

# Architectural and Engineering Research and Practice



**Editor**  
**Prof. Dr. Yeliz AŞÇI**



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# **PREFACE**

This book titled “Architectural and Engineering: Research and Practice” consists of fourteen chapters presenting current academic studies in the field of Architecture and Engineering. This book will also be an important resource for all academics, researchers and students. I would like to express my endless thanks to all the authors who contributed to the publication of this book, to all the referees who carried out the review of the work, and to Livre de Lyon Publishing House.

**Prof. Dr. Yeliz ASCI**  
**Editor**



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## CHAPTER I

# LOST MEMORY PLACES AND SENSES: A MEMORY ROUTE ON ISTIKLAL STREET

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### 1. Introduction

**T**he power that carries a society to the future is the memory of the city in which it lives. Memory is fed by the architectural structures that make up the city. The demolition and reconstruction of architectural structures create new layers of meaning for the city. This transformation of places directly affects the sense of belonging and urban memory. The ability of a place to take place in the memory is closely related to the sense of belonging there. Only those that belong to that place have meaning for the people. Places that have meaning for people are called memory places. Memory places undergo change and transformation over time. The new environment, which formed as a result of urban transformation and consumption society, causes the change of the layers of meaning of the city and the society living in it, thus also the memory places. It is seen that common values have been lost, and the city has lost its old identity due to the closure or destruction of these memory places that feed the society. According to Eleni Bastea (2004), the transformation of urban and architectural spaces

can change desires, needs, and expectations, destroy or build memories, and change the city's identity. On the other hand, memory establishes a relationship with the existing space.

In this respect, the memory should be kept fresh (Bastea, 2004). Preserving the urban identity is vital to research the places of memory that have meaning for people and raise awareness about protecting these places. For the spaces to preserve their meaning, they must either be re-experienced or gain new layers of meaning by preserving the old. The article titled "Istanbul: The city as an urban palimpsest" (2021), written by Hülya Turgut on this subject, revealed that the practices encountered in daily life affect social life and culture and revealed that dialogues could reproduce space (Turgut, 2021). Talking about, thinking about, and discussing places that carry cultural traces creates layers that maintain the existence of these places and carry traces from the past to the future. Turgut inspires this work by supporting the necessity of preserving the places bearing the traces of the past to protect urban and social memory.

This study aims to reveal the effect disappearance of memory places on the identity of the city and the bond these places establish with people through the senses. Sampling the bond established with places on Istiklal Street, contributing to the literature with qualitative research, and raising awareness about the preservation of memory places are among the objectives of this study. Within the scope of this research, first of all, the places of memory in the world are mentioned. In addition, the memory places in Istanbul were investigated, and the effects of the places that changed function on the memory of Istiklal Street were included in the research. While theoretical information is reached through literature review, this process is defined qualitatively with a semi-structured interview form. The relationship between memory places and senses was analyzed with the semi-structured interview form. This form applied to 60 participants, 30 women and 30 men, who lived in Istanbul between 2012 and 2022 and experienced the spaces on Istiklal Street. The interview form reveals which places are remembered on Istiklal Street according to different age groups. In addition, it gives information about how effective the senses are in investigating the bond

established between the individual and the city. The places on Istiklal Street in the past that can be remembered with senses such as sight, touch, smell, taste, and hearing constitute the focal point of this form. In this direction, the effect of memory on the preservation of urban identity has also been investigated.

## **2. The Relationship Between Memory and Space**

The meaning of memory in TDK is "Memory: The power to consciously store experiences learned subjects and their relationship with the past in the mind, vocabulary, mind, memory, mind." The Cambridge dictionary defines it as "the ability to remember information, experiences, and people." Memory: It is the power to store in mind to revive impressions, sensations, live events, and their relationship with the past (Güçlü et al., 2011). Some stimuli such as color, odor, light, texture, and sound perceived by the sense organs are transmitted to the brain after being filtered according to personal characteristics (Aydınlı, 1986). The image created by these stimuli in the brain gains meaning by being associated with past experiences. Memory is constantly reshaped according to the place's architecture built in the brain with the senses and experiences; every word, every face, every place, and every moment that is wanted to remember describes a corner of this palace (Brook & Spence, 1986). The concept of space plays an essential role in stimulating memory with the senses. While space is a void created by boundaries, the idea of place refers to the lived and experienced space (Taylor, 1999; Agnew, 2005). In this respect, all experiences related to space gain permanence by affecting the sense of belonging of the individual. People instinctively add traces that they associate with their own identities to the places they live in. The feeling of belonging that exists with these traces determines the character of the spaces and contributes to the formation of memory places (Çakır, 2015). Urban, architectural, and interior spaces are perceived primarily by the individual; are then stored in memory. The experienced space becomes meaningful in the user's memory within the framework of individual and social events.

The concept of 'home' is an important example of memory, space, and a sense of belonging. Houses, the most basic living space of the individual,

reflect their owners' lifestyles by carrying their owners' traces and revealing the house's identity. Similarly, inmates in a prison ward differentiate their bunk beds with their personal belongings to give them a sense of belonging, which shows that they establish a bond with that place. The sense of belonging that prisoners gain over time affects the formation of spatial memory (Taşçıoğlu, 2015).

The acquisition of spaces in the memory is realized through the phases of sensation, perception, and coding into memory. In the sensing process, the physical characteristics of the space draw attention first; Then, the senses such as hearing, smelling, tasting, and touching come into play. At this stage, the space's physical reality and the individual's sense organs transform into a spiral structure (Gökmen & Özak, 2009). The perception process begins when the physical components of the space, such as colors, textures, and surfaces, interact with the individual's senses. The space perceived by the individual is stored in permanent memory. The space items in the memory vary according to the person, time, past experiences, type, and frequency of use. In this respect, social and cultural characteristics play an important role in forming memory places.

Senses and experiences constantly reshape spatial memory; at the same time, they feed by past situations and events. Spatial features encoded in the brain are recalled with sensory associations. The senses construct the events in the perception and coding space, as well as by recalling them from memory. Thus, space is no longer an object; simultaneously, dreams are built and lived; it turns into a concept evaluated not with the naked eye but with the mind's eye (Turgay, 2013).

### **3. Relationship Between Spatial Memory and Senses**

In every moment of life, in a place experienced for the first time, in the first encounter with someone, in the smell of food, or the musical notes heard, All senses are activated through sound, smell, and color imprisoned in the memory. The relationship between the experiences of the individual and the space enables him to be aware of the events even without seeing or touching them. For example, the human brain establishes a conceptual sensory

relationship between the child, the sound of the bell and the school, the smell of food and the kitchen, and even between a hot and steamy room and a Turkish bath, thanks to spatial experiences (Gökmen & Özak, 2009).

Zumthor says some places make you feel at home. He emphasizes that the objects in a place, the events that take place, and even a sound that is heard leave a trace in our memory, reminding place again with a small spark. (Zumthor, 2006). Thus, an endless transition between time and space is provided. In other words, having a different color in the space, hearing different sounds, and the occurrence of various events change the atmosphere of the space. For example, The murder in an ice skating area places the events in people's memories. In this context, all experiences in the space turn into experiences and remind themselves over time.

The people who experience the space also change over time. In the wonderland, Alice grows and shrinks within moments and perceives the space from a different angle each time. She copes with the differences between her dimensions and the space's scale and reproduces the space in his memory. This experiential change sets an example for the individual to be born and grow up, age, and perceive space differently at every stage of life. Memory constantly renews itself with the changes in the perception of space; space, on the other hand, turns into a breathing subject that establishes relations with its environment rather than a frozen and solidified mass (Burton, 2006). As the perceptual process changes over time, the dominance of the senses over the individual also changes.

While the most dominant senses were touch and taste in ancient times, vision and hearing have come to the fore in the recent past (Kızıl, 2000). Marcel Proust wrote a whole life in his novel 'In Search of Lost Time' based on the smell of madeleine chocolate he experienced in his childhood (Proust & Hakmen, 2011). The taste and smell he perceived in Madeleine cake, and Linden tea took him to his past. Even if people die and objects are lost, taste and smell are enough to bring everything back. In a dark hall with no physical stimuli, the perception of the space is more complex than in a hall with physical stimuli. In this respect, the visual factor is more decisive than the senses of sound and touch. The sense of taste is one of the essential elements

that enable the perception of the environment. The sense of taste directly affects the human body and memory and brings along a reminiscence process. This sensory perception also activates memory. Space perception, memory, and time work together. One of the examples related to the sense of taste is İnci Patisserie. İnci Patisserie on Istiklal Street, one of the important memory places of the city, was vacated in 2012.

One of the senses that enables the establishment of urban space in people's memory is the smell. The smell and the City exhibition, exhibited at Koç University Anatolian Civilizations Research Center Anamed in 2016, drew attention to the smells of the changing city (Url 1). Inspired by ancient Anatolian civilizations, the exhibition includes examples from the Ottoman Empire, such as musk, coffee, and rose water, and the exhibition offered the opportunity to experience all scents with the setup. All scents enliven another place in the memory. There is a powerful connection between memory and smell. In this respect, Istanbul contains urban spaces where memory is constantly kept alive. Very specific smells about the city are also quickly processed in the brain. In this context, the smell of fish in Eminönü evokes strong emotions and connects with those in your memory. This scent defines a region of the city and forms a part of Istanbul's identity (Ergin, 2015). Kuru Kahveci Mehmet Efendi, located in Eminönü and remembered for the smell of coffee, is one of the memory places of Istanbul. Although there is the same brand of coffee in all markets, hundreds of people daily line up to buy coffee there. Kuru Kahveci Mehmet Efendi defines the identity of the street he is on with the smell of coffee he emits. To ensure the identity continuity, the cultural past, the urban location, and the function of the place should preserve.

#### **4. The Effect of Memory Places on Urban Identity**

The memory of a city consists of people who have experienced the city and its architectural structures. Walking on a filled sea, walking around a shopping mall built in a place that used to be a shantytown, or returning to the home of childhood years later ensures that that place is reconstructed in memory.

Urban identity, on the other hand, consists of the qualities that enable the city to be read separately from the others and make it meaningful for

people. Identity consists of determining factors such as roads, nodes, edges, regions, and monuments that make the city unique and formed over time (Linch, 2014). The people living in the city, their lifestyles, and the city's environment also contribute to the retention of these elements in memory. Thus, it becomes easier for the city to be read and to have a place in memory; However, cultural identities in which memory places are influential are constantly changing in managing history and power (Hall & Mc Arthur, 1998).

In addition to looking city from a physical point of view, its connection with its past also affects the memory of places (Rossi & Gürbilek, 2006). The place that the built environment acquires in the individual's memory over time forms urban memory places. The preservation of the memory indicators of urban spaces ensures the protection of memory places and the continuity of culture.

#### ***4.1 Examples from International Memory Places***

##### ***4.1.1 Jewish Museum***

The Berlin Jewish Museum draws attention both as an architectural structure and a museum. Daniel Libeskind aims to maximize the sensory perception of people by providing an environment they are not accustomed to and to understand, feel and experience the Holocaust (Maden & Şengel, 2009). Libeskind comes from a family of Holocaust victims and sheds light on the lost history of the Jews by spatializing memory with the design of the Jewish Museum (Maden & Şengel, 2009). Some traces, signs, references, and symbols in the museum are founded on the concepts of history and memory. Libeskind based the design of the building on three main themes. These are continuity, exile (migration), and genocide (Tokyav, 2002).

To enter the museum, one must pass through the underground corridor. Visitors were asked to experience the feelings of hiding anxiety and losing their way with three different routes created underground. These feelings begin with the ladder of continuity, extending from the past to the future; It continues with the "Garden of Exile and Immigration" to remind those forced to leave Berlin. The third route consists of a genocide stalemate. The 'void,'

the most emotional and powerful space of the building, was designed in a cold, overwhelming atmosphere created by the concrete walls. The floor of this space, on the other hand, is covered with iron plates, given the shape of 10,000 expressionless faces (Tokyay, 2002). These plates represent the people who disappeared during the genocide process. By stepping on the plates in a thin and dim corridor, visitors feel many emotions, from fear to hope, with senses such as sight, touch, and hearing. The space perceived by the senses ensures that the experienced pains are recalled from the memory.

#### ***4.1.2 Blur Building***

The Blur Building is located on Lake Neuchatel in Switzerland. The relationship with the lake creates visual continuity with the environment. Instead of looking at the building, it aimed to be included in the view. Thus, the body experiences it fully (Doğan, 2006). The building, which turns into a visual sculpture with water vapor, creates the space's spirit and expresses eternity by merging with the sky like a timeless and meaningless cloud.

Visitors reach the center of the fog bank by following the long ramp. Only the hum of pipes was heard here. The appearance of the fog mass is constantly changing according to the weather conditions. The Fuzzy Structure expands depending on the air temperature, and in strong winds, the springs form long fog tails (Canbulat, 2007).

Before entering the cloud, visitors are given raincoats by completing a questionnaire reflecting their character profile. When the raincoats pass by the visitors, they change color according to their emotions and turn into a communication tool (Canbulat, 2007). The combined effect of visual, tactile, and auditory senses on the perception of space ensures that the Blur building remains in people's memory.

#### ***4.1.3 Twin Towers/World Trade Center***

Terrorist attacks manifest themselves in different cities and different ways, regardless of east or west. Attacks are made especially against politicians, famous people, and buildings, leaving unforgettable memories. The planes crashing into the Twin Towers on September 11, 2001, caused the death of

thousands of people, and this terrorist incident has been engraved in our memories (Demir, 2016). 19 Terrorists hijacked four passenger flights from Boston, New York, and Washington to San Francisco and Los Angeles and crashed into the Twin Towers in New York and the US Department of Defense Pentagon in Virginia (Demir, 2016). This attack remains in memory as one of the most extraordinary terrorist acts in human history. The Twin Towers are currently used as a museum and attract thousands of visitors.

The articles written about the September 11 attacks and the images in the media cause this place to become permanent in memory. In this respect, the event is constantly reminded and recorded in the visual memory, despite the passing of years, refreshes the memories of the event. These visual and auditory repetitions transfer the attacks to permanent memory. Memory also affects space. It allows it to cease being a fixed structure and attribute different meanings to the city and its identity.

Emotions play a role as well as people and events in the type of information stored in the brain. In happy moments, positive things are noticed, and in sad moments, negative things are seen and recorded in memory. This situation is called processing appropriate to the mental state (Bower, 1981). Not only words and facts but also events lead to the conclusion that memory is associated with emotions. As soon as the attack on the Twin Towers was heard, the emotions felt during the event revived; everything laid out like a photographic frame.

## ***4.2 Examples from National Memory Places***

### ***4.2.1 Haydarpaşa Train Station***

Haydarpaşa Train Station symbolizes Istanbul and constitutes one of the essential transportation points of the city. The train station represents the first connection point between the city and the individual, where people from Anatolia first set foot in Istanbul and saw the seagulls for the first time (Olgun & Altınır, 2014). The building's historical past is an important meeting point making it a bridge between the past and the future. An essential role of Haydarpaşa is to represent the interface of the city with the public space it

creates and to create one of the long-term memory points (Olgun & Altiner, 2014). The station building, which was built during the reign of Abdülhamid II and was the first place where people came from Anatolia by train for years to meet with Istanbul, hosted the dispatch of soldiers during the First World War and the enthusiastic welcome and farewells experienced during Atatürk's arrival and departure to Istanbul (Sakaoğlu, 2007). 1998). In 2004, the restoration process started after the emergence of projects related to the station and its surroundings. After the fire on the roof in 2010, nationwide train services in 2012 and suburban train services stopped in 2013 (Olgun & Altiner, 2014). Train stations gain value with the city and the citizens. Restoration and repair works are continuing in 2022. The ineffectiveness of the station causes Istanbul to break away from its identity in terms of its culture and urban memory.

#### ***4.2.2 Atatürk Cultural Center (AKM)***

Places such as AKM, Gezi Park, and Taksim Square constitute the city's public spaces as a whole. Especially cultural centers give an idea about the social structure of cities. These areas have witnessed many good and bad events from the past to the present; they are also considered important representation places in terms of political and urban identity (Sudaş, 2014). Atatürk Cultural Center opened as Turkey's first opera house, completed by Architect Hayati Tabanlıoğlu. Two years after its opening, the great hall and stage of the building were destroyed in the fire that broke out while Arthur Miller's 'Witch Cauldron' was being played (Sudaş, 2014). AKM was closed in May 2008 for renovations. Tabanlıoğlu Architecture was commissioned again to carry out the restoration. In 2013, the work stopped. It became the symbol of the resistance due to the posters hung on its front during the Gezi resistance. A photograph of the center decorated with posters is also included in the "Places of Memory" exhibition curated by Architect Murat Tabanlıoğlu at the 14th International Venice Biennale in June 2014 (Uluşahin, 2016). After the Gezi events, AKM was used as a police station for over a year (Girit, 2015). After these processes, Atatürk Cultural Center was left to its fate for eight years. The façade of the cultural center was preserved, and the

interior was completely rebuilt, and it was reopened in 2021 and brought to Taksim Square.

## **5. Istanbul and Istiklal Street in Memory**

Istanbul is a theater of memory. There are sidewalks, memories, childhood games, fears, and streets inside this theater, but these city riches are erased from memories over time (Critchley, 2015). To walk in this big city is to reminisce about places. Istanbul consists of a spatial network map formed by traces in memory (Critchley, 2015). Streets, avenues, fountains, monuments, parks, buildings, all the elements that make up an urban space form a part of this map. The buildings that define Istanbul reflect social life by determining the city's identity with their features and the environment they belong to. The quality and number of the structures that meet the needs of the society also give an idea about the period's political, political, and economic environment.

Istanbul hosts the historical texture from the past and the social structure together. The buildings and society's changes from the past to the present ensure the continuity of the urban memory. Buildings are classified as "symbol structures," "memorial structures," "witness structures," and "period structures (documentary structures)" according to their role in the formation of urban memory (Madran, 2001). Landmarks are reference points that enable the city to be recognized and play a more active role in remembering a settlement than other structures. Commemorative structures are built to commemorate events that concern the city or society. Witnessing structures form urban memory by witnessing important events in the past of the city or society. Period structures (documentary structures) reflect the architectural and social trends of the period in which they were built. Istanbul creates a whole in people's memory by hosting together with the structures that have become the city's symbols, witnessing memories and events. In a conversation between Marco Polo and Kublai Khan, Kublai Khan asks which stone keeps a bridge standing, and when he learns that it is the arch that keeps the bridge standing, he argues that the stones do not matter.

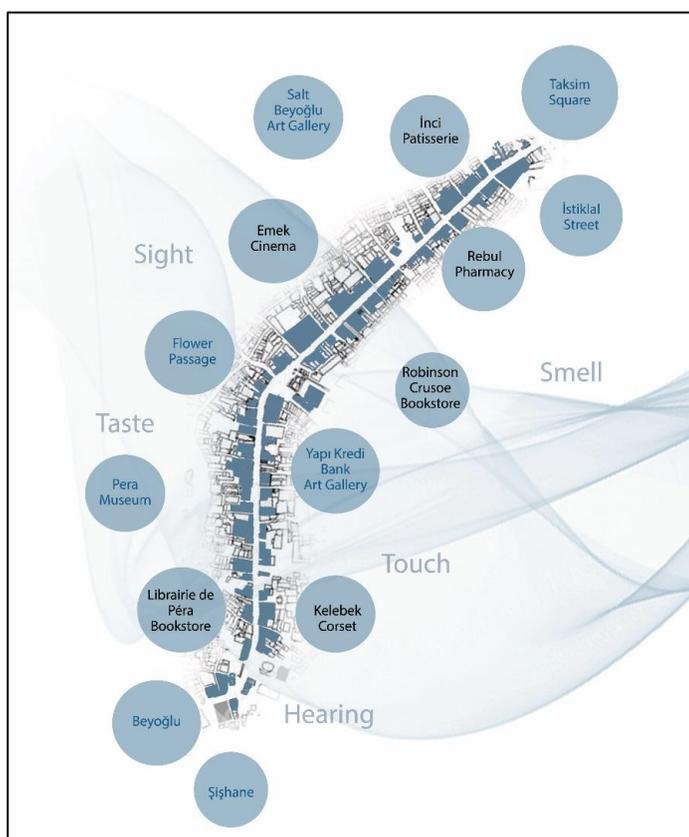
On the other hand, Marco Polo states that the bridge cannot stand without those stones (Calvino, 2012). What keeps Istanbul alive are the

structures that make up the city's identity with all its historical and social values. In this respect, the deletion of a building from the urban memory affects the identity of the whole city.

While parks, highways, bridges, shopping malls, and residences are seen as urban capitals in Istanbul, the places that are the collective memory of the society cease to belong to the local people (Kocabaş, 2006). Beyoğlu, one of the historical districts of Istanbul, has been undergoing change and transformation for years. İstiklal Street in Beyoğlu has been one of the places most affected by this transformation trend in recent times. For years, the street has managed to be a place where culture is created, shared, consumed, and reproduced. Today, however, the change in shopping trends due to shopping malls, the departure of local people from the region due to the increase in touristic businesses in the region, the change of society due to war and migration, the closure of places bearing the traces of the past, terrorist incidents change street's identity.

Beyoğlu-İstiklal Caddesi was affected by the migration from rural to urban in the 1950s. The street, known for its cultural identity in the past, caused visual pollution due to intense commercial use; the signs were removed because the tram was insufficient, and the street started to lose its identity due to heavy vehicle traffic. In the 90s, this situation was noticed, and the street was closed to traffic, and the tram reopened as the 'nostalgic tram.' These experiences have gained importance in terms of the identity and continuity of İstiklal Street's identity. In the 2000s, cultural activities started to be seen in Galata, art galleries in Tophane, and some of the food and beverage venues in Karaköy (Coşkun, 2016). During the Gezi events in 2014, the square came to the fore again (Göncü, 2007). The pedestrianization of Taksim Square and the criticism of the square's design finding a significant voice in the media have also been a part of urban renewal. In addition to all these; The fact that the population density of Syrians fleeing the war is frequently seen on İstiklal Street, the increase in terrorist incidents, and the constant change in entertainment venues and understanding increase in the number of foreign visitors harms the identity of the street and the city (Göncü, 2007).

Many places on Istiklal Street, from The House Cafe to Pasabahce, from Midpoint to Teknosa, have been closed and continue to close day by day. Arabic signs, hookah, kebab, Turkish delight, caftan, fortune-telling shops, 'residence' and 'suites' opened in their place. Due to the closure of cultural venues such as City Theatres, Muammer Karaca, Emek, Alkazar, Avrupa, and Sinpop, the proportion of families coming to the street is decreasing. However, local tradespeople who have been running shops for a long time are erased from their memories. It is noteworthy that new places have not opened in place of the places that have been closed for the last few years and that the shops on the street are empty. Many places in Beyoğlu, such as İnci Patisserie, Emek Cinema, Kelebek Corset, Robinson Crouse, Rebul Pharmacy, and Librairie de Pera, were closed due to rent increases and the sale of buildings. Local businesses, culture, and art venues on the street are turning into stores and shopping centers of famous brands one by one (Figure 1).



**Figure 1:** Lost Memory Places on Istiklal Street

### **5.1 *Emek Cinema***

Emek Cinema was a cultural venue that opened up to Yeşilçam Street on İstiklal Street and continued to exist in the crowd of the city. With a capacity of close to one thousand, it was vital, especially for film festivals. Every year, on festival dates, moviegoers queued up to buy tickets. Emek Cinema's location, which intertwined with urban life, was effective in terms of İstiklal Street. Emek's entrance, box office, and foyer identified with cinema history were on Yeşilçam street. Having witnessed every moment of Beyoğlu, the cinema hosted many domestic and foreign films until it was closed for renovation in 2009. Emek Cinema was demolished in 2013 to make it a shopping center. The building block, which included Cercle d'Orient, İskentinj Apartment, Melek Apartment, Emek Cinema, İpek, and Rüya cinemas, was reopened as Grand Pera and moved to the fifth floor of the mall under the name of "Emek Sahnesi."

Although such structures, which have a place in the city's memory, are cultural spaces that belong to the public, their evaluation with commercial criteria causes them to be demolished. In addition to the increasing economic value of the region, greed, prestige, and political power shows are also effective in destroying memory places. Urban identity, society demands, historical values, and memories are ignored. Going to the movies as an activity or socializing environment is related to the place and the experience (Allen, 2006; Berry, 2016; Öz & Özkaracalar, 2021). Events experienced there, such as first encounters, first encounters, and separations, affect the perception of urban space and the memory of the experienced space.

### **5.2 *Inci Patisserie***

İnci Patisserie represents one of Beyoğlu's memory places with its profiteroles. Its owner, of Albanian origin, Luka Zigori, invented profiteroles inspired by a dessert he saw in France (Biricik, 1994). In the early 1940s, Zigoris rented a workshop near the church opposite Galatasaray and started making the legendary profiteroles, and the profiteroles made in the workshop were distributed to other patisseries. With the profiteroles being very popular, it opened its place in Cercle d'Orient, Atatürk's shirt shop on İstiklal Street, as

Inci Patisserie. İnci Patisserie in Cercle d'Orient had few tables, making it very difficult to find a place. Those who found a place would eat their profiteroles, drink lemonade, and get up immediately. Those who were not so lucky would wait in line at the door, and if there were no room, they would eat their profiteroles standing up. Chocolate, cake, pastry, and profiteroles are sold in the patisserie produced in the workshop at the back of the shop. The historical building, including the patisserie, was transferred to a construction company with a build-operate-transfer model, and İnci Patisserie in Cercle d'Orient was evacuated by the police force in 2012 and cut off from the city's memory. A few months later, it reopened on Mis Street, but such spatial changes cannot take the memories with it. The difference in the location of the patisserie on the street and the historical place it is located causes a change in memories. Cafes, avenues, streets, and buildings form shelters in the individual's memory. What makes İnci a place of memory is the taste of its profiteroles and the fact that it hosts people from all generations, and the memories of its guests. The way to keep the memory alive is to remember where the events took place. The destruction of familiar memory places such as İnci Patisserie imprisons people in cities with no identity.

### 5.3 *Kelebek Corset*

Kelebek Corset, a family business, has continued its existence for 79 years. The adventure of the shop started in the 1920s on Istiklal Street in the Terkos Passage. It moved to its place on Istiklal Street in 1936 (Avramoğlu, 2016; Ender, 2018). She changed her name to Kelebek Corset because women felt as light as butterflies when wearing corsets. The wooden shelves of the shop, the yellow frosted glass cabinets, the drawers that don't close, and the walls covered with wainscots have managed to keep the historical texture alive for everyone who enters. In 2014, the owner of Kelebek Corset, Santa Maria Church, tripled the rental price of the shop, and İlya Avramoğlu had to evacuate his shop (Avramoğlu, 2016; Ender, 2018). The corset shop closed in 2015 and was reopened in Şişli in 2016. The memory places on Istiklal Street have been a source of bread for generations. Even if people change, memories are refreshed as long as places remain the same. The displacement of local

businesses, such as the Kelebek Corset, for financial reasons damages not only the spatial memory but also the memory of Istiklal Street and even Istanbul.

#### **5.4 *Robinson Crusoe Bookstore***

One of the essential memory places of Istiklal Street is its bookstores and second-hand booksellers. Many known bookstores in Beyoğlu, such as Galata, Tünel, Dünya, İmren, Sel, Simurg, Metropol, Sinem, Friends, Literatür, İstavrit, were closed (Url-2). Librairie de Péra, the 93-year-old bookstore in Galata and Turkey's first auction venue, could not pay its rent either. With the call made in 2014, the public brought the books to Salt Beyoğlu by arranging them side by side on Istiklal Street, but although the bookstore moved, it could not withstand the transformation process (Url-2). Robinson Crusoe was one of the bookstores that closed due to rising rents and demand for money. The closure of the bookstores surrenders the city to darkness (Tekin & Akgün Gültekin, 2017).

### **6. Method**

In this study, which examines the relationship between space and memory, the individual's ability to keep in mind and remember the space constitutes the structure of the research. The study is limited to the memory places on Istiklal Street in the past but emptied for different purposes. A 'Semi-Structured Interview Form' was applied with individual interviews on different age groups. This form includes predetermined questions (Smith, 2003) but is supported by sub-questions depending on the progress of the interview. Thus, it provides a more flexible interview environment (Yalçiner, 2006).

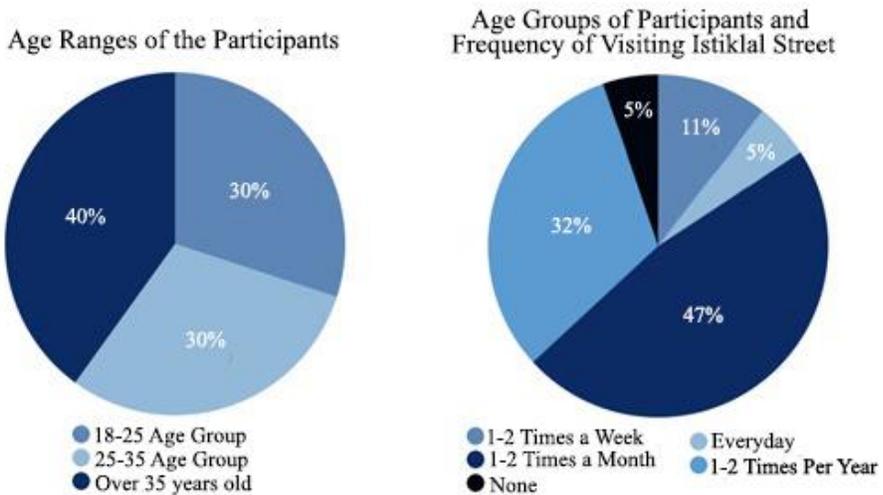
The research focuses on the memorable aspects of the space and which senses are effective in this process. In the process of perception and recall of places from memory, senses such as sight, touch, taste, hearing, and smell come into play. The processes of perceiving a place and keeping it in the memory of people from different age groups, who have different frequencies of being on Istiklal Street and belong to different cultures, also differ. This form, which we can also call memory probe, consists of 2 stages. Stage 1

consists of questions asked over Istiklal Street, and stage 2 through a memory space that the participants choose and remember.

## 7. Analysis and Findings

In the first question of the study's first phase, the age range regarding the demographic structures of the participants was determined. It is seen that 40% of the participants are over 35 ages. 30% are between the ages of 25-35, and 30% are between 18-25 ages (Figure 2).

Spaces gain permanent memory in direct proportion to the frequency of the individual's experience. The frequency of participants' presence on Istiklal Street affects their memories. Therefore, all interviewed participants reside in the European side of Istanbul. 5% of the respondents do not go to Istiklal Street for a long time, 5% go every day, 11%, 1-2 times a week, and 32%. 1-2 times a year. Those who go 1-2 times a month constitute 47% of the participants.

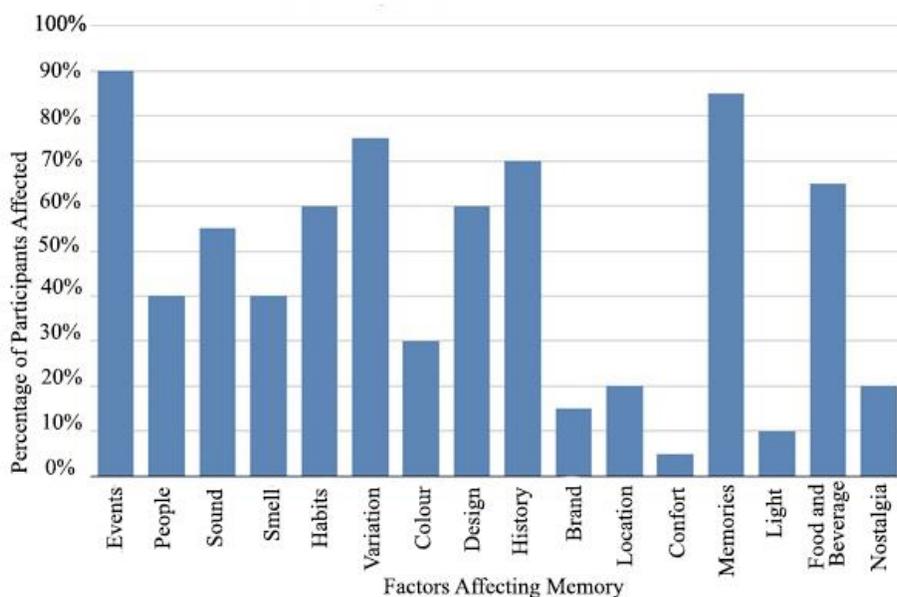


**Figure 2:** Age Groups of Participants and Frequency of Visiting Istiklal Street

In the second question of the interview form, the participants were asked to identify the closed and changed places on İstiklal Street that remained in their memories. Some of the closed or relocated venues; The House Cafe, Emek Cinema, İnci Patisserie, Kelebek Corset, Paşabahçe, İşbank, Vodafone, Finansbank, Pizza Hut, Yapı Kredi, Teknosa, Media Markt, Columbia, Re Bul Pharmacy, Hamurabi, Salt Beyoğlu, İstiklal Kuruyemis, Robinson Crusoe, Sinepop, Polo Garage, Seven Hill, Ayvalık Toaster, Bolu Hasan Usta, Adil Işık, HSBC Bank, Charley Temmel, Tuğba Kuruyemiş, Topshop, Erol Giyim, Neofly, Kiğılı, Kifidis, Starbucks Branch, Kent Optik, Kazım Taşkent Art Gallery, Mayer , Pastellias, Lazoro Frakko Furnishing Shop, Zahariadis, Le-bon, Saron Jewellery, Oriental Custard Shop, Sümerbank Store, Corsetist Roseto. These names were shared with the participants for reminder purposes.

As a result, 85% of the participants state that they have memories of Emek Cinema and that the place has an important place in their memories. 75% have experienced İnci Pastanesi and state that they still remember the taste of profiteroles. Of those who answered the questions, 55% preferred Paşabahçe, 45% Salt Beyoğlu and The House Cafe, 40% Robinson Crusoe, 30% Rebul Pharmacy, Ayvalık Toaster and Kelebek Corset, 25% ' Teknosa, Media Market and Colombia, 20% Tuğba Kuruyemiş, İstiklal Kuruyemiş, Yapı Kredi and İş Bankası, 15% Seven Hill, Bolulu Hasan Usta, Vodafone, 10% Hamurabi, He still remembers Polo Garage, Kfidis, Kent Optik, Le-Bon and Sümerbank.

In the 3rd question, the most common answers are; events, memories, diversity, and history. Food/drinks, habit, design, sound, people, smell, and sound, are secondary elements. The words color, business, location, comfort, light, and nostalgia are also the reasons preferred by fewer participants (Figure 3)



**Figure 3:** Percentage of Factors Affecting Memory

In Question 4, the participants asked what the first words come to their minds when they say İstiklal Caddesi. Most participants' words about the street were crowd and confusion. Words such as history, noise, tram, and entertainment are among the secondary preferences. In this respect, people and events significantly affect the identification of a street and its permanence in the memory of individuals.

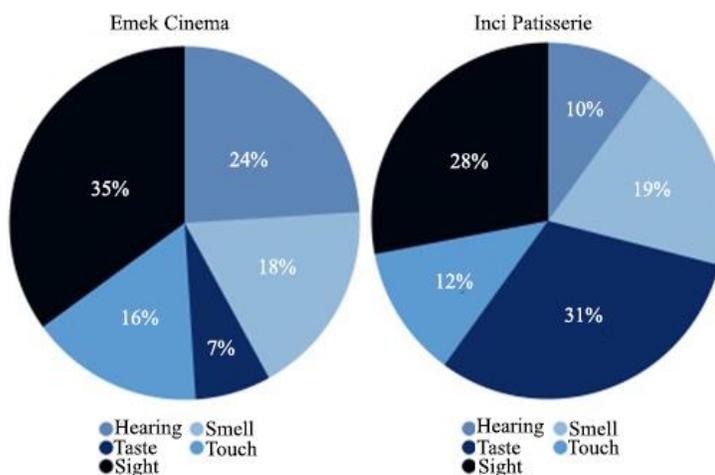
In Question 5, individuals who experienced İstiklal were asked to say the words that the street reminds, based on their memories. Most participants preferred common words such as history, confusion, crowd, noise, foreign, and expensive. Even if people have the same experiences on the same street or in the same place, they perceive events and places from different perspectives.

İstiklal Avenue succeeds in being a common meeting point for people of all nationalities, races, genders, and views. Participants state that they experience the street by touching the crowd, seeing historical buildings, hearing people speaking different languages, tasting special delicacies such as

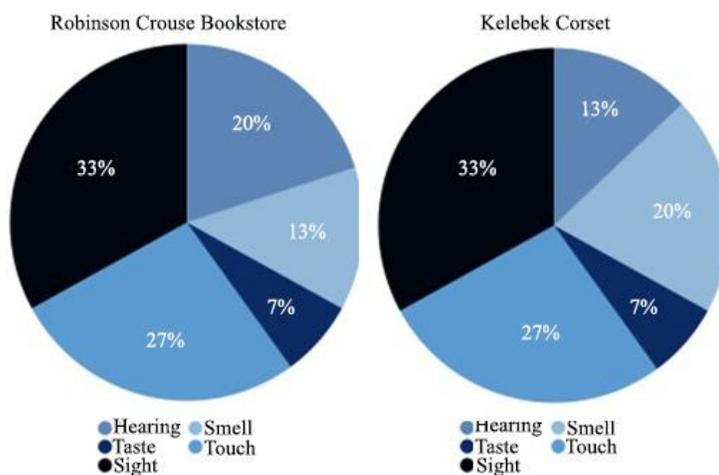
pearl profiteroles, and inhaling the smell of life from the dusty shelves of second-hand booksellers. In this respect, it is seen that the senses and perception play a significant role in the formation of memory places. One of the participants states that the street offers him the opportunity to listen to musicians from different cultures and watch their dances. Years ago, the novelist remembered that the artist Flarm's making music in Istiklal despite his disability greatly impacted him.

In the second interview stage, the participants were asked to choose one of the memory places they remembered and to tell the senses they remembered about that place.

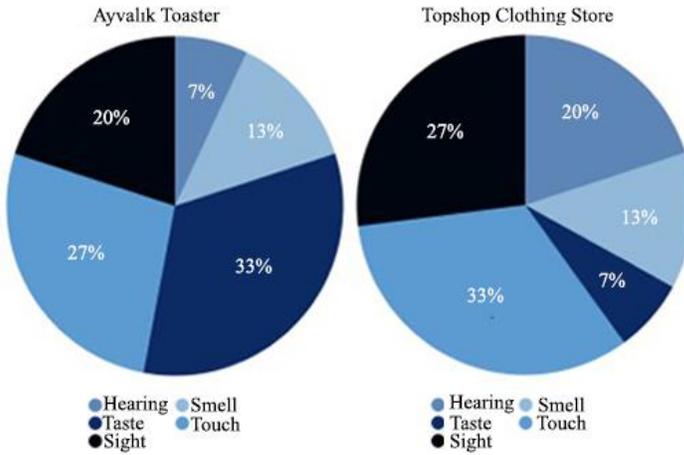
In the second part, 22% of the participants stated that they had memories of Inci Patisserie; 55% of them said that they have memories of Emek Cinema. 13% of the participants have memories of Robinson Crouse and 5% with Kelebek Corset; the remaining 5% of the participants state that they have established relationships in their memory with different places such as Topshop and Ayvalık Toaster. For this reason, questions advanced through the most selected places. When the participants remembered Inci Patisserie and were asked to rank their senses, participants stated that the senses they are most affected by are taste, sight, smell, touch, and hearing (Figure 4). When the participants who remember Emek Cinema were asked to rank their senses, Participants listed the most affected senses as seeing, hearing, smelling, touching, and tasting. The senses that Robinson Crouse reminds are respectively sight, touch, hearing, smell, and taste. The order of sight, touch, smell, hearing, and taste constitute the senses perceived by the Kelebek Corset (Figure 5).



**Figure 4:** Percentage of Awakening the Senses  
Emek Cinema / Inci Patisserie



**Figure 5:** Percentage of Awakening the Senses  
Robinson Crusoe Bookstore / Kelebek Corset



**Figure 6:** Percentage of Awakening the Senses  
Ayvalık Toaster/ Topshop Clothing Store

One of the participants remembers İnci Patisserie with the people waiting in line in front of it. According to him, the taste of profiteroles eaten by waiting in line in the cold left an unforgettable memory in his memory. Another participant states that the patisserie reminds him of his grandmother. In her childhood, they went to Istiklal Street together at the beginning of every month to collect her grandmother's salary; He remembers that his grandmother took him to İnci Patisserie and had him eat profiteroles before returning home. He states that handmade lemonade appeals to the senses to a great extent when remembering İnci Patisserie. Another participant recalls his experiences with Emek Cinema. He remembers that in the past, it was difficult for couples to meet for fear of family, so they always went to Emek Cinema to see their wife.

Most interviewees remember the Ayvalık toaster with its taste and Topshop with its fabric touches. Participants say the smell of books in old second-hand booksellers, such as Robinson Crusoe, is identified with Istiklal Street (Figure 6). Memory places are perceived by individuals through the senses and gain a place in permanent memory according to the frequency of experience. A tiny spark, a sound, or a smell makes that place remembered even if it is not in place right now.

## 8. Conclusion

The new environment, which formed as a result of spatial memory and social change, constantly renewed with senses and experiences, changes both the layers of meaning of the city and the places of memory. National and international memory places such as the Jewish Museum, Blur Building, Twin Towers, and Atatürk Cultural Center constitute the places that allow the city to read with their historical and semantic value. The fact that memory places host social events renews the memory of the citizens; It increases the social and economic value of buildings. Istanbul is in a rapid transformation process with its memory places. Istiklal Street, which hosts the victims of this transformation process, is one of the places where change can be seen most clearly with its historical texture and cultural diversity. It reveals that the cultural and artistic identity of Istiklal has changed and turned into a shopping, entertainment, and hotel-dominated street.

