, recreational-social function and aesthetic function.

- **Economically;** Open-green areas have the function of saving energy, providing tourism and job opportunities, increasing the value of land and housing around them, and providing production. As a result of the effects of trees, the energy consumption used for cooling or heating in buildings is significantly reduced. There are also trees that reduce terrestrial radiation during the night. These trees prevent the heat loss in the interior spaces to a great extent by reducing the wall temperature especially in cold periods (Tepe, 2018). It has the opportunity to provide tourism and job opportunities, increase the value of the land and housing around it, and provide production. In addition, it increases the housing costs and land values in the regions where it is located. It has been determined that a 40-year-old ash tree in an urban forest reduces the energy cost for the heating system by 7% with its shading effect (Yılmaz et al., 2011). It provides economic benefits by saving costs for heating or cooling and increasing the value of immovable properties. Residential buildings, etc., located around urban open green spaces. It is stated that it affects the prices of immovable properties. A study was conducted near Lake Tahoe in California, and accor-

ding to this research, it was determined that the forest wealth in the region increased the prices of real estate by 5%-20% (Thompson et al., 1999).

- **Socially;** It increases the aesthetic and recreational value of urban spaces and meets the psychological, social and cultural needs of urban people. It plays an important role in reducing people's stress and improving their psychological health. In short, people who live in areas surrounded by trees feel better (Ulrich, 1990). At the same time, they are important areas in the development of social relations, the increase of solidarity and the establishment of social relations. It is the place where young people, old people, neighbors and families from different age groups and social classes meet and do various activities. Aesthetically, green areas soften the harsh effects of architectural forms and prevent unwanted images. They help people feel more peaceful in the area they are in the city. It allows people living in the city to spend time in quality green areas where they feel peaceful when they go out of the buildings.

It contributes to social development by enabling educational activities, reducing crime rate, enabling recreational activities. For example, Central Park is to create more livable environments for people and to increase people's social and cultural well-being. It provides both the opportunity of green area in the city center and the opportunity of recreational activity for people. Apart from the social and cultural services it provides, it has a microclimate regulation effect thanks to the wide variety and number of plants it contains. Central Park (Figure 2) is an important example that reveals the social dimension of urban green areas established in various parts of the world.

Figure 2. Central Park, New York (Url-2; Url-3).

Recreational activities reduce crime rates in the society. This causes social development to increase. Since it contains recreational activities in green areas, it helps to reduce aggression in the society, relax and revitalize people. Access to activities is effective in reducing crime rates, especially juvenile delinquency. It keeps young people away from the dangers in cities and provides safe environments for group interactions. It enables them to use the time fully without getting into other problems (Bruch, 2006; Sherer, 2006).

- **Physically;** creating an architectural effect, providing physical balance with the effect of occupancy-space, providing light and air to buildings, and providing pedestrian comfort on vehicle roads. Open green areas (forest areas, slopes, ridges, coasts and valleys) can be effective as elements that divide or shape the city, even just because of their existence. They can prevent the formation of cores in dense residential areas and can be effective on the form of the city with the spatial structures they will create by dividing the city (Richter, 1982). In the city, they establish a balance between people and their environment in terms of size. It relieves the pressure on the people who balance in terms of size in cities that have an overwhelming effect on people with the building and the large structures in its immediate vicinity. They bring spaces to the human dimension. In addition, it has the effects of providing security, creating noise barriers, shaping the city, being a development area to be evaluated, and reducing noise. Architectural forms and soft textures add aesthetic value to the city. They create a background effect by softening the harsh effects of architectural forms and providing integrity, preventing undesirable views (Önen, 2015). They provide aesthetic value to the urban space with their vegetal materials and features such as form, size, texture, color and line. They contribute significantly to the structure of cities. It provides a balance between human and environment, structure and structure, building masses and spaces. They act as a buffer between areas of different nature, such as accommodation, trade, business and educational structures. By contrasting with the artificial and inanimate elements of the city; They enrich the urban landscape aesthetically with their vibrant, colorful and illuminated appearance and seasonal color features.

Figure 3. Bryant Park (Url-4; Url-5).

- **Ecologically;** filtering polluted air and providing oxygen production, reducing the greenhouse effect in the atmosphere, preventing erosion, maintaining water balance, and protecting ecological and biological diversity. Noise reduction creates habitat for plant and animal species and enables agricultural production near the city. It reduces pollution by filtering solid and gas particulate matter in the air. It occurs either by active absorption and adsorption by the leaves of the trees, or by passive dispersion and collapse by the dispersion of the direction of the air currents by the trees (Önen, 2015; Tepe, 2018; Toksoy et al., 2020; Bayramoğlu & Küçükbekir, 2022). The urban forest located in the city of Melbourne is a forest that has an aesthetic-ecological function by increasing the role of trees (Figure 4). From an ecological point of view, the urban forest strategy provides the society. Energy savings are evaluated within the scope of economic and social parameters that can be measured in terms of improving air quality and carbon sequestration (Shears, 2009).

Figure 4. Melbourne Urban Forest (Url-6)

It acts as a natural filter for trees and subsoil water pollution. It removes polluted particulate matter from the water before it reaches the sewer, along with its leaves, stems, roots and soil (Sherer, 2006). The filtering capacity increases with the increase of leaf area. This effect is more on trees than shrubs and grass areas. Conifers have more air cleaning capacity than deciduous leaves due to the excess of leaf areas. The effects of needle leaves are greater in the winter months when the weather conditions get worse (Bolund et al., 1999). Trees and other plants create nutrients by using CO_2 from the atmosphere along with water, sunlight and elements from the soil. vegetal tissue; It improves air quality by keeping pollutants that are harmful to humans and other living things. While absorbing CO_2 and other harmful gases, it also provides the atmosphere with O_2 gas, which is very important for living things. It provides enough O_2 for approximately 18 people per acre of land each day (Yılmaz et al., 2011).

In this study, the ecological functions of urban open green areas are emphasized. In this context, the importance of carbon sequestration of plants, one of the ecological functions, was emphasized. It has been stated that the importance of systematic and sustainable planning of the urban landscape of the carbon sequestration of plants has increased even more. Carbon sequestration has been considered very important in the world agenda since the end of the 20th century. Carbon dioxide accumulating in the atmosphere as a result of increasing human population and fossil fuel consumption is one of the most important causes of global warming. In the fight against global warming, forest ecosystems and forest products store the carbon dioxide (CO_2) they take from the atmosphere through photosynthesis as carbon in their structures (Zanchi et. Al., 2012).

2.1.Urban Open Green Area-Carbon Relationship

While plants absorb CO2 and other gases, they also provide O2 gas in the atmosphere, which is very important for living things. Thus, they keep the carbon dioxide and oxygen balance, which is very important for the world ecosystem, under control (Nowak, 1993). Plants improve air quality by filtering pollutants (dust, ash, pollen, smoke, etc.) that are harmful to humans and other living things (Meyer, 1977). In a study conducted in Beijing, China, it was determined that trees in the city center remove 1261.4 tons of pollutants from the air and absorb 0.2 million tons of CO_2 (Yang et al., 2005). In the research conducted by McPherson (2003), it was revealed that 6000000 trees hold approximately 304000 tons of atmospheric carbon dioxide and substances (Önder & Akbulut, 2011).

He stated that Barcelona urban forests contribute to urban ecosystem services by storing 113,437 tons of carbon and tying up a net amount of 5,422 t/y of carbon. In addition, urban forests also contribute to improving air quality, carbon sequestration, reducing temperature and noise, and regulating water flow (Choudhury et al., 2015; Çoban & Yücel, 2018).

Trees take the carbon in CO2 gas and store it as cellulose in the wood tissues and release the oxygen back into the atmosphere. A healthy tree can store 2.6 tons of carbon in approximately 6 kg area per year. Trees also reduce the greenhouse effect due to their shading effects. With this effect, it reduces the need for cooling by 30%. Therefore, it enables the use of less fossil fuels in the production of electrical energy required for these processes. CO2 is removed from the atmosphere. It stores carbon in wood tissues and creates cooling effects. Because of this, trees are an effective tool in the fight against the greenhouse effect (Barış et al., 2004). He stated that Barcelona urban forests contribute to urban ecosystem services by storing 113,437 tons of carbon and tying up a net amount of 5,422 t/y of carbon. When the studies carried out in 10 cities of the United States are evaluated, it has been determined that the urban forests in the USA hold and store 700 million tons of carbon. Again, it has been determined that the US urban forests meet the national average of carbon storage and forest areas meet the national average of carbon storage (Nowak et al., 2006).

3.Planting-Carbon Relationship in Landscape Area

Landscape is a socio-ecological system that creates a living environment for living things and people. The continuous increase in energy consumption and use of raw materials, the development of consumption culture and the parallel unlimited competition, along with all these, the unlimited use of nature has also increased carbon emissions. The importance of open and green areas has increased even more with the positive services and contributions it provides to the urban ecosystem. For this purpose, it

has recently become important to undertake the task of carbon capture and storage by increasing the number of trees and the surface area it covers in the urban area. With the increase in carbon emissions, the global balances have been disturbed, and the importance of the existence of open green areas in cities has led to the development of awareness. Open green areas in cities; roadside afforestation, residential gardens, plantings in central medians, in this sense, potential places for carbon sequestration are landscape areas. One of the most important ecosystem services provided by planting in landscape areas is the 'Carbon Footprint'.

Carbon footprint, which is one of the ecological footprint components; It is a measure of the CO_2 emissions that occur at each stage of the product life cycle (production, transportation, use and disposal) (Wiedmann & Minx, 2008). It arises from the combustion of fossil fuels, including domestic energy consumption and transportation (such as cars and airplanes). It is defined as a measure of the CO_2 emissions associated with the manufacture and eventual degradation of the products we use from the entire life cycle(Figure 5).

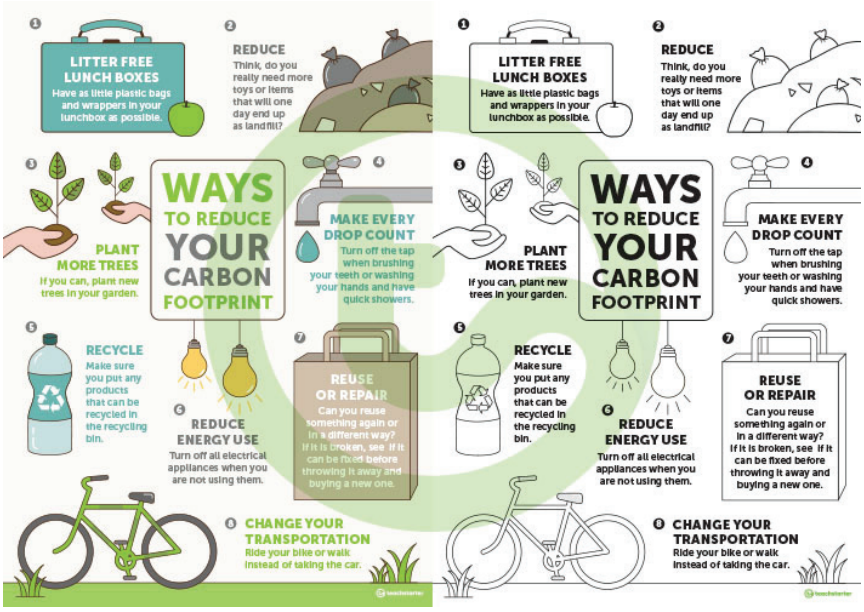

Figure 5. Reduce Carbon Footprint (Url-7)

The carbon footprints of the products and materials of the landscape elements used in landscape architecture applications should be low. From this point of view, urban equipment elements (seating units, plant boxes,

garbage cans, bus stops, billboards, lighting elements) should be made of wooden materials. When the carbon footprint values of the reinforcement materials used in open green areas are examined, it is seen that the carbon footprint of copper, PVC plastic and steel is at the highest level, and natural materials such as wood and similar wood materials are at the lowest level. This result reveals that the use of natural materials should be emphasized. Natural materials provide comfort in terms of supply, as well as provide great convenience in terms of economic reasons (Figure 6) (Karaçor, 2010).