In the interviews, the guiding feature of the senses on memory was revealed by considering the personal and social characteristics of the participants. Thus, results have been obtained that the individual constantly interacts with the spatial environment and can store and recall the results of this interaction in his memory. In this process, it has been observed that the senses are highly effective in the stages of perception, memorization, and recall.

Reminding some memory places on Istiklal Street, such as Emek Cinema, İnci Patisserie, Robinson Crusoe Bookstore, Kelebek Corset, and Topshop Clothing Store, which had to be closed or relocated for various reasons, helps the participants to refresh their memories. In this context, it turns out that the senses that come into play while perceiving the space are also effective in remembering it. In this memory probe, the places reminded to the participants are not in their places. Therefore, the senses that are recalled from memory also disappear over time.

The loss of memory of places and the change of urban identity cause the disappearance of the citizens' memories, experiences, and shared values. Changing society, its spaces, places, and the city's identity; Changing cities change the whole country. In this respect, transformation works should

protect the sense of belonging of the people, the identity of the city and the place, and social values; It should contribute to the acquisition of qualified and high-quality environments at the urban scale with references from the past.

## References

- Agnew, J. (2005). Space: place. Spaces of geographical thought: Deconstructing human geography's binaries, 81-96.
- Allen, R. C. (2006). The place of space in film historiography. *Tijdschrift voor Mediageschiedenis*, 9(2), 15-27.
- Avramođlu, İ. (2016). İlya Avramođlu ile sözlü tarih görüşmesi.
- Aydınlı, S. (1986). Mekânsal deđerlendirmede algı- sal yargılara dayalı bir model, Doktora Tezi, İ.T.Ü. Fen Bilimleri Enstitüsü, İstanbul.
- Bastéa, E., & Bastéa, E. (Eds.). (2004). Memory and architecture. UNM Press.
- Berry, V. (2016). The Excess and Potential of the Movie Theatre Ruin: The Midnight Star. *Transformations* (14443775), (28).
- Bower, G. H. (1981). Mood and memory. *American psychologist*, 36(2), S:129.[1]
- Brook, T., Spence, J. D. (1986). The Memory Palace of Matteo Ricci. *The Journal of Asian Studies* (Vol. 45). <https://doi.org/10.2307/2056104>, Erişim Tarihi: 02.01.2022
- Burton, T. (2006). "Edward Scissorhands," *Alice in Wonderland*, (ed.) Mark Salisbury, Faber and Faber Limited, Londra.
- Calvino, I. (2012). *Görünmez Kentler*. İstanbul. YKY.
- Canbulat, G. (2007). *Sanal Mimarlık ve Hiperyüzeyler*.
- Coşkun, B.S. (2016). Mirasa Koruma Yoluyla Kentlilik Bilincini Güçlendirmek ve Kaçırılmış Bir Fırsat Olarak Emek Sineması. *Mimar.ist*, Sayı:57, S:56
- Critchley, S. (2015). *Bellek Tiyatrosu*. Metis Yayınları, S:37.
- Çakır, H. (2015). Tarihi Yapılarda Mekansal Bellek ve İç Mekân İlişkisinin İrdelenmesi, Beykent Üniversitesi Fen Bilimleri Enstitüsü, İç Mimarlık Ana Bilim Dalı, İstanbul.

- Demir, B. (2016). Politika, Savaş, Tarih. İn Gündem.
- Doğan, D. (2006). Boşluk. Yüksek Lisans Tezi, Fen Bilimleri Enstitüsü, İTÜ, İstanbul.
- Ender, R. (2018). " Kolay Gelsin": Meslekler ve Mekânlar. İletişim Yayınları.
- Ergin, N. (2015). Kent & Hafıza. Kule Dergisi, 39, S:12.
- Gökmen, G., Özak, N. (2009). Bellek ve mekân ilişkisi üzerine bir model önerisi. İTÜ Dergisi, Sayı:8, Cilt:2, S:145-155.
- Göncü, N. (2007). Kent Öğelerinin Kent Kimliği Üzerinde Etkileri. Yüksek Lisans Tezi, Marmara Üniversitesi, İstanbul.
- Güçlü A, Uzun E., Uzun S. & Yolsal U. (2002). Felsefe Sözlüğü. Bilim ve Sanat Yayınları, Ankara.
- Hall, M. C., McArthur, S. (1998). Integrated Heritage Managemen. John Wiley and Sons Ltd. S:70-72
- Kızıl, F. (2000). Objelerin İki-Üç Boyutlu Grafik Anlatımı ve Zihinde Canlandırma. İstanbul: Mimar Sinan Üniversitesi Yayınları.
- Kocabaş, A. (2006). Urban conservation in Istanbul: evaluation and re-conceptualization. Habitat International, 30(1), 107-126.
- Lynch, K. (2014). Kent imgesi. A. Berktaş, & K. Özkan (Eds.). Türkiye İş Bankası Kültür Yayınları
- Maden, F., Şengel, D. (2009). Kırılan Temsiliyet: Libeskind'de Bellek, Tarih ve Mimarlık. METU Journal of the Faculty of Architecture.
- Madran, E. (2001). Kent Belleğinin Oluşumunda Mimarlık Yapıtları. Mimarlık Dergisi, (298), S:47-49.
- Öz, Ö., Özkaracalar, K. (2021). At the Nexus of cinema, city, and memory: Resisting the demolition of Istanbul's historical Emek movie theatre. Emotion, Space and Society, 40, 100804.
- Proust, M., Hakmen, R. (2011). Kayıp zamanın izinde: Swann'ların tarafı: Roman. Yapı Kredi Yayınları.
- Rossi, A., Gürbilek, N. (2006). Şehrin Mimarisi. Kanat Kitap.
- Sakaoğlu, N. (1998). Geçmiş Zaman Olur ki/Once Upon a Time: Haydarpaşa Station, Haydarpaşa Garı.
- Smith, J. A. (2003). Qualitative psychology: A practical guide to research methods. Sage Publications, Inc.

- Taylor, P. J. (1999). Places, spaces and Macy's: place–space tensions in the political geography of modernities. *Progress in human geography*, 23(1), 7-26.
- Taşçıođlu, M. (2013). Bir Görsel İletişim Platformu Olarak Mekân. *Yem Yayınları*, S:19.
- Tekin, İ., Akgün Gültekin, A. (2017). Rebuilding of Beyoglu-Istiklal Street: A comparative analysis of urban transformation through sections along the Street 2004-2014. *METU Journal of the Faculty of Architecture*, 34(2), 153-179.
- Tokuyay, V. (2002). Yahudi Müzesi Üzerine.
- Turgay, O. (2013). Mekanların Arayüz Nitelikleri Bağlamında Gündelik Yaşantıdaki Kalıcılığı. *Beykent Üniversitesi, Fen ve Mühendislik Bilimleri Dergisi*, Sayı:6(1).
- Turgut, H. (2021). Istanbul: The city as an urban palimpsest. *Cities*, 112, 103131.
- Url 1: <https://anamed.ku.edu.tr/events/koku-ve-sehir/> (Date of Access 12.06.2022.)
- Url 2: [http://www.yapi.com.tr/haberler/robinson-crusoe-35-bin-dolari-nasil-odesin\\_121147.html](http://www.yapi.com.tr/haberler/robinson-crusoe-35-bin-dolari-nasil-odesin_121147.html) (Date of Access 12.06.2022.)
- Yalçınır, M. (2006). Eğitimde gözlem ve değerlendirme. Ankara: Nobel Yayın.
- Zumthor, P. (2006). *Atmospheres*.

## CHAPTER II

# CREATIVITY AND CREATIVE THINKING IN DESIGN

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### 1. Creativity

“Creativity is meaning, is voice to the world, is the image. It is not to copy what someone else has done, but to freely leave the works to life in personal originality. It is not to go the way everyone goes or to look the other way on the way everyone goes.” (Çellek ve Sağocak, 2014).

Torance (1974) defines creativity as anticipating gaps, disturbing or missing elements, thinking about them or making assumptions, testing them later, comparing the results with each other and possibly changing these assumptions and testing them again and revealing the result. Creativity is also defined as leaving the main road, being open to trials and getting rid of stereotypes (Aslan et al., 1997; Yılmaz et al., 2021). Creativity is a lifelong

ability and intelligence, the capacity to use imagination and self-expression (Düzenli et al., 2017a; Düzenli et al., 2017b), and it means creating something new (Yolcu, 2000). The definition of creativity varies according to different fields. However, the common feature of all definitions is that creativity is the ability to think differently, be original, find extraordinary solutions to problems and produce new, original and useful products as a result of these. In this context, it is possible to summarize the creativity that starts with "seeing" as "exploring new things, seeing the existing in new ways, bringing innovation to the old ones". Creativity is an attitude that aims to do the unfinished and always seeks the original.

Designers, on the other hand, should be able to be evaluated by the "innovation" and "usefulness" of the products they create (Sarkar ve Chakrabarti, 2011; Georgiev & Georgiev, 2018; Kurdoğlu et al., 2019). Creativity in design can be summarized as follows (Casakin & Georgiev, 2000; Ertekin & Çorbacı, 2018 ). Creativity is;

- ◁ approaching the solution of the design problem from many different perspectives,
- ◁ ability to establish a relationship that has not been established before or to reconstruct the relationship between existing ideas easily-quickly-freely
- ◁ being able to think fluently and
- ◁ to be able to use them in the design product.

Creativity, which is at the core of design, can enable us to look at all kinds of problems from different perspectives and to propose solutions with multiple options in a short time.

## **2. Creative Thinking**

Thinking begins with our perception and understanding of our environment. In this beginning, new knowledge is combined with past experiences and new outputs are obtained (Eren & Var, 2017; Yılmaz et al., 2020). The basis of thinking is to be able to establish connections between events and concepts.

Creative thinking, on the other hand, is the structuring of the connections between events and concepts in a new and different thinking system (Tarakci Eren, 2019; Artut, 2004). For many years, creative thinking has been seen as an intellectual product peculiar only to naturally gifted and genius people. After the second half of the twentieth century, researchers have focused on creative thinking ensuring that this thought has been destroyed and revealed that every person has more or less creativity skills. For this reason, curricula at all levels of education aim to develop individuals' creativity and creative thinking skills, because studies on creativity and creative thinking show that these skills can be developed through education (Yeşilyurt, 2020).

Creative thinking is a way of thinking that includes imaginative and rational thinking processes such as using intuition, grasping, constructing, asking questions, analyzing and synthesizing, evaluating problems, producing new solutions and information (Kale, 1994; Casakin & Georgiev, 2020).

There are components of developing creative thinking such as curiosity, imagination, perceptions and games. The most used component for the creative thinking process is imagination. Imagination is the core of thought and includes creativity. For this reason, an individual who focuses on creative thinking obtains a large number of products (Yılmaz et al., 2020). It is very important for an individual to support his/her creativity with imagination while obtaining a product. This situation feeds the individual's creative thinking process. In order for the creative thinking process to occur, the brain must produce an infinite number of thoughts. This process is a thinking structure in which logic and intuition work in active ways. The aim here is to produce new information or products by establishing relations between pieces of information through thinking.

According to researchers, their thinking structures differ. Because of the nature and individuality of thinking, thinking is divided into different classes. According to most researchers, thinking is done in two ways: vertical and lateral thinking. Intellect is active in vertical thinking, and intuition is active in lateral thinking (De Bono, 1970).

*Vertical thinking* is a regular, systematic, step-by-step way of thinking that leads to a single correct solution. In vertical thinking, the individual acts

with his/her mind and reaches a single correct solution with a gradual thinking process. It is generally called reasoning and is defined as drawing logical conclusions from certain propositions (Hançerlioğlu, 1979).

*Lateral thinking* is an unruly, messy and free way of thinking that produces multiple solutions. In lateral thinking, the individual does not follow a predetermined path and produces options with scattered solutions. It is often called creative thinking and is thought to increase creativity as it provides multi-opportunity thinking (Koçkan, 2012).

Rawlinson (1995), on the other hand, considers creative thinking styles as analytical and creative thinking. Analytical thinking gives the individual few solutions with only one answer. Creative thinking involving imagination leads the individual to multiple answers, solutions or different thoughts. These two ways of thinking, which seem to be opposite to each other, actually act together and work in harmony with each other. Solutions that come as a result of creative thinking go through the logic of analytical thinking. Analytical thinking combines ideas and results, while creative thinking makes progress with analytical thinking (Rawlinson, 1995) (Fig. 1).

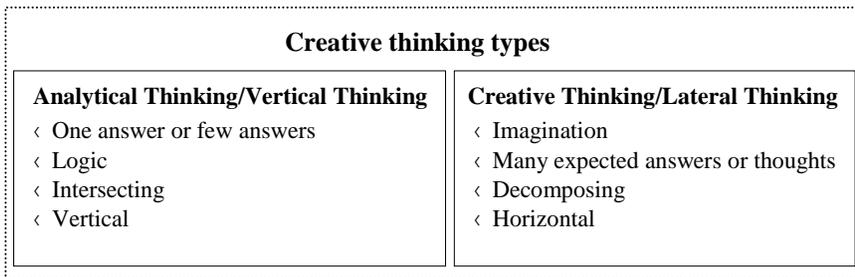


Figure 1. Creative thinking

### 2.1. *Creative Thinking Processes*

Creativity is a mental process that reveals an idea or formation in general, and this process is experienced in every situation where creativity is present. Creative thinking generates ideas freely. However, the ideas produced should be evaluated in order to come up with useful and original ideas. The process is also important to ensure this production. It is these evaluations that form the structure of the creative process.

The creative thinking process occurs when the brain produces a large number of thoughts. The individual uses his/her experiences and knowledge to produce thoughts. These experiences and knowledge determine a process. As a result of the thoughts produced through the creativity of the individual, original ideas or solutions to the problems are found.

In order for the individual to know how to think at which stage, he/she should have information about the creative thinking process, know the stages that make up this process and the components of the stages (Koçkan, 2012). Many researchers have different views on this subject:

The creative thinking process consists of four stages. These are the stages of preparation, incubation, enlightenment, and verification (Doğanay, 2012; Yeşilyurt, 2020).

- ◁ In the preparation phase, the problem is defined and data is collected. Hypotheses about the problem are examined and the individual criticizes previous studies about the problem.
- ◁ In the incubation phase, new syntheses arise and old information interacts with new ones. As a result, mental processes occur. In this process, thoughts are original because logic is removed.
- ◁ In the enlightenment stage, the solution of the problem is suddenly determined in the mind of the individual and the invention occurs.
- ◁ In the realization phase, logic comes into play and the accuracy of the invention is reviewed again, analyzes are made and a creative product emerges.

Rouquette (2007) divides creative thinking, which produces a new idea, object or result, into six phases. These are as follows:

- ◁ Realizing the need, identifying the needs and defining the problem;
- ◁ Gathering information, getting a detailed perspective on the subject;
- ◁ Detailed thinking, generating ideas about the solution of the problem;
- ◁ Imagining solutions, creating options for solving the problem;

- < Proving its reality, reaching a new or creative solution and discussing its feasibility;
- < Processing, translating and reaching the final product.

After all, creative thinking is a process in which mind and imagination are handled together.

## ***2.2. Techniques to Develop Creative Thinking***

For the development of creativity, free thinking and production skills are supported by certain techniques and methods. Techniques that develop creative thinking are effective in being creative in many areas, and also help the individual to expand his/her imagination while generating ideas about the problem encountered in design.

Creative thinking techniques are used to generate a creative idea, solve a problem, or optimize an existing situation. In addition, they are mind-opening methods used by the designer to develop ways of thinking and discover new solutions. In order to get a creative idea, it is possible to reach the result by choosing the appropriate one among these techniques. However, apart from these techniques that can be used, the individual also has the opportunity to learn to think creatively and develop his/her creativity with his/her own efforts. The following can be done personally in order to advance the creativity and creative thinking inherent in each individual (Şimşek, 2012): thinking without limitations, moving away from the ordinary and trying the new, being curious and asking questions, observing and listening, developing general abilities, duplicating interests, recognizing different cultures, playing games, reading, managing time, balancing oneself and others, and finding a suitable model.

Techniques based on expert opinion to develop creative thinking are as follows:

**Brainstorming:** It is a creative technique used to develop ideas by using imagination in order to find a solution to a subject (Demirel, 1995). According to another definition, brainstorming is a comprehensive method that enables generating ideas with a systemic structure (Rawlinson, 1995).

This technique was first developed by Osborn. According to Osborn (1963), there are four basic conditions for brainstorming to create imagination and creative thinking:

- ◁ Criticism should not be included in brainstorming because the ideas should not be criticized by others so that the individual can use his/her imagination in a comfortable way (Özden, 2003). Creative and original ideas come out more easily when there is no judgment.
- ◁ Unlimited thinking, called free association, should be provided. The fact that the produced ideas are unusual should not be evaluated negatively, on the contrary, more interesting ideas should be included as they can be encouraging. It is because unexpected ideas contribute to finding new solutions and thus diversity and efficiency are achieved.
- ◁ Quality should be unimportant, but quantity should be important. To increase the probability of achieving good results, as many ideas as possible should be generated.
- ◁ Developing combinations is essential. Ideas put forward allow the formation of new ideas and combinations.

The purpose of brainstorming is to generate various solutions by stimulating creative thinking. In order to use brainstorming more effectively, solutions such as making use of the like (analogy), establishing a thought relationship and producing benefit from harm are also used. The technique focuses on creating and demonstrating a large number of solutions, regardless of whether they are valuable or worthless. The more ideas are developed and solution options are created for a defined problem, the more likely it will be to find the most appropriate and correct solution to the problem.

What is expected from the brainstorming is that the designers put forward a large number of new ideas that they can produce by using associations without stopping the flow of thought with logical inferences.

**Concept Maps:** Concepts are formed by abstracting perceived objects, events and thoughts through mental processes. That is, thoughts that appear in the mind with images and the relations between thoughts reach the concept with

abstractions (Hançerlioğlu, 1979). Concept maps technique is the transfer of the relations of concepts to each other with diagrams. The technique helps to make connections between old knowledge and new knowledge.

Concept maps show how concepts and their relations with each other are connected by lines (Üstündağ, 2003). In concept maps, each of the concepts creates an idea and the number of concepts obtained affects creativity.

**Synectic Method (Similarity):** It is synectic to bring together and combine different and unrelated elements, and it is the use of instantaneous actions of the brain-nervous system in searching for a problem and finding a solution (Gordon, 1961; Jones, 1992). Its main task in the creative process is to bring together different ideas functionally (Roukes, 1984). In other words, bringing together the same data with new relationships in creativity is an important task. In order to help this work, serving the same task, synectic is a method that systematically brings together different and unrelated elements with analogies and metaphors.

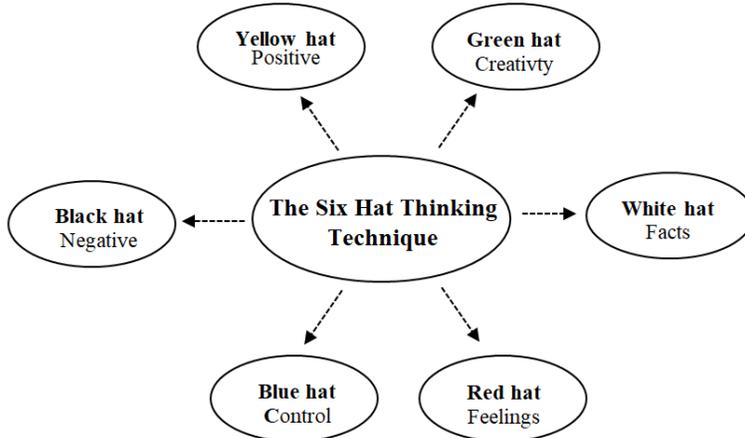
As in the Brainstorming method, group work is carried out in this method. Unlike the brainstorming method, Synectic uses analogy and comparison. Types of analogies that individuals unconsciously use in the synectic method are individual analogies, direct analogies, symbolic analogies and imaginary analogies. These are used to change one's perspective on objects known to everyone. Thus, these analogies are used to change the unknown to the familiar, and to change the familiar (Gordon, 1961).

**Qualification Ranking Technique:** In this creative training technique, certain qualities of the product are listed and the requirements for the development of these qualities are listed. When ranking the quality, something that will increase the quality of that thing must come out. Or another product is expected to emerge, that is, new combinations and new ideas are produced. In this way, the feature sorting technique evolves into a theory that explains the creative thinking process, and into a technique because it makes creative thinking practical (Özden, 2003).

**The Six Hat Thinking Technique:** This technique, which was founded by Edward De Bono in the beginning of the 1980's, is used in the

teaching-learning process with the purpose of improving the thinking skill, and it consists of the combination of the source of opinion and side opinions. The task of this technique is to help individuals with important decisions, conclusions and judgements. This technique is aimed to have a versatile thinking by looking at an issue from different perspectives and separating emotions from logic, and creativity from knowledge by doing so. It makes it easy to think multi-dimensionally in the face of a problem (Erişen & Katmer Bayraklı, 2016). It makes it easy to think multi-dimensionally in the face of a problem. This technique is used to present ideas in an orderly manner and systematize them. Hats are symbolic expressions used to separate ideas (Demirel, 2002). Hats help express ideas without hesitation.

Six different colors are used for six hats and there is a thought system for each color. Which hat to wear and when is decided according to the requirements. Hats are considered in different qualities from each other. Hats are worn considering these qualities (De Bono, 1998) (Fig. 2).



**Figure 2.** Concepts in the Six-Hat Thinking Technique

**Analogical Technique:** Analogy is a cognitive process that supports learning and enables to produce new information from the familiar (Casakin & Timmeren van, 2015; Yılmaz et al., 2020). It is a way of reasoning that the mind makes using analogies, or it is a way of obtaining the unknown with the help of analogies. Analogies aim to increase the quality of problem solutions,

develop knowledge-skills and creativity by supporting the habit of identifying and researching hidden information of the individual (Goncalves et al., 2014; Casakin & Timmeren van, 2015). In particular, analogies increase the creativity criteria of the individual in problem solving (Goldschmidt, 2006).

Making use of analogies is one of the most frequently used methods in design and is an effective tool in solving the design problem (Dunbar & Blachette, 2001; Yilmaz et al., 2020) and forms an important part of the creative process. It is because analogical thinking facilitates solving design problems while improving the ability of designers to solve design problems (Casakin & Goldschmidt, 2000), and also supports the creative process by helping to produce unexpected solutions as required by design problems. In the process of designing an analogical way of thinking, it is used first to develop the concept, secondly to develop the ideas that shape the design decisions and thirdly to transform the thoughts into form.

### **3. Conclusions**

Creativity is a necessity for all areas of life. Today, creativity is in a state that affects not only art but also all sciences and even daily life. It gains a wider meaning in terms of producing new and innovative solutions to all kinds of problems and causes the emergence of new concepts; such as the creative city, creative industries, etc. Since the design process is a problem-solving process that includes producing innovative solutions, it has become inevitable for the designer to approach the problem systematically and this includes creative thinking (Çubukcu & Gökçen Dünder, 2007).

Creative thinking enables the designer to grasp the problems he/she faces, to clarify the boundaries and to develop options for solving the problem. Thus, the designer presents an unusual end product with an original and innovative perspective that is open to change.

Creative thinking in design is defined as follows (Uzunarslan ve Polatkan, 2011):

- < ability to think from different perspectives,
- < being able to go beyond the imposed ideas and think differently from others,

- 
- ◁ to be able to consider the solution of problems from different perspectives,
  - ◁ establishing a new relationship or re-examining the relationship between existing ideas,
  - ◁ comfortable-quick-independent and fluent idea generation and transferring it to design.

In the first year of education that includes design education, the primary goal is to prepare individuals who have just encountered a design problem for this process and to teach ways of creative thinking. In this context, in the process, the individual learns to both design and develop their creativity. This knowledge and skill acquired in the first year develops creative thinking and prepares the infrastructure for the following years. In this creative process, the individual should be able to grasp the design and actively participate in the design organization. This is formed by the shaping of the basis of creative thinking. The individual reaches this potential only through education (Atalayer & Üstün, 2000; Casakin & Georgiev, 2020). For this reason, the basic design course, which is one of the main courses of the education process, is the first step in the structuring of creative thinking in departments, such as landscape architecture, which is built on design and creativity. This course is important for designer candidates to make general knowledge effective, to develop creative power and creative thinking. Problem solving skills are developed, and design principles and elements are taught with the design problems made within the scope of the course. With the basic design course, students learn to judge, to observe their environment sensitively, to distinguish between aesthetic and non-aesthetic, to connect different objects and concepts, to think with imagination, to turn abstract ideas into concrete, and to express them visually. Thus, while students develop their own knowledge and abilities, they start to read their environment in a different way and generate ideas from the animate and inanimate material around them. They use the sensory and cognitive manners they have developed while transforming the solutions of the design problem into forms. All these teach students to think creatively and enable them to discover and develop the creative talent within them.

**References**

- Artut, K. (2004). Sanat Eğitimi Kuramları ve Yöntemleri. Anı Yayıncılık, Ankara.
- Aslan, E., Aktan, E., & Kamaraj, I. (1997). Anaokulu Eğitiminin Yaratıcılık ve Yaratıcı Problem-Çözme Becerisi Üzerindeki Etkisi. Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 9(9), 37-48.
- Atalayer, F. & Üstün, B. (2000). Temel Tasarım Eğitim ve Öğretimi. Mimarlık Dergisi, 293, 51-52.
- Casakin, H. & Georgiev, G.V. (2000). Design Creativity and The Semantic Analysis of Conversations in the Design Studio. International Journal of Design Creativity and Innovation, 1-17.
- Casakin, H. & Goldschmidt, G. (2000). Reasoning by Visual Analogy in Design Problem-solving: The Role of Guidance. Environment and Planning B: Planning and Design, 27, 105-119.
- Casakin, H. & Timmeren van, A. (2015). Analogies as Creative Inspiration Sources in the Design Studio: The Teamwork. Athens Journal of Architecture, 1, 1, 51-63.
- Çellek, T., & Sağocak, M. (2014). Temel Tasarım Sürecinde Yaratıcılık. İstanbul: Grafik Kitaplığı.
- Çubukcu, E. & Gökçen DüNDAR, Ş. (2007). Can reativity be taught? An Empirical Study on Benefits of Visual Analogy in Basic Design Education. ITU A|Z, 4, 2, 67-80.
- De Bono, E. (1970). Lateral Thinking: Creativity Step by Step. New York: Harper & Row.
- De Bono, E. (1998). Altı Şapkalı Düşünme Tekniği. Remzi Kitabevi, Ankara.
- Demirel, Ö. (2002). Planlamadan Değerlendirmeye Öğretme Sanatı. Pegem Yayıncılık, Ankara.
- Doğanay, A. (2012). Öğretim İlke ve Yöntemleri (Ed. A. Doğanay). Üst Düzey Düşünme Becerilerinin Öğretimi İçinde, 303-356, Ankara, Pegem Akademi Yayınları.
- Dunbar, K. & Blanchette, I. (2001). The in Vivo/ in Vitro Approach to Cognition: The Case of Analogy. Trends in Cognitive Sciences, 5, 334-339.

- Düzenli T., Alpak E. M., Tarakci Eren E. (2017a). The Significance of Public Space Art In Landscape Architecture. *Yıldız Journal of Art And Design*, 4(2):143-158.
- Düzenli, T., Alpak, E. M., & Özkan, D. G. (2017b). Transition from intangible to tangible in landscape architecture basic design course. *European Online Journal of Natural and Social Sciences*, 6(4), pp-516.
- Eren, E. T., & Var, M. (2017). Education process and development of environmental design project. *International Journal of Educational Sciences*, 19(2-3), 144-151.
- Erişen, Y., & Katmer Bayraklı, V. (2016). Six hat thinking technique in program evaluation: The evaluation of the quality of mathematics teacher training program in Turkey.
- Ertekin M., Çorbacı Ö. L. (2018). Environmental Design Art in Seljuks. *Journal of Scientific and Engineering Research*, 5(3):122-126.
- Georgiev, G.V., & Georgiev, D.D. (2018). Enhancing User Creativity: Semantic Measures for Idea Generation. *Knowledge-Based Systems*, 151, 1-15.
- Goldschmidt, G. & Smolkov, M. (2006). Variances in the Impact of Visual Stimuli on Design Problem Solving Performance. *Design Studies*, 27, 549-569.
- Goncalves, M., Cardoso, C. & Badke-Schaub, P. (2014). What inspires designers? Preferences on Inspirational Approaches During Idea Generation. *Design Studies*, 35, 1, 29-53.
- Gordon, W.J.J. (1961). *Synectics: The Development of Creativity Capacity*. Harper, NY.
- Hançerlioğlu, O. (1979). *Felsefe Ansiklopedisi*. İstanbul: Remzi Kitabevi.
- Jones, C. (1992). *Design Methods: Seeds of Human Futures*. London: John Wiley & Sons.
- Koçkan, P. (2012). *Tasarım Araştırmaları Bağlamında Tasarımcı Düşünme ve Tasarım Süreci*. Yüksek Lisans Tezi, Hacettepe Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.
- Kurdoğlu B. Ç., Bayramoğlu E., Konakoğlu S. S. K. (2019). *Peyzaj Mimarlığı Eğitiminde Peyzaj Planlama Stüdyosu*. Eğitim Bilimleri Araştırmaları I, Ahmet Doğanay Oğuz Kutlu, Editör, Akademisyen Kitabevi, Ankara, 151-165.

- Osborn, A.F. (1963). *Applied Imagination: Principles and Procedures of Creative Problem Solving*. New York: Charles Scribner's Sons.
- Özden, Y. (2003). *Öğrenme ve Öğretme*. Ankara: Pegem Yayıncılık.
- Özer, D. G., & Turgay, O. (2016). Yaratıcılık ve Oyun Kavramlarının Bilgisayar Destekli Tasarım Sürecinde İncelenmesi. *Online Journal of Art and Design*, 4(3), 71-89.
- Rawlinson, J.G. (1995). *Yaratıcı Düşünme ve Beyin Fırtınası*. Rota Yayınları, İstanbul.
- Roukes, N. (1984). *Art Synectics, Stimulating Creativity in Art*. Worcester: Davis Publications.
- Rouquette, M.L. (2007). *Yaratıcılık*. Dost Yayınevi, Ankara.
- Sarkar, P., & Chakrabarti, A. (2011). Assessing Design Creativity. *Design Studies*, 32, 4, 348-383.
- Şimşek, B.K. (2012). *Yaratıcılık Özgürlüktür*. Ankara: Nobel Akademik Yayıncılık Eğitim Tic. Ltd. Şti, 249-253.
- Tarakci Eren, E. (2019). Creative Thinking Skills In Visual Arts. *Social Sciences Studies Journal*, 5(53), 7451-7461.
- Torrance, E. P. (1974). *The Torrance Tests of Creative Thinking: Norms-Technical Manual*. Princeton, NJ: Personal Press.
- Uzunarslan, Ş., & Polatkan, I. (2011). İç Mimari Tasarım Eğitiminde Yaratıcılık Etkinlikleri. 1. Sanat ve Tasarım Eğitimi Sempozyumu, Başkent Üniversitesi, Ankara.
- Üstündağ T. (2003). *Yaratıcılığa Yolculuk*. 2.Baskı, Ankara: Pegem A Yayıncılık.
- Yeşilyurt, E. (2020). Yaratıcılık ve Yaratıcı Düşünme: Tüm Boyut ve Paydaşlarıyla Kapsayıcı Bir Derleme Çalışması. *OPUS Uluslararası Toplum Araştırmaları Dergisi*, 15, 25, 3874-3915.
- Yılmaz S., Düzenli T., Alpak E. M. (2021). Peyzaj Mimarlığı Eğitiminde "Land Art" Etkisi. *Online Journal of Art and Design*, 9:1, 204-214.
- Yılmaz, S., Düzenli, T., Çiğdem, A. (2020). Residential Environmental Design with Nature Inspired Forms. *A|Z ITU Journal of the Faculty of Architecture*, 17, 211-223.
- Yolcu, E. (2000). *Yaratıcılık Kavramlar ve Tanım*. <http://www.geocities.com/enveryolcu/yaraticilik/kavramlar.html>.01 Nisan 2007.

## CHAPTER III

# MIGRATION, URBANIZATION PRESSURE AND ITS EFFECTS ON GREEN SPACES

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### 1. Introduction

**M**igration, an event experienced throughout human history, is a movement of people moving from one place to another, settling down. Although it is a concept that we can define briefly, the concept of migration has a very comprehensive content and has a very severe effect on a wide variety of issues in terms of its consequences. Migration is not only a social event, but a population movement that has very effective reflections on many issues such as social, economic, cultural, political, spatial, morphological, recreational, public health, quality of life, food access.

Migration is handled under two headings as internal and external migration. Internal migration is a population movement from one region to another within the borders of a country, and external migration (emigration) is a population movement from one country to another.

Migrations can be grouped as migrations with no return, temporary or seasonal migration. It is possible to include summer migrations in this migration movement.

The aim of this study is to investigate the changes of quality and quantity of green spaces with the population increase of Edremit District of

Balıkesir Province, which has over-population increase especially in the summer months. As a result of this research especially in the summertime, while with the growing population, some problems such as infrastructure, transportation, security, environmental pollution and lack of green spaces are experienced, also determined that one of the other important problem is the damages to the green spaces, especially olive groves, of the district periphery caused by urban sprawl. In this context, it was concluded that decisions and plans should be made for the protection, improvement and sustainability of green spaces.

## **2. Migration and Urbanization Process**

The pressure of urbanization caused by migration and population growth, rapid developments in tourism, industry and technology cause green spaces in and on the periphery of the city rapidly change, transform and even disappear. Green spaces provide sustainability and endurance against disasters such as drought, flood, earthquake, famine, that are experienced as a result of climate change and will make their impact even more seriously in the coming years. Also they are very important areas in terms of mental and physical human health. However, people who create new living spaces for themselves with urbanization, on the other hand, continue to destroy open and green spaces, which are extremely important for their own health.

In 2008, it was announced that the urban population in the world exceeded the rate of rural population. 55% of the world population in 2019 and today approximately 65% live in cities. According to the data of the United Nations, this rate will increase to 70% by 2050. In Turkey, in 1927, 75.8% of the population were living in the town and villages, while the 24,2% of the population were living in districts and cities. According to World Bank data; today, the rate of population living in urban areas is 75.1% (Url 1, 2021). Today, approximately 65% of the country's population lives in cities, while at the same time, migration from rural to urban continues at full speed. Cities that are inadequate for people are spreading and thus rural areas are also becoming urbanized. An important type of migration to cities for various reasons is secondary housing, especially summer housing.

In Turkey, especially in the post-1950 due to industrialization and increasing need for labor, population started to gather in urban areas. Since then, metropolitan cities such as Istanbul and Ankara have faced urbanization pressure due to intense immigration. In this process, which started with industrialization, these cities spread and pressurize the villages and rural areas in the city and in the city periphery.

As can be seen, migration does not only cause changes in the social structure of individuals and society, but also causes rapid change and transformation in abandoned and migrated places. While abandoned spaces gradually become desolate and turn into rundown areas, migrated spaces are rapidly transforming into unhealthy urban spaces due to population density pressure.

There are many reasons for migration, which is extremely effective in the change of cities. People migrated from rural areas to urban areas due to reasons such as natural disasters, economic reasons, security concerns, attractiveness of cities, access to food, educational opportunities, social opportunities, increase in quality of life and living standards, as well as social pressure, etc. However, migration is of course not only from rural areas to urban areas. Urban dwellers, who live in cities that have become almost uninhabitable with their increasing population, tend to migrate to places where they can escape from the busy urban life, be in touch with nature and breathe. This situation sometimes results abandonment of cities with no return and sometimes for seasonal. However, in both cases, cities and rural areas undergo change and transformation.

### **3. Urbanization Pressure and Effects on Green Spaces**

With migration, cities undergo great changes both socially and spatially. Those who come to cities from rural settlements try to keep on their own living culture in urban environments. The fact that those who migrate to the cities do not feel a sense of belonging to the city and the cities and urban values do not make sense and do not protect the city cause further deterioration of the cities. However, processes such as increasing population density, unplanned urbanization, slums, declining quality of life and economic

difficulties of cities have begun to leave attractive urban environments to adverse conditions. In addition, rural areas have become new attraction centers due to natural causes such as earthquakes, floods, the pandemic process experienced today, climate change, air pollution, and inability to access nature. Especially the neighboring provinces and districts close to the metropolitan cities, which can be accessed more easily, are the main attraction areas for the urban dwellers.

The fact that urban dwellers with the high income and education who are living in the cities prefer rural areas that are quite and intertwined with nature, changes the socio-cultural and socioeconomic structure of rural areas. Thus, it changes the general characteristic (identity and texture) of the rural areas. Today, rural areas are undergoing an administrative, functional, sociocultural and socioeconomic transformation. In the globalizing world, this process brings paradoxes in the concepts of rural-urban (Ceylan and Somuncu, 2018).

These areas, which are preferred especially to escape from urban life, to have a quieter life related to nature or to have a holiday, are starting to become concrete due to the incoming demands. These areas become to lose their attraction because of the destruction of nature and forest areas which are the reason to be preferred the region. But the worst part is that this cycle is continuous. With this cycle, human beings are in a continuous situation of migration. They are destroying the natural areas such as agriculture, forest, wetlands, etc., where they migrated, spreading urban areas and therefore seeking new areas to migrate.

The aim of this study is to examine the effects of migration on nature and green areas through these paradoxes and to discuss these processes through the sample area.

#### **4. Material and Method**

The material of the study is Edremit District of Balıkesir Province. Balıkesir is located at an important point in the Marmara Region due to its geographical location, in terms of its coasts from the west to the Aegean Sea and from the north to the Marmara Sea (Figure 1).



**Figure 1:** Location of Balıkesir Province and Edremit District

Source: Url 3, 2021

It is situated at the tip of the gulf with the same name (Gulf of Edremit), with its town centre a few kilometres inland, and is an important centre of trade, along with the other towns that are situated on the same gulf (namely Ayvalık, Gömeç, Burhaniye and Havran). It is also one of the largest district centres of Balıkesir Province. The district of Edremit, especially around Kazdağı, is largely covered with forests. Edremit's economy relies largely on the production of olives, as well as on tourism. Edremit is known as the olive capital of Turkey. Kaz Dağı National Park, extending around the ancient Mount Ida (mentioned in Homer's epic poems such as the Iliad), is situated within the boundaries of Edremit district and is an important tourist attraction with its natural scenery and a number of picturesque small villages around it (Url 2, 2021). Edremit District is an important district in terms of transportation. In addition to transportation by road and sea, another important transportation route is airway. There are also international scheduled flights from Koca Seyit Airport.

In ethno-cultural terms, the population of Edremit is a mixture of Balkan Turks and Balkan Albanians, descendants of immigrants from Balkans, Aegean Islands, some Circassians, as well as Tahtacı Turkmens, who pursue their own traditions and life-style to this day (Url 2, 2021).

For the year 2021, the population of Balıkesir Province was 1,250,610 and the population of Edremit District was 161,145. Edremit District is the

3rd most populous district of Balıkesir. Considering the data since 2007, it is seen that both the population of the province and the district have been increasing regularly (Table 1).

**Table 1:** Balıkesir and Edremit District Population by Years Source: Url 4, 2021

Year	Balıkesir	Edremit
2021	1.250.610	164.696
2020	1.240.285	161.145
2019	1.228.620	155.837
2018	1.226.575	154.487
2017	1.204.824	148.341
2016	1.196.176	144.995
2015	1.186.688	140.857
2014	1.189.057	140.161
2013	1.162.761	129.104
2012	1.160.731	127.459
2011	1.154.314	125.018
2010	1.152.323	120.955
2009	1.140.085	116.343
2008	1.130.276	113.453
2007	1.118.313	107.620

After Balıkesir Province became a Metropolitan, Edremit District had 47 neighbourhoods and Edremit District was expanded more.

#### **4.1. Evaluation of Immigration Movements**

Population movements of Edremit District can be evaluated as migrations with no return, seasonal migrations and daily labor movements.

It can be said that the migrations with no return in Edremit District are especially from Balkan countries to the district. Seasonal migration occurs due to intense tourism activities.

Edremit, which is the third largest district of Balıkesir, especially with

Altınoluk and Akçay neighbourhoods, is a popular destination with for thousands of local and foreign tourists. The population of Edremit, where 161,145 people live, exceeds 2 million in the summer months.

In addition, migrations that increase the summer population by coming to Edremit district center and coastal areas such as Altınoluk, Akçay, Güre and Zeytinli to work from outside the province are also included in the group of seasonal migrations.

Daily labor force movements occur within the working area and are directed towards the plain or coastal areas in order to meet the lacking workforce in agricultural activities and construction sector from the higher parts of the region. Considering the workforce mobility, which generally emerges in the form of agriculture and construction work, as a whole, Edremit is a district that attracts labor rather than an area that employs labor. In the district where olive agriculture is dominant, the harvesting of olives can take from November to the end of February. During these periods, the district hosts seasonal workers from inside and outside the city. Daily workers come from villages rather than city districts.

The natural wealth of Edremit region offers a potential for health tourism. The canyons (Şahindere Canyon, Zığındere Canyon and Ayı Deresi Canyon) along the southern slopes of Kazdağı constitute the source of the air in the region. Air corridors in the canyons transmit fresh air to the coastline at certain time intervals. For example, Şahin Deresi Canyon, which is covered with dense pine trees, 600 m deep and approximately 2 km long, transmits fresh air to Altınoluk Municipality through air corridors. For this reason, medical circles recommend the region to heart and asthma patients (Anon, 1995).

The opportunities offered by the district, holiday, health and tourism opportunities, employment and employment opportunities cause the population of the district to increase in certain periods. Housing is increasing day by day in order to meet the shelter needs of people. Although the agricultural areas and olive cultivation opportunities have existed for a long time, due to the developments in the construction sector, sub-sectors such as construction markets, hardware stores, furniture stores, furnishers, glassware have also developed to meet basic needs.