Figure 6. Reinforcement Element (Url-8;Url-9)

In particular, in the material selection of landscape reinforcement elements; Attention should be paid to the use of natural materials, attention should be paid to the use of edible plants, especially in residential gardens and small green areas, natural plant groups should be preferred, natural coatings or pebbles should be used for water management instead of grass areas, roof gardens or planted surfaces should be used. In plantings in urban areas, deciduous trees should be designed to provide an opportunity to benefit from the winter sun, and evergreen trees should be designed to provide a wind screen.

CONCLUSION

With urbanization, built environments have increased, and as a result of this situation, the amount of green space in cities has decreased. As a result of the decrease in open green areas in cities, cities and people have been adversely affected. Considering the functions and functions of urban open green spaces, future use is negatively affected in terms of sustainable planning. These areas are the areas that are naturally found or artificially established in and around the city and provide aesthetic and functional contributions to the urban structure. These are the areas that can offer different recreational opportunities to the people of the city and

have transportation opportunities in a short distance. Making cities livable spaces can be achieved by reducing carbon emissions and improving the urban ecosystem and aesthetics. Urban open spaces are the most important carbon sinks in terms of holding 76-78% of the organic carbon in the terrestrial ecosystem. In addition, they contribute significantly to reducing the negative effects of global warming and to climate protection at regional and global level. It is one of the important green infrastructure systems that can be used to reduce the negative effects on the climate.

Urban open green spaces are the largest terrestrial carbon reservoir among carbon sinks. Even as plants age and shed their leaves, they continue to capture and store carbon in the atmosphere. However, cities are faced with great risks due to the reduction of open green spaces in the city, deterioration and long-term effects of climate change. The most effective solution to this situation should be to increase open green areas.

In order to reduce greenhouse gas emissions that cause global warming and to be successful in combating climate change, carbon footprint determinations should be made in urban landscape applications. Carbon footprint calculations should be taken into account in future landscape design plans. It should be designed with the right decisions and rational results, especially considering the protection-use balance of natural and cultural components and environments. It should be planned, designed, repaired, protected and managed in accordance with ecological, economic, aesthetic and functional criteria. The carbon footprints of all structural materials used in landscape architecture should be calculated, and necessary studies should be carried out after the designers have sufficient environmental awareness.

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CHAPTER 5

MONITORING COMMERCIAL MARINE TRAFFIC VIA GEOGRAPHICAL INFORMATION SYSTEM CASE OF AEGEAN SEA[1]

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1 This article has been derived from "Monitoring Commercial Marine Traffic Via Geographical Information System-Case Of Aegean Sea" which is the post graduate thesis of Tekin ERDOĞAN under supervision of Muhammed AYDOĞAN, at The Graduate School of Natural and Applied Sciences of Dokuz Eylul University, Department of Geographical Information Systems; (Erdoğan, 2012).

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1. Introduction

The emergence of maritime relationships of societies dependent on water and water resources for the continuity and development of their existence is due to their concerns about utilizing large waters. The geographical and natural conditions of individuals, communities, and societies turned their maritime matters into self-interests and then such self-interests have been diversified and expanded. This is indicated by maritime transport accounting for 90% of the total transportation volume worldwide.

Maritime trade, which is the purpose of this study, is based upon the transport and exchange of commodities from one coast to another using accessible, cheap, safe marine transportation facilities. However, it has become a passenger and cargo transportation trade primarily over time.

With its growing economy and increasing trade capacity, Türkiye has become an important country with potential maritime trade within its region. Maritime trade is vital for Türkiye, a developing country with an increasing import and export volume; thus, it should be improved and increased. Due to its geopolitical position, Türkiye is a junction area between three continents. Hence, world maritime trade is essential not only at a national level but also at an international level. The Aegean Sea, with significant underground resources, ports, and many gulfs, is a junction between the Black Sea and the Mediterranean. However, the safe management of maritime trade in the Aegean Sea is a complex issue due to problems concerning continental shelf, etc.

This study examined how to utilize emerging technologies to clarify the rights and duties of different components within a given area and create an active control system to overcome complex management problems by using Geographical Information Systems. In line with this purpose, this study investigated the most effective method to monitor the whole sea surface for 24 hours uninterruptedly using the integrated maritime surveillance system. This study also sought answers to questions concerning the type of radars used during naval surveillance operations, the positioning of radars to ensure the most effective and maximum coverage area, the required number of radars, the coverage area of radars in the Aegean Sea, and the coverage ratio of radars under adverse conditions. DTED1 (Digital Terrain Elevation Data) maps were used during these investigations. These maps contain digital terrain elevation data and have one point per 100 meters sensitivity rate. Furthermore, the viewshed analyses were conducted using Global Mapper software. Based on these analyses, necessary propositions and results were developed.

2. Maritime Security for Türkiye

Turkish straits, one of the essential waterways in the world with no alternative, are the internal waters of Türkiye. Moreover Türkiye also controls the Suez Canal with many vital waterways. Therefore, any threat of terrorism in such geography, whether aimed at Türkiye or not, will directly affect Türkiye's security and economy.

Today, commercial maritime transport is much more freely and safely carried out all across the world when compared to road and air transport. Therefore, any interruption of maritime transport for some reason or failure to maintain its security may cause significant damage to the global economy. For example, oil prices almost doubled after both parties attacked oil tankers in the Persian Gulf during the Iran-Iraq war.

"Eight out of nine vital waterways among the most important 18 waterways in the world pass through the Mediterranean." (Davutoğlu, 2002) The blockage of the relevant eight waterways in some way will severely hamper the world maritime trade and oil transportation.

Türkiye is a country which has caught and maintained the growth trend and depends on the sea for 85% of its trade activities. Thus, it should develop strategic plans related to the use of maritime trade routes of great importance for Türkiye and maintain its security. This is a must not only for Türkiye's self-interests but also for other countries' interests.

3. Activities For Monitoring Marine Traffic

3.1 Turkish Straits Vessel Traffic Services

Turkish Straits Vessel Traffic Services (TSVTS) was commissioned on December 30, 2003, to improve the safety of navigation, protection of life, property, and environment in the Turkish Straits, to monitor and manage marine traffic in the respective area, and to reduce the risks of possible maritime accidents. In addition to both the Dardanelles and Bosphorus, the Sea of Marmara, with an attachment of 3 Traffic Monitoring Stations (TMS) (Armutlu TMS, Bozcaada TMS and Şarköy TMS), was also included in the system on July 02, 2008, to monitor the vessel traffic running within the traffic separation scheme in the Sea of Marmara. Figure 1 shows the integration of the Sea of Marmara into the central system, covering the whole area within the traffic separation outline of Marmara and the 20-mile area located on the west and southwest of Bozcaada (Tenedos). With this integration, it is now possible to continuously monitor the vessel traffic from the Aegean Sea to the Black Sea (TCS, 2010).