#### **4.2. Changes of Edremit District on Green Areas Due to the Urbanization and Migration process**

Edremit, a city founded 1443 years ago in the name of Pidasus in Karataş Mevkii near Burhaniye Pier, was taken into the borders of the Ottoman Empire by Orhan Gazi in 1336 (Anon, 2012).

The geographical proximity of Edremit with Istanbul and the islands especially Lesbos and the olive trade have accelerated the population mobility. The commercial value of olive oil and extensive olive groves has attracted investors and workers (Genç, 2013). In the city of Edremit, there were 38000 acres of fertile wheat cultivation in 1911 and 24000 acres in 1921. Again, in Edremit, there is a land of 15000 and 36000 decares of barley cultivated area in the same years (Gazali, 1927).

The 1950s represent an important date for Turkey. In this period, the renewal of Edremit is noteworthy. Especially the effort of Edremit Municipality between 1950-1954 is important in terms of forming the basic skeleton of the city. The roads were repaired, afforested, and housing construction was accelerated (Edremit Municipality, 1954; Yılmaz Çıldam, 2016), (Figure 2).



Figure 2: Edremit 1952  
Source: Url 5, 2021.

The city expanded northward after 1955. Since 1965, it has started to develop in almost all directions with the advantage of being located in an alluvial plain (Figure 3). In the 1960s, when Edremit Municipality bought the Akçay coastline, Akçay became active. Too many marshes in Akçay have been drained and turned into a summer resort and attraction center. The opening of tourism facilities such as hotels and motels after the 1960s and the opening of the "Turban Akçay Holiday Village" in Akçay-Altinkum accelerated the development of tourism (Kitapçioğlu, 1993: 208). However, the real development of tourism took place when Akçay Turban Holiday Village was rented by the French in 1969 (Edremit Newspaper, 6 October 1968).

In the 1970s, there were migrations from the surrounding villages and towns to Edremit. In the 1980s, the construction industry has gained momentum. A large number of people from the east of the country turned to Edremit to work in construction. (Edremit Newspaper, August 17, 1978; Yılmaz Çıldam, 2016).



**Figure 3:** Aerial Photograph of Edremit District, 1975

Source: General Directorate of Mapping, 2014; Yılmaz Çıldam, 2016.

Edremit has 15 neighborhoods in 1999. The bazaar forms the center of the city. Roads meet in this bazaar. Workplaces and residences coexist in the central area of the city. During this period, the city continued to grow horizontally.

In the city of Edremit, the total population increased from 26,110 to 27,145 between 1975-1980. A serious increase was observed in the annual growth rate of the total population between 1980-1985 (from 7.8% to 21.1%). Between the years 1985-1990 the population growth rate is above the average of Turkey. The total population has increased from 30,159 to 35,486. It is thought that tourism has a significant share in these increase amounts in Edremit city. Especially those who came to Edremit during holidays were not indifferent to this magnificent nature, and they had an impact on the population increase by buying a summer house or settling down when they retired (Yılmaz Çıldam, 2016).

It is seen that Edremit has a sufficient environment in the district peripheries in terms of natural green areas, but insufficient in the district in terms of urban green areas.

Considering the land use of the district, it is possible to talk about an identity in which agriculture and services take the first place in the district. Tourism is supported throughout the district and strategies are developed to meet the increasing population needs in seasonal uses. According to the labor force, the economy of the district is based on agriculture and services. While the largest share of agricultural activities is related to olive cultivation and other agricultural products, the efficiency in the services sector depends on the employment that develops due to tourism (Yılmaz Çıldam, 2016).

According to Balıkesir-Çanakkale Planning Region 1/100.000 Environmental Plan Research Report 2012, it is seen that Edremit district had forest at the rate of 70.93% and agricultural land with a rate of 20.58% (Table 2, Figure 4).

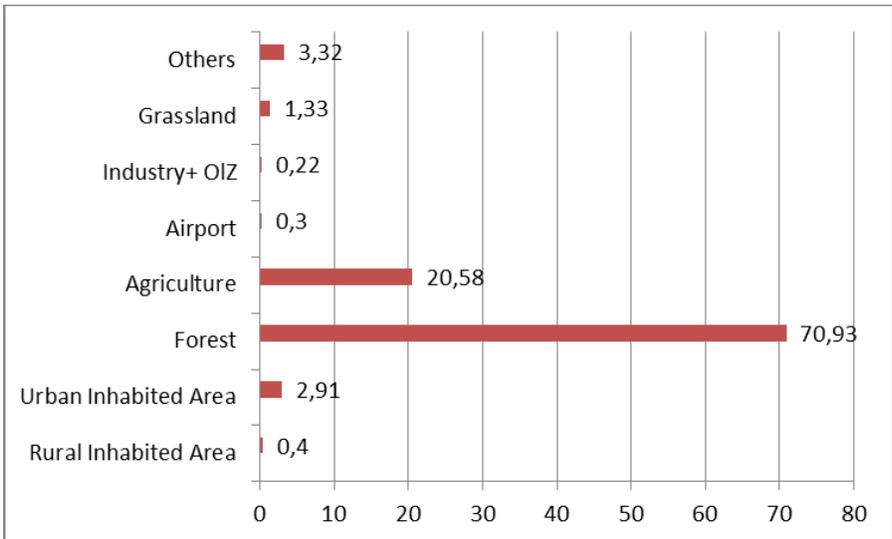
It is seen that urbanization has increased in direct proportion to the population increase and migration in Edremit District. In order to provide the migration and shelter needs of people for various reasons, construction is

increasing day by day and green spaces, especially olive groves are gradually decreasing (Figure 5, Figure 6).

**Table 2:** Land Use of Edremit District

Source: Anon, 2012

Usages	Area (ha.)	Percentage (%)
Rural Inhabited Area	302.45	0.40
Urban Inhabited Area	2177.60	2.91
<b>Forest</b>	<b>53079.86</b>	<b>70.93</b>
<b>Agriculture</b>	<b>15401.85</b>	<b>20.58</b>
Airport	223.90	0.30
Industry+ Organized Industrial Zone	161.63	0.22
Grassland	994.19	1.33
Others	2487.84	3.32
<b>Total District Area</b>	<b>74829.33</b>	<b>100.00</b>



**Figure 4:** Land Use Rates of Balıkesir Edremit District, 2012

Source: Anon, 2012



Figure 7 shows the urban development of Edremit District in 2020. The road drawn in yellow color, the ring road in 1952 and the area with borders with red also show the first settlement in 1952. During the period from 1952 to 2020, Edremit's urban development is clearly visible.



**Figure 7:** Overlay Map of Aerial Photograph of  
Center of Edremit District, 1952- 2020

Source: Google earth, 2021

As seen in Figure 7, the ring road in 1952 (shown with the yellow line), remains inside the city center today. From 2004 to 2020, it is seen that the city has entered a rapid construction process and urbanization has increased very rapidly, and since 2010, urbanization has developed towards the lower part of the E87 Highway, that is to the south and in the east-west direction.

The fertile agricultural areas and olive groves of the district were destroyed with opening to construction in order to provide the shelter and vacation and summer sites and hotels in the coastal areas were built for people needs due to the intense population increase and migration especially in the summer season.

It is observed that it has developed in the summer site area due to being a tourism region in neighborhoods especially such as Tahtakuşlar, Güre,

Zeytinli and Altınoluk, which are near the coast. At the same rate, it is possible to say that the hotels are located in the parcels in the coastal areas (Figure 8, Figure 9, Figure 10).



**Figure 8:** Example of construction sites built by destroying green areas

Source: Url 6



**Figure 9:** Example of construction sites built by destroying green areas

Source: Url 7



**Figure 10:** Example of construction sites built by destroying green areas

Source: Url 8

Edremit has become one of the attraction centers for tourism with long season, the proximity of the metropolitan cities to the South Marmara and Aegean Regions compared to the Mediterranean Region, the nature and clean air of the Kazdaglar where has the highest oxygen after the Alps. Under these effects, the intensity of urbanization is felt especially in the coastal areas.

In these coastal regions where the winter population is very low, the population is much higher than the capacity in summer. This creates a pressure for green spaces. Human density and crowding cause destruction and environmental pollution that can be considered as a threat to green areas.

## 5. Conclusion

Urbanization is a dimension of both social change and spatial change process. With the population growth and the phenomenon of immigration, cities are gradually growing, and green areas are getting smaller and smaller to meet the needs of cities or citizens.

The increase in the demands of today's social life, the use of advanced technology, the conversion of agricultural areas to residential areas and the unaccounted use of resources cause irreparable damage to the natural environment.

With industrialization, people move away from the idea that they are a part of nature and have the idea that human beings can dominate nature and use nature as a resource that can be exploited. Factors such as the destruction of resources from long-term and multi-dimensional evaluation, the development of economic systems that create consumer societies, the rapid decline of agricultural lands, accumulation in cities and increasing population problems cause environmental problems to grow gradually.

Considering that most of the people live in cities today, it is known that the physical and social structure of the city has significant effects on the people, as well as the people living in the city, on the development and socio-economic structure of the city. In this interaction process, it is seen that the need for an effective city management is increasing both in order to meet the needs of the city residents effectively and to protect the cities. The most important reasons for the increase of urban needs are the new needs arising from the overpopulation of the cities and the urban and environmental problems that come with it.

The district of Edremit, which is a study area, is faced with problems such as housing, infrastructure, transportation, employment, security, environmental pollution, especially with the increase of the population experienced with the migration in the summer season.

However tourism-oriented activities take place in the coastal settlements of Edremit, the economic actor of Edremit District is olive, as the region is surrounded by olive groves. But, especially due to touristic activities, urbanization is increasing very rapidly and most of the areas where construction permits are given are olive groves and agricultural areas (Figure 11).



**Figure 11:** Aerial Photograph of Edremit District, 2021

Source: Google earth, 2021

The tourism potential of the area and the increase in population, especially the high demand for touristic facilities and summer houses, and the fact that the value of the olive groves are much higher than their real value, the olive groves are seen as a real estate investment tool cause great destruction of the olive groves.

The economic and social conditions brought about by rapid urbanization can render the people ineffective for their consciousness and sensitivity towards green. Without having a green consciousness, it is not possible to effectively protect green areas, which provide economic profit, food, and the greatest need of people in terms of mental, physical and physical aspects. It is of great importance that both citizens and villagers know the value and importance of the place where they live and have protection awareness. At this stage, especially local governments, non-governmental organizations and professional organizations should carry out studies and projects that raise awareness and awareness among people living in cities and villages.

As a result, Edremit is in a central position in terms of olive and olive oil production and tourism and both sectors affect its environment. The presence of tourism in the district of Edremit, the activity of the construction

sector and the improvements in the service sector show that the population will increase even more and the region will retain its current attraction power for a long time. As the touristic aspect of Edremit develops, reinforced concrete construction increases. Therefore, tourism and olive cultivation activities are in contention in Edremit. This conflict should be abandoned and solution-oriented plans and policies should be produced. The decisions taken at this stage should not harm the unique identity of the city throughout its history. Therefore, olive groves should be protected with care. Otherwise, the existence of green areas (olive groves, agricultural areas, forest areas) will be greatly damaged and the district will become an uninhabitable place with a population above its capacity.

## References

- Anonymous, 1995. *Mc/fc , " Pcvkqpcn" Rctm" Ocuvgt" Rncp" Tgrqtv0" Igpqtcn"* Directorate of National Parks, Hunting and Wildlife, 1995.
- Anonymous, 2012. *Dcn,mgukt-Çanakkale Planning Region 1/100.000 Environmental Plan Research Report*, 2012.
- <https://docplayer.biz.tr/2856704-Balikesir-canakkale-planlama-bolgesi-1-100-000-cevre-duzeni-plani-arastirma-raporu.html>
- Ceylan, S.& Somuncu, M., 2018. *Rethinking From Conceptual Perspective of Twtcn" Ctgcuo" Vtcpuht o cvkqp*. International Geography Symposium on the 30th Anniversary of TUCAUM, 3-6 October 2018, Ankara.
- Edremit Municipality Studies (1950-1954), Edremit.
- Edremit Newspaper, 6 October 1968.
- Edremit Newspaper, August 17, 1978.
- Gazali, 1927. *Dcn,mgukt" Xknc{gv" Eq tch{cu,*, Balıkesir. Balıkesir Vilayet Matbaası.
- Genç, S., 2013. *ZKZ0" [Ã/{,n,p" nm" [ct,u,pfc"Gftgokvøvg" [cdcpe,nct*. Prof.Dr. Mustafa Çetin Varlık Armağanı, KTB Yayınları, İstanbul 2013, s. 358-379.
- Kitapçioğlu, F., (1993). *Gftgokv" gjtk*. Türk Coğrafya Dergisi, Sayı: 28, Sayfa: 189-214.
- Yılmaz Çıldam S., 2016. *Gftgokv" gjtk" Eq tch{cu,0* Doktora Tezi. Balıkesir

Üniversitesi Sosyal Bilimler Enstitüsü, Balıkesir.

- Url 1, 2021. [https://cevreselgostergeler.csb.gov.tr/kentsel---kirsal-nufus-orani-i-85670#\\_edn1](https://cevreselgostergeler.csb.gov.tr/kentsel---kirsal-nufus-orani-i-85670#_edn1).
- Url 2, 2021. [https://en.wikipedia.org/wiki/Edremit,\\_Bal%C4%B1kesir](https://en.wikipedia.org/wiki/Edremit,_Bal%C4%B1kesir).
- Url 3, 2021. <https://tr.wikipedia.org/wiki/Bal%C4%B1kesir#/media/Dosya:Latrans->
- Url. 4, 2021. [https://www.nufusu.com/ilce/edremit\\_balikesir-nufusu#:~:text=Edremit%20n%C3%BCfusu%202020%20y%C4%B1l%C4%B1na%20g%C3%B6re%20161.145](https://www.nufusu.com/ilce/edremit_balikesir-nufusu#:~:text=Edremit%20n%C3%BCfusu%202020%20y%C4%B1l%C4%B1na%20g%C3%B6re%20161.145).
- Url 5, 2021. <https://tr.facebook.com/altinolukavcilar/photos/pcb.3425888147460572/3425887410793979/?type=3&theater>
- Url 6,2021. [https://www.google.com/imgres?imgurl=https%3A%2F%2Fstatic.birgun.net%2Fresim%2Fhaber-detay-resim%2F2019%2F11%2F04%2Fmahkeme-edremit-halkini-hakli-buldu-645126-5.jpg&imgrefurl=https%3A%2F%2Fwww.birgun.net%2Fhaber%2Fmahkeme-edremit-halkini-hakli-buldu-275030&tbnid=c0WeqC2cORn4aM&vet=12ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ..i&docid=1TzxDT4-2n\\_BcM&w=620&h=344&q=edremit%20&hl=tr&ved=2ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ#imgrc=oX9o11uG11REeM&imgdii=wWVfdkjulYdCeM](https://www.google.com/imgres?imgurl=https%3A%2F%2Fstatic.birgun.net%2Fresim%2Fhaber-detay-resim%2F2019%2F11%2F04%2Fmahkeme-edremit-halkini-hakli-buldu-645126-5.jpg&imgrefurl=https%3A%2F%2Fwww.birgun.net%2Fhaber%2Fmahkeme-edremit-halkini-hakli-buldu-275030&tbnid=c0WeqC2cORn4aM&vet=12ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ..i&docid=1TzxDT4-2n_BcM&w=620&h=344&q=edremit%20&hl=tr&ved=2ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ#imgrc=oX9o11uG11REeM&imgdii=wWVfdkjulYdCeM)
- Url 7, 2021. [https://www.google.com/imgres?imgurl=https%3A%2F%2Fstatic.birgun.net%2Fresim%2Fhaber-detay-resim%2F2019%2F11%2F04%2Fmahkeme-edremit-halkini-hakli-buldu-645126-5.jpg&imgrefurl=https%3A%2F%2Fwww.birgun.net%2Fhaber%2Fmahkeme-edremit-halkini-hakli-buldu-275030&tbnid=c0WeqC2cORn4aM&vet=12ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ..i&docid=1TzxDT4-2n\\_BcM&w=620&h=344&q=edremit%20&hl=tr&ved=2ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ#imgrc=qIYf3b9N17rerM&imgdii=oX9o11uG11REeM](https://www.google.com/imgres?imgurl=https%3A%2F%2Fstatic.birgun.net%2Fresim%2Fhaber-detay-resim%2F2019%2F11%2F04%2Fmahkeme-edremit-halkini-hakli-buldu-645126-5.jpg&imgrefurl=https%3A%2F%2Fwww.birgun.net%2Fhaber%2Fmahkeme-edremit-halkini-hakli-buldu-275030&tbnid=c0WeqC2cORn4aM&vet=12ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ..i&docid=1TzxDT4-2n_BcM&w=620&h=344&q=edremit%20&hl=tr&ved=2ahUKEwjEudH6jovwAhUCihoKHTe4AkYQMyhlegUIARCzAQ#imgrc=qIYf3b9N17rerM&imgdii=oX9o11uG11REeM)
- Url 8,2021. <http://www.balikesir.com.tr/tr/ilceler/edremit>



## CHAPTER IV

# THE ROLE OF LEAGILITY IN HUMANITARIAN RELIEF SUPPLY CHAINS AND POST-DISASTER RE-CONSTRUCTION ACTIVITIES

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### 1. Introduction

As the world is being re-shaped around a highly nimble and quick-responding principles, conventional methods are effected including organizations, supply chain strategies and disaster management activities. The world is becoming more volatile, uncertain, complex and ambiguous. In this transformation, some of the concepts including lean, agile and leagile, which is the combination of two, are stepping forward. As conditions change rapidly, disaster management components and activities need to adapt. So, humanitarian relief supply chains and post-disaster reconstruction activities, which are two of fundamental components of disaster management, need to reshape themselves and adopt contemporary strategies like leagility which seems promising as being one of the most suitable strategies for disaster situations.

The aim of this study is to emphasize the importance and explore the suitability of leagility in humanitarian relief supply chains and post-disaster reconstruction activities which are major parts of disaster management efforts. The study builds on literature review. Firstly, related concepts which are lean, agile, leagile, supply chain and disaster management are explained.

Next, leagile supply chain concept is investigated and the importance of leagility in both commercial and humanitarian supply chains is reviewed. Then, the potential benefits of integrating leagility to humanitarian relief and post-disaster construction activities are explored.

## **2. Lean, Agile and Leagile**

Lean concept and its fundamental principles are based on Toyota's production system (Womack and Jones, 2003). The ideas of lean thinking formed from complex ideas including: continuous improvement, flattened organisation structures, teamwork, the elimination of waste, efficient use of resources and cooperative supply chain management (Green, 2000). There are 14 basic principles of the lean as: (1) Think Long-Term, (2) Create the Flow, (3) Avoid Overproduction, (4) Level out the workload, (5) Stop to fix problems and get quality right at the first time, (6) Use standardised tasks, (7) Use visual indicators and visual control to reveal problems that can be hidden, (8) Use only reliable tested technology to support people, not to replace them, (9) Choose the leaders who understand and live the philosophy, (10) Develop Teamwork, (11) Help your partners to improve, (12) Be in the field to understand, (13) Think slow, act fast, (14) Become a learning organization (Url-1).

The whole lean universe can roughly be summarised as 1) Understanding and maximizing the value, 2) Optimizing the value stream, 3) Pull production, 4) Single-piece flow and 5) Continuous improvement, (6) long-term philosophy, (7) the right process will produce the right results, and (8) add value to the organization by developing your people and continuously solving root problems drives organisational learning (Medinilla, 2012; Liker, 2004).

Agility is the ability of company to anticipate, sense and respond to volatile environment to create competitive advantage. In short, agility is equal to sum of adaptability, speed and execution (Silverstone, Tambe & Cantrell, 2015). Agile is built on iterative development, which involves the participation of self-organizing and cross-functional teams to build an evolving process of requirements and solutions. It encourages a disciplined

project management method that includes frequent inspection, adaptation, teamwork, self-organization, responsibility, rapid reaction and high-quality product delivery. To do so, agile suggests to collaborate with customers to meet their demands as well as the company's objectives. At first, agile was some kind of modification of lean into the software/product development area (Medinilla, 2012), but then adopted by different sectors and has been widely used.

The foundation of the Agile is based on The Agile Manifesto which was formed by a group of fourteen software developers. It constitutes the ideas of what to do and what not to do in the process of software development. There are twelve principles of Agile, can be summarised as prioritising satisfaction of customer with early and continuous delivery; welcoming changes even late in development; encouraging self-organising teams and empowered individuals as well as face-to-face, frequent and quick interactions; simplicity; constant development and adjusting the pace at regular intervals (Url-2).

Leagile is the hybrid form of lean and agile with a decoupling point. Lean part attempts to reduce all types of wastes to cut costs, while agile part aspires to respond rapidly to demands. Leagility combines flexibility and reactivity with a focus on cost reduction and waste reduction.

### **3. Supply Chain Management**

Supply chain management can be described as the network of interconnected organisations that collaborate to manage the flow of resources of all kinds from one point to another in order to produce value and meet the needs at the lowest feasible cost for everyone involved (Christopher and Peck, 2004; Lambert et al., 1998). The aim of supply chain management is to maximize customer value and achieve a sustainable competitive advantage. Supply chain activities cover everything from product development to sourcing, from production to logistics. It also covers information systems for coordination of activities.

There are two types of flows in supply chains: physical and information. Physical flows cover transformation, movement and storage of

goods and materials. It's the tangible and visible part of a supply chain. Information flow provides stakeholders to coordinate plans and control physical flows.

With globalisation and information technology advances, competition is becoming fiercer and customer demands are getting more personalized and diversified. This change is effecting product life-cycles to get shorter and forces organisations to respond more quickly to changes. But, traditional supply chains are insufficient to respond to this demand. Therefore, six main trends in supply chain management comes forward to take place of the traditional approach. These trends and their main tendencies, as categorised by Bukowski and Felix (2012), are: (1) Lean supply chain - seek reduced costs, (2) Flexible supply chain – ability to respond changes, (3) Agile supply chain – ability to respond quick changes, (4) Responsive supply chain – increased speed and flexibility supported by IT, (5) Leagile supply chain - seek reduced costs & ability to respond quick changes, (6) Resilient supply chain – seek reduced risks.

According to Zhang et al. (2012) shortages of traditional supply chains are: (1) Information cannot be shared in the supply chain as there is a direct downstream, (2) The length of supply chain is too long and (3) Demand prediction is unpredictable. Comparison of main attributes of traditional, lean, agile and leagile supply chains made by Konecka (2010) can be seen in Table 1.

**Table 1.** Attributes of traditional, lean, agile and leagile supply chains (Konecka, 2010)

supply chain attributes	traditional	Lean	Agile	Leagile
demand	unpredictable	predictable	unstable (undulant)	unstable and unpredictable
products	standard	functional	personalized	personalized
the major share in the total supply chain costs	physical costs and marketability costs	physical costs	marketability costs	physical costs and marketability costs
elimination of waste	low priority	basic	desirable	arbitrary
quality	market winners	market qualifiers	market qualifiers	market qualifiers
cost	market winners regarding costs	market winners	market qualifiers	market winners
web integration	not existing	desirable	necessary	mandatory
virtual integration	low priority	desirable	necessary	mandatory
information decoupling	not existing	beneficial	necessary	desirable
postponement	not existing	not required	necessary	desirable
product's concept	producer's	producer's	producer's and consumer's	producer's and consumer's
measures of quality	the percentage of defective products	the percentage of defective products	customer satisfaction	customer satisfaction
legal sanctions for the supply	not big	enclosed in long-term contracts	order's loss	order's loss
the ability to absorb risk in the supply chain	moderate	low	high	moderate

#### **4. Leagile Supply Chain**

Leagile supply chain uses combination of lean and agile practices like continuous improvement, information sharing, waste management value stream, demand management and etc. to reach the optimum performance in terms of service quality, flexibility, cost reduction and delivery dependability. As it is stated by Bukowski and Felix (2012), a supply chain can be lean and efficient, but if it can't locate an alternate delivery route soon enough, it will be vulnerable to system shocks and disruptions. Furthermore, lean supply chains are unable to respond rapidly to the personalised demands. However, agile supply chains alone sacrifice the cost advantages of standardised processes that comes with lean supply chains. Therefore, leagile supply chains distinguish from the others as it combines the cost advantages of lean and ability of respond to quick changes of agile. Lean processes are on the upstream side and agile processes are on the downstream side. Finding the right balance is the key to find the optimal level of leanness to emplace resiliency and not being vulnerable to potential risks (Christopher and Rutherford, 2004).

Leagile supply chains seek to provide optimum material supply to ensure satisfied customers (Matawale, 2015). Agile processes are at the pull stage of end customer driven demand pulled side, lean processes are at the push stage of supplier driven product pushed side (Zhang et al., 2012). In leagile, lean part aims to reduce all kind of wastes to minimize cost while agile part aims to quickly respond to nimble demands. Leagility also contains flexibility and responsiveness in terms of demands. According to Matawale (2015), leagile supply chains have advantages through sharing information and reducing information asymmetry, strengthening the cooperation between parties involved, shortening the length of supply chain, providing low cost with high efficiency, reducing the complexity of supply chain and fulfilling the customer needs more precisely compared to traditional supply chains.

#### **5. Disaster, Humanitarian Relief and Post-Disaster Re-Construction**

Disaster is defined by the United Nations (UN) as a breakdown in the normal functioning of community that has a significant adverse impact on people,

their works, and their environment which exceed the ability of the affected people to cope using only its own resources; therefore, it may require external help from different sources, which can be national or even international level. Disasters can be resulted from a human activity or a natural event. The disaster's impact can be rapid and confined, but it's usually extensive and can persist for a long time (Url-3). As it is stated by Chandraprakaikul (2010), there are four phases of a disaster management process, which are:

- ◁ **Preparedness:** Governments, organizations, and individuals establish plans to preserve lives, minimize disaster damage, and improve disaster response operations.
- ◁ **Mitigation:** Include activities that either prevent an emergency from occurring or lessen the community's vulnerability in ways that reducing the negative effects of a disaster.
- ◁ **Response:** The focus is on providing people's fundamental needs until more permanent and long-term solutions can be developed.
- ◁ **Recovery:** Aim is at restoring the lives of those who have been impacted as well as the infrastructure.

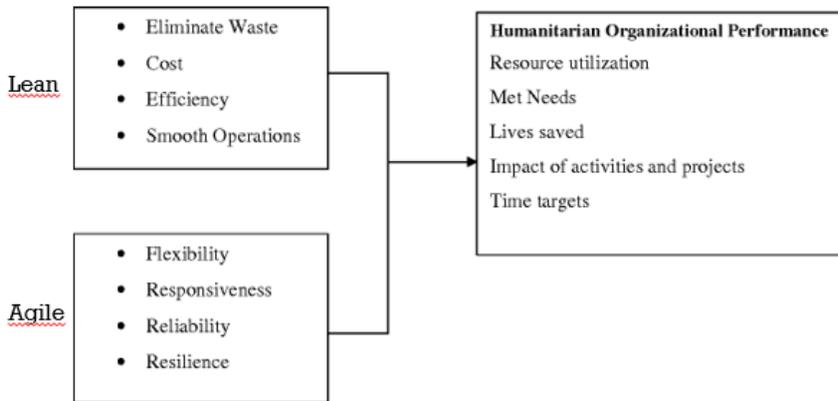
In disaster management literature, supply chain term is named as humanitarian relief supply chain. Like commercial supply chain, in which connects the sources to demands (in other words, connects suppliers to customers), humanitarian relief supply chains provides the continuous flow from donors to consumers. The main principles of both supply chains do not change. The ultimate goal of both is the same, to deliver right supplies in right quantities to right location at right time. But, even though the structure of humanitarian relief supply chains are similar to commercial supply chains, the humanitarian relief supply chains are often more unstable (Chandraprakaikul, 2010). Disaster relief, also known as humanitarian relief, process consists of three phases in a cycle as: pre-disaster, disaster and post-disaster (Lettieri et al., 2009). Post-disaster re-construction activities take place in post disaster phase aiming to restore the infrastructure of ones who were effected from disaster to return to normal conditions. According to the joint publication of

the Emergency Preparedness and Disaster Relief Coordination Program of the Pan American Health Organization (PAHO) and the Department of Emergency and Humanitarian Action of the World Health Organization (WHO) done in 2001;

*ōc" fkucwgt" rncegu" gzevrkqpcn" fgocpfu" qp" vjg" uwrrn{" ejckp." logistical and organisational skills of the affected country. Mobilising the staff, equipment and goods of humanitarian assistance organisations, the evacuation of the injured or the resettlement of those directly affected by disaster, requires a logistics and supply chain system to maximize ghlgevkxgpguuö)*

## **6. Leagility in Humanitarian Relief Supply Chains and Post-Disaster Re-Construction Activities**

As it is stated earlier, even though the structure of humanitarian relief supply chains is similar to commercial supply chains, the humanitarian relief supply chains are often more unstable (Chandraprakaikul, 2010). Also, according to Jahre et al. (2009), the hardest thing in humanitarian supply chains is to balance between ability of making quick response and providing cost efficiency. So, leagility stands out for humanitarian relief as it promises to provide a possible and feasible solution to this trade-off. Lean inputs such as eliminating waste, cost advantage, efficiency and smooth operations gels together with agile inputs such as flexibility, responsiveness, reliability and resilience in the process of creating successful humanitarian organisational supply chain resulting performance measured by resource utilisation, met needs, saved lives, time targets and impact of activities and projects (Figure 1).

**Figure 1.** Lean and agile for humanitarian organisational performance

Disasters create an unpredictable and nimble pull-demand. As it is stated by Chandraprakaikul (2010), a humanitarian supply chain should be lean in upstream activities, such as needs assessment, mobilisation of sufficient financing, people, skills and goods, procurement, transportation sourcing, disaster preparation and planning; and it should be agile in downstream activities, such as recipient specific deliveries, site selection planning, decision making and sensitive needs assessment. Thus, leagility combines cost effectiveness of the upstream chain and high service levels of the downstream chain.

In humanitarian relief supply chains, both lean and agile phases of leagile supply chain should carefully be used in different parts of the disaster management. In pre-disaster period, mitigation and preparedness activities are held, so lean principles are most appropriate for this period, because strategic planning as an approach and resource management as a performance management are the key. In disaster period, response activity takes place, so agile principles should be taken into account in this period as short term project management, flexibility and nimbleness are the most important subjects. In after-disaster period, recovery activity replaces the premises, so lean principles are back on the track again. A detailed framework for humanitarian relief supply chains formed by Chandraprakaikul (2010) can be seen in Table 2.

**Table 2.** A framework for humanitarian relief supply chains  
(Chandraprakaikul, 2010).

	Phase	Activities	Approach	Supply chain strategy	Key elements	Key performance measurement
Before	Preparation	Mitigation Preparedness	Strategic planning	Lean	<ul style="list-style-type: none"> <li>• Collaboration</li> <li>• Coordination</li> <li>• Resource planning</li> <li>• Knowledge management</li> </ul>	Resource
During	Response	Response	Short term project management	Agile	<ul style="list-style-type: none"> <li>• Information management</li> <li>• Demand management</li> <li>• Supply management</li> <li>• Fulfillment management</li> </ul>	Resource Output Flexibility
After	Reconstruction	Recovery	Long term project management and completing	Lean	<ul style="list-style-type: none"> <li>• Collaboration</li> <li>• Coordination</li> <li>• Resource planning</li> <li>• Knowledge management</li> <li>• Continuous improvement</li> </ul>	Resource Output Flexibility

Another thing is, having a contingency plan is a key point for humanitarian relief operations. Which means, deciding on at least two possible alternative solutions is important at the beginning of the planning process of disaster management. This contingency plan ensures that, when a problem, which can be a delay or a defected process in the supply chain, has occurred, for the sake of supply chain's continuity, supply can be shifted from problematic chain to a ready and already decided backup with an agile decision-making strategy. That way, everything runs smoothly as it should be, and supply chain gets back to its original state as soon as possible. It's very important for a commercial supply chain as an idle time means the money lost or the customer satisfaction lost, which are the most important aspects of leagile philosophy; but also it's more than important, in fact it's vital, for a humanitarian supply chain as every minute is important in the process of relief and continuity of supply chain could mean many saved lives instead of unwanted idle time.

Besides harming people, disasters have major damages on built environment also. As it is stated by Mojtahedi and Oo (2012) natural disasters damage built environment as nearly \$10 billion per annum worldwide. Therefore, one of the most crucial disaster management phases is reconstruction phase. In built environment issue, reconstruction, together with rehabilitation, is equivalent to recovery phase of humanitarian relief supply chain. It consists recovery activities as a reactive approach (Table 3).

**Table 3.** Disaster management phases (Mojtahedi and Oo, 2012).

Response Time	Disaster Management Phase	Activities	Approaches
Before	Prediction	Mitigation	Proactive
		Preparedness	
During	Warning	Response	Reactive
	Emergency Relief		
After	Rehabilitation	Recovery	
	Reconstruction		

Post-disaster re-construction differs from traditional construction in aspect of: (1) greater degree of coordination with policy and legislation is required for post-disaster reconstruction, (2) different communities and stakeholders will be involving in post-disaster reconstruction, (3) the aim of post-disaster reconstruction is to produce non-profit oriented unique product in certain duration to elevate living condition of people, (4) post disaster reconstruction can be used as an accelerator to improve people's lives and make communities safer.

Post-disaster re-construction, because it is a hard and fragile process that needs quick actions, has some downsides like poor planning, ad hoc decision making, haphazard recovery, poor quality of built environment, waste of material, environmental damages, long reconstruction life cycle and excess cost. Therefore, to overcome these downsides, leagility can be used in order to improve reconstruction processes and activities in recovery stage of a disaster. So, leagility stands out for disaster management in terms of re-

construction as it offers important philosophies like agility, quick mobilisation and pull scheduling, etc. which can be critically practical in post-disaster re-construction activities. Some possible leagile practices which can contribute to post-disaster re-construction activities can be seen in Table 4.

**Table 4.** Leagile practices which can contribute to post-disaster re-construction activities (Mojtahedi and Oo, 2012).

Response Time	Disaster Management Phase	Activities	Approaches
Before	Prediction	Mitigation	Proactive
		Preparedness	
During	Warning	Response	Reactive
	Emergency Relief		
After	Rehabilitation	<b>Lean Recovery</b>	
	<b>Lean Reconstruction</b>	<ul style="list-style-type: none"> <li>• Quick mobilization</li> <li>• Pull scheduling</li> <li>• Just-in-Time (JIT)</li> <li>• Six Sigma</li> </ul>	

## 7. Conclusion

Organizations that are able to adapt to changing conditions will take crucial operational advantage as the world becomes more volatile, uncertain, complex and ambiguous. Leagility, which combines the advantages of lean (which are cost advantage, waste reduction, etc.) and agile (which are responsiveness, flexibility, etc.) stands out in terms of supply chain management.

Humanitarian relief supply chains usually differ from commercial supply chains as humanitarian relief supply chains are often more unstable. So, a proper humanitarian relief supply chain strategy should consist some major attributes, one of which is ability of maintaining control against disturbance and the other is adaptiveness and response capability to sudden changes. Also, the hardest thing in humanitarian relief supply chains is the trade-off between cost and responsiveness. Leagility, which can offer feasible solutions to problems that occur due to the unique characteristics of humanitarian relief supply chains, seems as a suitable alternative for these

operations. Lean inputs such as eliminating waste, cost advantage, efficiency and smooth operations gels together with agile inputs such as flexibility, responsiveness, reliability and resilience in the process of creating successful humanitarian organisational supply chain resulting performance measured by resource utilisation, met needs, saved lives, time targets and impact of activities and projects.

In disaster management literature; reconstruction, together with rehabilitation, is equivalent to recovery phase of humanitarian relief supply chain. Leagility seems very suitable for post-disaster re-construction activities as well, as it combines ability of quick changes of agile while not sacrificing the cost advantages of lean which are two of the most important necessities in that phase.

One thing to consider is, although leagility combines ability of quick changes of agile while not sacrificing the cost advantages of lean, it has the potential of having one possible fatal point that is risk management strategies to respond to disturbances in the supply chain. When a major disruption happens, almost all of the supply chains tend to break down and take very long times to get back to the original point. As it is stated by Machado and Duarte (2010), leagility without resilience can create an overexposed organization that emphasizes leanness, boundary destruction, openness, and speed so much that severe shocks and disruptions can severely damage its performance, even threaten its survival; which may have irreparable consequences in the case of disaster relief. So it is advised to include a proper risk management strategy, including a response plan to disturbances, to core leagile principles; to enhance the effectiveness of the relief operations.

## **8. References**

- Bukowski, L., A., Feliks, J. (2012) *Multi-dimensional concept of supply chain resilience*. Carpathian Logistics Congress, 7- 9. 11. 2012, Jeseník, Czech Republic, EU
- Chandraprakaikul, W. (2010) *A guiding framework for designing humanitarian relief supply chains ó A case study in Thailand*. POMS 21st Annual Conference. 7-10 May, 2010. Vancouver, Canada.

- Christopher, M., Peck, H., (2004) Building the Resilient Supply Chain. *International Journal of Logistics Management*, vol. 15, no. 2.
- Christopher, M., Rutherford, C. (2004) Creating Supply Chain Resilience Through Agile Six Sigma. *Critical Eye*. June - August 2004
- Green, S. (2000) *The future of lean construction: a brave new world*. In: 9th Conference of the International Group for Lean Construction (IGLC 9), 17-19 Jul 2000, University of Sussex, UK.
- Jahre, M., Jensen, L. M., & Listou, T. (2009). Theory development in humanitarian logistics: a framework and three cases, *Management Research News*, 32(11) pp.1008-1023.
- Konecka S., 2010, Lean and agile supply chain management concept in the aspect of risk management. *Log Forum* 6 (4) Url: [http://www.logforum.net/pdf/6\\_4\\_3\\_10.pdf](http://www.logforum.net/pdf/6_4_3_10.pdf) Accepted: 24.09.2010, Retrieval Date: 02.15.2018.
- Lambert, D. M., Stock, J. R. and Ellram, L. M., 1998, *Fundamentals of Logistics Management*, Irwin/McGraw-Hill, Boston.
- Lettieri, E., Masella, C., & Radaelli, G. (2009) Disaster management: findings from a systematic review, *Disaster Prevention and Management*, 18(2). pp.117-136.
- Liker, J., K. (2004) *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, McGraw-Hill, New York.
- Machado, V., C., Duarte, S. (2010) *Tradeoffs among Paradigms in Supply Chain Management*. Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management Dhaka, Bangladesh, January 9 – 10, 2010
- Matawale, C., R. (2015) *Evaluation of Leanness, Agility and Leagility Extent in Industrial Supply Chain*. PhD thesis. National Institute of Technology, India
- Medinilla, A. (2012). *Agile Management: Leadership in an Agile Environment*. Springer, London.
- Mojtahedi, S., M., H., Oo, B., L. (2012). Possibility of applying lean in post-disaster reconstruction: An evaluation study. *Proceedings for the 20th Annual Conference of the International Group for Lean Construction*.

url: <https://www.researchgate.net/publication/287329126>

Pan American Health Organization (2001). *Humanitarian supply management in logistics in the health sector*. Washington, D.C.

Silverstone, Y., Tambe, H., & Cantrell, S. M. (2015). HR Drives the Agile Organisation. *Accenture Strategy*.

URL-1: Lean Management: The 14 Principles of the Toyota Way. Retrieved on 5th June 2022 from <https://leminimaliste.com/lean-management-14-principles-the-toyota-way/>

URL-2: Agile Manifesto. Retrieved on 5th June 2022 from <http://agilemanifesto.org/principles.html>

URL-3: United Nations Office for Disaster Risk Reduction. Retrieved on 7th June 2022 from <https://www.undrr.org/terminology/disaster>

Womack, J., P., Jones, D., T. (2003). *Lean thinking: banish waste and create wealth in your corporation, revised and updated*. Free Press: USA

Zhang, Y., Wang, Y., Long, W. (2012) Research on Demand-driven League Supply Chain Operation Model: A Simulation Based on AnyLogic in System Engineering. *Systems Engineering Procedia* 3. pp.249-258



## CHAPTER V

# CAMPUS OPEN SPACE SCENARIOS FOR YOUTH

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### 1. Introduction

**W**e can define university campuses as complexes that contain many functions. There are different analyzes within the different functions of the campus and their relations with each other.

Campuses show mixed use features where students can meet all their needs within short distances. For this reason, there is an indoor-outdoor event integrity in campus environments. As a result, campus exteriors have the potential to offer venues for a wide variety of student activities (Yıldız and Şener, 2006; Düzenli et al.,2009).

While the university campus is being designed, a city open to youth for 4-5 years is actually being designed. The city has functions such as accommodation, work, rest and transportation, and the same functions are found within a system in campuses. In other words, the settlements where work, accommodation, rest-recreation, transportation functions are provided and social communication is established are called university campuses (Yıldız and Şener, 2006).

The campus is much more than just an isolated place with buildings. It

is complemented by the planned environment for the educational process (Düzenli et al., 2018; Özkan et al., 2017). It includes buildings, grounds, equipment and all learning objects. Using the campus environment is more important than all of this; It is defined as the total atmosphere in a place that allows the student to want to learn. The word campus thus gains a new content and undertakes the task of guiding the person in the learning process. According to Reed, the systematic presentation of “people, processes and time = campus” ensures that possible activities are included in the plan (Williams, 1970). For this reason, it is important to create campus open spaces that allow young people who are campus users to realize their wishes, the activities and activities they carry out in line with these requests. In this study, scenarios were produced in this context.