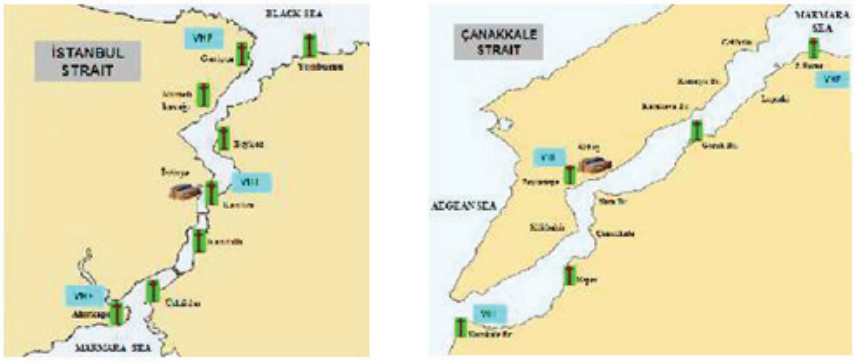

Figure 1: *TSVTS and Traffic Monitoring Stations (TCS, 2010)*

3.2 The Project for the Vessel Traffic Management System

The bodies of water that make up the Turkish Straits are the Dardanelles (37 miles), the Sea of Marmara (110 miles) and the Bosphorus (17 miles). The Turkish Straits, stretching from the Black Sea to the Aegean, with a total length of 164 nautical miles, have no alternative and thus are of high importance for the economies of all countries, especially the Black Sea countries.(TBGTH, nd, http://www.kegki.gov.tr/)

The Project for the Vessel Traffic Management System is intended to install a system which collects information on any vessel movement in the Turkish Territorial Waters (whether within the area of Vessel Traffic Services or not) to improve the safety of navigation in the areas of İzmit, İzmir, İskenderun, and Mersin where the vessel traffic is heavy and dangerous, a large part in hazardous cargos is handled, and passenger transportation is carried out. (TCS, 2010)

3.3 Automatic Identification System (AIS)

An Automatic Identification System (AIS) is an automated tracking system used on ships to identify and locate vessels within a close range.

The International Convention for the Safety of Life at Sea (SOLAS) adopted by the International Maritime Organization (IMO) requires AIS to be fitted aboard international voyaging ships with gross tonnage (GT) of 300 or more and all passenger ships regardless of size. The AIS operates on VHF marine frequencies. AIS transponders broadcast information at VHF marine channels 87B (161.975 MHz) and 88B (162.025 MHz) using Gaussian minimum shift keying (GMSK) modulation. As the sound is unclear, the AIS requires a receiver or transponder to process the sound (GemiTrafik.com, 2011) .

The vessels using the AIS system (and VTS stations regulating the

marine traffic) can display a great deal of detailed information provided by AIS equipment, such as unique identification, call signs, coordinates, course, speed, vessel dimensions, destination port, and the estimated time of arrival. AIS covers a shorter range than the radar systems used on ships but provides much more detailed information.

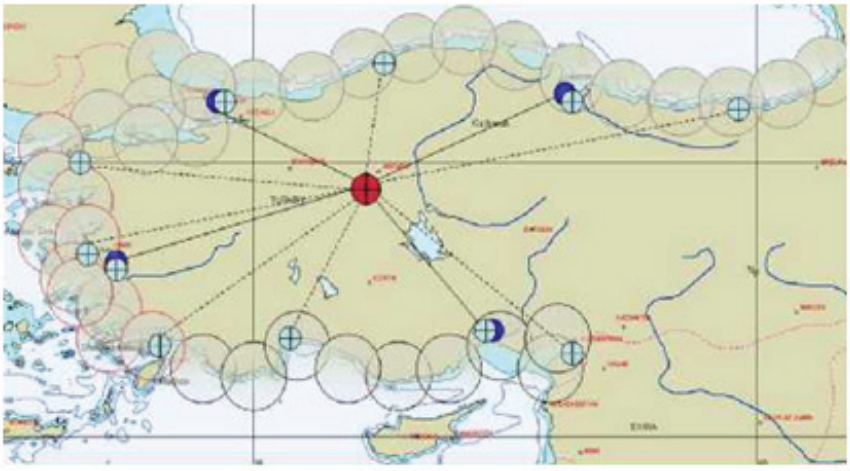

Figure 2: *AIS terminals and their coverage (Kuloğlu, 2008)*

The AIS system can be used effectively for national security by the relevant institutions and organizations of Türkiye to interrogate ships navigating in the surrounding seas and narrow waters such as straits and inland waters, and to automatically get necessary information related to boats such as unique identification, speed, position, etc. Furthermore, the real-time tracking of civilian vessels navigating the sea is imperative for effectively performing tasks and activities such as maritime search and rescue, combating trafficking, and preventing marine pollution. (TCS, 2010). Therefore, the AIS system serves many purposes, including:

- Maintaining more secure and safe navigation on Turkish coasts
- Preventing maritime accidents and contributing to emergency response operations during maritime accidents
- Improving effectiveness in search and rescue activities
- Preventing trafficking and illegal immigration
- Controlling fishery activities

(TCS, 2010)

3.4 Long-Range Identification and Tracking System

Maritime security has become one of the major issues after the September 11 attacks in the USA. Considering that the AIS system has the capability of tracking only ships navigating at a close range from the coast, a project for Long Range Identification and Tracking (LRIT)

The IMO developed a system to track vessels at a longer distance from the coast (beyond AIS coverage) as terrorists target maritime transport. (LRIT System, nd, http://www.polestarglobal.com)

The LRIT project applies to the following ship types engaged on international voyages:

- All passenger ships, including high-speed craft,
- Cargo ships, including the high-speed vessel of 300 gross tonnages and above, and
- Mobile offshore drilling units.

In this scope, IMO member countries can get long-range identification and tracking information related to ships for security and other aspects agreed upon by IMO and the responsibilities of the flag, port or coastal countries have been identified.