## **2. Campus Open Spaces**

Campus open spaces are defined according to changing user requirements. Different types of open spaces other than educational buildings and areas allow for different recreational functions;

1. Areas for Sports Activities
2. Outdoor Discussion Areas with Educational Opportunities
3. Areas Allowing Wandering
4. Spaces Allowing Seating
5. Workable Quiet Spaces (Crowe, 1979)

In a study conducted on the Istanbul Technical University Campus (Yıldız and Şener, 2006); The factors that have an impact on the use value of the outdoor spaces defined by the buildings around the campus were investigated. The intensity of use in different parts of the spaces obtained as a result of the observations and the results of the place preferences for different activities obtained from the surveys generally confirmed each other. Different locations within the spaces selected according to the observations supported different usage patterns in line with their physical qualities (Düzenli et al., 2012; Düzenli et al., 2019; Düzenli et al., 2020). For example, the walls at the border

of the building entrances and the space support activities such as short-term sitting-resting, smoking, watching the surroundings, on the other hand, the tree-lined, shaded open-grass areas have eating-drinking, reading, chatting, lying-sleeping on the grass, listening to music. It has been noticed that it supports many different activities such as In this context, it has been determined that grassy areas with trees are the most “behaviour-producing” physical elements for this field study (Yıldız and Şener, 2006; Düzenli et al.,2017; Özkan et al.,2022). It has been determined that different places (in terms of spatial and physical characteristics) exhibit different activities.

The majority of the students preferred low walls and benches in areas where they could see people coming and going from their place. In this context, benches, low walls, shaded grass areas have been the physical elements that have the most impact on the use value of outdoor spaces defined by buildings. In all places, the main entrances or front gardens of the surrounding buildings (welcoming areas) were used very intensively. The majority of users defined these areas as convenient (suitable) and as the closest places to their own departments on the campus they accept (Yıldız and Şener, 2006). For this reason, space elements and components such as walls, benches, and grass areas should be included in the design of campus open spaces, and the selected equipment should offer activity opportunities to young people.

Moos (1979) also revealed that being a student is affected by the campus atmosphere and stated that the social atmosphere of the campus is affected by three factors.

1. A person's relationship with an environment on campus
2. Opportunities offered by the environment to the user
3. Behavioral expectations and spaces for changes in the environment.

According to Moos (1979), the conditions of the environment, students' perceptions of possibility and student behaviors interact with campus environments. For this reason, the opportunities around the campus should be determined depending on the psychosocial structure of the youth.

Educational policies, large-scale planning, etc. related to the use of campus open spaces. A study that sheds light on these issues has also been published (Schemertz, 1972). However, research on the use of open spaces on campuses is lacking. However, it is very important to “reveal the needs” of the users (young people) in the campus open spaces, “determine the activity areas suitable for these needs” and analyze the “spatial features that allow these activities to take place” in terms of creating criteria for designs.

### **3. Production of Campus Outdoor Scenarios Suitable for Youth**

It is important to know what needs young people have different from adults or children, to determine what their psychosocial structures reveal, what they need to have a positive development process, and the relationship of young people's environments, especially campus open spaces, with these needs. Mobility, naturalness and openness are positive opportunities for campus open spaces used by young people, the presence of these opportunities increases the use of these facilities, allows various activities to be held, and helps the development processes of young people by meeting their socialization needs. In other words, these facilities should be stronger than others in campus open spaces, which are mostly used by young people.

The level of use of a space is related to the rate at which it meets the needs of its users. It is expected that more diverse activities will take place in campus open spaces, which have facilities for the needs of young people, and that they will be used by more young people.

In this context, firstly, the open spaces in Karadeniz Technical University Kanuni Campus were examined and their problems were determined, then solution proposals were determined and appropriate scenarios were created.

#### **3.1. Area 1**

The first area was determined as the library area. When the state of the field is examined; The problems of the lack of cover elements suitable for weather conditions, the lack of activity, the weak spatial perception, the neglect of the plants, the lack of appeal to young users and the lack of equipment have been

identified. Problems, suggestions and design main decisions for the area are presented in figure 1.

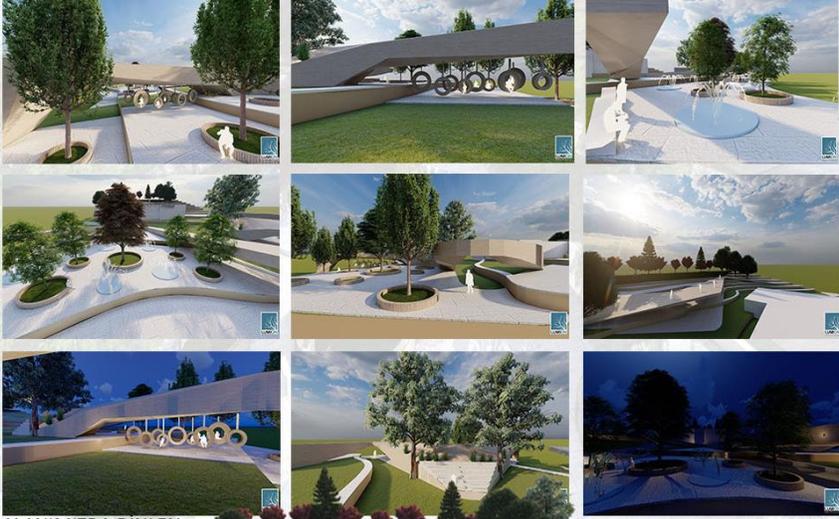


Figure 1. Identifying problems, suggestions and design decisions regarding the library environment

Then, to solve these problems; A more colorful and active spatial scenario was produced that allows for different activities with appropriate reinforcement and cover elements. The scenario is given in figure 2.



ÇALIŞMA ALANIMIZ KARADENİZ TEKNİK ÜNİVERSİTESİ FAİK AHMET BARUTÇU KÜTÜPHANESİDİR. YAPILAN ARAŞTIRMALAR SONUCU ALANIMIZIN EKSİKLİKLERİ DÜŞÜNÜLÜP SORUNLARA ÇÖZÜM NİTELİĞİNDE TASARIMLAR YAPILMIŞTIR. BAŞLICA SORUNLARDAN BİRİ AÇIK ALAN DA YETERİ KADAR ÖRTÜ ELEMANININ OLMAMASIDIR. HAVA KOŞULLARININ KÖTÜLEŞMESİYLE DIŞARIDA DİNLENME ALANLARI OLMADIĞI TESPİT EDİLMİŞTİR. TASARIM DA DAHA ÇOK TASARIMSAL ÖRTÜ VE DİNLENME DONATILARI TASARLANMIŞTIR.



ALANIMIZDA DİNLENME ALANLARI DAHA RAHAT OLUP DİNLENME, UZANMA, YASLANMA GİBİ İŞLEVLERİ DE EKLENMİŞTİR. HAMAK TARZI DİNLENME ALANLARI MEVCUTTUR.

ALANIMIZDA SEYİR ALANLARI MEVCUTTUR. BU SAYEDE DERS ARALARINDA ÖĞRENCİLERİN GELİP MANZARAYI İZLEYEBİLECEĞİ DİNLENEBİLECEĞİ ALAN OLUŞMUŞTUR.

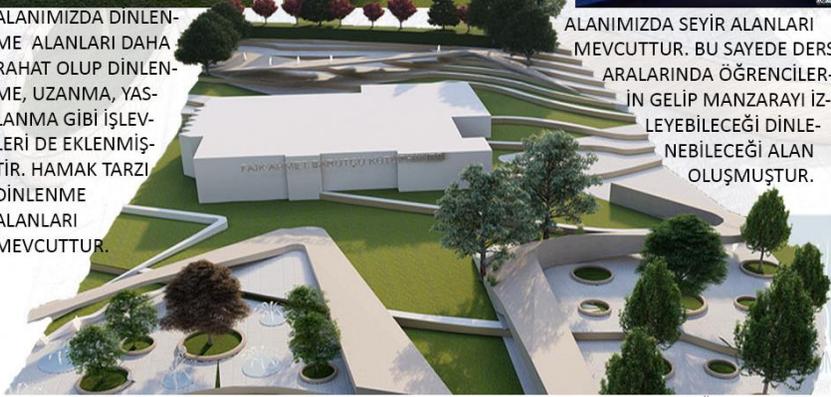


Figure 2. Scenario for the area

### 3.2. Area 2

The second area is designated as the back of the biology department. When the state of the field is examined; It has been determined that it has a bad image, weak perception of space, non-functionality, lack of access to the area, and lack of environmental integrity. Problems, suggestions and main design decisions for the area are presented in figure 3.

## MEVCUT DURUM



## SORUN

- KOTU GÖRÜNTÜ OLMASI
- MEKAN ALGISİNİN ZAYIF OLMASI
- İŞLEVSİZ OLMASI
- ALANA GİRİŞ OLMAMASI
- ÇEVRESEL BÜTÜNLÜĞE SAHİP OLMAMASI

## ÇÖZÜM

- Yeşil teras ile alana işlev kazandırmak
- Alanın donatı eksikliğini gidererek kullanıcılar için konforlu bir alan oluşturmak
- Kot farkı ile engelli rampası çözmek
- Alanda bitki çeşitliliği sağlayabilmek

## TASARIM ANA KARARLARI

- YEŞİL TERAS ANLAŞIYSIYA DOĞAYLA BÜTÜNLÜK SAĞLAMAK
- ALANA EKOLOJİK YAKLAŞIMA UYGUN OLACAK ŞEKİLDE İŞLEV KAZANDIRMAK
- ALAN İÇİNDEKİ DONATI EKSKİKLİĞİNİ GİDEREREK TASARIMA UYGUN OLARAK DÜZENLEMEK
- SERBEST KULLANIMA OLANAK SAĞLAYAN YEŞİL ALANLAR TASARLAMAK
- FARKLI FORM, BOY VE RENKLERDE BİTKİLER KULLANILARAK ALANA CANLILIK KATMAK
- TASARIM İLKELERİNE DİKKAT EDEREK HAREKETLİ, CANLI VE DOĞAL BİR MEKAN OLUŞTURMAK
- KULLANICILARIN DİKKATİNİ ÇEKECEK DONATI TASARLAMAK



## ESİNLENİLEN ÖRNEKLER



-YEŞİL ÇATI SİSTEMİ KURGULANARAK GEÇİRİMLİ YÜZEYLER ARTTIRILMIŞ VE KULLANICILARIN YEŞİLLE İÇİÇE OLMASINI SAĞLADIK.

-YEŞİL YÜKSELTİLERLE KULLANICILARA HEM OTURMA HEM DE YAŞLANMA OLANAĞI SAĞLADIK.

-KULLANICIYA YEŞİL ALANDA ETKİNLİK OLANAĞI SAĞLANIRKEN AYNI ZAMANDA ALANIN ORANTILU BİR ŞEKİLDE PARÇALAYARAK ARMONİ VE KONTRASTLIK DENGESİNİ SAĞLAMIS OLUĐUK.

-ÇOK AMAÇLI MERDİVEN ÇÖZÜMÜYLE İNSANLARIN OTURASINA DA OLANAK SAĞLADIK VE AYNI ZAMANDA ENGELLİ RAMPASI ÇÖZÜMÜ AMAÇLADIK

## TASARIM ÖNERİSİ



## VİZYON

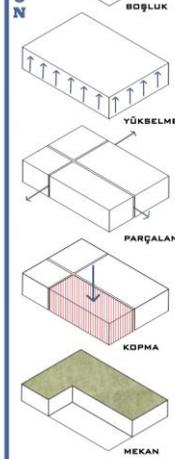


Figure 3. Identifying problems, suggestions and design decisions related to the biology department environment

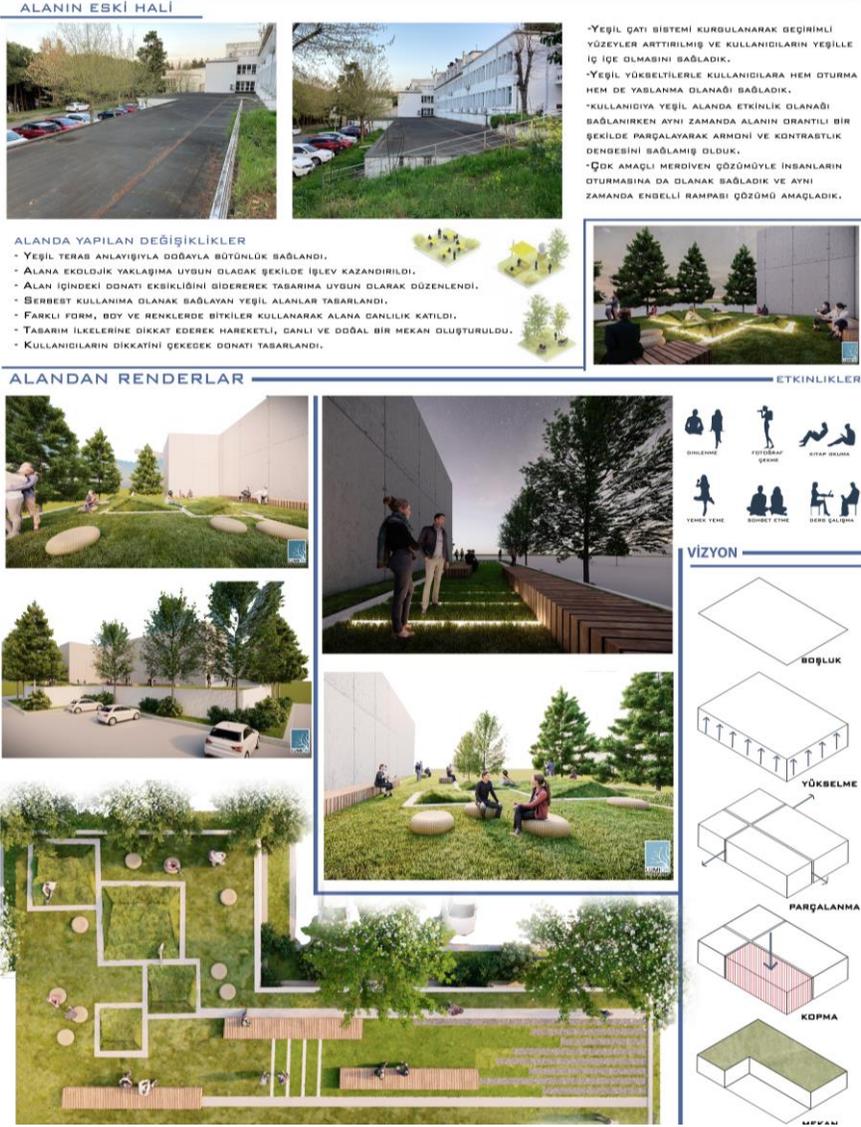


Figure 4. Scenario for the area

Then, to solve these problems; A scenario was created in order to add function to the area with the green terrace, to create a comfortable space for users by eliminating the lack of equipment, to solve the level difference and the disabled ramp, and to balance the plant design. The scenario is given in figure 4.

### 3.3. Area 3

The third area was determined as the area of the mathematics department. When the state of the field is examined; The problems of hard ground density, lack of vegetation, formality and artificiality, monotony, inadequate and dysfunctional reinforcements were determined. Problems, suggestions and design main decisions for the area are presented in figure 5.



**Figure 5.** Identifying problems, suggestions and design decisions regarding the mathematics department environment

Then, to solve these problems; A scenario was created in order to create green areas and axes, transition from artificial to naturalness, provide diversity in materials, colors and textures, get rid of monotony, renew the floors, and create useful equipment. The scenario is given in figure 6.



Figure 6. Scenario for the are

#### **4. Conclusion and Recommendations**

When suitable spaces are created for young people, their relations with the environment increase, their chances of socializing increase and their skill development levels increase. Most of the venues are planned by ignoring the needs of young people due to their psychosocial development. Generally, social spaces are formed in line with the needs of other age groups such as children and adults.

Openness, mobility and naturalness opportunities are effective in the use of campus open spaces. The positive effect of naturalness and mobility in use is certain. However, it has been determined that although the opening value is low, the level of use can be positive (wood park), because the presence of plants with high branching does not adversely affect the use, even if it reduces the openness value. Because the field of view, the width of the landscape was not affected by the plants. Since activities take place more frequently in spaces with high possibilities (mobility, openness, naturalness) and these spaces are mostly used by young people, open space scenarios have been developed for this purpose. Thus, the use value of campus open spaces has been increased.

In line with these findings, in order to design a campus open space for young people and to better meet the needs of young people; It should enable young people to act actively. Elements that increase naturalness such as grass surfaces, plants, water should be included (open, hard or soft grounds suitable for movement, changes in topography). Uninterrupted and wide viewing areas should be provided, so trees with high branches should be used. The need for grouping of young people should be taken into account while designing the equipment. Spatial elements such as steps, borders and parapets should be included, not only seating equipment. The equipment and spatial elements should be designed to support various activities for young people such as sitting, lying, chatting in groups.

#### **References**

Crowe, S., (1979). Site Planning, Landscape Techniques, Buller And Tanner Ltd., Frume, London, U.K.

- Düzenli T., Bayramoğlu E., Özbilen A. (2009). Needs and preferences of adolescents in open urban spaces. *Scientific Research and Essays*, 5, 201-216.
- Düzenli T., Mumcu S., Yılmaz S., Özbilen A. (2012). Analyzing Youth' s Activity Patterns in Campus Open Spaces Depending on Their Personal and Social Needs. *Journal of Adult Development*, 19(4); 210-214.
- Düzenli T., Mumcu S., Akyol D. (2017). Üniversite Kampüsü Açık Mekânlarının Gençler Tarafından Kullanım Amaçlarının Belirlenmesi Determining The Usage Purposes of University Campus Open Spaces by Youth, *Uluslararası Sosyal Araştırmalar Dergisi / The Journal of International Social Research*, 10, 766-772.
- Düzenli T., Özkan D. G., Alpak E.M. (2018). Landscape Design Criteria of Open Spaces For Youth, İn: *Recent Researches In Science And Landscape Management* , Efe R., Zencirkiran M.,Curebal İ., Eds., Cambridge Scholars Publishing , Newcastle, 237-251.
- Düzenli T., Tarakçı E. E., Alpak E. M. (2019). Gençlerin Açık Mekân Kullanımları: Ktü Kanuni Kampüsü Örneği, *Social Sciences (NWSASOS)*, 14(1):33-45.
- Düzenli T., Tarakçı E. E., Alpak E. M. (2020). The affordance theory in sustainable open space design: The KTU Festival Area Case, in: *Theory And Practice In Sustainable Planning And Design* , Editor: Murat Özyavuz. Eds. Peter Lang, Berlin, 333-349.
- Moos, R., H., (1979). *Evaluating Educational Environments*, San Francisco: Jossey-Bass.
- Özkan, D. G., Alpak, E. M., & Var, M. (2017). Design and construction process in campus open spaces: A case study of Karadeniz Technical University. *Urban Design International*, 22(3), 236-252.
- Özkan, D. G., Özlü, S. & Dedeoğlu Özkan, S. (2022). Measuring place satisfaction by university campus open space attributes. *A| Z ITU Journal of the Faculty of Architecture*, 19(1).
- Schemertz, M. F. (Ed.), (1972). *Campus planning and design*. New York: McGraw-Hill.

- 
- Williams, H., (1970). An Analysis Of The Process Of Campus Planning In Florida's Community Junior Colleges, Doctor Of Philosophy, The Florida State University College of Education.
- Yıldız D. ve Şener, H., (2006). Binalarla Tanımlı Dış Mekânların Kullanım Değeri Analiz Modeli. İTÜ Dergisi/A Mimarlık, Planlama, Tasarım, 5, 1, 115-127.



## CHAPTER VI

# ARTISTIC APPROACHES IN URBAN OPEN SPACE DESIGN

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### 1. Introduction

Unlike other creatures in nature, human beings interpret and shape the environment and city they live in (Kovel, 2004). Urban open space design, which is among the study subjects of landscape architecture, has a special importance in the urban environment where natural areas are gradually decreasing and problems such as density and accessibility are encountered (Düzenli et al., 2018). Today, most of the open space life takes place in squares, plazas, pedestrianized areas and urban parks. For this reason, urban open spaces are seen as spaces where the social, cultural and recreational needs of the society are met, and urban open space designs gain importance.

The landscape-art relationship also emerges as a topic to be considered in urban open spaces (Düzenli and Alpak, 2021). The phenomenon of art, which has developed as a part of daily life since ancient times, also forms the basis of open space arrangements, so landscape and art naturally appear as related concepts. However, since the industrial revolution, it has been seen that art has left its place to technology and continues to exist as an introvert.

This is because the landscape-art relationship is realized in artificial ways; The art phenomenon, which is tried to be conveyed to the society through the objects exhibited in urban open spaces, moves away from the urban environment in order to establish its connection with nature. The aim of this study is to evaluate the relationship between urban open spaces and art in today's conditions.

## **2. Nature, Environment And Art**

Today's new artistic trends are the result of the close relations between the artist and urban life. After the 1960s, the rediscovery of the body and the crisis of cultural identity, the spread of new media opportunities, the dynamics of fashion and pop culture strongly influenced art. Art now aims to serve the purpose of making the world a more livable place (Ertekin and Corbaci, 2018). In particular, the fact that artists are more interested in social issues is also reflected in the formation of the works. By dealing with nature with greater intensity, urban problems lead to the emergence of new fields of art. Art has turned into a kind of call for awareness, and in this period, artists have begun to seek new ways to bring nature and human harmony. From this point of view, the earth attracts the attention of artists and designers as a vast exhibition space with unlimited materials (Oğuz,2015; Düzenli et al., 2018b).

Artists, designers and landscape architects; use art to express their concerns about natural processes by turning to “different applications from using open spaces in nature to the use of natural materials, raising environmental awareness, solving urban problems, restoration, recycling, renewal, and site-specific projects” (Aydın & Zümrüt, 2013; Kurdoğlu et al. 2019; Yılmaz et al., 2018). These works have taken their place in the history of art with various denominations such as "Land Art", "Earth Art", "Environmental Art", "Ecological Art". Although a complete limitation cannot be made between these terms and definitions, there are some differences between them in terms of the materials used and their purposes (Aydın and Zümrüt, 2013). However, they have similar concerns about raising awareness towards nature, urban problems and destroying the distance that modern man puts between himself and nature. These artists started to question

the technology-human-nature relationship again and turned their eyes to nature with an unusual new consciousness and a new perspective (Bilir, 2014, Düzenli et al., 2017b; Yılmaz et al., 2021). The idea and perception of "environment", which has developed and changed in the period from the 1960s to the present, has brought about very different art formations that have evolved towards concerns involving the ecosystem and environmental problems. These; They are numerous and diverse, which can be exemplified as 'Art in Nature', 'Eco-art', 'Green Art', 'Restoration Art', 'Ecoventions', 'Sustainable Art' (Ataseven, 2016). Today, it is seen that the naming of "Eco-art" or "Environmental art" is used as a common term to name these works that center environmental, urban and nature problems (Mamur, 2017).

### **3. Art in The Urban Open Space**

Art in urban open spaces can be defined as objects with historical, aesthetic and functional features, which are necessary to meet the physical and emotional needs of the people in the living environment. Within the scope of this definition, art in urban space can find itself not only in the form of monuments and sculptures, but also in the form of wall paintings, graffiti, signboards, billboards and many similar elements. For example, the work of a designer who exhibits his art with the pictures he draws and with different motifs can be considered as an art product for the urban space, as it is watched by the public during his journey in the city and arouses certain feelings on the people (Düzenli et al., 2017a).

Public art is the name given to any form that is performed in public space and evokes certain feelings in the person. From this point of view, apart from two- or three-dimensional objects, all kinds of performances, temporary arrangements, film shows, music concerts and interactive street theaters are also included in the scope of public art. Environmental art, which finds value when used skillfully by its designer and artist, in a wide range from a rare work of art exhibited in a museum to a drawing that comes to life on the city walls by reflecting the paints of graffiti artists, offers us new visuals every day. Public art should contribute positively to the life of the city and its inhabitants; arousing a feeling of happiness, should activate the imagination,

and should be in a structure that can advance communication and sociality (Çağatay Seçkin, 2005).

Unlike the artists of the previous eras, today's artists and designers do not see nature only as an external structure to be emulated, but also produce works that include the process of nature. With the works they created with the aim of incorporating art into the life process and redefining the ties between society and art through nature, they aim to make the audience or participants rethink about nature. They were not only affected by the environmentalist movements of the period, but also pioneered these movements. In this sense, these artists brought new definitions to the new relations to be established between society, nature and art, and reinforced the bonds between art and life. They did this by providing new awareness to people on the earth where they applied their works, and by opening new living spaces for other living things.

Considering the place of urban open spaces in social life, the role of art in landscape design emerges as an issue that needs to be taken seriously. In this context, the landscape-art relationship contains different possibilities within itself.

- In the first of these, the landscape functions as a stage and creates an environment for the exhibition of other branches of art.
- In the second, landscape is used as a material for art, and the space itself can be shaped like a work of art by being differentiated by color and texture. In the case where art serves as a floor, wall or furniture element in the design by assuming a certain function, the space is perceived as a composition arising from the cooperation of different arts.

In reality, landscape art emerges with the inseparable unity of these possibilities (Oosterling, 2001, Eckbo, 1964). In the next section, art practices in urban open spaces will be exemplified.

#### **4. Examples of Art Applications in Urban Open Spaces**

*Examples of urban open spaces in which the landscape serves as a stage and creates an environment for the display of other branches of art (Table 1);*

- 
- In the project they developed for Schouwburgplein Square, the West 8 landscape architecture office proposed huge articulated lighting elements that change in a certain route during the day. Here you can find different music etc. The square can be transformed into an art scene by exhibiting shows. In this urban open space design, they combined urbanism with landscape architecture and proposed high structures with modern materials, a large hard-floored square, artificial light effects. With this perspective, West 8 has designed everything from urban furniture to squares and parks with innovative ideas such as the suggestion of palm trees growing through the lighting, the use of concrete as the main material, the construction of huge structures; Whatever the scale, no distinction was made between urbanism, landscape architecture, architecture and botany.
  - For New York-based landscape architecture practice Field Operations, the concept is a vital component of modern landscape design. According to James Corner, “Landscape architects are the unsung heroes of the public sphere.” Landscape; It deals with society, politics and our own existence on a planet where we are bound by natural forces. It is how we give form to places and our cities, and ultimately how we relate to places. In this context, it redesigned the 2.33 km long unused railway line, which is considered an extraordinary public space in the heart of Manhattan's West Side, as a park. A defining element in the region since it opened in 2009, the High Line has become an icon that inspires global cities, becoming a powerful catalyst for innovative design and investment. The design characterizes an intimate choreography with alternative landscapes and experiences. At the same time, it creates a unique experience with different floor coverings, plantation, urban furniture, lighting elements and social areas. The High Line is widely recognized as a success, and new public spaces in the city demonstrate the value of creating a landscape scene.
  - The Presidio Parkland project in San Francisco becomes a landscape scene by renovating an elevated highway with a new tunnel and guiding spectacular views of the San Francisco bay, including views of the

Golden Gate bridge. "Panorama" was designed to make the most of the stunning views of the place; a plan is planned to connect the place with other landmarks nearby. It is aimed to act as a "stage" by providing the park with the opportunity to host various events and meetings.

**Table 1.** Examples where landscape is used as a scene

**Schouwburgplein, Rotterdam/Hollanda, West 8, 1991**



URL 1

**High Line, New York/Amerika, Field Operations, 2009**



URL 2

**Presidio Parklands by Field Operations, 2015**



URL 3

*Examples of urban open spaces where landscape can be shaped like a work of art by differentiating it with color and texture as a material for art (Table 2);*

- 
- Pappajohn Sculpture Garden, the 4.4-acre garden landscaped by Louise Bourgeois and Jaume Plensa, opened in 2008 after John and Mary Pappajohn resided there in Des Moines. Covered in curly grass, the expansive space was designed by New York-based architects Diana Agrest and Mario Gandelsonas to create a sculptural foundation.
  - The 2019 London Design Biennale hosted a large-scale installation called *Please Be Seated* by Paul Cocksedge. Cocksedge has transformed Broadgate by producing one of the UK's most ambitious installations to date. On the installation made of scaffolding boards, Paul Cocksedge collaborated with ARUP and state-of-the-art interior design company White & White to rethink and reuse building wood. Each angle of the installation is designed in harmony with its environment and the function it serves. The folds rise upward to create places to lay back and sit, while also creating a space for people to stroll under or find a shaded spot. The installation stands somewhere between the craft work and the design solution, occupying the Square but not blocking it.
  - The design of “Moving Dunes”, which was realized as an extension of the temporary exhibition “From Africa to America: Face-to-face Picasso, Past and Present” at the Montreal Museum of Fine Arts (MMFA), was inspired by ancient artists. The plastic approach of cubist painters was made to question the role of perspective in visual representation. Anamorphosis method, which is a perspective technique that makes the picture appear normal when viewed from a certain point, and distorted and distorted when viewed from another point, was used in the design. Throughout the exhibition process, *Moving Dunes* aimed to introduce the essence of this method to the public in a playful way. By manipulating the street surface, large waves reminiscent of the features of a body or a face are produced. Reflective spheres and geometric shapes strengthened the patterns and increased the perspectives. As the observer moves, the street is transformed, the shapes are reversed and the ground comes alive. *Moving Dunes* is brought to life as an experiential illusion in the heart

of downtown Montreal. It is intended for passers-by to discover the existence of spheres reflecting the different buildings of the Montreal Museum of Fine Arts, all of which are unique in architecture and history.

**Table 2.** Examples where landscape is used as an art material

**Pappajohn Sculpture Garden, 2008**



URL 5

**LDF by Cocksedge, 2019**



URL 6

**Moving Dunes, 2018**



URL 7

## 5. Conclusion And Recommendations

Although the concepts of art, landscape and urban open space can be defined in different ways, they contain meanings that cover each other. In this direction, their development over time takes place in parallel and in mutual interaction. Art object is a concept that encompasses all landscape elements such as walls, floors, and reinforcement elements, not just sculptures and plastic items. These objects, as a result of their inclusion in the design, contribute to the space aesthetically, physically, socially and economically. Today, in urban open space designs made in the world, it is seen that the subject is handled with importance and landscape elements are evaluated as art objects by applying different art branches on them.

Landscape elements such as land forms, plants, urban furniture, structural elements and buildings, which are called three-dimensional elements, can be shaped as materials for volume arts or gain an aesthetic value with the types of art applied on them. In this way, while the functions that the elements undertake in the space are emphasized, the harmony of the art objects that play a role as a landscape element with the space can naturally be realized. Monuments, figurative sculptures and plastics, which are called visual elements, are also considered as elements that make up the space and are designed together with other landscape elements. Thus, with the collaboration of the artist-designer, the qualities of the art object can be decided at the design stage. The inclusion of art objects in the design not only increases the aesthetic value of the space, but also enables them to contribute to urban life in a social sense. This situation is taken into account in establishing the relationship with the user, which is seen as the determining factor in the success of the open space design. In this direction, art objects are used as moving or functional elements that allow visual and physical communication, so that these objects, which increase the attractiveness of the space, can also be permanent by being protected from damage. In order to strengthen the visual effect and increase the use in landscape designs, artistic elements should be reflected in the urban design. The importance of art in space is an issue that should be considered in environmental designs. The most ideal way of nourishing visually and psychologically in urban space; It

is the use of urban objects that are pleasing to the eye, give aesthetic pleasure and have a message value. It is necessary to examine the city and open spaces within the scope of space and art. A spatial setup that creates an image should be created by transforming the landscape into a stage with art. Urban open spaces need to create integrity in the space with urban objects that guide and create surprises.

## References

- Ataseven, O. (2016). Heykelin çevresel serüveni. SDU ART-E Güzel Sanatlar Fakültesi Sanat Dergisi, 9(17), 262-277.
- Aydın, İ. ve Zümrüt, Y. (2013). Doğa ve sanat ekseninde farklı yaklaşımlar, Anadolu Üniversitesi Sanat ve Tasarım Dergisi, 4, 53-65.
- Bilir, A. (2014). Plastik sanatlar eğitiminde çevresel sanat uygulamaları, Anadolu Üniversitesi Sanat ve Tasarım Dergisi, 6, 20-41.
- Damla, O. (2015). Sanat perspektifinden çevre sorunları. Sanat ve Tasarım Dergisi, 5(8), 48-61.
- Damla, O. (2015). Sanat perspektifinden çevre sorunları. Sanat ve Tasarım Dergisi, 5(8), 48-61.
- Düzenli T. , Alpak E. M. (2021). Interpreting Urban Open Spaces As An Art Object: Trabzon Pazarkapı Environmental Design Projects. Eurasian Academy of Sciences Social Sciences Journal, 36: 64-82.
- Düzenli T. , Alpak E. M., Tarakci Eren E. (2017). The Significance of Public Space Art In Landscape Architecture. Yıldız Journal of Art And Design, 4(2):143-158.
- Düzenli T. , Mumcu S., Tarakci Eren E. (2018).Peyzaj Mimarlığında Heykel Kullanımı: Trabzon Kenti Örneği. Journal Of History Culture And Art Research, 7,553-564.
- Düzenli T. , Tarakci Eren E., Akyol D. (2017). Concept Of Sustainability And Biophilic Design In Landscape Architecture. Asosjournal-The Journal of Academic Social Science, 5(48):43-49.
- Düzenli T. , Yılmaz S. , Alpak E. M. (2018). Peyzaj Mimarlığı Eğitiminde Bir Tasarım Yaklaşımı: Doğal Örüntülerden Esinlenme. SED Sanat Eğitimi Dergisi, 6(1):21-35.

- Eckbo, G., 1964. *Urban Landscape Design*, McGraw-Hill Book Co., New York.
- Ertekin M., Çorbacı Ö. L. (2018). *Environmental Design Art in Seljuks*. *Journal of Scientific and Engineering Research*, 5(3):122-126.
- Kovel, J. (2004), “Doğanın Anlamlandırılması” (Çev. Caner Doğan), *Üç Ekoloji-Doğa, Düşünce, Siyaset*, 2:99-107.
- Kurdoğlu B. Ç. , Bayramoğlu E. , Konakoğlu S. S. K. (2019). *Peyzaj Mimarlığı Eğitiminde Peyzaj Planlama Stüdyosu. Eğitim Bilimleri Araştırmaları I, Ahmet Doğanay Oğuz Kutlu, Editör, Akademisyen Kitabevi, Ankara, 151-165.*
- Mamur, N. (2017). *Ekolojik sanat: çevre eğitimi ile sanatın kesişme noktası. Mersin Üniversitesi Eğitim Fakültesi Dergisi*, 13(3), 1000-1016.
- Oosterling, H., 2001. *Art works, making interesse public*, *Archis*, 5.
- Seçkin, Y. (2005). *Kentsel Peyzaj İçinde Sanat. Journal of the Faculty of Forestry Istanbul University*, 55(1), 225-236.
- Yılmaz S. , Düzenli T. , Alpak E. M. (2021). *Peyzaj Mimarlığı Eğitiminde “Land Art” Etkisi. Online Journal of Art and Design*, 9:1, 204-214.
- Yılmaz S. , Düzenli T. , Çiğdem A. (2018). *A Form Creating Method in Landscape Design Education: Inspiration from Nature. Journal of History Culture and Art Research*, 7(2):376-389.
- URL 1. <https://nieuws.top010.nl/schouwburgplein-rotterdam.htm>
- URL 2. <https://archleague.org/event/james-corner-lecture/>
- URL 3. <https://in.pinterest.com/pin/222013456608087689/>
- URL 4. <https://www.spur.org/events/2015-02-11/presidio-parklands-design-new-presidio-landscape>
- URL5. <https://www.nytimes.com/2009/10/30/travel/escapes/30desmoines.html>
- URL 6. <https://www.inexhibit.com/it/marker/anticipazioni-dal-london-design-festival-2019-please-be-seated-di-paul-cocksedge/>
- URL 7. <https://www.arkitera.com/haber/montreal-sehir-merkezinin-kalbinde-deneyimsel-bir-tasarim/>



## CHAPTER VII

# BLOOD DONATION PREDICTION SYSTEM USING THE AGGREGATED FUZZY TREE

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### 1. Introduction

**B**lood donations are critical to health care systems. Estimating donor flow is becoming increasingly important for hospitals. As the demand for blood increases daily due to the need for blood transfusions for various reasons (surgeries, accidents, and illnesses), an accurate estimate of the number of blood donors needed can help physicians plan for future blood supplies. An expert system based on machine learning can predict donor behavior and solve the blood donation problem. Data science and classification-based learning concepts are used to predict blood donor intentions. This work aims to contribute to science by proposing a simplified method for estimating the number of donors willing to donate blood again and applying the bulk fuzzy tree technique to achieve this simplification. We developed an expert system based on the theory of planned behavior. In such a system, it is better to use cascading systems rather than build models for individual systems. To this end, this paper presents an aggregate fuzzy tree inference system (AFS) for blood donation prediction.

Data mining is an interdisciplinary field that transforms data into absolute values by combining traditional disciplines such as databases and

distributed systems with new technologies. Data science approaches have been extensively used in previous outbreaks to help health professionals and government agencies take more effective action against the disease (Adar & Adamic, 2005; Latif et al., 2021). There are three key areas where data science applications are struggling today: scanning, monitoring and prediction, and medical support (Pereira, 2004; Salazar-Concha et al., 2021a; Shahid et al., 2021; Shih & Rajendran, 2019). It is critical to the functioning of state-of-the-art supply chain activities based on Big Data (Bungartz, Kranzlmüller, Weinberg, Weismüller, & Wohlgemuth, n.d.; Panda, n.d.) analytics. Over the years, there has been a great deal of interest in blood donors and their donation patterns in data science. Controlling blood flow and demand is critical to the healthcare supply chain because blood plays a critical role in saving lives. Accurate blood supply estimation is critical for supply chain decisions such as donor unit planning, transport procedures, and inventory management in transfusion clinics and hospitals (Hajjema, van Dijk, & van der Wal, 2017; Rajendran & Ravi Ravindran, 2019). The need to accurately predict the need for blood components with limited shelf life, such as platelets, ensures that as little blood material as possible is wasted (Nagurney, Masoumi, & Yu, 2012; Rajendran & Ravindran, 2017). This is a component to improve the strategy to manage the blood supply and reduce the risk of excess in hospitals. If certain types of donors are discovered, such as those with unusual blood types or those most likely to donate without adverse events, this study material has the potential to reach appropriate individuals for further investigation. In addition to accurately predicting future blood demand and reducing the imbalance between healthcare supply and demand, blood banks are also responsible for the efficient and timely organization of blood donation drives and the safety of the entire blood supply chain (Mahadevan, Poornima, Tripathi, & Pushpalatha, 2019a, 2019b; Shih & Rajendran, 2020). Hospitals where physicians arrange blood transfusions for patients, a blood donation center that serves as a central location for receiving requests from hospitals and providers (blood donation centers), and an organization engaged in donor management all fall under this umbrella term. Characteristics and elements that have a significant impact on blood management include uncertainty in blood donation and demand,

perishability of blood products, and varying degrees of blood supply chains (Nagurney et al., 2012; Rajendran & Ravi Ravindran, 2019; Shih & Rajendran, 2020). Consistent with predicting the demand for blood material, it is necessary to anticipate donor behavior to determine whether or not the person will want to donate again in the future. It is possible that this assessment will help to personalize and optimize the approach process for potential repeat donors. Some studies have used machine learning algorithms to predict blood donors (Bahel, Ghosh, Sarkar, & Lanham, n.d.; Cloutier, Grégoire, Choucha, Amja, & Lewin, 2021; Kauten, Gupta, Qin, & Richey, 2021; Salazar-Concha et al., 2021b; Shashikala, Pushpalatha, & Vijaya, 2019). Specifically, this project involves the development of a data-driven expert system to monitor and predict potential blood donors. Based on a person's past donation behavior, we can use fuzzy tree classification approaches to predict whether or not they will donate blood in the future. The prediction model used to identify potential donors affects the results and helps reduce the lag between supply and demand.

The aim of this article is to present the most common approaches to classification and regression problems using fuzzy decision trees, which can serve as inspiration for further testing and applications. It can also show readers how to further develop methods in the context of fuzzy trees and forests and motivate them, among other things, to develop their own methods or improve existing ones. A fuzzy inference system (FIS) (Kaburlasos & Kehagias, 2014; Mahapatra, Nanda, & Panigrahy, 2011) is widely recognized as a useful tool for solving many difficult engineering problems, especially when the system under consideration is subject to ambiguity and uncertainty. The models of Mamdani and Takagi, Sugeno and Kang (TSK) are simple in modeling, but their ability to predict system performance decreases dramatically as the complexity of the problem increases (Mamdani & Assilian, 1975; Takagi & Sugeno, 1985). When a system consists of several subsystems and different results are needed from each component, an extended version of the FIS should be used instead of developing a separate FIS for each subsystem. Instead of building models for separate systems, it is better to use cascading systems, if such a system is involved. To this end, this paper presents an aggregate fuzzy inference system whose performance is

tested using a blood donation estimation model. When a system consists of several subsystems and different results are needed from each component, an extended version of the FIS should be used instead of developing a separate FIS for each subsystem. Instead of building models for separate systems, it is better to use cascading systems, if such a system is involved. To this end, this paper presents an aggregate fuzzy inference system whose performance is tested using a blood donation estimation model. Compared to current standards, the proposed progressive fuzzy system (Heider & Drabe, n.d.; Kaburlasos & Kehagias, 2014; Lendek, Babuška, & Schutter, 2009) simplifies and speeds up the computation of the model. According to the results of this study, a few characteristics can be used to predict a donor's willingness to donate blood. This study procedure is a good example of how to use the symmetry-based ideas of data science and learning for specific categorization and subsequent prediction. An important scientific contribution of this article is that it proposes a simplified method for measuring a multifaceted social phenomenon such as intention to donate blood again. The application of the fuzzy tree technique for this purpose is an important contribution to the field of data science in general. On the practical side, the contribution of this work relates to better information gathering to anticipate future blood donations, an event that is essential given the environment in which this activity is carried out and the current global health crisis. For academic purposes, the main contribution of this study is the novel application of an established data science technique in the social sciences, specifically the identification of some characteristics that predict behavior based on social theory.