Thanks to the LRIT system, within the regulations adopted by the IMO, a country will be able to interrogate:

- Ships flying their flag
- Inbound and outbound vessels in its port
- Vessels navigating at a distance of up to 1000-mile from their coast
- Vessels navigating for search and rescue purposes

3.5 Cospas-Sarsat System

Cospas-Sarsat (COSPAS: Cosmicheskaya Sistyema Poiska Avariynich Sudov- Space System for the Search of Vessels in Distress – SARSAT: Search And Rescue Satellite Aided Tracking) is an international satellite-based search and rescue (SAR) distress alert detection and information distribution system established by Canada, France, the United States, and the former Soviet Union in 1979. It is best known as the system that detects and locates emergency beacons activated at the frequencies 121.5 MHz, 243 MHz or 406 MHz by aircraft, ships, and backcountry hikers in distress and then starts to search and rescue operations as soon as possible. Türkiye has been involved in COSPAS-SARSAT system in the capacity of Ground Segment Provider as from June 11, 2005 (TCS, 2010)

4. Integrated Maritime Surveillance System

The continuous surveillance of borders, including maritime boundaries, of a country like Türkiye, surrounded by seas on three sides, is critical concerning security and national defence. Furthermore, continuous surveillance is also necessary for various reasons, such as terrorism, smuggling, illegal fishing, environmental protection, fishery activities, oceanography, and illegal immigration. Maritime surveillance systems play a crucial role for a country like Türkiye, which has substantial potential for maritime trade.

The utilization and improvement of maritime trade are of vital importance to Türkiye, which is the 16th largest economy of the world and an essential power in its region, due to its strategic position surrounded by seas on three sides, its increasing import and export volumes, and its rapidly developing country profile. Therefore, Türkiye must monitor its coasts, especially the Aegean Sea with numerous gulfs, cliffs, and thousands of nested islands.

Considering the chronic disputes with the neighboring countries, the importance of surveillance and monitoring traffic in the Aegean Sea for Türkiye becomes more apparent. Türkiye, located at the junction point of three continents, is an essential route for illegal immigration and trafficking via the Aegean Sea into the European Union, with a high level of welfare. Therefore, it is necessary to maintain the safe execution, monitoring, and control of maritime trade on coasts.

The Aegean Sea, with a coastline of 3484 kilometers, excluding the geographical formations such as islands, islets and rocks whose sovereignty has not been transferred by agreements, is not only of commercial importance for Türkiye but also of great importance for other world countries. Furthermore, the Aegean Sea is a special zone where even minor events draw public's attention. Thus, it is targeted by terrorists and interest groups aiming to create regional instability. Considering this, the Aegean Sea, where terrorist actions can make a tremendous and quick impact, should be protected meticulously and controlled without causing any crisis or allowing terrorist activities.

The surveillance of maritime boundaries is a must for Türkiye, which depends on its ports for 90% of its foreign trade activities in parallel with its increasing tourism revenues and growing economy. In addition, Türkiye, which has ongoing territorial disputes with Greece, highly needs surveillance systems for security and defense purposes to determine border violations and take necessary measures to respond to emergencies, such as accidents, in the areas of responsibility.

4.1 Surveillance of Aegean Sea by Microwave Radar

"Microwaves" describe electromagnetic waves with a wavelength of 1 cm to 1 m. The corresponding frequency range is 300 MHz up to 30 GHz. Electromagnetic waves with a 1 to 10 mm wavelength are called millimeter waves. The infrared radiation spectrum comprises electromagnetic waves with a wavelength of 1 μm to 1 mm. Beyond the infrared scope is the visible optical spectrum, the ultraviolet spectrum, and finally X-Rays. Several classification schemes are used to designate electromagnetic spectrum and frequency bands. The term "microwave engineering" is generally the engineering and design of information-handling systems in the frequency range from 1 to 100 GHz corresponding to a wavelength of 30 cm to 3 mm. The characteristic feature of microwave technology is the short wavelengths involved (Görür, 1996).

The use of microwave radars is limited to the horizon line. Therefore, for example, the field of view does not exceed 40 km even at a platform 40-50 m high from the ground. Microwave radars are deployed on aircraft or high hills to cover larger areas. During World War Second and shortly afterwards, the microwave was almost synonymous with radar because of the great stimulus given to the development of microwave systems due to the need for high-resolution radar capable of detecting and locating enemy aircraft and ships. Even today, many varied forms, such as weather-detecting radar, missile-tracking radar, missile-guidance radar, airport traffic-control radar, fire-control radar, etc., use a considerable part of microwave frequencies. As the propagation of microwaves is effective along the line-of-sight, it requires high towers with reflector or lens-type antennas as repeater stations installed at certain intervals along the communication path. Frequent travellers often see these links because of their regular use by highway authorities, utility companies, and television networks. A further means of communication by microwaves is using satellites as microwave relay stations. (Görür, 1996)

4.2 Purpose of Integrated Maritime Surveillance Systems

The objectives and functions of Integrated Maritime Surveillance Systems are as follows:

- To control coastal waters and maritime boundaries,
- To control marine traffic,
- To ensure the effective prevention of any form of smuggling and illegal immigration,
- To improve the effectiveness of marine search and rescue operations,

- To control fishery activities and maritime resources,
- To enhance the effectiveness of data and intelligence-gathering activities,
- To provide effective C4ISR systems (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance),
- To build a Maritime Picture and a Recognized Maritime Picture.

4.3 Components of the Integrated Maritime Surveillance System

Surface Wave Radar: The type of radar used varies according to the requirements. Two types of radars, including groundwave HF-VHF and microwave radars, are used in surveillance systems depending on the features of the area chosen for surveillance.

Other Sensors and Information Sources: The ships detected by radars may be identified using a database containing the records obtained via the AIS system of those ships registered to IMO. Furthermore, even webcam marine images published online may be used as an information source to build a Recognized Maritime Picture.