The structure of this article is as follows: Data set, fuzzy tree and clustered fuzzy tree structures, and pattern search method are discussed as subsections in Section 2 under the heading Material and Method. In section 3, the results are presented. In section 4, the conclusion of the paper is presented.

## **2. Materials and methods**

The objective of this study is to predict whether a person would donate blood or not, using a marketing model that considers the factors of recency, frequency, quantity, and time, using the fuzzy tree approach. The proposed

fuzzy tree approach and the data set used are described in detail under this heading. The binary variable to be predicted is either donation or rejection of donation. Thus, we want to estimate the probability of a person donating blood using artificial intelligence and machine learning based on their characteristics, since this is a binary classification project and we are working with binary classifications.

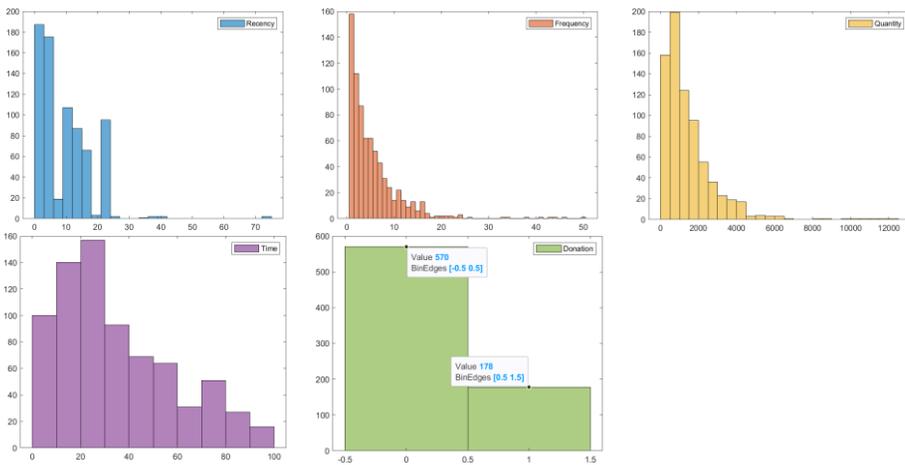
## 2.1. Data

The donor database of the Blood Transfusion Service Center in Taiwan provided in the UCI Machine Learning Repository (“UCI Machine Learning Repository: Blood Transfusion Service Center Data Set,” n.d.; Yeh, Yang, & Ting, 2009) served as the database for this study, and the data were collected in this database. The information file used to create the model has 748 rows and 5 variables in its structure (columns). In this diagram, the instances are represented by columns, while the variables are represented by rows. The input variables for each sample are numerically valuable and indicate characteristics of the blood donors. Donation is the target variable; a value of 0 indicates no blood donation and a value of 1 indicates blood donation. Information on the variables is summarized in Table 1.

**Table 1:** Variables used and information on the individual variables

Attribute	Explanation	Minimum	Maximum	Mean	Std.Dev
<b>Recency</b>	Months since the last donation	0	74	9.507	8.095
<b>Frequency</b>	Total number of donations	1	50	5.515	5.39
<b>Quantity</b>	Total blood donated	250	12500	1378.676	1459.827
<b>Time</b>	Months since the first donation	2	98	34.282	24.377
<b>Donation</b>	True if the person donated in the last campaign, false otherwise	0	1	0.238	0.426

Each patient is represented by a pattern with input and target variables. The fuzzy tree divides the data into two subsets: Training and Test. For training and test, 50% and 50% of the samples were selected. It is capable of calculating data statistics for all variables in a data collection, descriptive statistics, and data distributions for each variable. Figure 1 shows plots of data distribution based on the number of donors (positive) and non-donors (negative) in the data set.



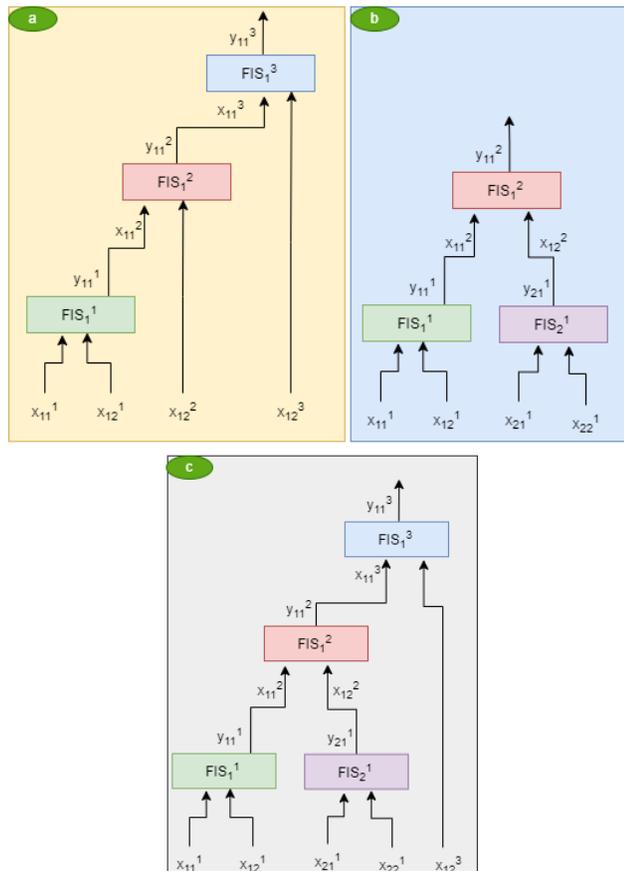
**Figure 1:** Histogram representation of all data features

As the data distribution in Figure 1 shows, the number of non-donors is 76% and the number of donors is 23%. Input-output correlations can reveal which variables have the greatest influence on whether a person will donate blood.

## 2.2. Fuzzy Tree

The number of rules in a fuzzy system (Zadeh, 1965) increases exponentially with the number of inputs. This large rule base affects the computational efficiency of the fuzzy system and makes it difficult to understand how the fuzzy system works and to configure the parameters of the rules and membership functions. To overcome this problem, a fuzzy inference system (FIS) can be constructed as a tree (Khanum, Mufti, Javed, & Shafiq, 2009; Mahapatra et al., 2011; Siddique & Adeli, 2013) of linked smaller FIS objects instead of a single monolithic FIS object. Since fuzzy systems are organized

in hierarchical tree structures, these fuzzy trees are also called hierarchical fuzzy systems. The outputs of low-level fuzzy systems serve as inputs to higher-level fuzzy systems in a tree structure. A fuzzy tree with the same number of entries is computationally more efficient and easier to understand than a single FIS. There are a number of fuzzy tree topologies that can be used as hierarchical structures. A typical fuzzy tree architecture can be seen in Figure 2. The structure used is the aggregated structure.

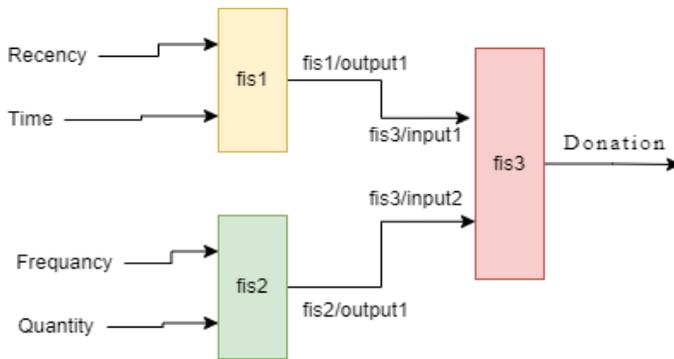


**Figure 2:** Hierarchical structure of fuzzy trees: a) Incremental, b) Aggregate, c) Cascaded (combined)

**2.2.1. Aggregated Fuzzy Structure (AFS)**

In this article, we have attempted to predict donors based on the factors of frequency, recency, and time using the aggregate fuzzy inference system

(AFS). AFS is a kind of hierarchical fuzzy system used in architecture, which is different from other kinds of fuzzy systems. In an aggregated structure, the input values are recorded as groups at the lowest level, and each group is fed into a FIS. Using the higher level fuzzy systems, the outputs of the lower level fuzzy systems are aggregated (combined). For example, the structure shown in Figure 2b is a two-level aggregated fuzzy tree with fuzzy inference systems  $FIS_i^n$ , where  $i$  indicates the index of a FIS in the  $n$ th level. In this aggregated fuzzy tree,  $i_1 = 1,2$  and  $i_2 = 1$ . Figure 3 shows the general organizational structure of the proposed aggregate fuzzy inference system.



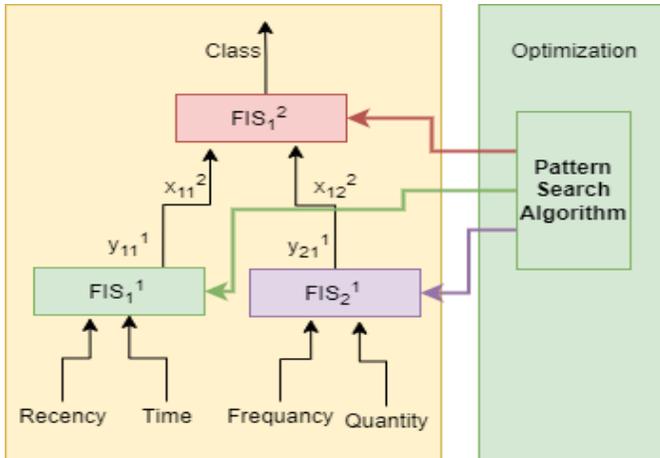
**Figure 3:** An aggregate fuzzy inference system (AFS) for donation prediction

Consequently, each level contains a certain set of FIS. The  $j$ th input of the  $i_n$ th FIS is shown in the figure as input  $x_{i_n,j}$ , and the  $k$ th output of the  $i_n$ th FIS is shown as output  $y_{i_n,k}$ . In the figure,  $j = 1,2$  and  $k = 1$ . Each FIS has two inputs and one output. If each input consists of  $m$  MFs, then each FIS has a complete set of  $m^2$  rules. In an aggregate fuzzy tree, input values are organically clustered for decision-making purposes. For example, the task of predicting when a person would donate blood includes the "frequency-time" and "frequency-quantity" sub-information about their previous donation status. The fuzzy tree can predict the yields with four inputs, but imagine the final FIS has only two inputs and one output. As shown in Figure 3, the inputs in this case are naturally at the lowest level. Two fuzzy systems independently analyze the inputs of each group, while a third fuzzy system combines their outputs to produce an estimate ("Fuzzy Trees - MATLAB & Simulink," n.d.).

### **2.3. *Pattern Search Optimization***

Hooke and Jeeves (Hooke & Jeeves, 1961) are credited with coining the term "pattern search." Since then, the word pattern search has been used to refer to any technique that searches for a better function value from an existing point in a predefined direction (Nocedal & Wright, n.d.), which is a collective term for all methods that do this. If a more suitable search location is discovered that location is designated as the new base and the search is restarted from there. If the search remains unsuccessful, the direction of the search is adjusted, or the scope of the search is reduced by shortening the stride length of the searcher. Over the years, a variety of pattern search strategies have been developed and refined, with each approach tailored to the optimization problems it is designed to solve. In pattern search, the methodology is often relatively simple, making it easy to apply as an initial optimization step. In addition to their simplicity, pattern search algorithms are also adaptable and reliable (Lewis, Torczon, & Trosset, 2000), which are two other advantages. This method has the advantage of global convergence, which means that it does not get stuck in the local minimum, since it allows a complete search over the search range, which is a desirable property. Another major advantage of PSM is that it gets by with simple mathematical operations, making it overall very easy to implement (Abramson, Brezhneva, Dennis, & Pingel, 2008; Palacio-Morales, Tobón, & Herrera, 2021). The pattern search method (PSM) is a type of optimization approach that belongs to the family of metaheuristic algorithms, i.e., algorithms that search for patterns. The pattern search algorithm is mainly composed of two parts: the boundary conditions and a network of particles that all have the same distance from each other. This technique consists of a matrix in which a constrained search is performed, and it is implemented as follows. An example of a matrix is a network of relationships between a collection of study conditions (Abramson et al., 2008; Bogani, Gasparo, & Papini, 2007, 2009; Palacio-Morales et al., 2021). With a few minor changes, this simple algorithm provides a powerful and easy way to optimize. The objective function need not have a gradient. It also works for problems with constraints, but this example and explanation apply only to problems without constraints. In the proposed AFS model, the

parameters must be optimized to obtain the best FIS. For this purpose, a pattern search algorithm was used to tune the parameters of the proposed aggregated fuzzy tree (see Figure 4).



**Figure 4:** Aggregated Fuzzy Inference System

### 3. Experimental Results

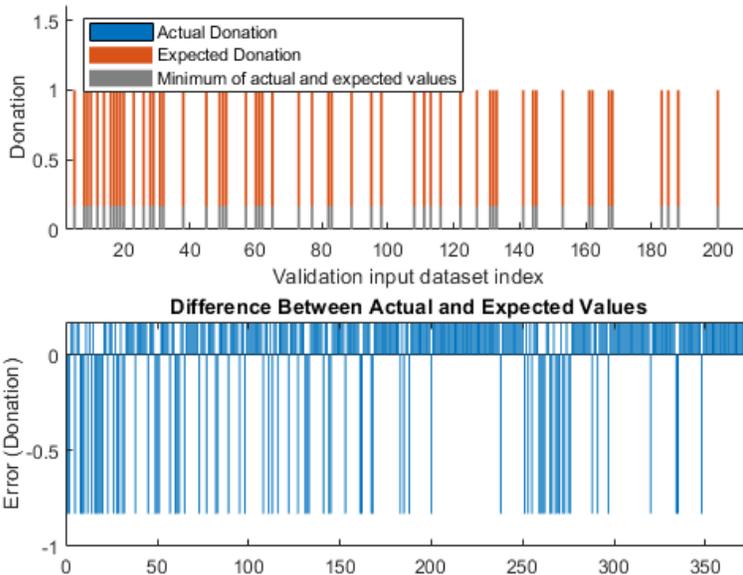
This paper investigates how to optimize the parameters of an FIS tree, which is a collection of AFS, using particle swarm and pattern search, and then estimates the number of donors using this model. Estimating donors is a standard problem in nonlinear regression. Each row of the generated data set corresponds to a unique donor profile. The first four columns of the data used (Recency, Time, Frequency, and Quantity) comprise the input properties, while the fifth column represents the output, i.e., the state of the donor. Depending on the correlations between the input and output properties, several FIS objects are created. The first four components of the last row of the correlation matrix represent the correlation coefficients between the input data characteristic and the output data characteristic. The last line of correlation is shown below.

ans = 1×5					
	1	2	3	4	5
1	-0.2799	0.2186	0.2186	-0.0359	1.0000

The first and fourth input attributes are partitioned as the first group and the second and third input attributes as the second group (see Figure 3). The goal of this method is to reduce the total number of rules used in the inference process. *fis1* and *fis2* receive the input data directly and provide intermediate values for prediction, which are then merged with *fis3*. Adjustments are made to the inputs to balance the positive and negative effects of the output. Each FIS consists of two inputs and one output, with each input containing two triangular standard membership functions (MF) and the output containing four standard MF, which are fixed. The final FIS combines the outputs of *fis1* and *fis2* and produces the estimated value.

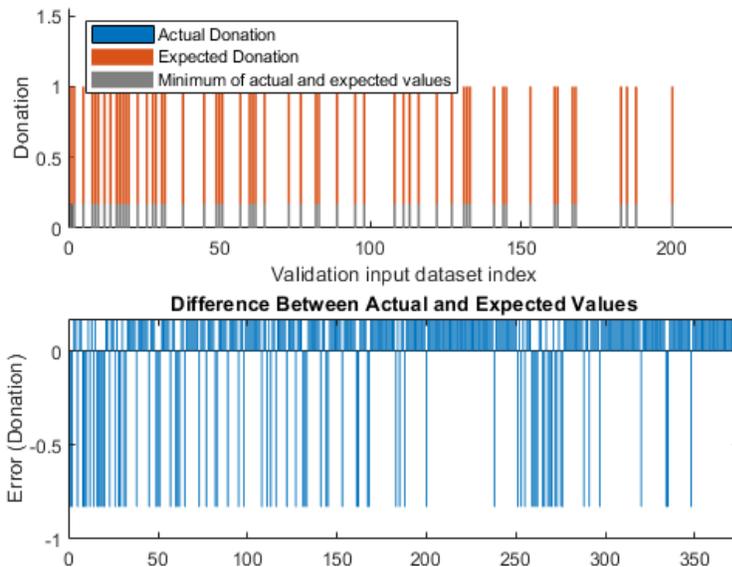
### 3.1. Tuning Of the Aggregated FIS Tree with the Training Data.

The reconciliation process consists of two phases: first the reconciliation of the expert system rules and then the reconciliation of all parameters (input/output MFs and rules). Due to the limited control factors, the first phase is computationally more advantageous and quickly converges to a fuzzy rule base during training. The following diagrams are from the implementation of the first phase. The number of rules obtained here is 11 and the maximum number of iterations is 50.



**Figure 5:** Graphs obtained by implementing the tuning of the FIS rules

Using the rule base from the first phase as the initial condition in the second phase facilitates the rapid convergence of the parameter setting procedure. After learning new rules, the input/output MF parameters are set in conjunction with the learned rule parameters. The maximum number of iterations when setting the FIS tree parameters is 75. Using too many iterations may increase validation errors because the parameters are overfitted to the training data. Using the training data and tuning options, the parameters of the FIS tree has been adjusted with the *tunefis* function. At the end of the tuning process, the error is expected to decrease compared to the previous step. The performance of the tuned FIS tree was evaluated against the validation dataset by comparing the expected "donation" to the actual value. After the second step was completed, the following diagrams were created.



**Figure 6:** Graphs obtained by implementing the tuning of the FIS rules and MFs.

Compared to the results of the rulemaking process, the RMSE appears to have decreased. Table 2 shows the statistical calculation results of both the first digit tuning (rule assignment) and the second digit tuning (rule and MFs).

MSE, RMSE, and St.D values are compared in this table. Below is a breakdown of these metric calculations.

### Mean Squared Error (MSE)

A mean square error (Chai & Draxler, 2014) measures the closeness of a regression curve to a collection of points. The MSE quantifies the performance of the estimator of a machine learning model. It is always positive, and estimators with MSE values close to zero are considered better. The calculation is as given in Eq.1.

$$\text{RMSE} = \frac{1}{N} \sum_{i=1}^N (x_i - y_i)^2 \quad (1)$$

### Root Mean Square Error (RMSE):

The RMSE (Mostafaei, Javadikia, & Naderloo, 2016)(Chicco, Warrens, & Jurman, 2021) is a quadratic metric that assesses the magnitude of error in a machine learning model and is often used to calculate the distance between expected and actual values. The RMSE indicates how close the data is to the best fit line. An RMSE value of 0 means that the model was error-free. The RMSE has the advantage of penalizing large errors more harshly, allowing for a better fit in some cases. In various mathematical calculations, the RMSE eliminates absolute values that are not needed. The RMSE is calculated using the formula in Eq. 2.

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - y_i)^2} \quad (2)$$

### Mean Absolute Error (MAE)

The mean absolute error (MAE) (Mostafaei et al., 2016)(Chicco et al., 2021) quantifies the discrepancy between two continuous variables. The average vertical distance between each actual value and the line that best fits the data is MAE. It is a linear value that evaluates the average number of errors in a set

of predictions without considering their direction, with each error contributing equally to the mean. The MEA is calculated using the formula in Eq. 3.

$$\text{MSE} = \frac{1}{N} \sum_{i=1}^N (x_i - y_i)^2 \quad (3)$$

### Standard Deviation

In descriptive statistics (Biau, 2011; el Omda & Sergent, 2021), the standard deviation (Andrade, 2020; el Omda & Sergent, 2021) is the degree of dispersion or distribution of data points compared to the mean. It describes the distribution of values within the data sample and measures how the data points deviate from the mean. The standard deviation is a number that indicates the proper ordering of the data. A small standard deviation indicates that the majority of the numbers are close to the mean. A large standard deviation indicates that the results have a wide range. The formula for calculating the standard deviation is shown in Eq. 3.

$$\text{Error St. D} = \sqrt{\sum_{i=1}^N \frac{(x_i - \bar{x}_i)^2}{N - 1}} \quad (4)$$

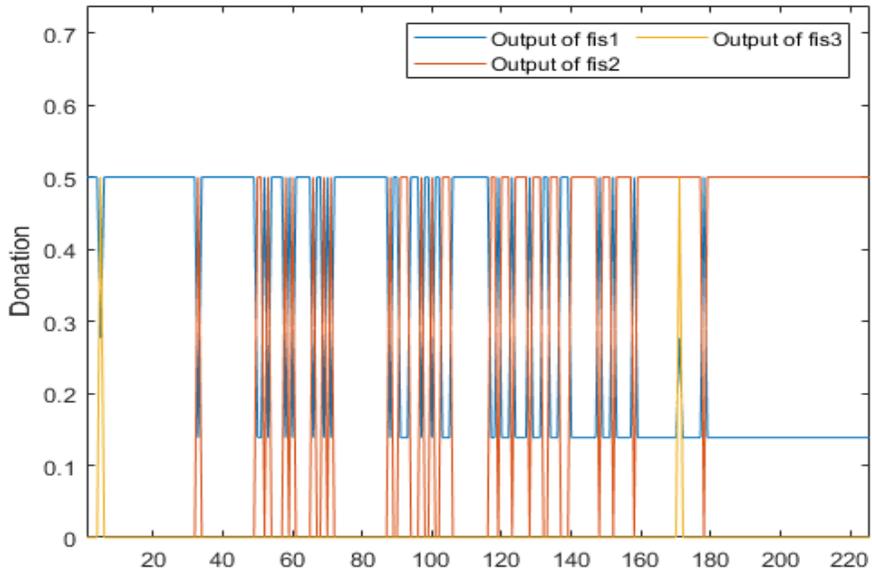
where  $N$  is the number of data,  $\bar{x}$  is the average of the predicted,  $x_i$  and  $y_i$  are the predicted and actual values, respectively.

**Table 2:** Experimental result

	<b>MSE</b>	<b>RMSE</b>	<b>MAE</b>	<b>St.D</b>
<b>Tuning AFS rule table</b>	0.1632	0.404	0.164	0.398
<b>Tuning AFS rule table and MFs</b>	0.1552	0.394	0.302	0.392

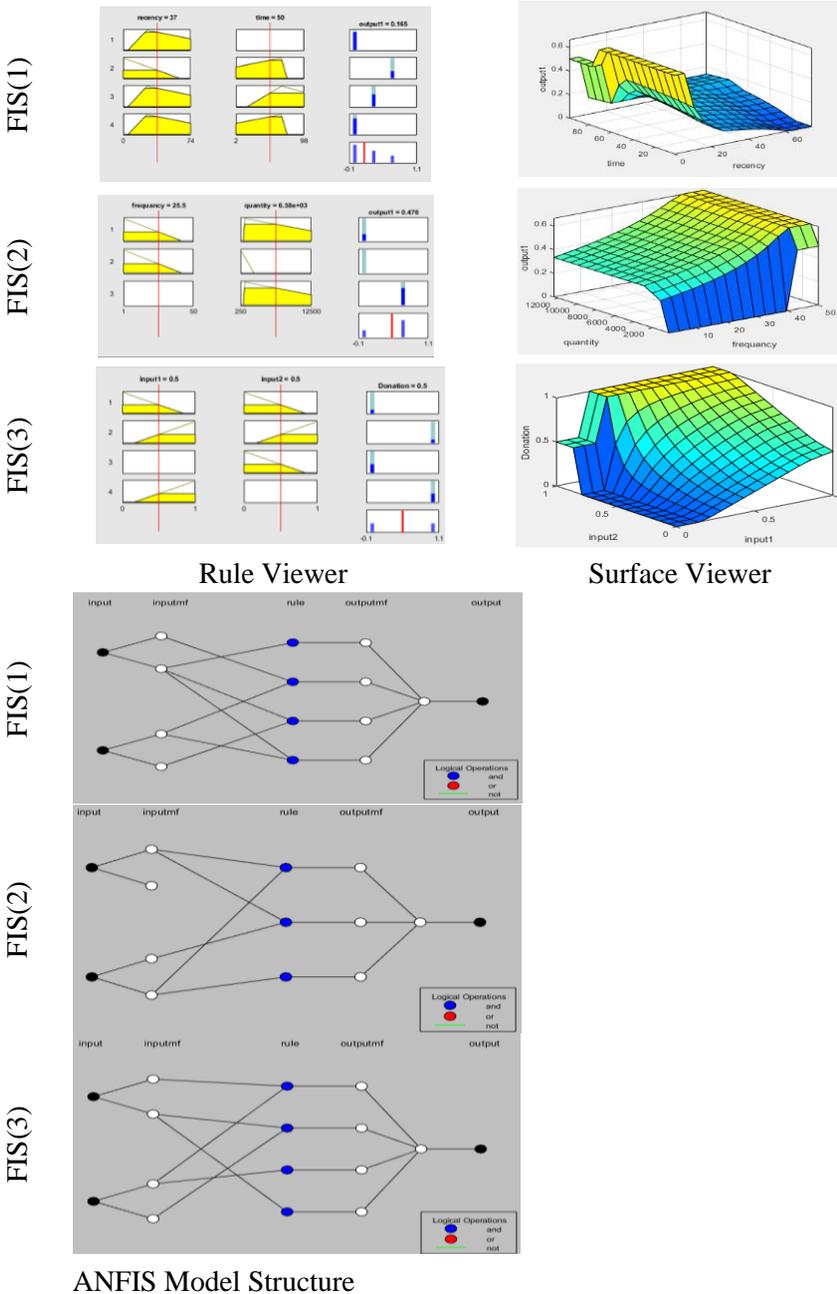
After improving both the rule table and the membership functions of the proposed model, the obtained results show that the proposed model provides an accurate estimate. It has been shown that matching the MFs with a rule

table further improves the result. Figure 7 shows the output of each fuzzy tree (fis1, fs2, fis3). The final output of the FIS tree (fi3/output) seems to show a significant correlation with the outputs of fis1 and fis2.



**Figure 7:** Intermediate and results of fis1, fis2 and fis3

The figure 8 show the rule viewer, which indicates which rules are active for each FIS or membership function that affects the results; the surface viewer, which shows how inputs and outputs are connected; and the structure of the ANFIS model.



**Figure 8:** The rule viewer, the FIS interface, and the ANFIS structure for the aggregated fuzzy tree in the blood donation prediction system (FIS1, FIS2, and FIS).

The study used 16 rules to create a model to estimate the number of donors. The inference methods used in the study were the Takagi-Sugeno and Tsukamoto methods. This method requires less work on the computer, and this difference becomes apparent when working with larger data sets. Figure 8 shows how the output changes when the membership functions of the input variables are considered, based on the conditions in the rule base created with AFS for this system. A surface is created on which the input-output function is represented in three-dimensional space, based on the membership functions, rules, and operation definitions specified in the Surface Viewer representation. Here is the output value resulting from the combination of the two input values.

#### **4. Conclusion**

A system that makes predictions is needed to improve the healthcare supply chain. Therefore, blood supply estimation is essential for supply chain decision making and can also help potential donors improve the process. In this paper, we propose the use of an aggregate fuzzy tree inference system-based model to estimate blood donors based on a small number of criteria. The proposed AFS model was implemented, trained, and validated using MATLAB. We compared the performance of our proposed model with the metrics MSE, RMSE, MAE, and St. D to see if we could improve our ability to predict whether a person will donate blood. The values of  $MSE = 0.1552$ ,  $RMSE = 0.394$ ,  $MAE = 0.302$ , and  $St. D = 0.302$  were calculated as the results of the experiment to estimate a person's repeat donation using only four factors. The proposed model provides results that are quite similar to the actual values. The simulation results show that the proposed AFS system is superior to the conventional fuzzy system. This work adds to the existing literature a model that predicts whether a blood donor will donate again. Of the control factors considered as predictors, only previous donations were beneficial. Experienced donors are more likely to donate again, regardless of their education level, age, gender, or primary motivation for donation. However, the model shows that prior donation is an important predictor. People who have donated blood before are more likely to do so again. By

capturing the desire to donate, it will be possible to design applications to be targeted and attractive. This will increase the number of people who voluntarily and selflessly want to donate blood again, thus improving the blood supply. It is expected that the cost of contacting blood donors and managing the blood management system will be reduced by the new installation. This study has some limitations, including a small sample size and donors from different cultures. Because of the small sample size, it is impossible to generalize this conclusion to the entire universe. Furthermore, the culture of generous donors does not mean that these results can be generalized to a nation with a different culture. Future research would benefit from studying more cultures and using a larger sample.

## References

- Abramson, M. A., Brezhneva, O. A., Dennis, J. E., & Pingel, R. L. (2008). Pattern search in the presence of degenerate linear constraints. *Optimization Methods and Software*, 23(3), 297–319. Retrieved May 10, 2022 from <https://doi.org/10.1080/10556780701521670>
- Adar, E., & Adamic, L. A. (2005). Tracking information epidemics in blogspace. *Proceedings - 2005 IEEE/WIC/ACM International Conference on Web Intelligence, WI 2005*, 2005, 207–214. Retrieved April 29, 2022 from <https://doi.org/10.1109/WI.2005.151>
- Andrade, C. (2020). Understanding the Difference Between Standard Deviation and Standard Error of the Mean, and Knowing When to Use Which. *Indian Journal of Psychological Medicine*, 42(4), 409–410. Retrieved May 11, 2022 from <https://doi.org/10.1177/0253717620933419>
- Bahel, D., Ghosh, P., Sarkar, A., & Lanham, M. A. (n.d.). PREDICTING BLOOD DONATIONS USING MACHINE LEARNING TECHNIQUES. Retrieved April 29, 2022 from
- Biau, D. J. (2011). In brief: Standard deviation and standard error.

- Clinical Orthopaedics and Related Research*, 469(9), 2661–2664. Retrieved from <https://doi.org/10.1007/s11999-011-1908-9>
- Bogani, C., Gasparo, M. G., & Papini, A. (2007). Pattern search method for discrete L 1-approximation. *Journal of Optimization Theory and Applications*, 134(1), 47–59. Retrieved May 10, 2022 from <https://doi.org/10.1007/S10957-007-9204-2>
- Bogani, C., Gasparo, M. G., & Papini, A. (2009). Generalized Pattern Search methods for a class of nonsmooth optimization problems with structure. *Journal of Computational and Applied Mathematics*, 229(1), 283–293. Retrieved May 10, 2022 from <https://doi.org/10.1016/J.CAM.2008.10.047>
- Bungartz, H.-J., Kranzlmüller, D., Weinberg, V., Weismüller, J., & Wohlgemuth, V. (n.d.). *Progress in IS Advances and New Trends in Environmental Informatics Managing Disruption, Big Data and Open Science*. Retrieved from <http://www.springer.com/series/10440>
- Chai, T., & Draxler, R. R. (2014). Root mean square error (RMSE) or mean absolute error (MAE)? -Arguments against avoiding RMSE in the literature. *Geoscientific Model Development*, 7(3), 1247–1250. Retrieved from <https://doi.org/10.5194/gmd-7-1247-2014>
- Chicco, D., Warrens, M. J., & Jurman, G. (2021). The coefficient of determination R-squared is more informative than SMAPE, MAE, MAPE, MSE and RMSE in regression analysis evaluation. *PeerJ Computer Science*, 7, 1–24. Retrieved from <https://doi.org/10.7717/PEERJ-CS.623>
- Cloutier, M., Grégoire, Y., Choucha, K., Amja, A.-M., & Lewin, A. (2021). Prediction of donation return rate in young donors using machine-learning models. *ISBT Science Series*, 16(1), 119–126. Retrieved April 29, 2022 from <https://doi.org/10.1111/VOXS.12618>
- el Omda, S., & Sargent, S. R. (2021). Standard Deviation. *StatPearls*. Retrieved May 11, 2022 from <http://europepmc.org/books/NBK574574>

- Fuzzy Trees - MATLAB & Simulink. (n.d.). Retrieved May 8, 2022, from <https://www.mathworks.com/help/fuzzy/fuzzy-trees.html>
- Haijema, R., van Dijk, N. M., & van der Wal, J. (2017). Blood platelet inventory management. *International Series in Operations Research and Management Science*, 248, 293–317. Retrieved April 29, 2022 from [https://doi.org/10.1007/978-3-319-47766-4\\_10](https://doi.org/10.1007/978-3-319-47766-4_10)
- Heider, H., & Drabe, T. (n.d.). *Fuzzy System Design with a Cascaded Genetic Algorithm*.
- Hooke, R., & Jeeves, T. A. (1961). "Direct Search" Solution of Numerical and Statistical Problems. *Journal of the ACM (JACM)*, 8(2), 212–229. Retrieved May 10, 2022 from <https://doi.org/10.1145/321062.321069>
- Kaburlasos, V. G., & Kehagias, A. (2014). Fuzzy inference system (FIS) extensions based on the lattice theory. *IEEE Transactions on Fuzzy Systems*, 22(3), 531–546. Retrieved April 19, 2022 from <https://doi.org/10.1109/TFUZZ.2013.2263807>
- Kauten, C., Gupta, A., Qin, X., & Richey, G. (2021). Predicting Blood Donors Using Machine Learning Techniques. *Information Systems Frontiers*, 1–16. Retrieved April 29, 2022 from <https://doi.org/10.1007/S10796-021-10149-1/FIGURES/5>
- Khanum, A., Mufti, M., Javed, M. Y., & Shafiq, M. Z. (2009). Fuzzy case-based reasoning for facial expression recognition, 160, 231–250. Retrieved from <https://doi.org/10.1016/j.fss.2008.05.022>
- Latif, S., Usman, M., Manzoor, S., Iqbal, W., Qadir, J., Tyson, G., ... Crowcroft, J. (2021). Leveraging Data Science to Combat COVID-19: A Comprehensive Review. *IEEE Transactions on Artificial Intelligence*, 1(1), 85–103. Retrieved April 29, 2022 from <https://doi.org/10.1109/TAI.2020.3020521>
- Lendek, Z., Babuška, R., & Schutter, B. de. (2009). Stability of cascaded fuzzy systems and observers. *IEEE Transactions on Fuzzy Systems*, 17(3), 641–653. Retrieved from <https://doi.org/10.1109/TFUZZ.2008.924353>

- Lewis, R. M., Torczon, V., & Trosset, M. W. (2000). Direct search methods: then and now. *Journal of Computational and Applied Mathematics*, 124(1–2), 191–207. Retrieved May 10, 2022 from [https://doi.org/10.1016/S0377-0427\(00\)00423-4](https://doi.org/10.1016/S0377-0427(00)00423-4)
- Mahadevan, S., Poornima, S., Tripathi, K., & Pushpalatha, M. (2019a). A survey on machine learning algorithms for the blood donation supply chain. In *Journal of Physics: Conference Series* (Vol. 1362). Institute of Physics Publishing. Retrieved from <https://doi.org/10.1088/1742-6596/1362/1/012124>
- Mahadevan, S., Poornima, S., Tripathi, K., & Pushpalatha, M. (2019b). A survey on machine learning algorithms for the blood donation supply chain. In *Journal of Physics: Conference Series* (Vol. 1362). Institute of Physics Publishing. Retrieved from <https://doi.org/10.1088/1742-6596/1362/1/012124>
- Mahapatra, S. S., Nanda, S. K., & Panigrahy, B. K. (2011). A Cascaded Fuzzy Inference System for Indian river water quality prediction. *Advances in Engineering Software*, 42(10), 787–796. Retrieved from <https://doi.org/10.1016/j.advengsoft.2011.05.018>
- Mamdani, E. H., & Assilian, S. (1975). *An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller*. *Int. J. Man-Machine Studies* (Vol. 7).
- Mostafaei, M., Javadikia, H., & Naderloo, L. (2016). Modeling the effects of ultrasound power and reactor dimension on the biodiesel production yield: Comparison of prediction abilities between response surface methodology (RSM) and adaptive neuro-fuzzy inference system (ANFIS). *Energy*, 115, 626–636. Retrieved from <https://doi.org/10.1016/j.energy.2016.09.028>
- Nagurney, A., Masoumi, A. H., & Yu, M. (2012). Supply chain network operations management of a blood banking system with cost and risk minimization. *Computational Management Science*, 9(2), 205–231. Retrieved April 29, 2022 from <https://doi.org/10.1007/S10287-011-0133-Z>
- Nocedal, Jorge., & Wright, S. J. (n.d.). *Numerical Optimization*.

Retrieved May 10, 2022 from

- Palacio-Morales, J., Tobón, A., & Herrera, J. (2021). Optimization based on pattern search algorithm applied to ph non-linear control: Application to alkalization process of sugar juice. *Processes*, 9(12). Retrieved from <https://doi.org/10.3390/pr9122283>
- Panda, M. (n.d.). *Big Models for Big Data using Multi objective averaged one dependence estimators*.
- Pereira, A. (2004). Performance of time-series methods in forecasting the demand for red blood cell transfusion. *Transfusion*, 44(5), 739–746. Retrieved April 29, 2022 from <https://doi.org/10.1111/J.1537-2995.2004.03363.X>
- Rajendran, S., & Ravi Ravindran, A. (2019). Inventory management of platelets along blood supply chain to minimize wastage and shortage. *Computers & Industrial Engineering*, 130, 714–730. Retrieved April 29, 2022 from <https://doi.org/10.1016/J.CIE.2019.03.010>
- Rajendran, S., & Ravindran, A. R. (2017). Platelet ordering policies at hospitals using stochastic integer programming model and heuristic approaches to reduce wastage. *Computers & Industrial Engineering*, 110, 151–164. Retrieved April 29, 2022 from <https://doi.org/10.1016/J.CIE.2017.05.021>
- Salazar-Concha, C., Ramírez-Correa, P., Karwowski, W., Parsaei, B., Parsaei, H. R., Carlos, J., & Alcantud, R. (2021a). Predicting the Intention to Donate Blood among Blood Donors Using a Decision Tree Algorithm. *Symmetry 2021, Vol. 13, Page 1460*, 13(8), 1460. Retrieved April 29, 2022 from <https://doi.org/10.3390/SYM13081460>
- Salazar-Concha, C., Ramírez-Correa, P., Karwowski, W., Parsaei, B., Parsaei, H. R., Carlos, J., & Alcantud, R. (2021b). Predicting the Intention to Donate Blood among Blood Donors Using a Decision Tree Algorithm. *Symmetry 2021, Vol. 13, Page 1460*, 13(8), 1460. Retrieved April 29, 2022 from <https://doi.org/10.3390/SYM13081460>

- Shahid, O., Nasajpour, M., Pouriyeh, S., Parizi, R. M., Han, M., Valero, M., ... Sheng, Q. Z. (2021). Machine learning research towards combating COVID-19: Virus detection, spread prevention, and medical assistance. *Journal of Biomedical Informatics*, 117, 103751. Retrieved April 29, 2022 from <https://doi.org/10.1016/J.JBI.2021.103751>
- Shashikala, B. M., Pushpalatha, M. P., & Vijaya, B. (2019). Machine Learning Approaches for Potential Blood Donors Prediction. *Lecture Notes in Electrical Engineering*, 545, 483–491. Retrieved April 29, 2022 from [https://doi.org/10.1007/978-981-13-5802-9\\_44](https://doi.org/10.1007/978-981-13-5802-9_44)
- Shih, H., & Rajendran, S. (2019). Comparison of Time Series Methods and Machine Learning Algorithms for Forecasting Taiwan Blood Services Foundation's Blood Supply. *Journal of Healthcare Engineering*, 2019. Retrieved April 29, 2022 from <https://doi.org/10.1155/2019/6123745>
- Shih, H., & Rajendran, S. (2020). Stochastic Inventory Model for Minimizing Blood Shortage and Outdating in a Blood Supply Chain under Supply and Demand Uncertainty. *Journal of Healthcare Engineering*, 2020. Retrieved April 29, 2022 from <https://doi.org/10.1155/2020/8881751>
- Siddique, N., & Adeli, H. (2013). Computational Intelligence: Synergies of Fuzzy Logic, Neural Networks and Evolutionary Computing. *Computational Intelligence: Synergies of Fuzzy Logic, Neural Networks and Evolutionary Computing*, 1–512. Retrieved May 8, 2022 from <https://doi.org/10.1002/9781118534823>
- Takagi, T., & Sugeno, M. (1985). Fuzzy Identification of Systems and Its Applications to Modeling and Control. *IEEE Transactions on Systems, Man and Cybernetics*, SMC-15(1), 116–132. Retrieved from <https://doi.org/10.1109/TSMC.1985.6313399>
- UCI Machine Learning Repository: Blood Transfusion Service Center Data Set. (n.d.). Retrieved May 8, 2022, from <https://archive.ics.uci.edu/ml/datasets/Blood+Transfusion+Servic>

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- Yeh, I. C., Yang, K. J., & Ting, T. M. (2009). Knowledge discovery on RFM model using Bernoulli sequence. *Expert Systems with Applications*, 36(3 PART 2), 5866–5871. Retrieved May 8, 2022 from <https://doi.org/10.1016/J.ESWA.2008.07.018>
- Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, 8(3), 338–353. Retrieved May 9, 2022 from [https://doi.org/10.1016/S0019-9958\(65\)90241-X](https://doi.org/10.1016/S0019-9958(65)90241-X)

## CHAPTER VIII

# ROUTE OPTIMIZATION FOR THE MAINTENANCE OF WIND POWER PLANTS BY USING METAHEURISTIC ALGORITHMS

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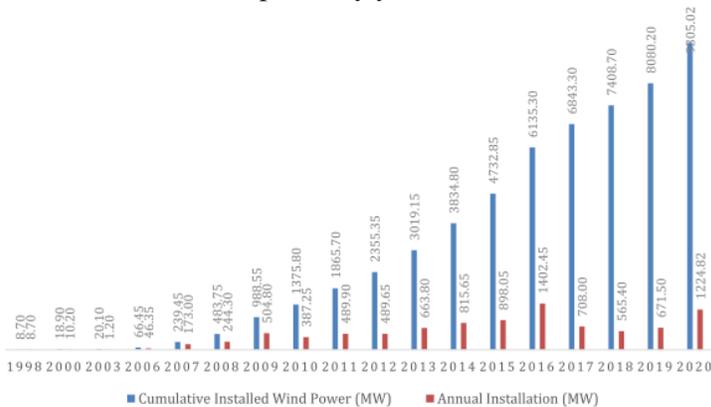
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### 1. Introduction

**E**nergy plays a crucial role in economic and social development (Ur Rehman et al., 2019). Countries depend on energy from various sources for their economic power (Kaplan and San, 2011). In addition, increasing production in response to increasing consumption all over

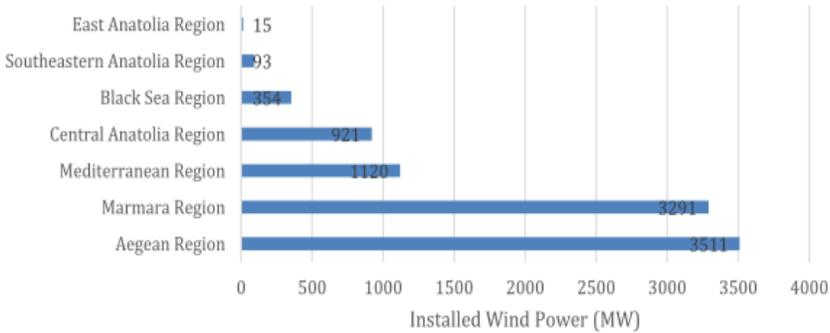
the world has boosted energy demands (Siddiqui et al., 2019). Concurrently, interest in renewable energy sources has been growing in recent years due to global pollution created by traditional energy sources reaching concerning levels (Yong et al., 2016). The use of sustainable and green energy generated from solar, wind, biomass and geothermal energy sources has increased. Through the use of renewable energy sources, adverse impacts on the environment and climate can be mitigated (Mizsey and Racz, 2010). The widespread use of environmentally friendly technologies helps to reduce the use of energy and resources in industrial production as well as the waste generated as a result (Dovì et al., 2009).

Wind technology has seen steady innovation since the early 1970s – to the extent that wind energy had become one of the most important renewable energy sources by the end of the 1990s (Burton et al., 2011). Turkey has a high wind energy potential (Kaygusuz, 2010), and the first commercial WPP in Turkey became operational with an installed power of 8.70 MW in 1998 in Çeşme, Izmir (Yılmaz, 2012). By the end of 2020, Turkey had a total installed wind power of 9305.02 MW (TÜREB, 2021a). Figure 1 shows the installation and cumulative installed wind power by year.



**Figure 1:** Cumulative installed wind power and installation by years (TÜREB, 2021a)

The Aegean Region has the most installed wind power in Turkey. Figure 2 shows the distribution of Turkey's total installed wind power by region.



**Figure 2:** Distribution of Turkey's total installed wind power by region (TÜREB, 2021b)

On a provincial basis, Izmir ranks first with its 1798 MW installed wind power. Izmir is followed by Balıkesir with 1220 MW, Çanakkale with 751 MW, Manisa with 717 MW and Hatay with 415 MW (TÜREB, 2021c).

The reliability of the wind turbine system used is a very important factor in evaluating the success of a wind power project (Walford, 2006). Wind turbines are generally purchased with a 2–5-year all-inclusive-service contract. These contracts include warranties as well as scheduled (preventive) and unscheduled (failure-related) maintenance provisions. To ensure uninterrupted maintenance of the turbines, these contracts are usually renewed at expiration (Andrawus et al., 2007).

The goal of preventive maintenance is to replace various components and to renew the system because the life of these components is generally shorter than the expected life of the turbine. Periodic inspection of equipment, oil and filter changes, calibration or adjustment of sensors, actuators, brake pads, and gasket replacement, etc. fall in this category. Cleaning –notably including blades– can also be included in this category. These tasks and how often they will be performed are clearly defined in the maintenance manuals provided by the turbine manufacturer. Unplanned (failure-related) maintenance, on the other hand, is performed in the event of a malfunction. Because commercial wind turbines are complex systems, the failure of a small component can cause the turbine to fail. In this case, maintenance personnel should be involved (Walford, 2006).

Both preventive maintenance and failure-related maintenance are activities that require time for companies. To carry out these activities in an economical way, various planning and optimizations are required.

This study applies two metaheuristic algorithms, the ICA and SSO algorithms, to the optimization of preventive maintenance on the same-brand wind turbines in different WPPs within the borders of Izmir province. These two novel algorithms are capable of converging on the global optimum points efficiently. Moreover, the route optimization problem has been extensively studied in the literature, to the best of the authors' knowledge the subject has not been approached from the angle of metaheuristic optimization.

Knowing the optimum route connecting a number of locations has certain advantages such as lower fuel consumption and effective use of workforce. The main goal of this study is to obtain an optimum route connecting WPPs in Izmir province. To this end, two different metaheuristic algorithms have been utilized and their results have been demonstrated.

The remainder of the study is organized as follows: in the second section, a detailed literature review is included. In the third section, the ICA and SSO algorithm are explained. The fourth section is devoted to the application, and the results are discussed in the last section.

## **2. Literature Review**

Various studies have been published on maintenance planning as well as using the ICA and SSO algorithm. In this section, we discuss these studies in detail.

Maintenance planning and scheduling have been extensively studied in the electrical industry, particularly in thermal power plants (Froger et al., 2016). The problem of wind turbine maintenance scheduling in onshore wind farms is addressed. A maintenance plan is provided, which includes assignments to a highly skilled workforce in a short-term period, detailed resource management, and maximizing wind power generation. It has been found that the calculation time grows depending on the size of the problem. Therefore, a constraint programming approach based on neighborhood search was proposed (Froger et al., 2018).

Maintenance optimization for wind turbines has gained attention in the literature (Ding et al., 2013). Unlike burning fossil fuels, wind energy is abundant, clean and renewable. Humankind has been using wind energy for hundreds of years. Wind turbines are often operated in harsh environments and must withstand high wind speeds and extreme temperatures. The maintenance cost of wind turbine equipment is generally higher than the cost of its procurement. A wind farm will face many challenges such as powertrain system failures, splintered bearings and broken gears, so the operation and maintenance of the wind turbine have become important areas of research (Yeh et al., 2019).

A wind turbine is one of the main elements of the wind power generation system. Recent studies reveal that the maintenance costs of wind turbines take up a greater proportion of the total operating costs (Amayri et al, 2011).

In general, studies of routing and scheduling have focused on the vehicle routing problem. In recent years, such studies have diversified to include extensions and variations of vehicle routing problems (Fan et al., 2019). For the dynamic vehicle routing problem, using evolutionary algorithms, several routes serving multiple customers at the lowest travel cost have been found. Due to differential traffic density, travel time between points may vary (Sabar et. al, 2019). The split delivery vehicle routing problem, which provides service with the desired number of vehicles to the requested point of delivery, has been addressed (Wilck IV and Cavalier, 2012). A special vehicle routing problem has been investigated considering the time interval and simultaneous service variables (Liu et al., 2019). Utilizing the integer programming model, an efficient large neighborhood search heuristic has been proposed to minimize the computing time and cost (Moura, 2019). The multi-depot vehicle routing problem has been optimized by integrating multi-objective large neighborhood search and tabu search. While optimizing, products were delivered by visiting customers, starting from different depots. Vehicles do not have to return to depots at the end of their tour (Soto et al., 2017).

ICA was introduced into the literature by Atashpaz-Gargari and Lucas

(2007), at which time four minimization problems were discussed. Many subsequent studies appear to have used ICA in various fields, and these are summarized in Table 1.

**Table 1: Studies with ICA**

Article Subject	Methods	Author(s)
Fuzzy controllers design of vehicles	ICA, Fuzzy Logic	Jasour et al., 2008
Solving the minimum bit error rate (MBER) minimization problem in communication applications	ICA, Genetic Algorithm (GA)	Khabbazi et al., 2009
Elasto-plastic material property characterization	ICA, Artificial Neural Network (ANN), Finite Element Analysis	Biabangard-Oskouyi et al., 2009
Solving three different optimization problems with improved ICA	Improved ICA	Zhang et al., 2009
Designing four different steel skeleton structures	ICA	Kaveh and Talatahari, 2010
Solving the problem of determining the distribution of the materials to be produced and outsourced by an enterprise	ICA, Theory of Constraints, Standard Accounting	Nazari-Shirkouhi et al., 2010
Designing a linear induction motor	ICA, GA, Finite-Element Analysis	Lucas et al., 2010
Application of CICA in some benchmarking functions and comparison of results	Imperialist Competitive Algorithm using Chaotic Maps (CICA), Particle Swarm Optimization (PSO), GA	Bahrami et al., 2010
Examination of the exchange of stocks in Tehran Stock Exchange Market with AICA	Adaptive Imperialist Competitive Algorithm (AICA), Perceptron Neural Network	Abdechiri et al., 2010
Simulating the localization accuracy of the wireless sensor network application and analyzing the results	ICA, PSO	Sayadnavard et al., 2010
Solving the clustering problem with K-MICA and comparing the results	Modified Imperialist Competitive Algorithm and K-means (K-MICA), ICA, ACO, PSO, Simulated Annealing (SA), GA, Tabu Search (TS), Honey Bee	Niknam et al., 2011

	Mating Optimization (HBMO)	
Prediction of asphaltene precipitation	ICA-ANN, Scaling Model	Ahmadi, 2011
The solution for the two-stage assembly flow-shop scheduling problem	ICA, SA, Taguchi Method	Shokrollahpour et al., 2011
Resolving the stochastic U type assembly line balancing problem	ICA, Computer Method for Sequencing Operations for Assembly Lines	Bagher et al., 2011
Using CICA in four benchmarking functions	CICA, Orthogonal ICA, ICA	Talatahari et al., 2012
Solving brushless direct current wheel motor comparison problem with MICA	Modified Imperialist Competitive Algorithm (MICA)	Coelho et al., 2012
Solving four integrated process planning and scheduling problems	ICA	Lian et al., 2012
The solution to the problems of determining the most accurate design of a type of heat exchanger	ICA, GA	Yousefi et al., 2012
Estimating the oil flow rate of a reservoir in the oil field	ICA-ANN, Fuzzy Logic	Ahmadi et al., 2013
Determining the parameters of the PID controller for load frequency control (LFC) and comparing the results	ICA, GA, Neural Network	Shabani et al., 2013
Performing skin color segmentation study	HNNICA	Razmjoooy et al., 2013
Prediction of corrosion current density in concrete with ICA-ANN	ICA-ANN	Sadowski and Nikoo, 2014
Route planning optimization of an unmanned combat aerial vehicle	ICA	Duan and Huang, 2014
Finding solutions to traveling salesman problems with ICA	ICA, Random Key GA, Discrete Differential Evolution Algorithms	Ardalan et al., 2015
Application of FAICA in seven different benchmarking functions and comparison of results	Fuzzy Adaptive ICA (FAICA)	Khaled and Hosseini, 2015
Determining the optimal field development planning of well locations for four different situations and comparing the results	ICA, PSO	Al Dossary and Nasrabadi, 2016

Determination of optimum setting of STATCOM parameters with ICA and comparison with GASTATCOM	ICA based STATCOM (ICASTATCOM), GASTATCOM	Abd-Elazim and Ali, 2016
Using MOICA for three different multi-purpose engineering design problems and comparing the results	Multi-Objective ICA (MOICA)	Bilel et al., 2016
A study of estimating the optimum parameters of the Photovoltaic (PV) generation unit with ICA for two different situations and comparing the results	ICA, Adaptive Differential Evolution Algorithm (ADE)	Fathy and Rezk, 2017
Solving the problem of scheduling flexible job-shops with transportation times between machines	ICA, Chemical Reaction Optimization (CRO), GA, MILP	Karimi et al., 2017
Solving the virtual machine placement problem and comparing the result with other algorithms	ICA	Jamali et al., 2017
Using RVM-ICA for landslide susceptibility prediction modeling in Vietnam and examining results statistics	Relevance Vector Machine and ICA (RVM-ICA), GIS	Tien Bui et al., 2018
Optimal design of four benchmarking problems related to steel frame structures, and comparison of results	Enhanced ICA (EICA), GA, PSO, ACO, Tabu Search, HS, Adaptive HS, EHS, ICA	Maheri and Talezadeh, 2018
Prediction and classification of saw machine performance used in stone processing factories in Iran	ICA, K-means	Mikaeil et al., 2018
Using AC-ICA for automatic clustering and comparing the results with other produced ICA (K-MICA, IICA-G, EXPLICA, ICA)	Automatic clustering using ICA (AC-ICA)	Aliniya and Mirroshandel, 2019
The solution to the hybrid flow shop scheduling problem, taking into account energy efficiency targets	Two Level ICA (TICA)	Li et al., 2019
Examining three benchmark problems in damage detection	ICA, Damage Function	Gerist and Maheri, 2019
Designing the controller for automatic voltage regulator estimation	ICA, GA	Elsisi, 2019
Solving some type of machine scheduling problem and comparing the	ICA with memory (MICA)	Lei et al., 2020

results		
Solving a cloud computing load balancing problem with ICA and Firefly Algorithm (FA)	ICA, FA	Kashikolaie et al., 2020
A study of modeling a geothermal energy system supported by renewable energy sources with two different algorithms and comparing the results	Multilayer perceptron (MLP) Optimized with GA (MLP-GA), MLP Neural Network Optimized with ICA	Khosravi and Syri, 2020
Solving the resource-constrained hybrid flow shop problem with DICA from an energy consumption perspective and comparing the results with the results of DABC, LABC, and HICA algorithms	Discrete ICA (DICA)	Tao et al., 2021

The SSO algorithm (sometimes also abbreviated as social spider algorithm, SSA) has also been used in this study. This up-to-date metaheuristic algorithm was put forward more recently than ICA; it was introduced to the literature by Yu and Li (2015). A wide literature search produced the list of studies using the SSO algorithm in Table 2.

**Table 2:** Studies employing the SSO algorithm

Article Subject	Methods	Author(s)
Solving the economic load dispatch problem with SSA and comparing the results with other algorithms	SSA	Yu and Li, 2016
Solving the economic load dispatch problem with Modified SSA (MSSA) and comparing the results	MSSA	Elsayed et al., 2016
Solving integer programming and minimax problems with Simplex SSA (SSSA)	SSSA	Tawhid and Ali, 2016
Selecting Quality of Service-aware web services	SSA, PSO	Mousa and Bentahar, 2016
Estimating the current used in the operation of DC motors	NN, SSA	Hameed et al., 2016
Finding solution for the static transmission expansion planning problem using SSA	SSA	El-bages and Elsayed, 2017
Comparison of K-means and Simplex Method-based Social Spider Optimization	SMSSO	Zhou et al., 2017

(SMSSO) algorithm results for data clustering problems		
Solving a 0-1 knapsack problem using Binary SSA (BSSA) and comparing results to GA and PSO	BSSA	Nguyen et al., 2017
The spectrum allocation problem in Cognitive Radio Networks and comparing results to PSO	SSA, PSO	Dang et al., 2017
Solving the minimum number attribute reduction problem with social spider optimization algorithm based on rough sets (SSORS)	SSORS	Abd El Aziz and Hassanien, 2018
Determining the distribution scheme of a wireless sensor using SSA and comparing the results with other algorithms	SSA	Zhou et al., 2018
Solving the two-stage assembly flow scheduling problem with SSO-based Memetic Algorithm (MSSO) and comparing the results with other algorithms in small and large-scale cases	MSSO	Zhang and Xing, 2018
Choosing the band used to obtain information from hyper-specific images with the aid of Binary SSO (BSSO) and comparing results to alternative algorithms	BSSO	Shukla and Nanda, 2018
Planning the electricity usage of electrical devices on the demand side	SSA, Harmony Search Algorithm (HSA)	Junaid et al., 2018
Planning a task in cloud computing and comparing the results with those of other algorithms	Chaotic SSA (CSSA)	Arul Xavier and Annadurai, 2019
Solving the problem of optimum power flow for different modifications	Novel improved SSO (NISSO)	Nguyen, 2019
Cloud detection and clustering in satellite images	Multi-objective SSO (MOSSO), MOSSO-C	Gupta et al., 2019
Application of the variations of the BinSSA method in three different problem types	Binary SSA (BinSSA)	Baş and Ülker, 2020
Study of estimating soil erosion susceptibility	MARS machine learning, SSA	Vu et al., 2020
Developing a model of antenna array design	SSA, modified SSA (MSSA)	Das et al., 2020

### 3. Methods

Metaheuristic algorithms are finding increasing application in many different areas of science and engineering. Some of the most frequently applied metaheuristic techniques are the harmony search algorithm (Bekdaş, 2015; Geem et al., 2001), particle swarm optimization (Kennedy and Eberhart, 1995), the artificial bee colony technique (Karaboga, 2009) and the ant colony algorithm (Abachizadeh and Tahani, 2009; Abachizadeh et al., 2010). This study introduces two novel metaheuristic techniques and demonstrates their application to the problem of route optimization.

#### 3.1. *Imperialist Competitive Algorithm (ICA)*

The starting point of this algorithm is the random generation of a certain number of countries that constitute a population. In the case of route optimization, a country is an abstraction for a sequence of points on the route or a sequence of route segments. Once the countries are generated, the next step is their classification into imperialists and colonies, which occurs based on the power of each country. In this process, commonly the top 5% to 10% of the population are assigned the imperialist status (Hosseini and Al Khaled, 2014). The countries that have greater power –or in the case of route optimization, routes with smaller total travelling distances– are classified as imperialists and other countries are assigned to them as colonies. Each imperialist and its colonies make up an empire. The power of an empire is determined by the power of its imperialist and a percentage of the average power of its colonies. Let  $N_{pop}$  be the total number of countries and  $N_{imp}$  be the total number of imperialists in the population. Then the total number of colonies can be denoted with  $N_{col} = N_{pop} - N_{imp}$ . The colonies are divided among the imperialists in such a way that the number of colonies that belong to an empire is directly proportional to the power of the imperialist of this empire. In the case of route optimization, the first step in the distribution of the colonies is to calculate the normalized travelled distance associated with each imperialist as shown in Eq.(1) (Hosseini and Al Khaled, 2014).

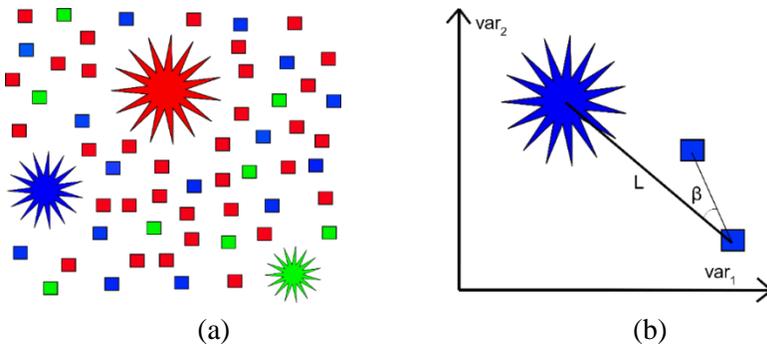
$$ND_n = \max(D_i) - D_n \quad (1)$$

In Eq.(1)  $ND_n$  is the normalized travelled distance of the  $n$ -th imperialist and  $\max(D_i)$  is the maximum travelled distance among all imperialists. It follows that an imperialist with less travelled distance has greater normalized travelled distance and therefore greater power than the rest of the imperialists, which is calculated as in Eq.(2).

$$p_n = \frac{ND_n}{\sum_{i=1}^{N_{imp}} ND_i} \quad (2)$$

Finally, the number of colonies that will be part of the  $n$ -th empire ( $NC_n$ ) in the initial population is calculated using Eq.(3) where the function round gives us the nearest integer to its argument.

$$NC_n = \text{round}(p_n \cdot N_{col}) \quad (3)$$



**Figure 3:** a) A two-dimensional example for ICA,  
b) Colonies move towards their imperialists (assimilation)

Figure 3a shows a conceptual two-dimensional example for ICA where the imperialists are represented with star symbols of different sizes and colors, and the colonies are represented with rectangles of colors corresponding to their empire. In Figure 3a the imperialist represented by the green star has the smallest size of all imperialists and therefore has the smallest number of colonies represented by green rectangles. On the other hand, the empire with the red color has the imperialist with the greatest size and the highest number of colonies.

Once the initial state of empires has been established, the next step is the assimilation of the colonies by the imperialist to which they belong. This

process is visualized in Figure 3b, where the states of imperialists and colonies are determined by the variables  $\text{var}_1$  and  $\text{var}_2$ . In the process of assimilation, the colony moves a certain distance towards the imperialist, which is a multiple of the distance  $L$ . In addition to the movement along the straight line connecting the colony to the imperialist, the colonies also make deviational movements represented by the angle  $\beta \in \left(-\frac{\pi}{4}, \frac{\pi}{4}\right)$ .

Once the entire population has gone through the process of assimilation, the weakest colony of the weakest empire is taken by one of the more powerful empires. In the process of assigning the weakest colony of the weakest empire to a new owner, those empires having more power also have greater likelihood of owning this colony. This process of changing the ownership of certain weaker colonies leads to the eventual collapse of the weaker empires. An empire collapses when it loses all of its colonies. Eventually all empires are expected to collapse except for the most powerful empire.

### 3.2. *Social Spider Optimization (SSO)*

This algorithm was proposed by Cuevas et al. (2013) and applied to the problem of wind speed characterization by Alrashidi et al. (2020). The algorithm replicates the behavior of a spider species called social spider that lives in colonies. These spiders are connected to each other through a communal web which serves the purpose of transmitting the vibrations emitted by individual spiders. These vibrations carry information about the physical fitness and gender of each spider based on which the colony members are attracted towards each other to varying degrees (Salomon et al., 2010). The initial step of the algorithm is the generation of a spider population which consists of females and two different types males where females constitute the larger portion of the population. The males are classified as dominant and non-dominant ones according to their fitness. In the context of optimization, a spider represents a set of design variables. During the initial generation of the population as well as in the later iteration phases the design variables are always kept with certain boundaries. If the total number of females and males in the population are denoted with  $N_f$  and  $N_m$  respectively

the entire spider population can be shown as a set  $S = F \cup M = \{f_1, f_2, \dots, f_{N_f}\} \cup \{m_1, m_2, \dots, m_{N_m}\}$ . Then the total number of spiders is  $N = N_f + N_m$ .

In the current study, we are dealing with routes connecting different WPPs. Each WPP is given a node number and each route is defined by a sequence of WPPs (nodes) and the road distances connecting them. Since the aim of the study is to find the optimum route connecting 13 WPPs where the start and the end points are identical, this constitutes a total of 14 design variables where each design variable is the length of a link between two nodes of the route. Each unique combination of these design variables corresponds to a spider (design vector) in the population of spiders. The iterations of the spider population towards an overall better state happens through the attractions of the spiders towards each other and the generation of new colony members through mating. Since the attraction happens based on the fitness of each spider the entire population has to be ranked according to their fitness. In the case of route optimization, the indication of fitness is the total length of the route where the route leading to the shortest total distance traveled is regarded as the best design (fittest spider). The fitness of a colony member with index  $i$  is computed through Eq.(4) with the help of a fitness function  $F$  (Cuevas et al., 2013).

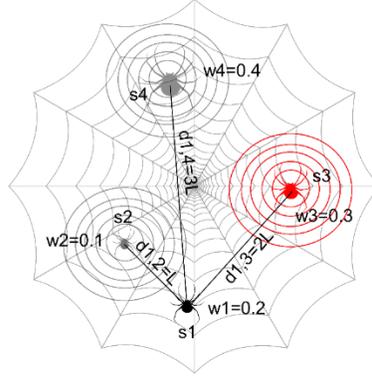
$$w_i = \frac{F(s_i) - F(s_{worst})}{F(s_{best}) - F(s_{worst})} \quad (4)$$

During the iteration phase of the algorithm the male and female colony members exhibit different attraction patterns. A decisive factor in this process is the intensity of a vibration emitted by a spider. This intensity can be computed as in Eq.(5) where  $i$  and  $j$  are the indices of the spiders at the receiving and emitting end of a vibration. Here  $d_{i,j}$  is the Euclidean distance between the receiving and emitting spiders which should be normalized in order to prevent the rapid convergence to zero of the exponential part in Eq.5.

$$I_{i,j} = w_j \cdot e^{-d_{i,j}^2} \quad (5)$$

During an iteration step the female spiders exhibit two types of attraction or repulsion. The first one of these is the attraction towards the nearest colony member which performs better (has more weight) than the female spider itself

( $s_c$  in Eq.(6)). This type of attraction is visualized in Figure 4. The second type of attraction is towards the best performing spider in the entire colony ( $s_b$  in Eq.(6)). In addition to these a spider does also a random movement in every iteration step. These movements are expressed through the female iteration equation given in Eq.(6).



**Figure 4:** Attraction towards the nearest better performing colony member

$$f_i^{k+1} = \begin{cases} f_i^k + \alpha I_{i,c}(s_c - f_i^k) + \beta I_{i,b}(s_b - f_i^k) + \delta \left( \gamma - \frac{1}{2} \right) & \text{for } \varepsilon < PF \\ f_i^k - \alpha I_{i,c}(s_c - f_i^k) - \beta I_{i,b}(s_b - f_i^k) + \delta \left( \gamma - \frac{1}{2} \right) & \text{for } \varepsilon \geq PF \end{cases} \quad (6)$$

$\alpha, \beta, \gamma, \delta, \varepsilon, PF \in (0,1)$

In Eq.(6)  $PF$  determines the probability of an attraction happening instead of repulsion such that a greater value of  $PF$  implies a higher probability of the first line of Eq.(6) being executed. The female iteration step can be summarized as in Algorithm 1.

**Algorithm 1:** Female iteration

**Function** female iteration

Random number generation  $\alpha, \beta, \gamma, \delta, \varepsilon \in (0,1)$

**For**  $i = 1$  to  $N_f$

Find  $s_c$  and  $s_b$  in Eq. (6)

**If**  $\varepsilon < 0.7$  **then** attraction towards  $s_c$  and  $s_b$

**Else** repulsion from  $s_c$  and  $s_b$

Compute route length

The dominant male spider iteration consists of an attraction towards the nearest female in the colony (denoted by  $s_f$  in Eq.8) and a random motion as demonstrated in Eq.(7) and Eq.(8). On the other hand, non-dominant males are attracted towards the weighted mean of the entire male population denoted by  $WMM$ . In Eq.(8) the first line corresponds to the dominant male iteration and the second line corresponds to the non-dominant male iteration. To be classified as a dominant male a spider has to perform better than the median member of the set of all male spiders. The weight of the median member of the male population is denoted by  $w_{N_f+m}$  in Eq.(8). A summary of the male iteration is given in Algorithm 2.

$$WMM = \frac{\sum_{h=1}^{N_m} m_h^k w_{N_f+h}}{\sum_{h=1}^{N_m} w_{N_f+h}} \quad (7)$$

$$m_i^{k+1} = \begin{cases} m_i^k + \alpha I_{i,f}(s_f - m_i^k) + \delta \left( \gamma - \frac{1}{2} \right) & \text{for } w_{N_f+i} > w_{N_f+m} \\ m_i^k + \alpha (WMM - m_i^k) & \text{for } w_{N_f+i} \leq w_{N_f+m} \end{cases} \quad (8)$$

**Algorithm 2:** Male iteration

**Function** male iteration

Random number generation  $\alpha, \delta \in (0,1)$

Calculate  $WMM$

Ranking and classification of all males

**For each** male spider  $\in M$

**If** male spider is dominant **then** find  $s_f$

Attraction towards  $s_f$

**Else** Attraction towards  $WMM$

The generation of new colony members happens through the involvement of dominant males and the females within the radius of mating of these dominant males. The radius of mating is computed as in Eq.(9) where  $n$  is the total number of design variables and  $v_j^{high}$  and  $v_j^{low}$  are the upper and lower bounds of the variable with index  $j$ . The newly generated spiders are ranked

against the existing spiders in the colony and depending on their performance they either replace the worst performing spiders or they are not included in the colony. The spiders involved in the mating have an influence on the properties of the newly generated spider in proportion to their weights. The mating process can be summarized as in Algorithm 3. Figure 5 shows a flowchart for the social spider algorithm.

$$r = \frac{\sum_{j=1}^n (v_j^{high} - v_j^{low})}{2n} \tag{9}$$

**Algorithm 3:** Mating

**Function** mating

**For each** male spider  $\in M$

**If** male spider is dominant **then** generate empty set  $G$

Add male spider to  $G$

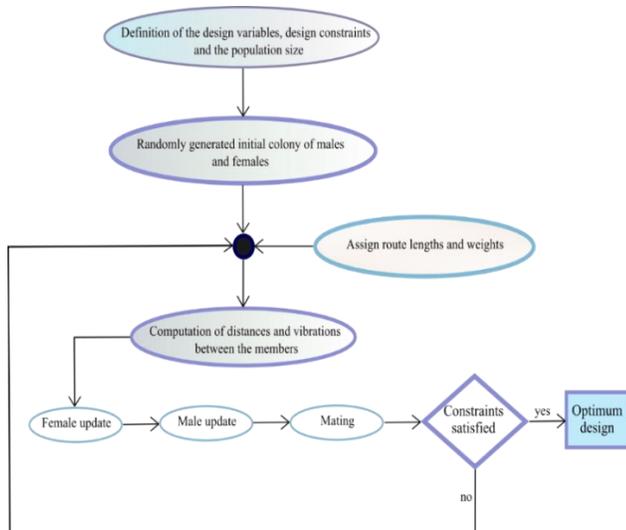
**For each** female spider  $\in F$

**If** distance(male spider, female spider)  $< r$  **then**

Add female spider to  $G$

Generate new spider with the weighted properties of the spiders in  $G$

**If**  $w_{new} > w_{worst}$  **then** Replace the worst spider



**Figure 5:** SSO flowchart

#### 4. Results and discussion

The data in Table 3 were obtained from Turkish Wind Energy Association (Türkiye Rüzgar Enerjisi Birliği - TÜREB) (TÜREB, 2021d). In this database, only the province of Izmir was selected and the latitude and longitude information of 13 different WPPs with turbines belonging to the same company within the boundaries of this province were determined with the help of Google Maps. The latitude of the service center in Izmir Çiğli is 38.47414 degrees and its longitude is 27.03183 degrees, as obtained from Google Maps; these coordinates were taken as the starting point (0). With all latitude and longitude data obtained, the distance matrix in Table 4 was created. The following points were taken into account while creating the distance matrix:

- 1) The distances are given in km.
- 2) While finding the distances between coordinates on Google Maps, the shortest route was taken if there are several different routes.
- 3) The distance matrix is considered to be symmetrical. That is, distance 0-1 is assumed to be equal to distance 1-0. There may be slight differences in reality.

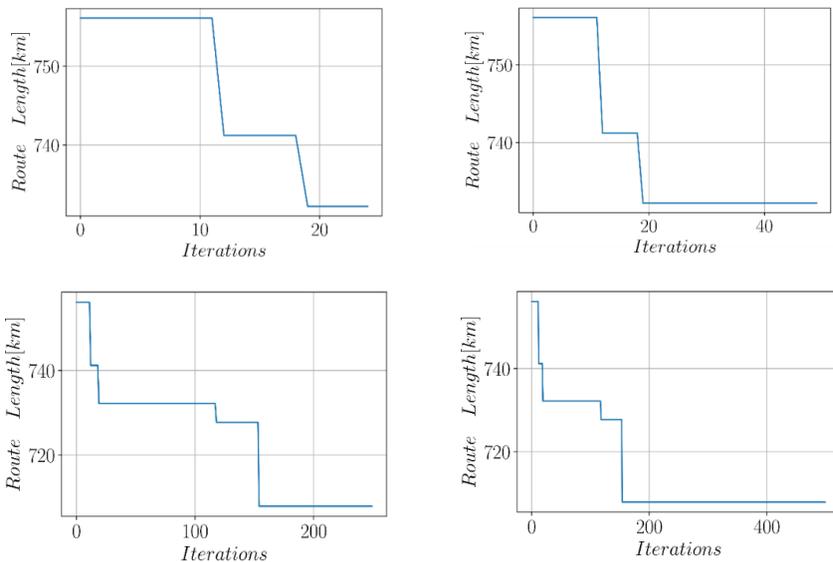
**Table 3:** Latitudes and longitudes of WPPs

WPP Identity	Latitude (degree)	Longitude (degree)
WPP 1	38.934800321	27.130501222
WPP 2	38.6532562948	26.4455381231
WPP 3	38.3052072733	26.4618992188
WPP 4	38.7101935471	26.8813063223
WPP 5	38.7110786273	27.1076818574
WPP 6	38.2759766994	26.464962517
WPP 7	38.2930024745	26.3460815051
WPP 8	38.3241405195	26.4328843731
WPP 9	38.4883805636	26.5813817111
WPP 10	38.3280624135	26.6045585051
WPP 11	38.4787077887	27.528569908
WPP 12	38.8873546364	27.1803902923
WPP 13	38.5908399955	26.4418045157

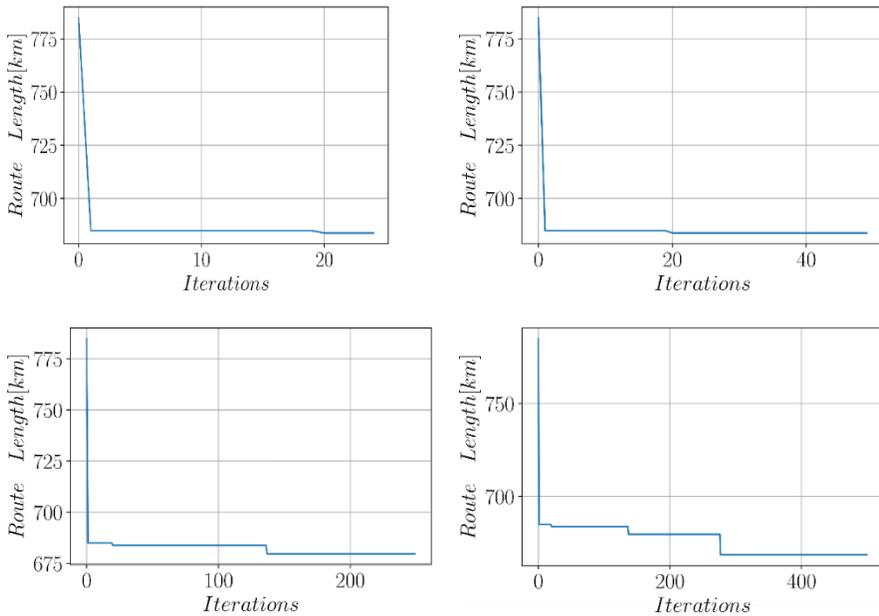
**Table 4:** Distance matrix

0	WPP1	WPP2	WPP3	WPP4	WPP5	WPP6	WPP7	WPP8	WPP9	WPP10	WPP11	WPP12	WPP13
0	-	-	-	-	-	-	-	-	-	-	-	-	-
WPP1	74.3	-	-	-	-	-	-	-	-	-	-	-	-
WPP2	133	224	-	-	-	-	-	-	-	-	-	-	-
WPP3	87.8	179	73.1	-	-	-	-	-	-	-	-	-	-
WPP4	41.9	49	204	159	-	-	-	-	-	-	-	-	-
WPP5	39.5	66.1	191	147	42.1	-	-	-	-	-	-	-	-
WPP6	93.2	185	80.9	7.4	142	129	-	-	-	-	-	-	-
WPP7	103	195	81.2	18.8	152	139	15.7	-	-	-	-	-	-
WPP8	92.9	184	71.5	5.7	142	129	14.3	12.9	-	-	-	-	-
WPP9	96.2	188	36.6	36.6	138	132	44.3	43.8	34.9	-	-	-	-
WPP10	78.3	158	72.8	15.8	127	114	19.5	30	21	36.2	-	-	-
WPP11	50.7	102	165	121	97.5	83.7	126	135	126	129	111	-	-
WPP12	76.9	21.4	228	184	55.8	69.3	189	198	189	192	153	87.4	-
WPP13	137	228	22.8	54.9	179	172	62.6	62.1	53.2	40.6	58.9	169	203

The development of the minimum route length through optimizations performed by the ICA and SSO algorithms are shown in Figures 6 and 7, respectively. Figure 6 shows the variation of the optimal route length obtained through the ICA at four different stages of the optimization. An optimal total traveled distance of 707.9 km could be obtained after approximately 150 steps of iterations. This route length corresponds to the following sequence of the WPPs: (0-5-11-12-1-4-9-2-13-6-10-7-3-8-0). Similarly, four different stages of the SSO algorithm can be seen in Figure 7. The minimum traveled distance obtained through the SSO algorithm was 668.6 km with a WPP sequence of (0-12-1-4-5-11-10-13-2-9-7-8-6-3-0).



**Figure 6:** Optimal route length with ICA



**Figure 7:** Optimal route length with SSO

A comparison of Figure 6 and Figure 7 shows that around 200 iterations were needed in the optimization with ICA to reach convergence to an optimum result whereas around 300 iterations were needed in case of SSO. The convergence is assumed when subsequent iterations no longer provide better results. The longer process of convergence in case of SSO can be attributed to the fact that the SSO algorithm is considerably more complex and includes more evolutionary steps compared to ICA.

## 5. Conclusion

Wind energy is undoubtedly one of the most important renewable energy sources. Turkey has a high wind energy potential and a large number of new WPPs become operational every year. The wind turbine systems used in WPPs consist of many different components. Because the life of these components is usually shorter than the expected life of the wind turbine, preventive maintenance is performed to replace these components. Therefore, preventive maintenance has a major role in increasing the reliability of the wind turbine system used.

This paper employs two novel metaheuristic algorithms, the ICA and SSO algorithm, in the field of wind energy. The current study is a demonstration of their performance in terms of route optimization. In the context of environmental sustainability, the route optimization for the maintenance of WPPs bears great significance. Optimal route planning for the preventive maintenance of same-brand wind turbines in 13 different WPPs within the borders of Izmir province was performed by using these algorithms. Izmir province was selected for this study as it has the highest installed wind power in Turkey. Figures 6 and 7 show the route lengths obtained by ICA and SSO algorithms, respectively, at different numbers of iterations. While the optimal route length obtained with ICA is 707.9 km, this length is 668.8 km for the SSO algorithm. With both algorithms, the optimal route length does not change after a certain number of iterations. This number is smaller for the ICA than for the SSO algorithm. However, the optimal route length obtained with the SSO algorithm is shorter as stated.

Since these two algorithms have the ability to efficiently converge to global optimum points, their application to finding the optimal route for the preventive maintenance of wind turbines makes a contribution to the literature.

It should be noted that there are some assumptions and limitations in this study. There are different numbers of wind turbines in the WPPs considered in this study; some WPPs have more wind turbines, while others have less. Considering this variability, different priorities can be set for WPPs in future studies for creating an optimal route, such as prioritizing WPPs with a high number of wind turbines.

For the preventive maintenance of wind turbines, it is assumed that the relevant company has only one service vehicle. In future studies, we will attempt to solve the problem using multiple service vehicles.

In addition, it has been assumed that all the necessary equipment is in the service vehicle as preventive maintenance is performed, i.e. there is never a need to return to the service center.

Finally, we obtained different total optimal route lengths with two algorithms. It would be informative to further compare these results with those from other metaheuristic algorithms.