Data Fusion Engine: Data fusion engine is the core of the IMS system. Utilizing fusion, different sources of information are combined to improve the existing surveillance capability. The most obvious illustration of fusion is using various sensors to detect a target or build a layered picture. A central data fusion engine automatically correlates target detections or tracks from HF and microwave radars. This function is called a "correlator". It is used to reduce two or more channels, derived from other sources whenever HF radar is not in use, to one way in real-time and in an accurate manner. (Ding & Kannappan & Benameur& Farooq & Kirubarajan, 2003)

Data Distribution Server: Data Distribution Server provides all necessary data and services for authorized clients.

IMS Administration: Manages changing configurations, operating and non-operating conditions of IMS system, user accounts and security, and data areas, and maintains logs and backups and retrieves them. Furthermore, it provides a Recognized Maritime Picture to the authorized clients within the scope of their rights.

Communications Infrastructure of the IMS: An architecture of data transfer infrastructure is constructed (Figure 3). Satellite systems may be used for data transfer on land at high points where microwave radars are deployed.

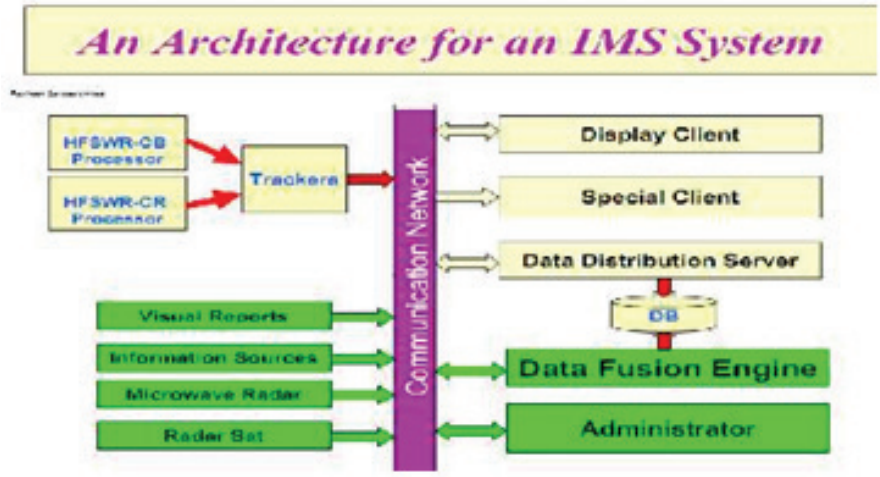

Figure 3: *The proposed IMS architecture (Ding & Kannappan & Benameur& Farooq & Kirubarajan, 2003)*

5. Viewshed Analyses Of Maritime Surveillance Radars

Radars are one of the significant elements of integrated maritime surveillance systems. The target detections or tracks derived from radars help build a recognized maritime picture with other information sources. This picture contains numerous elements, including trade ships, fishery ships, and passenger ships. It will help the officials to control commercial traffic and combat trafficking and respond to emergencies. To build the most effective recognized maritime picture, Microwave X-Band radars, whose coverage is limited to the horizon line, should be deployed at the highest points with the best line of sight in the Aegean Region. The Aegean Sea has numerous islands, so HF radars were not used in this case as they lose conductivity on land.

The Aegean Sea, having different features from the Black Sea, the Mediterranean, the Sea of Marmara, and even most of the world, has been chosen for our analyses as it has numerous cliffs, bays, and thousands of islands. Monitoring the commercial traffic in the Aegean Sea, radar viewshed analyses were made by Global Mapper software using DTED1 Maps between the latitudes E-20 and E-36 and between N-35 and N-41.

The purpose is to simulate the change in the capability of monitoring the current situation in case radars of different types, which were placed at different positions on the maps built via GIS tools. For this purpose, creating a structure to model the topography on digital base maps was necessary. Therefore, in the first stage of the application, different base maps

used for interpreting elevation data were handled, and then the possible analyses on such maps were assessed.

5. 1 Viewshed Analysis with a Microwave Radar

X-Band radars, operating in the frequency range of 8 to 12 GHz, are used for maritime surveillance (Camponeschi, M., Bevilacqua, A., Tiebout, M., & Neviani, A., 2012). In addition, most companies worldwide produce X-Band Radars for military and civilian purposes. Therefore, within the scope of this study, a standard coastal surveillance radar was taken into consideration and analyses were carried out considering the technical specifications of this radar.

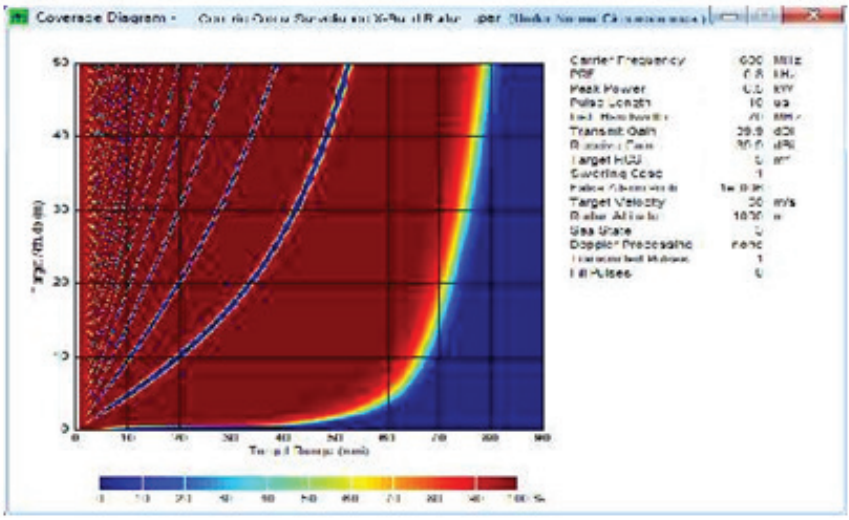

Figure 4: *Coverage diagram of a generic coastal watcher X band radar at a radar altitude of 1000 meters*

As shown in Figure 4, the coverage of a Generic Coastal Watcher X Band Radar, operating at a frequency of 600 MHz and deployed at an altitude of 1000 meters, is approximately **65 nautical miles** at the sea surface (Dowdeswell, J. A., Whittington, R. J., & Hodgkins, R., 1992). This result was obtained at an air temperature of 15° C, under still wind and a humidity of 70%. Therefore, in the scope of this study, the viewshed analyses under normal conditions were performed based on a radar coverage of 65 nautical miles.