## References

- Abachizadeh, M., & Tahani, M. (2009). An ant colony optimization approach to multi-objective optimal design of symmetric hybrid laminates for maximum fundamental frequency and minimum cost. *Structural and Multidisciplinary Optimization*, 37(4), 367–376.
- Abachizadeh, M., Shariatpanahi, M., Yousefi-Koma, A., & Dizaji, A. F. (2010). Multi-objective optimal design of hybrid laminates using continuous ant colony method. *Engineering Systems Design and Analysis*, 49187, 371–378.
- Abd El Aziz, M., & Hassanien, A. E. (2018). An improved social spider optimization algorithm based on rough sets for solving minimum number attribute reduction problem. *Neural Computing and Applications*, 30(8), 2441–2452.
- Abdechiri, M., Faez, K., & Bahrami, H. (2010). Adaptive imperialist competitive algorithm (AICA). *9th IEEE International Conference on Equivkxg"Kphqt o cvkeu"\*KEEË32+*, 940–945. IEEE.
- Abd-Elazim, S. M., & Ali, E. S. (2016). Imperialist competitive algorithm for optimal STATCOM design in a multimachine power system. *International Journal of Electrical Power & Energy Systems*, 76, 136–146. <https://doi.org/10.1016/j.ijepes.2015.09.004>
- Ahmadi, M. A. (2011). Prediction of asphaltene precipitation using artificial neural network optimized by imperialist competitive algorithm. *Journal of Petroleum Exploration and Production Technology*, 1(2–4), 99–106. <https://doi.org/10.1007/s13202-011-0013-7>
- Ahmadi, M. A., Ebadi, M., Shokrollahi, A., & Majidi, S. M. J. (2013). Evolving artificial neural network and imperialist competitive algorithm for prediction oil flow rate of the reservoir. *Applied Soft Computing*, 13(2), 1085–1098. <https://doi.org/10.1016/j.asoc.2012.10.009>
- Al Dossary, M. A., & Nasrabadi, H. (2016). Well placement optimization using imperialist competitive algorithm. *Journal of Petroleum Science and Engineering*, 147, 237–248. <https://doi.org/10.1016/j.petrol.2016.06.017>

- Aliniya, Z., & Mirroshandel, S. A. (2019). A novel combinatorial merge-split approach for automatic clustering using imperialist competitive algorithm. *Expert Systems with Applications*, *117*, 243–266. <https://doi.org/10.1016/j.eswa.2018.09.050>
- Alrashidi, M., Rahman, S., & Pipattanasomporn, M. (2020). Metaheuristic optimization algorithms to estimate statistical distribution parameters for characterizing wind speeds. *Renewable Energy*, *149*, 664–681. <https://doi.org/10.1016/j.renene.2019.12.048>
- Amayri, A., Tian, Z., & Jin, T. (2011). Condition based maintenance of wind turbine systems considering different turbine types. *2011 International Conference on Quality, Reliability, Risk, Maintenance, and Safety Engineering*, 596–600. <https://doi.org/10.1109/ICQR2MSE.2011.5976683>
- Andrawus, J. A., Watson, J., & Kishk, M. (2007). Wind turbine maintenance optimisation: Principles of quantitative maintenance optimisation. *Wind Engineering*, *31*(2), 101–110.
- Ardalan, Z., Karimi, S., Poursabzi, O., & Naderi, B. (2015). A novel imperialist competitive algorithm for generalized traveling salesman problems. *Applied Soft Computing*, *26*, 546–555. <https://doi.org/10.1016/j.asoc.2014.08.033>
- Arul Xavier, V. M., & Annadurai, S. (2019). Chaotic social spider algorithm for load balance aware task scheduling in cloud computing. *Cluster Computing*, *22*(1), 287–297. <https://doi.org/10.1007/s10586-018-1823-x>
- Atashpaz-Gargari, E., & Lucas, C. (2007). Imperialist competitive algorithm: An algorithm for optimization inspired by imperialistic competition. *2007 IEEE Congress on Evolutionary Computation*, 4661–4667. <https://doi.org/10.1109/CEC.2007.4425083>
- Bagher, M., Zandieh, M., & Farsijani, H. (2011). Balancing of stochastic U-type assembly lines: An imperialist competitive algorithm. *The International Journal of Advanced Manufacturing Technology*, *54*(1–4), 271–285. <https://doi.org/10.1007/s00170-010-2937-3>
- Bahrami, H., Faez, K., & Abdechiri, M. (2010). Imperialist Competitive Algorithm Using Chaos Theory for Optimization (CICA). *2010 12th*

*International Conference on Computer Modelling and Simulation*, 98–103. <https://doi.org/10.1109/UKSIM.2010.26>

- Baş, E., & Ülker, E. (2020). A binary social spider algorithm for uncapacitated facility location problem. *Expert Systems with Applications*, 161, 113618. <https://doi.org/10.1016/j.eswa.2020.113618>
- Bekdaş, G. (2015). Harmony Search Algorithm Approach for Optimum Design of Post-Tensioned Axially Symmetric Cylindrical Reinforced Concrete Walls. *Journal of Optimization Theory and Applications*, 164(1), 342–358. <https://doi.org/10.1007/s10957-014-0562-2>
- Biabangard-Oskouyi, A., Atashpaz-Gargari, E., Soltani, N., & Lucas, C. (2009). Application of imperialist competitive algorithm for materials property characterization from sharp indentation test. *International Journal of Engineering Simulation*, 10(1), 11–12.
- Bilel, N., Mohamed, N., Zouhaier, A., & Lotfi, R. (2016). An improved imperialist competitive algorithm for multi-objective optimization. *Engineering Optimization*, 48(11), 1823–1844.
- Burton, T., Jenkins, N., Sharpe, D., & Bossanyi, E. (2011). *Wind Energy Handbook*. John Wiley & Sons.
- Coelho, L. D. S., Afonso, L. D., & Alotto, P. (2012). A Modified Imperialist Competitive Algorithm for Optimization in Electromagnetics. *IEEE Transactions on Magnetics*, 48(2), 579–582. <https://doi.org/10.1109/TMAG.2011.2172400>
- Cuevas, E., Cienfuegos, M., Zaldívar, D., & Pérez-Cisneros, M. (2013). A swarm optimization algorithm inspired in the behavior of the social-spider. *Expert Systems with Applications*, 40(16), 6374–6384. <https://doi.org/10.1016/j.eswa.2013.05.041>
- Dang, B. T., Vo, M. C., & Truong, T. K. (2017). Social spider algorithm-based spectrum allocation optimization for cognitive radio networks. *International Journal of Applied Engineering Research*, 12(13), 3879–3887.
- Das, A., Mandal, D., & Kar, R. (2020). Side lobe suppression of concentric circular antenna array using social spider algorithm. *IETE Journal of Research*, 1–10.

- Ding, F., Tian, Z., & Jin, T. (2013). Maintenance modeling and optimization for wind turbine systems: A review. *2013 International Conference on Quality, Reliability, Risk, Maintenance, and Safety Engineering (QR2MSE)*, 569–575. IEEE.
- Dovi, V. G., Friedler, F., Huisingh, D., & Klemeš, J. J. (2009). Cleaner energy for sustainable future. *Journal of Cleaner Production*, 17(10), 889–895. <https://doi.org/10.1016/j.jclepro.2009.02.001>
- Duan, H., & Huang, L. (2014). Imperialist competitive algorithm optimized artificial neural networks for UCAV global path planning. *Neurocomputing*, 125, 166–171. <https://doi.org/10.1016/j.neucom.2012.09.039>
- El-bages, M. S., & Elsayed, W. T. (2017). Social spider algorithm for solving the transmission expansion planning problem. *Electric Power Systems Research*, 143, 235–243. <https://doi.org/10.1016/j.epsr.2016.09.002>
- Elsayed, W. T., Hegazy, Y. G., Bendary, F. M., & El-bages, M. S. (2016). Modified social spider algorithm for solving the economic dispatch problem. *Engineering Science and Technology, an International Journal*, 19(4), 1672–1681. <https://doi.org/10.1016/j.jestch.2016.09.002>
- Elsisi, M. (2019). Design of neural network predictive controller based on imperialist competitive algorithm for automatic voltage regulator. *Neural Computing and Applications*, 31(9), 5017–5027. <https://doi.org/10.1007/s00521-018-03995-9>
- Fan, D., Ren, Y., Feng, Q., Zhu, B., Liu, Y., & Wang, Z. (2019). A hybrid heuristic optimization of maintenance routing and scheduling for offshore wind farms. *Journal of Loss Prevention in the Process Industries*, 62, 103949. <https://doi.org/10.1016/j.jlp.2019.103949>
- Fathy, A., & Rezk, H. (2017). Parameter estimation of photovoltaic system using imperialist competitive algorithm. *Renewable Energy*, 111, 307–320. <https://doi.org/10.1016/j.renene.2017.04.014>
- Froger, A., Gendreau, M., Mendoza, J. E., Pinson, É., & Rousseau, L.-M. (2016). Maintenance scheduling in the electricity industry: A literature review. *European Journal of Operational Research*, 251(3), 695–706.

<https://doi.org/10.1016/j.ejor.2015.08.045>

- Froger, A., Gendreau, M., Mendoza, J. E., Pinson, E., & Rousseau, L.-M. (2018). Solving a wind turbine maintenance scheduling problem. *Journal of Scheduling*, 21(1), 53–76. <https://doi.org/10.1007/s10951-017-0513-5>
- Geem, Z. W., Kim, J. H., & Loganathan, G. V. (2001). A new heuristic optimization algorithm: Harmony search. *Simulation*, 76(2), 60–68.
- Gerist, S., & Maheri, M. R. (2019). Structural damage detection using imperialist competitive algorithm and damage function. *Applied Soft Computing*, 77, 1–23. <https://doi.org/10.1016/j.asoc.2018.12.032>
- Gupta, R., Nanda, S. J., & Shukla, U. P. (2019). Cloud detection in satellite images using multi-objective social spider optimization. *Applied Soft Computing*, 79, 203–226. <https://doi.org/10.1016/j.asoc.2019.03.042>
- Hameed, W. I., Kadhim, A. S., & Al-Thuwaynee, A. A. K. (2016). Field Weakening Control of a Separately Excited DC Motor Using Neural Network Optemized by Social Spider Algorithm. *Engineering*, 8(1), 1–10. <https://doi.org/10.4236/eng.2016.81001>
- Hosseini, S., & Al Khaled, A. (2014). A survey on the Imperialist Competitive Algorithm metaheuristic: Implementation in engineering domain and directions for future research. *Applied Soft Computing*, 24, 1078–1094. <https://doi.org/10.1016/j.asoc.2014.08.024>
- Jamali, S., Malektaji, S., & Analoui, M. (2017). An imperialist competitive algorithm for virtual machine placement in cloud computing. *Journal of Experimental & Theoretical Artificial Intelligence*, 29(3), 575–596.
- Jasour, A. M., Atashpaz-Gargari, E., & Lucas, C. (2008). Vehicle fuzzy controller design using imperialist competitive algorithm. In *Second First Iranian Joint Congress on Fuzzy and Intelligent Systems, Tehran, Iran* (pp. 1-6).
- Junaid, M., Rahim, M. H., Ur Rehman, A., Ali, W., Awais, M., Bilal, T., & Javaid, N. (2018). Demand Side Optimization in Smart Grid Using Harmony Search Algorithm and Social Spider Algorithm. In F. Xhafa, S. Caballé, & L. Barolli (Eds.), *Advances on P2P, Parallel, Grid, Cloud and Internet Computing* (pp. 16–25). Cham: Springer

- International Publishing. [https://doi.org/10.1007/978-3-319-69835-9\\_2](https://doi.org/10.1007/978-3-319-69835-9_2)
- Kaplan, Y. A., & San, I. (2011). Current situation of wind energy in the world and turkey. *Green Energy Conference-VI (IGEC-VI), Eskisehir, Turkey*.
- Karaboga, N. (2009). A new design method based on artificial bee colony algorithm for digital IIR filters. *Journal of the Franklin Institute*, 346(4), 328–348. <https://doi.org/10.1016/j.jfranklin.2008.11.003>
- Karimi, S., Ardalan, Z., Naderi, B., & Mohammadi, M. (2017). Scheduling flexible job-shops with transportation times: Mathematical models and a hybrid imperialist competitive algorithm. *Applied Mathematical Modelling*, 41, 667–682.
- Kashikolaei, S. M. G., Hosseinabadi, A. A. R., Saemi, B., Shareh, M. B., Sangaiah, A. K., & Bian, G.-B. (2020). An enhancement of task scheduling in cloud computing based on imperialist competitive algorithm and firefly algorithm. *The Journal of Supercomputing*, 76(8), 6302–6329. <https://doi.org/10.1007/s11227-019-02816-7>
- Kaveh, A., & Talatahari, S. (2010). Optimum design of skeletal structures using imperialist competitive algorithm. *Computers & Structures*, 88(21–22), 1220–1229. <https://doi.org/10.1016/j.compstruc.2010.06.011>
- Kaygusuz, K. (2010). Wind energy status in renewable electrical energy production in Turkey. *Renewable and Sustainable Energy Reviews*, 14(7), 2104–2112. <https://doi.org/10.1016/j.rser.2010.03.022>
- Kennedy, J., & Eberhart, R. (1995). Particle swarm optimization. *Proceedings of the IEEE International Conference on Neural Networks*, 4, 1942–1948 vol.4. <https://doi.org/10.1109/ICNN.1995.488968>
- Khabbazi, A., Atashpaz-Gargari, E., & Lucas, C. (2009). Imperialist competitive algorithm for minimum bit error rate beamforming. *International Journal of Bio-Inspired Computation*, 1(1–2), 125–133.
- Khaled, A. A., & Hosseini, S. (2015). Fuzzy adaptive imperialist competitive algorithm for global optimization. *Neural Computing and Applications*, 26(4), 813–825. <https://doi.org/10.1007/s00521-014-1752-4>

- Khosravi, A., & Syri, S. (2020). Modeling of geothermal power system equipped with absorption refrigeration and solar energy using multilayer perceptron neural network optimized with imperialist competitive algorithm. *Journal of Cleaner Production*, 276, 124216. <https://doi.org/10.1016/j.jclepro.2020.124216>
- Lei, D., Yuan, Y., Cai, J., & Bai, D. (2020). An imperialist competitive algorithm with memory for distributed unrelated parallel machines scheduling. *International Journal of Production Research*, 58(2), 597–614.
- Li, M., Lei, D., & Cai, J. (2019). Two-level imperialist competitive algorithm for energy-efficient hybrid flow shop scheduling problem with relative importance of objectives. *Swarm and Evolutionary Computation*, 49, 34–43. <https://doi.org/10.1016/j.swevo.2019.05.006>
- Lian, K., Zhang, C., Gao, L., & Li, X. (2012). Integrated process planning and scheduling using an imperialist competitive algorithm. *International Journal of Production Research*, 50(15), 4326–4343.
- Liu, R., Tao, Y., & Xie, X. (2019). An adaptive large neighborhood search heuristic for the vehicle routing problem with time windows and synchronized visits. *Computers & Operations Research*, 101, 250–262. <https://doi.org/10.1016/j.cor.2018.08.002>
- Lucas, C., Nasiri-Gheidari, Z., & Tootoonchian, F. (2010). Application of an imperialist competitive algorithm to the design of a linear induction motor. *Energy Conversion and Management*, 51(7), 1407–1411. <https://doi.org/10.1016/j.enconman.2010.01.014>
- Maheri, M. R., & Talezadeh, M. (2018). An Enhanced Imperialist Competitive Algorithm for optimum design of skeletal structures. *Swarm and Evolutionary Computation*, 40, 24–36. <https://doi.org/10.1016/j.swevo.2017.12.001>
- Mikaeil, R., Haghshenas, S. S., Haghshenas, S. S., & Ataei, M. (2018). Performance prediction of circular saw machine using imperialist competitive algorithm and fuzzy clustering technique. *Neural Computing and Applications*, 29(6), 283–292. <https://doi.org/10.1007/s00521-016-2557-4>

- Mizsey, P., & Racz, L. (2010). Cleaner production alternatives: Biomass utilisation options. *Journal of Cleaner Production*, 18(8), 767–770. <https://doi.org/10.1016/j.jclepro.2010.01.007>
- Moura, A. (2019). A model-based heuristic to the vehicle routing and loading problem. *International Transactions in Operational Research*, 26(3), 888–907.
- Mousa, A., & Bentahar, J. (2016). An efficient QoS-aware web services selection using social spider algorithm. *Procedia Computer Science*, 94, 176–182.
- Nazari-Shirkouhi, S., Eivazy, H., Ghodsi, R., Rezaie, K., & Atashpaz-Gargari, E. (2010). Solving the integrated product mix-outsourcing problem using the Imperialist Competitive Algorithm. *Expert Systems with Applications*, 37(12), 7615–7626. <https://doi.org/10.1016/j.eswa.2010.04.081>
- Nguyen, T. T. (2019). A high performance social spider optimization algorithm for optimal power flow solution with single objective optimization. *Energy*, 171, 218–240. <https://doi.org/10.1016/j.energy.2019.01.021>
- Nguyen, P. H., Wang, D., & Truong, T. K. (2017). A novel binary social spider algorithm for 0–1 knapsack problem. *International Journal of Innovative Computation Information Control*, 13(6), 2039–2049.
- Niknam, T., Taherian Fard, E., Pourjafarian, N., & Roustaei, A. (2011). An efficient hybrid algorithm based on modified imperialist competitive algorithm and K-means for data clustering. *Engineering Applications of Artificial Intelligence*, 24(2), 306–317. <https://doi.org/10.1016/j.engappai.2010.10.001>
- Razmjoooy, N., Mousavi, B. S., & Soleymani, F. (2013). A hybrid neural network Imperialist Competitive Algorithm for skin color segmentation. *Mathematical and Computer Modelling*, 57(3–4), 848–856.
- Sabar, N. R., Bhaskar, A., Chung, E., Turkey, A., & Song, A. (2019). A self-adaptive evolutionary algorithm for dynamic vehicle routing problems with traffic congestion. *Swarm and Evolutionary Computation*, 44,

1018–1027. <https://doi.org/10.1016/j.swevo.2018.10.015>

- Sadowski, L., & Nikoo, M. (2014). Corrosion current density prediction in reinforced concrete by imperialist competitive algorithm. *Neural Computing and Applications*, 25(7), 1627–1638. <https://doi.org/10.1007/s00521-014-1645-6>
- Salomon, M., Sponarski, C., Larocque, A., & Avilés, L. (2010). Social organization of the colonial spider *Leucauge* sp. in the Neotropics: Vertical stratification within colonies. *The Journal of Arachnology*, 38(3), 446–451.
- Sayadnavard, M. H., Haghghat, A. T., & Abdechiri, M. (2010). Wireless sensor network localization using imperialist competitive algorithm. *2010 3rd International Conference on Computer Science and Information Technology*, 9, 818–822. IEEE.
- Shabani, H., Vahidi, B., & Ebrahimpour, M. (2013). A robust PID controller based on imperialist competitive algorithm for load-frequency control of power systems. *ISA Transactions*, 52(1), 88–95. <https://doi.org/10.1016/j.isatra.2012.09.008>
- Shokrollahpour, E., Zandieh, M., & Dorri, B. (2011). A novel imperialist competitive algorithm for bi-criteria scheduling of the assembly flowshop problem. *International Journal of Production Research*, 49(11), 3087–3103.
- Shukla, U. P., & Nanda, S. J. (2018). A Binary Social Spider Optimization algorithm for unsupervised band selection in compressed hyperspectral images. *Expert Systems with Applications*, 97, 336–356. <https://doi.org/10.1016/j.eswa.2017.12.034>
- Siddiqui, O., Dincer, I., & Yilbas, B. S. (2019). Development of a novel renewable energy system integrated with biomass gasification combined cycle for cleaner production purposes. *Journal of Cleaner Production*, 241, 118345. <https://doi.org/10.1016/j.jclepro.2019.118345>
- Soto, M., Sevaux, M., Rossi, A., & Reinholz, A. (2017). Multiple neighborhood search, tabu search and ejection chains for the multi-depot open vehicle routing problem. *Computers & Industrial*

- Engineering*, 107, 211–222. <https://doi.org/10.1016/j.cie.2017.03.022>
- Talatahari, S., Farahmand Azar, B., Sheikholeslami, R., & Gandomi, A. H. (2012). Imperialist competitive algorithm combined with chaos for global optimization. *Communications in Nonlinear Science and Numerical Simulation*, 17(3), 1312–1319. <https://doi.org/10.1016/j.cnsns.2011.08.021>
- Tao, X., Li, J., Huang, T., & Duan, P. (2021). Discrete imperialist competitive algorithm for the resource-constrained hybrid flowshop problem with energy consumption. *Complex & Intelligent Systems*, 7(1), 311–326. <https://doi.org/10.1007/s40747-020-00193-w>
- Tawhid, M. A., & Ali, A. F. (2016). A simplex social spider algorithm for solving integer programming and minimax problems. *Memetic Computing*, 8(3), 169–188. <https://doi.org/10.1007/s12293-016-0180-7>
- Tien Bui, D., Shahabi, H., Shirzadi, A., Chapi, K., Hoang, N.-D., Pham, B. T., Bui, Q.-T., Tran, C.-T., Panahi, M., Bin Ahmad, B. (2018). A novel integrated approach of relevance vector machine optimized by imperialist competitive algorithm for spatial modeling of shallow landslides. *Remote Sensing*, 10(10), 1538.
- TÜREB (2021a). WPP Installation Table. Available online: <https://app.powerbi.com/view?r=eyJrIjoiZjc1ZjU1N2EtMDU0MS00OGUyLThjM2ItYTdlMWE4ZDMwZjYzIiwidCI6ImU5YzY0NjU4LWFkMWQtNDUwOS1hODk0LTE2NWZhYjU2NjEyMyIsImMiOjI9&pageName=ReportSection8015113d5c5203d1d8c9>.
- TÜREB (2021b). Distribution by regions. Available online: <https://app.powerbi.com/view?r=eyJrIjoiZjc1ZjU1N2EtMDU0MS00OGUyLThjM2ItYTdlMWE4ZDMwZjYzIiwidCI6ImU5YzY0NjU4LWFkMWQtNDUwOS1hODk0LTE2NWZhYjU2NjEyMyIsImMiOjI9&pageName=ReportSection8015113d5c5203d1d8c9>.
- TÜREB (2021c). Distribution by provinces. Available online: <https://app.powerbi.com/view?r=eyJrIjoiZjc1ZjU1N2EtMDU0MS00OGUyLThjM2ItYTdlMWE4ZDMwZjYzIiwidCI6ImU5YzY0NjU4LWFkMWQtNDUwOS1hODk0LTE2NWZhYjU2NjEyMyIsImMiOjI9&pageName=ReportSection8015113d5c5203d1d8c9>.

- TÜREB (2021d). WPPs in İzmir. Available online: <https://app.powerbi.com/view?r=eyJrljoiZjc1ZjU1N2EtMDU0MS00OGUyLThjM2ItYTdlMWE4ZDMwZjYzliwidCI6ImU5YzY0NjU4LWFkMWQtNDUwOS1hODk0LTE2NWZhYjU2NjEyMyIsImMiOjI9&pageName=ReportSection8015113d5c5203d1d8c9>.
- Ur Rehman, S. A., Cai, Y., Mirjat, N. H., Walasai, G. D., & Nafees, M. (2019). Energy-environment-economy nexus in Pakistan: Lessons from a PAK-TIMES model. *Energy Policy*, 126, 200–211. <https://doi.org/10.1016/j.enpol.2018.10.031>
- Vu, D. T., Tran, X.-L., Cao, M.-T., Tran, T. C., & Hoang, N.-D. (2020). Machine learning based soil erosion susceptibility prediction using social spider algorithm optimized multivariate adaptive regression spline. *Measurement*, 164, 108066. <https://doi.org/10.1016/j.measurement.2020.108066>
- Walford, C. A. (2006). *Wind turbine reliability: understanding and minimizing wind turbine operation and maintenance costs* (No. SAND2006-1100). Sandia National Laboratories (SNL), Albuquerque, NM, and Livermore, CA (United States).
- Wilck Iv, J. H., & Cavalier, T. M. (2012). *A Construction Heuristic for the Split Delivery Vehicle Routing Problem*. 2012. <https://doi.org/10.4236/ajor.2012.22018>
- Yeh, C.-H., Lin, M.-H., Lin, C.-H., Yu, C.-E., & Chen, M.-J. (2019). Machine learning for long cycle maintenance prediction of wind turbine. *Sensors*, 19(7), 1671.
- Yılmaz, M. (2012). Türkiye'nin enerji potansiyeli ve yenilenebilir enerji kaynaklarının elektrik enerjisi üretimi açısından önemi. *Ankara Üniversitesi Çevre Bilimleri Dergisi*, 4(2), 33–54.
- Yong, J. Y., Klemeš, J. J., Varbanov, P. S., & Huisin, D. (2016). Cleaner energy for cleaner production: Modelling, simulation, optimisation and waste management. *Journal of Cleaner Production*, 111, 1–16.
- Yousefi, M., Darus, A. N., & Mohammadi, H. (2012). An imperialist competitive algorithm for optimal design of plate-fin heat exchangers. *International Journal of Heat and Mass Transfer*, 55(11–12), 3178–

3185. <https://doi.org/10.1016/j.ijheatmasstransfer.2012.02.041>
- Yu, J. J. Q., & Li, V. O. K. (2015). A social spider algorithm for global optimization. *Applied Soft Computing*, 30, 614–627. <https://doi.org/10.1016/j.asoc.2015.02.014>
- Yu, J. J. Q., & Li, V. O. K. (2016). A social spider algorithm for solving the non-convex economic load dispatch problem. *Neurocomputing*, 171, 955–965. <https://doi.org/10.1016/j.neucom.2015.07.037>
- Zhang, G., & Xing, K. (2018). Memetic social spider optimization algorithm for scheduling two-stage assembly flowshop in a distributed environment. *Computers & Industrial Engineering*, 125, 423–433. <https://doi.org/10.1016/j.cie.2018.09.007>
- Zhang, Y., Wang, Y., & Peng, C. (2009). Improved imperialist competitive algorithm for constrained optimization. *2009 International Forum on Computer Science-Technology and Applications*, 1, 204–207. IEEE.
- Zhou, Y., Zhao, R., Luo, Q., & Wen, C. (2018). Sensor Deployment Scheme Based on Social Spider Optimization Algorithm for Wireless Sensor Networks. *Neural Processing Letters*, 48(1), 71–94. <https://doi.org/10.1007/s11063-017-9701-8>
- Zhou, Y., Zhou, Y., Luo, Q., & Abdel-Basset, M. (2017). A simplex method-based social spider optimization algorithm for clustering analysis. *Engineering Applications of Artificial Intelligence*, 64, 67–82. <https://doi.org/10.1016/j.engappai.2017.06.004>



## CHAPTER IX

# SELECTION OF DAM SITE USING MULTIPLE CRITERIA DECISION- MAKING METHODS

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### 1. Introduction

**W**ith the rapid progress of technological and scientific developments, societies have started to endeavor to control nature. From the end of the nineteenth century, they have been accumulating the water of the rivers in dam lakes for purposes such as flood control, water saving, irrigation and energy production. The effective and efficient construction of these strategic structures has been as important as the establishment (Başkan, 2013).

One of the most important factors that will ensure a high efficiency of a dam is to determine the location of the project correctly. There are many interrelated quantitative and qualitative criteria in choosing the location. In the

feasibility phase of the projects, the optimum dam location is selected by the joint action of all project stakeholders, and these criteria are evaluated in accordance with the purpose (Uludağ & Doğan, 2011).

Proper location of dams and getting the most benefit from waterpower is a very difficult and complex problem (Doğanoğlu, 2011). In other words, determining the precise location contains multivariate selection problems. Multi-Criteria Decision-Making (MCDM) methods are one of the best methods that can be employed for solution of these difficult and complex selection problems (Yasser, Jahangir, & Mohmmad, 2013). The purpose of using MCDM methods is to keep the decision-making mechanism under control in cases where there are numerous alternatives and criteria and to obtain the decision result as easily and quickly as possible (Yalçiner & Karaatlı, 2018). Analytic Hierarchy Process (AHP) method and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method used for dam site selection, which is the main subject of this study, appear as important strategies in dealing with problems with MCDM.

## 2. Literature Review

**Table 2.1.** Summary of the Literature Review Findings

Source	MCDM Method Used	Purpose
Hagos, Y. G. et al. (2022)	AHP	Choosing the optimum location for a dam construction.
Othman, AA. et al. (2020)	Fuzzy AHP and gray MCDM	Identifying suitable sites to build new dams within the Al-Khabur river basin
Chien, F. et al. (2020)	FANP and TOPSIS	Choosing the best option for the installation of a river hydroelectric power stations
Bid, S. and Siddique, G. (2019)	TOPSIS and WASPAS	Human risk assessment of Panchet Dam in India
Chezgi, J. (2019)	AHP and TOPSIS	Determination and sequencing of suitable places for underground dams
Cuoghi, K. G., and Leoneti, A. B. (2019)	AHP	Selection of the construction alternatives for Belo Monte Dam
Noori, A. et al. (2018)	Fuzzy TOPSIS	Choosing the optimum location for a dam construction
Jozaghi, A. et al. (2018)	AHP, TOPSIS and PROMETHEE	Choosing the optimum location for a dam construction

**Table 2.2.** Summary of the Literature Review Findings

Source	MCDM Method Used	Purpose
Bakhtavar, E. and Lotfian, R. (2017)	Fuzzy AHP and gray MCDM	Selection of suitable region for the ore processing plant
Njiru, F. M. (2017)	AHP	Choosing the optimum location for a dam construction
Yang, Y. (2017)	TOPSIS	Choosing the best location for a dam considering natural disasters
Peng, Z. (2017)	AHP	Choosing the optimum location for a dam construction
Adeyanju, O. I., and Adedeji, A. A. (2017)	TOPSIS	Choosing the optimum location for a dam construction
Li, C. (2016)	AHP	Finding the best repair path for efficient operation of the dam
Dai, X. (2016)	AHP	Creating a suitability map of a dam construction site
Minatour, Y. et al. (2015)	Fuzzy AHP and VIKOR	Choosing the optimum location for a dam construction

As indicated in Table 2.1 and 2.2, MCDM methods have been used in the literature as an effective tool in the decision-making process of location selection problems in many different regions.

### 3. Material and Method

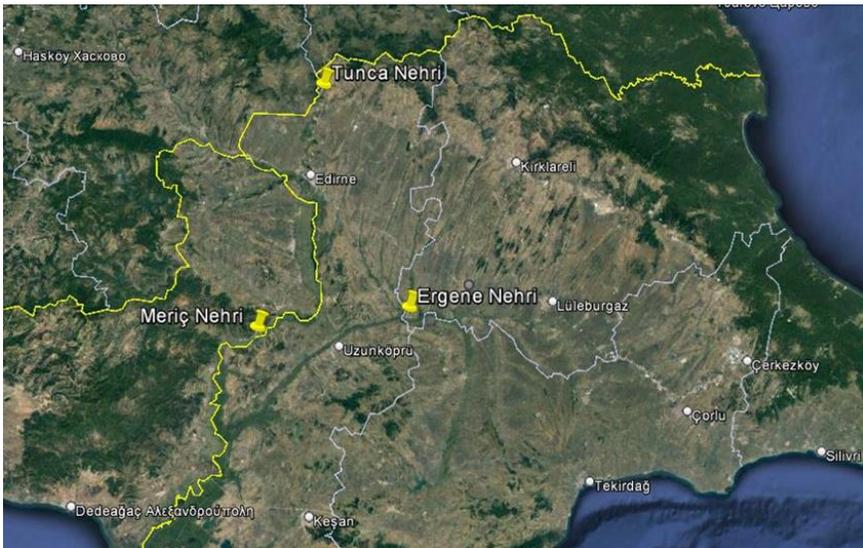
In this study, it is aimed to define the problems that may be encountered in the determination of the project location during the feasibility phase for a dam project to be built for energy production and to establish a scientific decision support system that will enable the location to be determined using decision methods in order to operate the dam at optimum efficiency.

#### 3.1. Dam Site Selection with AHP Method

In the first stage of this study, regions suitable for dam construction in Turkey were investigated. Although the Eastern Thrace region has wide rivers, it has

been determined that the number of dams in this region is not very high. For this reason, it was desired to determine the best location for a dam project planned to be built in Eastern Thrace region with AHP, one of the MCDM methods. The criteria and sub-criteria affecting this aim were determined by interviewing experts after a general literature review.

The AHP structure established for dam site selection is shown in Figure 3.2. The goal is situated at the top of this hierarchy. The second step consist of the main criteria determined to be of equal importance. The third step combines the sub-criteria. And the options, Tunca River, Meriç River and Ergene River in the Thrace region, which can be seen in Figure 3.1. are situated in the fourth and final step. 3 different possible dam locations on these rivers have been determined by the Geological Engineer working at the General Directorate of State Hydraulic Works, taking into account the principle of high efficiency after detailed investigations.



**Fig. 3.1.** Display of the Rivers Selected as the Options on the Map

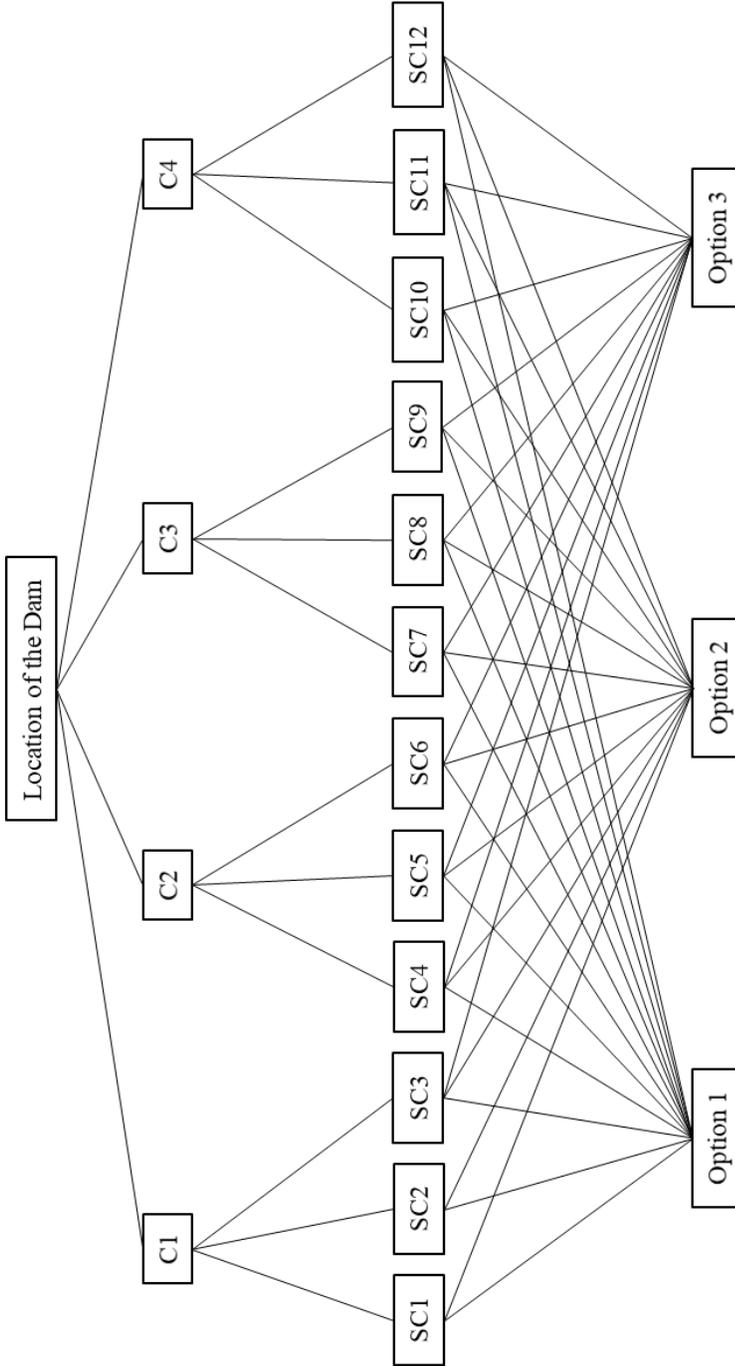


Fig. 3.2. AHP Structure

**Table 3.1.** Criteria and Sub-Criteria Affecting the Purpose in the AHP Structure

<b>C1: Geological factors</b>	<b>C2: Hydrological factors</b>	<b>C3: Economic factors</b>	<b>C4: Environmental and social factors</b>
SC1: Topography of the Dam Site	SC4: Precipitation	SC7: Access to Materials and Facilities	SC11: Vegetation
SC2: Seismic Activity	SC5: Water Consumption	SC8: Expropriation and Renovation Costs	SC12: Recreation Areas
SC3: Soil Type	SC6: Flood Prevention	SC10: Electricity Generation	SC9: Aquaculture

After the entire hierarchical structure was established for the AHP method, pairwise comparison matrices were created as seen in Table 3.2. Pairwise comparison matrix is the comparison of criteria having the same importance in hierarchical structure with each other in terms of a higher factor.

**Table 3.2.** Pairwise Comparison Matrix

	<b>C1</b>	<b>C2</b>	<b>C3</b>	...	<b>C<sub>N</sub></b>
<b>C1</b>	1	$a_{12}$	$a_{13}$	...	$a_{1n}$
<b>C2</b>	$a_{21} = 1/a_{12}$	1	$a_{23}$	...	$a_{2n}$
<b>C3</b>	$a_{31} = 1/a_{13}$	$a_{32} = 1/a_{23}$	1	...	$a_{3n}$
...	...	...	...	1	...
<b>C<sub>N</sub></b>	$a_{n1} = 1/a_{1n}$	$a_{n2} = 1/a_{2n}$	$a_{n3} = 1/a_{3n}$	...	1

The nine-point scale suggested by Saaty, shown in Table 3.3. was used for the comparison. At this phase, the pairwise comparison matrices of the criteria according to the goal, the pairwise comparison matrices of the sub-criteria according to the main criteria and the pairwise comparison matrices of the options according to the sub-criteria were created.

**Table 3.3.** The Fundamental Scale of Absolute Numbers (Saaty, 2008)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favor one activity over another
6	Strong plus	
7	Very strong	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

After the pairwise comparison matrices were created, each element in the matrix was normalized by dividing by its column sum.

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}}$$

Importance weights, called the priority vector, were calculated by dividing the sum of each row of the normalized matrix by the size of the matrix and averaging it.

$$w_i = \frac{1}{n} \sum_{j=1}^n a'_{ij} \quad i, j = 1, 2, \dots, n$$

To determine whether the matrices are consistent, the value called Consistency Ratio (CR) must be found. Therefore, Consistency Index (CI) must be calculated first. In order to calculate CI value,  $\lambda_{\max}$ , which is called

eigenvalue, was calculated. If the pairwise comparison matrix is fully consistent,  $\lambda_{max}$  is expected to be equal to the size (n) of the normalized matrix (Saaty, 2008).

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{\sum_{j=1}^n a_{ij} w_j}{w_i}$$

With the aim of evaluating the consistency, the Random Index (RI) value was determined by looking at Table 3.4.

**Table 3.4.** RI Values for Matrices (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

After the CI and RI indices were determined, the CR was calculated. This ratio was found to be less than 0.10 for all matrices. If this ratio is greater than 0.10, it means that the matrix is inconsistent (Saaty, 1980).

$$CR = \frac{CI}{RI}$$

In the last step, to determine the final ranking of the options, the priority vectors ( $w_i$ ) determined for each criterion were multiplied and all the priorities matrix was formed. Then, by multiplying the priority vectors of the options with this matrix, the weighted values of the options were found. These values are summed for each option. Tunca River, whose weighted values are the largest in total, was determined as the most suitable option.

**Table 3.5.** All Priorities Matrix

	Option 1	Option 2	Option 3
SC1	0,199	0,072	0,050
SC2	0,022	0,008	0,006
SC3	0,053	0,015	0,010
SC4	0,015	0,038	0,099
SC5	0,016	0,009	0,029
SC6	0,005	0,011	0,023
SC7	0,017	0,003	0,006
SC8	0,030	0,009	0,017
SC9	0,134	0,018	0,043
SC10	0,002	0,016	0,005
SC11	0,008	0,003	0,005
SC12	0,012	0,007	0,009
Score	0,501	0,201	0,293
Rank	1	3	2

### 3.2. Dam Site Selection with TOPSIS Method

The first step in determining the best location for the dam project with TOPSIS, one of the MCDM methods, was the determination of the options and the criteria. In the next step, the criteria were evaluated by the decision makers with a scale from 1 to 9, and the weights ( $w_i$ ) of the criteria were found as seen in Table 3.5. Here, criterion 2 and criterion 9 were determined as cost criteria, while other criteria were determined as benefit criteria. Then, the decision matrix seen in Table 3.6 was created. The decision matrix and criterion weights are determined by the methods used in AHP.

$$D_{ij} = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ \vdots & \vdots & \dots & \vdots \\ d_{i1} & d_{i2} & \dots & d_{in} \\ \vdots & \vdots & \dots & \vdots \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix}$$

$$\forall d_{ij} \neq 0: r_{ij} = \frac{d_{ij}}{\sqrt{\sum_{k=1}^m d_{kj}^2}} \quad \forall_i = 1, \dots, m \quad \forall_j = 1, \dots, n$$

$$\forall d_{ij} = 0: r_{ij} = 0 \quad \forall_i = 1, \dots, m \quad \forall_j = 1, \dots, n$$

The square root of the sum of the squares of the values of each criterion in the decision matrix was taken. By dividing these values by the calculated square root, the decision matrix was normalized as seen in Table 3.7.

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \vdots & \vdots & \dots & \vdots \\ r_{i1} & r_{i2} & \dots & r_{in} \\ \vdots & \vdots & \dots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix}$$

As seen in Table 3.8, the weighted normalized decision matrix was obtained by multiplying the criterion weights ( $w_j$ ) with the elements of the normalized decision matrix.