Radar cross-sectional area and, thus, radar coverage are reduced under adverse conditions such as rain, moisture, wind, fog, and noise. Figure 5 shows the behaviour of a Standard Maritime Surveillance Microwave Radar under adverse conditions.

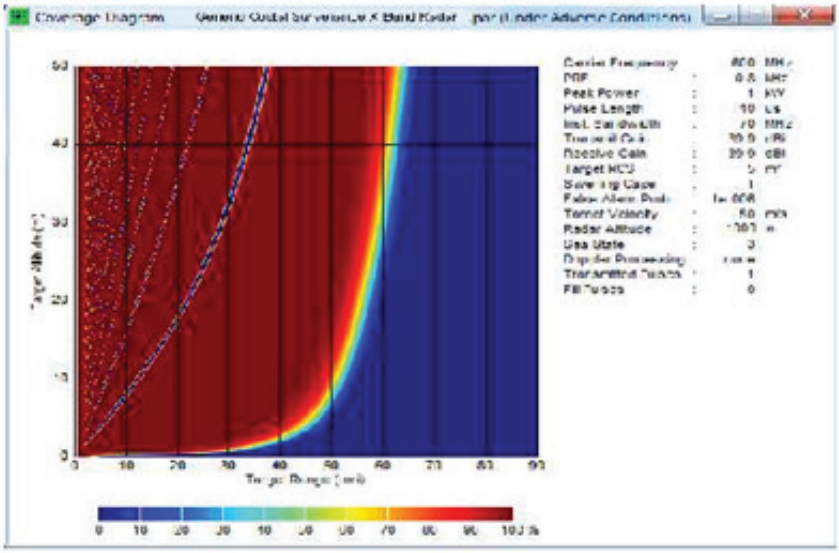

Figure 5: *Coverage diagram of generic coastal watcher X band radar at a radar altitude of 1000 meters*

As shown in Figure 5, the coverage of a Generic Coastal Watcher X Band Radar is approximately **50 nautical miles** at an altitude of 1000 meters. Therefore, in the scope of this study, the viewshed analyses under adverse conditions were performed based on a radar coverage of 50 nautical miles.

5.2 Viewshed Analysis of Territorial Waters

As shown in Figure 4, a Generic Coastal Watcher Radar covers an area of 65 nautical miles at a radar altitude of 1000 meters. Figure 6 shows the viewshed analysis of the Turkish territorial waters with radars deployed at the most appropriate positions according to the 6-mile limit.

Radar 1, with an antenna height of 10 meters, was deployed at an altitude of 694 meters in the Dardanelles region to cover the north Aegean Sea region. Figure 6 shows the coverage of Radar 1, which covers the entrance to the Dardanelles strait and a large part of the north Aegean Sea region. Radar 1 has a field of view of 47.9% surrounding the sea surface in a circle of 360 degrees. This result indicates territorial waters of Türkiye and some of the high seas within the related region of interest are covered by Radar 1.

Radar 2, with an antenna height of 10 meters, was deployed at an altitude of 1206 meters in the Izmir region to cover the middle Aegean Sea region. Radar 2 has a field of view of 36.8% surrounding the sea surface in a circle of 360 degrees. The cross-sectional area of Radar 2, covering the

Izmir Region and the middle Aegean Sea region, is lower than the north Aegean Sea region due to the higher number of islands, islets, cliffs, and gulfs in the coverage area of Radar 2. This analysis indicates that not all but a large part of the territorial waters of Türkiye and high seas within the related region of interest are covered by Radar 2, with a coverage of 65 nautical miles under normal conditions.

Radar 3, with an antenna height of 10 meters, was deployed at 1145 meters in the Marmaris region to cover the south Aegean Sea region. Radar 3 has a field of view of 45.5% surrounding the sea surface in a circle of 360 degrees. Radar 3, deployed at a lower altitude than Radar 2 and substituting the eastern Mediterranean region and the south Aegean Sea region with more islands, islets, cliffs and gulfs, as compared to the middle Aegean Sea region, does not have a coverage of less than that of Radar 2. The result is the favourable position of Radar 3 and deployment at a much higher point than the surrounding elevations. The change indicates that almost all territorial waters of Türkiye and the high seas within the related region of interest are covered by Radar 3, with a coverage of 65 nautical miles under normal conditions.

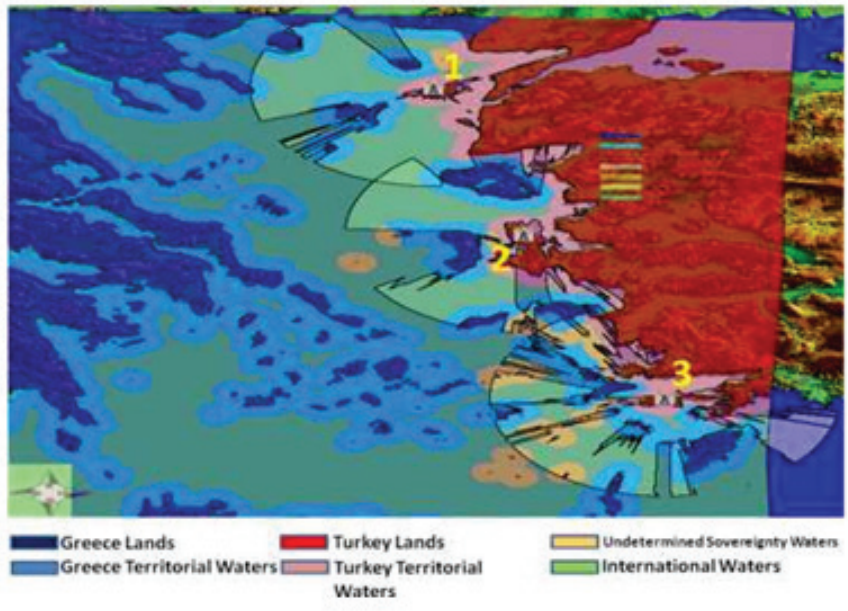

Figure 6: *Viewshed analysis of territorial waters under normal conditions*

Consequently, it is seen that almost all Turkish territorial waters in the Aegean Sea region and a large part of the high seas in this area are covered by three microwave radars with a coverage of 65 nautical miles under normal conditions. Furthermore, the study reveals radars should deploy at the best field viewpoint rather than at the peak point.

5.3.Viewshed Analysis of Territorial Waters under Adverse Conditions

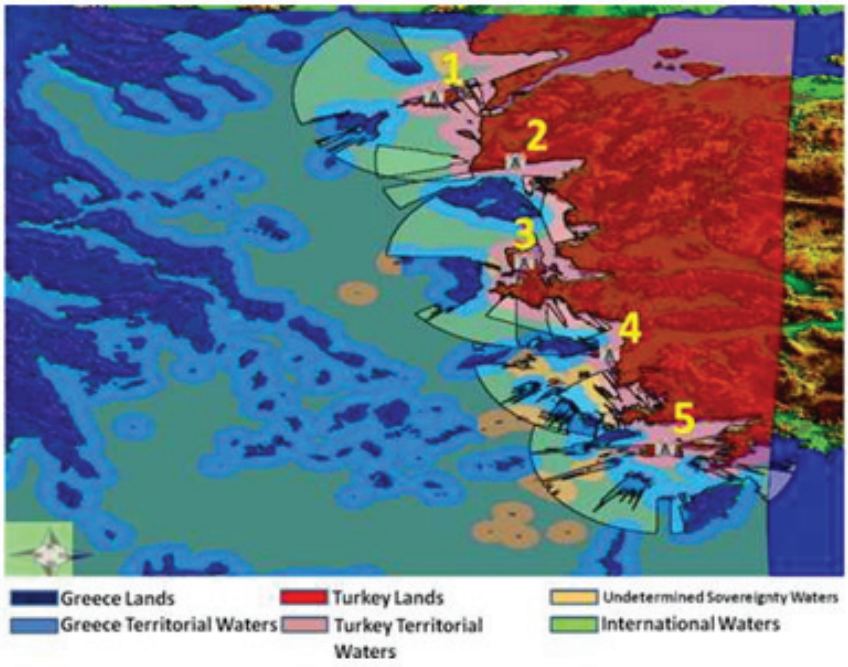

***Figure** 7 Viewshed analysis of territorial waters under adverse conditions*

Figure 7 shows radars with a cross-sectional area of 50 nm. It has been demonstrated that the coverage provided by three radars used in the analyses conducted under normal conditions was insufficient to cover the Turkish territorial waters under adverse conditions. Therefore, two more radars were deployed in addition to three radars with an optimum performance under normal conditions. These radar points are numbered 2 and 4 in Figure 7.

Consequently, it is seen that all Turkish territorial and a large part of the high seas within the related interest of the region are covered with the deployment of two additional radars. Especially, Radar 2 was deployed to provide complete coverage inside the gulf.

6. Conclusion

The Aegean Sea, having different features concerning geographical difficulties and diversity, was chosen as the subject of our study. Furthermore, a methodology was developed to correct the deployment of radars as one of the significant components of the IMS system. Also, the applicability of this methodology to other regions was evaluated.

The Aegean Sea is a valuable asset for Türkiye's economy, and its surveillance is vital for security. However, this critical region is targeted by terrorists due to its location on international transit routes and the related ongoing disputes between Türkiye and Greece. Therefore, the safety and security of commercial traffic in this region should be controlled. Furthermore, the Aegean Sea is on a route for illegal immigration into EU countries. Today, 90.4% of worldwide crude oil production is transported by sea. Therefore, it is vital to maintain the safe navigation of ships carrying dangerous cargo as Türkiye is close to the energy corridors, namely Russia, Azerbaijani and Arabian countries, as energy exporters, and to the EU countries, as energy importers. For any possible accident, the scene of the accident should exactly be located and immediately reported to the relevant security units.

Due to such reasons, the construction of a recognized maritime picture, which enables monitoring of commercial traffic in Türkiye's territorial waters, especially in the Aegean region, is of considerable importance. As a result of evaluations in the scope of this study, Integrated Maritime Surveillance (IMS) system has been chosen as the most effective method for monitoring the sea surface. This study describes the architecture and features of the IMS system. The primary objective of the IMS system is to construct a recognized maritime picture.

To build a comprehensive maritime trade picture, the required number and deployment locations of radars, one of the most critical components of the IMS system, and their coverage under different conditions were examined in the scope of our study. The breadth of the area chosen for surveillance and the features and positions of radars determine the number of radars for coverage processes. It is assumed that the best coverage is provided by deploying microwave radars, whose range is limited to the horizon line, at the highest possible point. However, numerous deployment attempts in this study's scope have revealed that the highest point does not have the best angle of vision (coverage).

X-Band radars are sufficient to monitor the territorial waters of Türkiye and international transit routes within the respective region of interest. Maritime control is maintained, thanks to the high resolution of X-Band radars, meticulously. Moreover, a system backup can be supported using mobile X-Band radars for situations such as war, disaster etc. Mobile X-Band radars can provide the desired focus, and the outputs can be evaluated within the scope of the IMS system. Therefore, it may be helpful to develop and use such radars.

Thanks to radar stations, a meaningful regional maritime picture will be built by fusing data from AIS and other information sources

and thus pooling them in a single center. Assuming that our coverage area is 65 nautical miles under normal conditions, it is concluded that additional information sources, such as LRIT and COSPAS-SARSAT, are required to cover more extensive regions, such as search and rescue areas. Furthermore, it is shown that the recognized maritime picture will provide meaningful data when combined with target detections and tracks derived from radars.It is evaluated that more precise analyses may be conducted in the case of DTED Level 2 and DTED Level 3 maps, which are more accurate than the DTED Level 1 map used in our studies.

The security of Turkey's territorial waters is more important than ever these days. The territorial waters problems with Turkey and its neighbours have been brought to the international courts. In addition, irregular migration, illegal trade, accidents, and sudden interventions make it essential for Turkey to monitor its territorial waters carefully and analyze this traffic in detail. In this context, the Aegean Sea is the region that needs to be examined most straightforwardly and effectively in order to obtain a picture of commercial maritime traffic. This study explains how the infrastructure and information technology architecture should be in order to create a maritime traffic picture that will not leave a blind area and will be watched most effectively. It also examines where the radars, which are the information providers of this fission system to be created, should be positioned most effectively. Factors such as weather conditions, altitude, and visibility were considered, and the most optimal commercial sea traffic was analyzed.

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