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ \vdots & \vdots & \dots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix}$$

Ideal ( $A^*$ ) and negative ideal ( $A^-$ ) solutions were created as seen in Table 3.9, considering the criteria such as benefit and cost. Then, the distance of each option from the positive ideal solution set ( $S_i^*$ ) and the negative ideal solution set ( $S_i^-$ ) were calculated as seen in Table 3.10.

$$A^* = \left\{ \left( \max_i v_{ij} \mid j \in J \right), \left( \min_i v_{ij} \mid j \in J' \right) \mid i = 1, \dots, m \right\}$$

$$A^- = \left\{ \left( \min_i v_{ij} \mid j \in J \right), \left( \max_i v_{ij} \mid j \in J' \right) \mid i = 1, \dots, m \right\}$$

$$J = \{j = 1, \dots, n \mid \text{benefit criteria}\}$$

$$J' = \{j = 1, \dots, n \mid \text{cost criteria}\}$$

$$S_i^* = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^*)^2} \quad \forall_i = 1, \dots, m$$

$$S_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad \forall_i = 1, \dots, m$$

**Table 3.5.** The Weight of Criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Point	5	5	8	9	9	7	9	4	2	3	4	2
$w_i$	0.082	0.082	0.131	0.148	0.148	0.115	0.148	0.066	0.033	0.049	0.066	0.033

**Table 3.6.** The Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Option 1	9	4	4	6	8	8	7	2	3	3	3	4
Option 2	6	6	6	4	4	4	5	4	3	3	3	4
Option 3	3	4	5	4	6	6	5	8	3	5	3	4

**Table 3.7.** The Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Option 1	0.802	0.485	0.456	0.728	0.743	0.743	0.704	0.218	0.577	0.457	0.577	0.577
Option 2	0.535	0.728	0.684	0.485	0.371	0.371	0.503	0.436	0.577	0.457	0.577	0.577
Option 3	0.267	0.485	0.570	0.485	0.557	0.557	0.503	0.873	0.577	0.762	0.577	0.577

**Table 3.8.** The Weighted Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Option 1	0,066	0,040	0,060	0,107	0,110	0,085	0,104	0,014	0,019	0,022	0,038	0,019
Option 2	0,044	0,060	0,090	0,072	0,055	0,043	0,074	0,029	0,019	0,022	0,038	0,019
Option 3	0,022	0,040	0,075	0,072	0,082	0,064	0,074	0,057	0,019	0,037	0,038	0,019

**Table 3.9.** Ideal and Negative Ideal Solutions

	A*	A <sup>-</sup>
C1	0,066	0,022
C2	0,040	0,060
C3	0,090	0,060
C4	0,107	0,072
C5	0,110	0,055
C6	0,085	0,043
C7	0,104	0,074
C8	0,014	0,057
C9	0,019	0,019
C10	0,037	0,022
C11	0,038	0,038
C12	0,019	0,019

**Table 3.10.** The Separation Measures from the Positive Ideal Solution and The Negative Ideal Solution

	S1*	S2*	S3*	S1 <sup>-</sup>	S2 <sup>-</sup>	S3 <sup>-</sup>
C1	0	0.048	0.192	0.192	0.048	0
C2	0	0,040	0	0,040	0	0,040
C3	0.089	0	0.022	0	0.089	0.022
C4	0	0.128	0.128	0.128	0	0
C5	0	0.300	0.075	0.300	0	0.075
C6	0	0.182	0.045	0.182	0	0.045
C7	0	0.088	0.088	0.088	0	0
C8	0	0.020	0,184	0,184	0.082	0
C9	0	0	0	0	0	0
C10	0.022	0.022	0	0	0	0.022
C11	0	0	0	0	0	0
C12	0	0	0	0	0	0

Finally, as seen in Table 3.11, the relative closeness to the ideal solution was calculated. Here, by calculating the relative closeness to the positive ideal solution and the relative distance to the negative ideal solution for each alternative  $C_i^*$  was found and the option with the closest distance to the positive ideal solution was determined as the most suitable option.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad 0 \leq C_i^* \leq \forall_i = 1, \dots, m$$

**Table 3.11.** The Relative Closeness to Ideal Solution

Si*		Si-		Ci*		Rank	
O1*	0.334	O1-	1,055	C1*	0.759	Option 1	1
O2*	0.910	O2-	0.468	C2*	0.340	Option 2	3
O3*	0.857	O3-	0.453	C3*	0.345	Option 3	2

#### 4. Conclusion

There are many factors in evaluating the efficiency of a project during the feasibility phase, and making optimum decisions is critical to the success of a project. The MCDM approach supports the decision-making process by explicitly considering multiple criteria. (Al-Harbi, 2001).

In this study, it was emphasized that the determination of the location of a dam planned to be built on one of 3 different rivers in the Eastern Thrace region should be supported by scientific techniques. It was decided to choose the optimum dam site by using Multi-Criteria Decision-Making methods from scientific decision support systems. AHP and TOPSIS methods, which are MCDM methods, were compared with each other and the location to provide optimum efficiency was obtained.

Quantitative and qualitative factors affecting the efficiency of the dam were determined by reviewing the literature and interviewing the experts on the subject. Then, with the AHP method, the location where the dam and the water resources can be used most efficiently among 3 different alternatives was determined as the location on the Tunca river. And in the TOPSIS method, the closest alternative to the positive ideal solution was determined as the location on the Tunca River, as in the AHP method.

## 5. References

- Adeyanju, O. I., & Adedeji, A. A. (2017). Application of Hybrid Fuzzy-Topsis for Decision Making in Dam Site Selection. SSRG International Journal of Civil Engineering.
- Al-Harbi, K. M. A. S. (2001). Application of the AHP in project management. International journal of project management, 19(1), 19-27.
- Başkan, S. (2013). Artvin Deriner Barajı Suları Altında Kalan Bazı Tescilli Tarihi Yapıların Koruma ve Sürdürülebilirlik Uygulamaları. Türk Dünyası Kültürel Değerleri Uluslararası Sempozyumu Bildirileri, 719-736.
- Bakhtavar, E., & Lotfian, R. (2017). Applying an integrated fuzzy gray MCDM approach: a case study on mineral processing plant site selection. International Journal of Mining and Geo-Engineering, 51(2), 177-183.
- Chezgi, J. (2019). Application of SWAT and MCDM Models for Identifying and Ranking Suitable Sites for Subsurface Dams. In Spatial Modeling in GIS and R for Earth and Environmental Sciences (pp. 189-211). Elsevier.
- Chien, F., Wang, C. N., Nguyen, V. T., Nguyen, V. T., & Chau, K. Y. (2020). An evaluation model of quantitative and qualitative fuzzy multi-criteria decision-making approach for hydroelectric plant location selection. Energies, 13(11), 2783.
- Cuoghi, K. G., & Leoneti, A. B. (2019). A group MCDA method for aiding decision-making of complex problems in public sector: The case of Belo Monte Dam. Socio-Economic Planning Sciences, 68, 100625.
- Dai, X. (2016). Dam site selection using an integrated method of AHP and GIS for decision making support in Bortala, Northwest China (Master's thesis, University of Twente).
- Doğanoğlu, K. (2011). Sarıgözü barajı çevresel etki maliyet analizi (Doctoral dissertation, Karadeniz Teknik Üniversitesi/Fen Bilimleri Enstitüsü).
- Hagos, Y. G., Andualem, T. G., Mengie, M. A., Ayele, W. T., & Malede, D. A. (2022). Suitable dam site identification using GIS-based MCDA: a

case study of Chemoga watershed, Ethiopia. *Applied Water Science*, 12(4), 1-26.

- Jozaghi, A., Alizadeh, B., Hatami, M., Flood, I., Khorrami, M., Khodaei, N., & Ghasemi Tousi, E. (2018). A comparative study of the AHP and TOPSIS techniques for dam site selection using GIS: A case study of Sistan and Baluchestan Province, Iran. *Geosciences*, 8(12), 494.
- Li, C. (2016, June). The Solution To The Damage Of Kariba Dam. In 2017 2nd International Conference on Machinery, Electronics and Control Simulation (MECS 2017). Atlantis Press.
- Minatour, Y., Khazaie, J., Ataei, M., & Javadi, A. A. (2015). An integrated decision support system for dam site selection. *Scientia Iranica*, 22(2), 319-330.
- Njiru, F. M. (2017). Hydrological Information for Dam Site Selection by Integrating Geographic Information System (GIS) and Analytical Hierarchical Process (AHP) (Doctoral dissertation, University of Nairobi).
- Noori, A., Bonakdari, H., Morovati, K., & Gharabaghi, B. (2018). The optimal dam site selection using a group decision-making method through fuzzy TOPSIS model. *Environment Systems and Decisions*, 38(4), 471-488.
- Othman, A. A., Al-Maamar, A. F., Al-Manmi, D. A. M. A., Liesenberg, V., Hasan, S. E., Obaid, A. K., & Al-Quraishi, A. M. F. (2020). GIS-based modeling for selection of dam sites in the Kurdistan Region, Iraq. *ISPRS International Journal of Geo-Information*, 9(4), 244.
- Peng, Z. (2017). Location of dam using Analytic Hierarchy Progress. *Proceedings of the Advances in Materials, Machinery, Electrical Engineering (AMMEE 2017)*, 114, 441-444.
- Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International journal of services sciences*, 1(1), 83-98.
- Saaty, T. L. (1980). *The analytic hierarchy process* McGraw-Hill. New York, 324.

- Uludağ, A. S., & Doğan, H. (2016). Çok kriterli karar verme yöntemlerinin karşılaştırılmasına odaklı bir hizmet kalitesi uygulaması. Çankırı Karatekin Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 6(2), 17-48.
- Yalçınır, D., & Karaatlı, M. (2018). Mevduat Bankası Seçimi Sürecinde Topsis Ve Electre Yöntemlerinin Kullanılması. Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 23(2), 401-423.
- Yang, Y. (2017, May). The Method and Basis of Dam Location Selection. In 2017 2nd International Conference on Materials Science, Machinery and Energy Engineering (MSMEE 2017) (pp. 681-684). Atlantis Press.
- Yasser, M., Jahangir, K., & Mohmmad, A. (2013). Earth dam site selection using the analytic hierarchy process (AHP): a case study in the west of Iran. Arabian Journal of Geosciences, 6(9), 3417-3426.



## CHAPTER X

# USE OF EPS IN GEOTECHNICAL ENGINEERING

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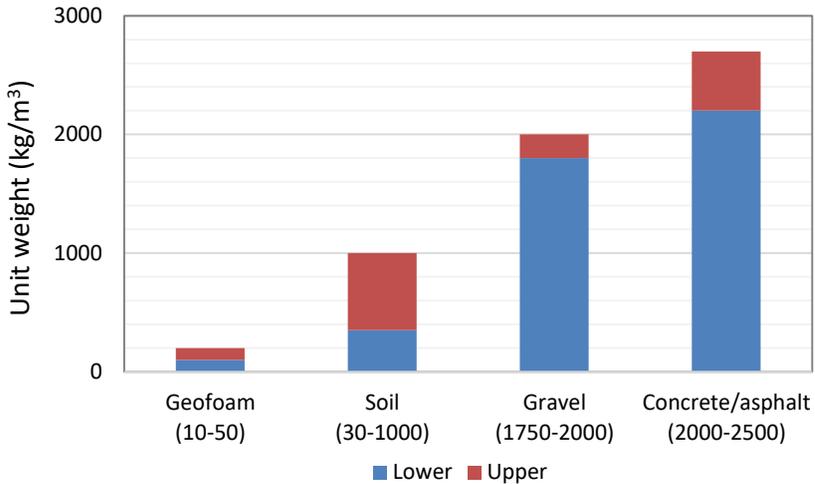
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### 1. Introduction

**E**xpanded Polystyrene (EPS) foam is a closed-pored, typically white, thermoplastic material in foam form obtained from petroleum by the polymerization of styrene monomer, and can take on different colors in special productions. In EPS products obtained by swelling and fusing polystyrene particles, pentane, an organic component, is replaced by air as blowing gas in a very short time during and after production and allowing the formation of many small pores in the particles. The released pentane gas turns into CO<sub>2</sub> and water vapor-H<sub>2</sub>O, which are already in the atmosphere. With the release of pentane, stagnant air is trapped in a large number of small closed-pore cells (3-6 billion in 1 m<sup>3</sup> EPS, depending on the density) in the material. As a result, a material consisting of 98% trapped air and 2% polystyrene emerges. The material reaches the desired density at this swelling stage. Then, the expanded particles resting in a special silo are allowed to fuse with each other in the mold with the help of water vapor and the material gains its properties. As a result of the fusion of the grains with each other, a continuous mass of polygons fused with each other without gaps is formed in the appearance of a honeycomb.

In civil engineering applications, EPS has been used for many years as an economical and effective thermal insulation material. It was used as a lightweight road fill material in 1972 by the "Norwegian Road Research Laboratory" in Norway to reduce settlements in the road fill. Although the successful results of using EPS geofoam as a lightweight road filling material in Oslo are well known, the use of this material was limited in Scandinavian countries for a long time. However, EPS is now used as blocks, beads and compressible layers in a variety of geotechnical applications all around the world. Reinforcing the low bearing capacity soils, reducing the thrusts on the supporting structures, stabilization of landslide risky areas and slopes, to meet surcharge loads on the buried structures, reducing the swelling pressure on the soils with high swelling potential, absorbing the seismic energy that structures are exposed to during earthquakes are the main functions of EPS that the construction industry heavily benefits from.

As lightweight filling material, geofoam is quite light compared to other structural materials. The EPS geofoam that forms the backfill of a retaining structure is 25 to 35 times lighter than the ground, 50 to 180 times lighter than gravel, and 60 to 200 times lighter than concrete or asphalt material (Fig. 1). The strength properties of EPS geofoam are summarized in Table 1. The material at the specified strength behaves as linear elastic with respect to the design load limit. The engineering properties of the EPS geofoam; its structural weight and strength are presented comparatively, thus, the advantage it provides in terms of the application comes to the fore once again.



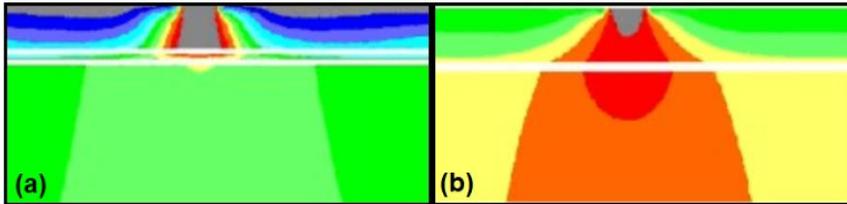
**Fig. 1** The comparisnal representation of unit weight of EPS geofoam with other constructional materials

**Table 1.** Strength properties of EPS Geofoam (TSEN14933)

Type	EPS40 (kPa)	EPS60 (kPa)	EPS10 0 (kPa)	EPS120 (kPa)	EPS160 (kPa)
Density (kg/m <sup>3</sup> )	12	16	20	24	30
Compressive strength (2%)	20	30	60	80	100
Compressive strength (5%)	30	50	80	100	120
Compressive strength (10%)	40	60	100	120	150
Bending strength	50	100	150	170	200

In addition to the features that make EPS geofoam efficient for civil engineering and geotechnical engineering applications, in particular, there are also some additional issues to be considered. For instance, geofoam is not puncture-resistant. The direct application of concentrated loads is not reasonable. Therefore, in some applications, a cover layer may be placed on

the final surface so that it cannot be directly exposed to the load. Another method is to lay the ground cover of sufficient thickness in order to minimize the load and stress density or to ensure its uniform distribution. Fig. 2 shows the conceptual stress distributions in an EPS geofoam fill with and without a load distribution slab.



**Fig. 2** The stress distribution of geofoam  
(a) with and (b) without load distribution slab

On the other hand, EPS geofoam can dissolve when it comes into contact with liquid petroleum products or organic compounds. Therefore, it is necessary to take protective measures in the application area where this is a potential hazard. This can be achieved by directing the liquid that may spill into the application area away or protecting the geofoam blocks with impermeable layers. If the soil surrounding the EPS geofoam is contaminated or saturated with organic seepage, encapsulation can occur in the geofoam blocks. Additionally, the interface shear strength must withstand the design loads if the EPS geofoam blocks are protected with a geomembrane.

Geofoam has the potential to absorb water into the cell structure over time. This amount of water is mostly related to how long the EPS geofoam will be exposed to water, but the experience is that this amount will not exceed 1%. Therefore, this amount of water does not adversely affect the strength or engineering properties of EPS geofoam. However, some deterioration in thermal properties may occur, especially under the freeze-thaw effect.

Geofoam under pavement has the potential to inhibit freeze penetration and upward flow of ground heat. Layers on geofoam may be icy under unfavorable conditions, while layers on adjacent pavement constructed

without geofoam may not experience freezing due to the transfer of ground heat. This sudden change in icing may adversely affect the driving safety and comfort of vehicles transferring on the pavement. The extent of differential icing on the roads can be minimized by increasing the thickness of the granular base.

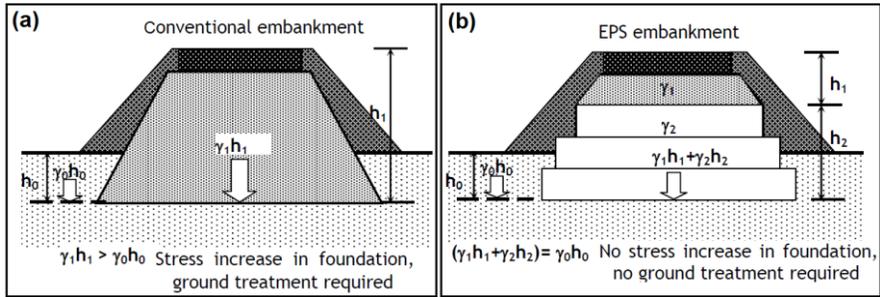
On the other hand, the variations in the character of urbanization leads to the structural need to gain diversity. The subject of engineering science is to produce the optimum solution to structural needs and related problems in the most economical way. The main motivation of geotechnical engineering is to determine the geological features of the construction site and to implement the final design in the most economical and reliable way by using scientific methods and engineering principles. This study focuses on the use of EPS, a new and unique material, in geotechnical engineering applications. In this context, a study including the advantages of EPS in different forms and geometric forms, its use in geotechnical applications, experimental and numerical studies, and a comprehensive literature review are presented.

## **2. EPS in Geotechnics**

EPS is evaluated in different physical forms to provide solutions to challenging problems in the field of geotechnical engineering. It has been used in slope stabilization, embankments, landscape design, retaining structures, shallow foundations, under slabs, bridge constructions, highway constructions, parking structures, airport runways, earthen dams, and load control/buried pipes applications. It is also used as a composite material together with the soil with its prominent engineering properties. EPS also has usage as seismic isolation due to its high damping capacity and as a new method of geotechnical seismic isolation (GSI). Horvath (1992) made a functional classification regarding the use of EPS geofoam in engineering applications. According to this classification, four main features of EPS geofoam are listed as; lightweight filling, compressibility, thermal insulation, and low amplitude wave damping. In further studies, the additional functions were stated as drainage and suitability for other structural uses (Horvath 1997).

### **2.1. Embankments**

Significant stability problems occur in road fills built on soft soils such as peat or soft clays. The common approach in all of the remedial methods applied is to overcome this problem by improving the shear strength of the soil, reducing its compressibility, and thus improving the engineering properties of the filling material. Uncertainties about the selection of the appropriate soil improvement method push practitioners to use lightweight backfill to reduce the lateral earth pressures. The inability to measure the improvement in the shear strength of the sub-foundation is an example of uncertainty in soil improvement methods. Additionally, improvement in engineering properties of foundation soils must be verified prior to embankment construction to ensure satisfactory performance. In contrast, the properties and geometry of a man-made lightweight fill like geofoam can be well defined, providing greater confidence in its use and less uncertainty than conventional soil improvement methods since it is a fabricated material instead of natural existence. Hence, the need to accurately know the engineering properties of the replaced soil is significantly reduced or eliminated. Due to the high unit weight of conventional filling materials, excessive settlements can cause stability problems. In order to avoid this problem, EPS geofoam has been used as a lightweight filling material as other materials such as waste tires, lightweight clay aggregate, and fly ash pellet aggregate. It provides significant advantages in terms of stability especially in filling constructions where the slope inclination of the edge is high. The comparative representation of conventional and EPS embankments demonstrates the advantage of EPS geofoam in a practical way as an example design. The settlement and low bearing capacity problems associated with untreated soft soils can be easily overcome with EPS geofoam embankment (Leo et al. 2007) (Fig. 3).



**Fig. 3** The schematical view of (a) conventional, (b) EPS embankment (Leo et al, 2007)

Since EPS geofoam's design unit weight is  $0.5 \text{ kN/m}^3$ , it has the feature of being an ultra-light material. Typical unit weights of other lightweight materials are the waste tire,  $5.0 \text{ kN/m}^3$ ; the fly ash pellet aggregate,  $10 \text{ kN/m}^3$ ; and lightweight clay aggregate  $6.0 \text{ kN/m}^3$ . In addition to being an ultra-light material, EPS geofoam has characteristic features such as a very large void ratio (closed cells filled with air), high rigidity and strength values, and low Poisson's ratio. Therefore, EPS geofoam monoblock elements are also preferred for protecting underground structures, transmission lines, or structural elements that are likely to be damaged due to structural loads from heavy filling loads. The first application of EPS geofoam was carried out in Norway in 1972. After the successful results, it has been widely applied in different countries, in particular, having problematic soil conditions. In the following years, 1.5 million cubic meters of geofoam were used in projects implemented in Japan. The successful results of geofoam, used in the projects and tested for performance, have shown that this new material can be used as a potential lightweight filling material. EPS geofoam has started to be used as a very common engineering solution after both the results obtained from numerical and experimental studies and the long-term high performance observed in the application areas. Pictures of the construction phase of a road fill and the completed view of the highway are shown in Fig. 4.



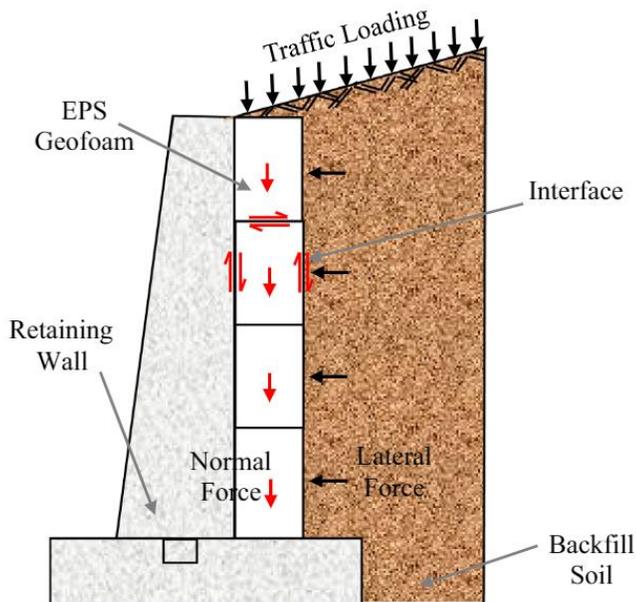
**Fig. 4** Use of EPS geofoam in highway constructions  
(Giuliani et al. 2020)

Attention should be paid to the design details that will affect the geofoam performance in filling applications. Geofoam blocks should be oriented vertically with an appropriate thickness. All blocks must fit tightly against each other in all directions. It should consist of at least two block layers. Experience shows that pavement collapses occur under traffic loads in applications where single-row geofoam blocks are used. Blocks should be laid in a pattern with minimum vertical joints. The general aim is to create a geometrically interlocking block layout to the greatest extent possible. This in turn aligns all blocks in a given layer longitudinally, parallel to their axes but adjacent and offsetting the ends of the rows of blocks, orienting the longitudinal axes of all blocks perpendicular in a given layer, positioned above or below, and the blocks in the topmost layer aligned transversely to the longitudinal axis.

## 2.2. Retaining Walls

There is numerous of research on reducing lateral earth pressures with materials such as rock wool or sawdust (Rehman and Broms, 1972).

However; Horvath (1997) reports that the use of these materials as filler cannot provide the desired benefit, since the stress-strain properties of these materials are not obvious and they are prone to decay. In contrast, geofabric in most geotechnical applications has been used successfully solely or by constituting a composite system with additional constructional materials. A schematic view of EPS behind a retaining wall is shown in Fig. 5. The interface friction between the wall and backfill soil is the key parameter for a successful design. The horizontal loads on the retaining wall are directly proportional to the weight of the backfill material. With the geofabric, which is stable in itself, the horizontal loads on the retaining walls are reduced incomparably with traditional fillings. Considering the decrease in vertical loads and the fact that geofabric will act as a natural seismic isolator, the lateral and vertical movements of the walls will be minimized. An additional technical feature of geofabric material is its impact damping potential which protects the wall from environmental effects as well as the horizontal loads.



**Fig. 5** EPS geofabric inclusion behind a retaining wall  
(Meguid and Khan, 2019)

Analytical, experimental and numerical analyses have been carried out on lateral earth pressure problems. Generally, literature studies have shown that compressible materials between a rigid retaining wall and backfill reduce the static forces (Partos and Kazaniwsky 1987; Abdelsalam and Azzam 2016). Chauhan and Dasaka (2017) proved the effectiveness of EPS geofoam in the reduction of lateral earth pressure. They noticed that use of geofoam behind the retaining wall provided a reduction in the range of 8 to 42% for surcharge pressures ranging from 10 to 50 kPa. Ertuğrul et al. (2012) also stated that the lateral pressures acting on rigid retaining walls can be reduced by the use of EPS filler. Matsuda et al. (1996) indicated that a decrease of up to 85% in bending moments at the foundation level was observed in the 0.5 m thick EPS fill application of a retaining wall in a 14 m high bridge approach. The decrease in moments is dependent on EPS unit weight and thickness. Ertuğrul and Trandafir (2011) presented graphics that design engineers can benefit from by performing parametric analyzes with the finite element model, which is later verified with model experiments.

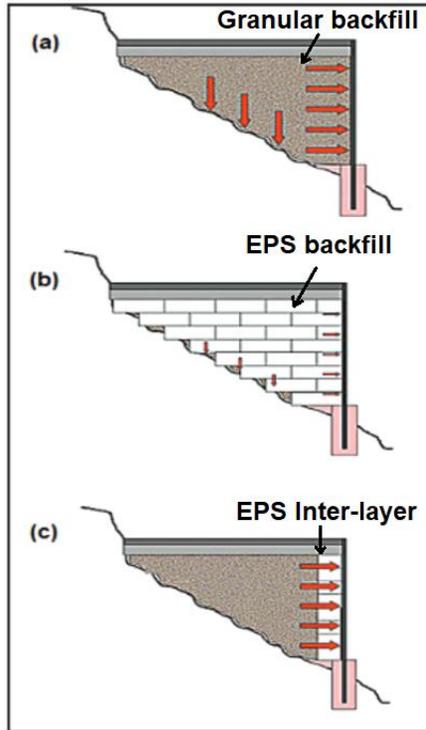
Current practices show that EPS geofoam fill can be used in two different ways for the design of retaining walls (Fig. 6). Retaining walls can be exposed to very high lateral loads if cohesionless natural filling material is used. If EPS material is used instead of a natural filling, a significant reduction in lateral thrust on the wall can be achieved (Fig. 6b). However, the performance of an EPS filling under the vertical loads should be considered in the selection of EPS material to be used. The second alternative is to place a deformable EPS interlayer between the natural filling and the retaining wall (Fig. 6c). This layer will be compressed due to lateral loads and will enable the shear strength of the natural fill to be mobilized at a higher rate, and in addition to this, the formation of a horizontal arching effect will reduce the lateral loads that will affect the retaining structure. Alaie and Chenari (2018) indicated that the efficiency of EPS-sand mixtures in reducing seismic earth pressure on retaining walls with its low shear modulus and Poisson's ratio. In addition to experimental studies, numerical models based on the finite element method also indicate that the use of deformable interlayers has a positive effect on the lateral pressures acting on the rigid retaining walls

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(Karpurapu and Bathurst, 1992; Trandafir et al. 2010; Ertuğrul and Trandafir, 2011).

Ertuğrul and Özkan (2012) stated that the use of EPS filler in rigid walls provides a higher reduction in lateral thrust values compared to the use of flexible walls. With the decrease in the relative flexibility, the deflection ability of the retaining structure decreases and the observed lateral pressures become higher. Increasing the EPS foam thickness results in reducing the lateral earth pressure on yielding and non-yielding retaining walls and accordingly increases the factor of safety against sliding and overturning. The efficiency of EPS foam was higher in the case of medium and dense sand backfills against yielding walls, compared to loose sand backfills (Ibrahim et al. 2020).

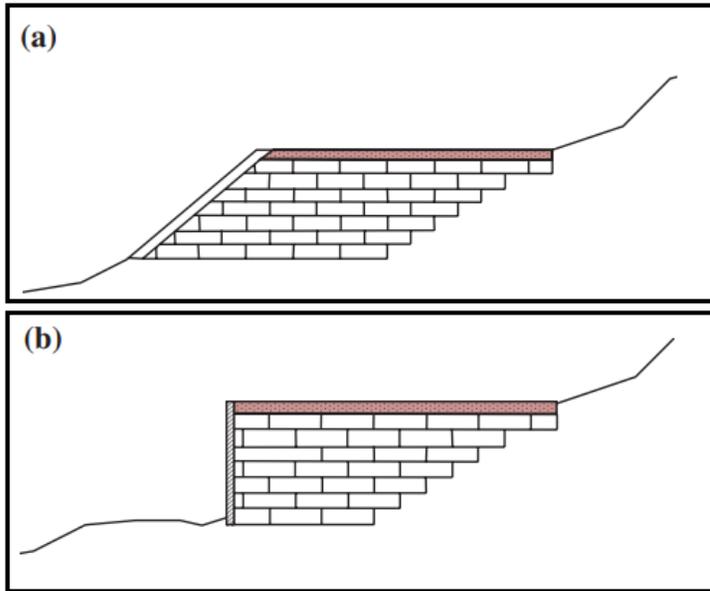
Experimental and numerical studies show that the use of EPS significantly improves the bearing capacity. The most important parameters affecting this performance are the thickness of the EPS layer and its engineering properties, the type and design features of the retaining structure, the ratio of the height of the blocks used to the wall height, and the type of backfill soil, its density and strength properties. It is reasonable to decide with numerical simulations before applying the thickness, height, and engineering properties of the EPS layer that will show the best performance for the retaining structure. During the construction stage, the placement of the EPS blocks used should be tight, it should be manufactured in such a way that the joint joints create a clamping, and the effects of other environmental factors are minimized.



**Fig. 6** EPS geofom retaining walls (Ertuğrul and Özkan, 2012)

### 2.3. *Slope Stabilization*

Slope stability is defined as the resistance of slopes to slip or collapse due to their own weight and additional loads. An instability problem occurs when the forces acting on the slope to slide or collapse are superior to the resisting forces. Those slopes are called unstable slopes. Geofom blocks, which have a much lower unit weight than compacted soil, have been developed as an alternative and effective method to provide slope stability. In order to provide slope stability by using geofom, researchers conducted parametric studies. (Sheely 2000; Jutkofsky et al. 2000; Srirajan 2001). In fact, they are considered as a type or category of geosynthetics in literature (Arellano et al. 2011). The use of EPS geofom blocks in slope applications may include slope edge fill (Fig. 7a) or vertical edge fill (Fig. 7b). The second type application is sometimes referred to as geofom wall and this application is specific to EPS block geofom. The use of vertical-sided fill will minimize the impact of fill loads on nearby structures (Arellano et al. 2011).

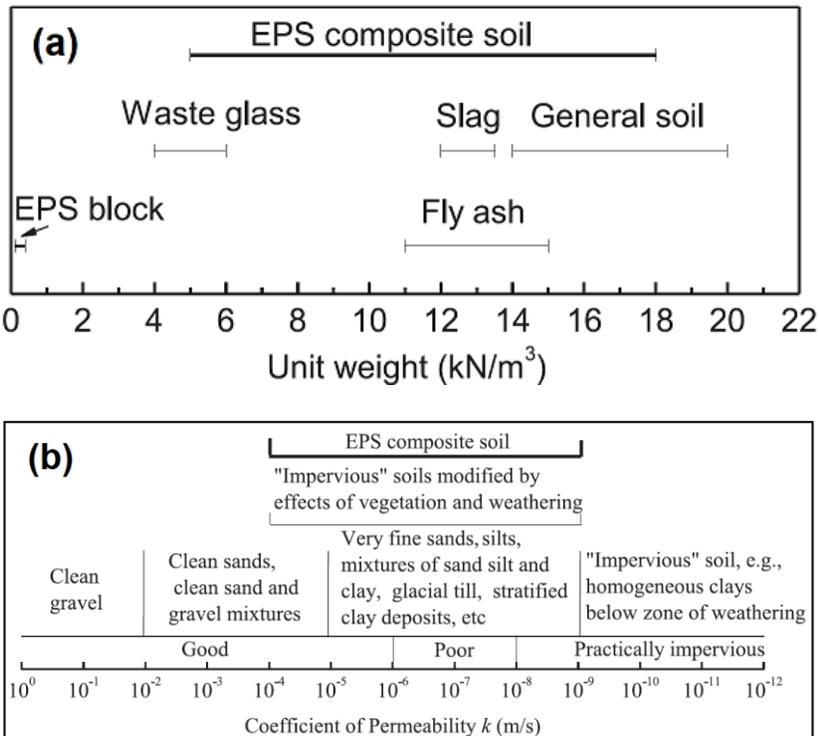


**Fig. 7** EPS geofoam applications of (a) slope-sided, (b) vertical sided (Arellano et al. 2011)

#### **2.4. EPS-soil composites**

EPS composite soil is an environmentally friendly material used in many different applications to increase the various properties of soils. It has been used successfully in many engineering applications, especially as a filling material for bridge piers, embankments, and retaining walls. EPS-soil composites, which were introduced in Japan for the first time, are produced from a mixture of soil, water, EPS, and in some cases a binder. Road embankments, backfill of retaining walls, and bridge abutments, filling pipeline trenches, etc. are used in engineering applications. They come into prominence as suitable solutions, especially in cases where pavement loads will cause settlement problems or soil bearing capacity is insufficient (Stark et al. 2004). Its weak resistance makes it ineligible to use in some cases (Negussey and Jahanandish 1993; Monahan 1993). The improvements generated by the composite environment resulting from the combination of EPS and different soil types in the soil properties have been studied by many researchers. These soils are cohesive in some cases and cohesionless soils in some cases. Mixtures formed by the combination of EPS beads in different

types, sizes, or contents have been tested under static and cyclic loadings. The results obtained are undoubtedly dependent on the type of soil, EPS properties, and loading method. For example, Edinçliler and Özer (2014) investigated the stress-strain behavior of EPS beads-sand mixtures with varied contents and EPS size. Hongmei et al. (2011) stated that the durability under dynamic and long-term monotonic loading makes EPS composite soil suitable for pavement construction. The geomechanical properties of EPS-soil composites are shared in the form of practical charts. As can be seen, the unit weight of EPS soil composites varies in a wide range depending on the type of constituting materials (Fig.8a) and the permeability coefficient is quite low, which is mostly classified as poor (Fig. 8b).



**Fig. 8** Comparative representation of the geomechanical properties of EPS soil composites (Hongmei et al. 2011).

The creep behavior of EPS soil composites was investigated and a creep model was proposed to describe the undrained creep behavior of EPS beads-clay mixtures (Hongmei et al. 2011). The cyclic behavior of sand polyurethane foam mixtures with 5,10 and 15% was investigated and it was revealed that the dynamic properties of mixtures were enhanced with the inclusion of polyurethane foam (Golpazir et al. 2016). Fard et al. (2015) studied the effect of EPS beads content on the properties of the sand-EPS beads mixtures. In contrast to the results of other tests, a noticeable difference was not observed in the deformation behavior of EPS-sand mixtures. Miao et al. (2013) proposed an embankment fill consisting of EPS beads, sand, and cement mixture. The lightweight fills having an adequate CBR value and strength parameters were observed to have less than half of the settlement of the lime-stabilized soil embankment on the untreated soil and 20% less than the settlement of the lime stabilized embankment on the treated soil. The compressibility of EPS beads and steel pellets was tested through a set of oedometer tests. The results revealed that the compressibility and lateral pressure at rest increase as the EPS introduced to the mixture increases (Tizpa et al. 2019). El-Sherbiny et al. (2018) stated that the EPS beads inclusion in sand mixtures reduced the shear strength. Abbasimadeh et al. (2021) drew attention to the drastic decays that emerged as a result of extensive experimental studies examining the geomechanical properties of EPS beads in soil mixtures and expressed reservations about adding particulate EPS beads to soils for producing uncemented lightened fill for geotechnical engineering applications. A comprehensive review of monotonic and cyclic properties of soil-EPS composites was performed by Khajeh et al. (2020).

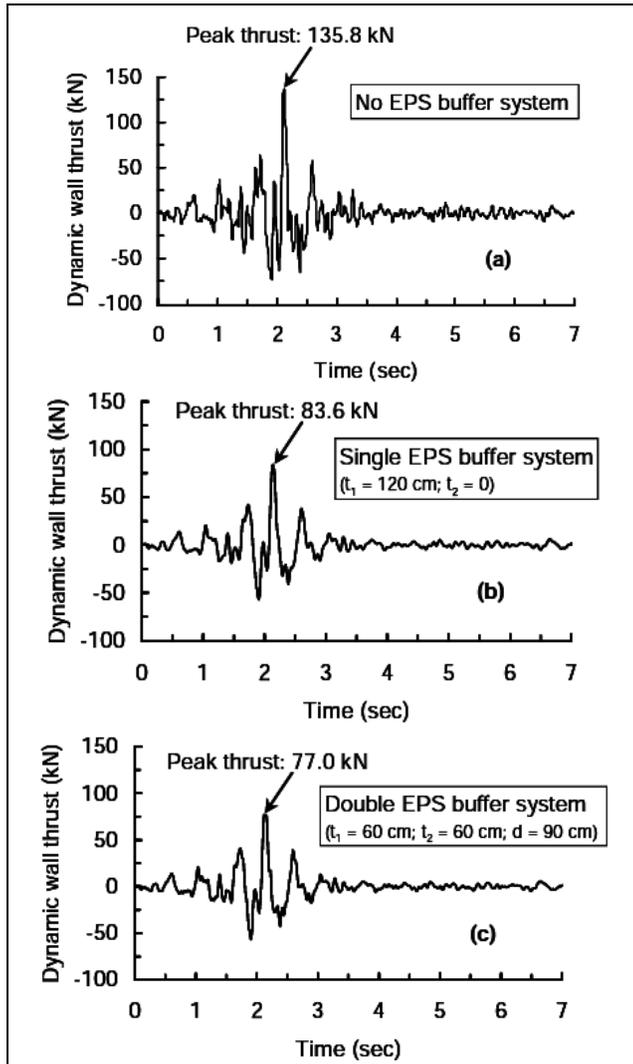
### ***2.5. Seismic isolation***

One of the two main features of EPS that makes it effective for seismic design is its lightness and the other is its compressibility. The compressibility and high damping ability of EPS ensure that the seismic forces acting on buried structures and pipelines or retaining structures are considerably reduced. Because EPS geofoam is moderate to highly compressible, it can deform and act as a "buffer" to reduce the seismic energy introduced into the system.

When EPS geofoam is used behind a structure, the structure interacts with the soil via the EPS blocks as a hybrid interactive system (Hazarika and Okuzono 2004). Model analyzes have shown that seismic forces applied to retaining walls and other buried structures can be reduced by up to 50%, depending on the thickness and other properties of EPS geofoam.

Due to the compressible characteristics of geofoam, the cushion material absorbs much of the pressures coming from the backfill and transfers only a few of the load to the structure. This kind of structural stabilization technique becomes particularly useful in upgrading already existent structures in seismically active areas, which were designed based on seismic criteria because this material can also reduce the seismic load imposed on the structure (Hazarika and Okuzono 2004).

Experimental and numerical studies have been carried out on the use of EPS in different forms (ie. beads, blocks, etc.) as a seismic buffer. The use of EPS as a seismic buffer was first described by Inglis et al. (1996). It has been observed that the EPS layer with 1 m thicknes placed vertically between the basement walls of a tower structure reduces the earthquake loads by 50%. Trandafir and Bartlett (2010) investigated the efficiency of double geofoam buffer pannels. The seismic efficiency of the model is also affected by the thickness of the panel used in the EPS buffer system (Fig. 9).



**Fig. 9** Time history of the (a) non-isolated and (b) isolated models (Inglis et al 1996)

The EPS beads-sand mixture under cyclic loading displayed a successful resilient elasticity with the key role of EPS played with its energy absorption capacity (Hongmei et al. 2011). Athanasopoulos-Zekkos et al. (2012) performed centrifuge tests with retaining wall models seismically isolated with EPS compressible inclusions. The isolation efficiency of EPS geofoam reached up to 50% for 0.2g input motion at 2 Hz frequency. Additionally they

revealed that the isolation efficiency of EPS geofoam retaining wall is dependent on the thickness of EPS geofoam. Alaie et al. (2018) performed a set of shaking table tests with sand-EPS beads mixtures which is an attempt to utilize a less expensive and recycled geo-material for the purpose of seismic isolation. At larger shaking intensities, use of EPS leads to a decrease in surface displacements and a reduction of the peak acceleration. EPS geofoam inclusion reduced the lateral earth forces at a level depending on the thickness of EPS geofoam and wall height (Ertuğrul and Trandafir 2011). The inclusion of EPS into sand decreases the permeability and increases the constant of earth pressure of the EPS-sand mixture (Chenari et al. 2016). The numerical model developed to simulate the behavior of EPS geofoam isolated retaining wall captured the dynamic response of the experimental model (Zarnani and Bathurst 2008). EPS-sand mixtures can be used as seismic pressure alleviators due to their high damping capacity (Alaie and Chenari 2019). EPS with its low density, low cost, and strain hardening after yielding improved the seismic performance of structures (Maleki and Ahmadi 2011). The hyperbolic stress-strain behavior of EPS-sand mixtures was observed as completely different from pure sand. The influence of EPS content on stress-strain behavior and the shear strength of the mixtures are therefore significant (Deng and Xiao 2010).

### **3. Conclusion**

As a lightweight material, EPS has been used in civil engineering applications in different forms and shapes since the 1960s. It is an alternative solution that has been applied all over the world, first in Scandinavian countries, then in Western Europe, Japan, and America. As a light filling material, it has found a place in many different areas of use. The most obvious superior technical features compared to traditional filling materials are its lightweight, high strength/density ratio, and very easy shape, ductility, dimensional stability, very low water absorption rate, resistance to environmental factors, compressibility, energy absorption ability, and economical and very fast workableness. These features have made EPS a preferred material in road construction on weak soils, bridge road approach fills and for embedded

structures, culverts, retaining structures, slopes, embankments, seismic isolations, etc. In geotechnical engineering applications, the advantages of EPS are used in a very efficient way. In this study, the main uses and benefits of EPS for geotechnical engineering are discussed as briefly listed below;

- It can be used as a thermal insulator in highway and airport constructions where the foundations cannot be lowered to the lower level of the frost depth.
- It is used behind the retaining structures to reduce lateral pressure and settlements, provide waterproofing and absorb seismic energy.
- EPS is used as fill embankments where the ground is soft and would require preloading to control post-construction settlements.
- EPS is used in slope stabilization as a soil substitute fill to reduce driving forces that can lead to global instability.
- They are used to reduce the loads on buried pipes and culverts for various purposes, which are pre-installed underground facilities.
- Since it is a lightweight material with high compression and energy absorption capacity, it is used in the damping of seismic or repeated loads.
- It can be evaluated as a lightweight material within the Geotechnical Seismic Isolation (GSI) concept, which has been proposed as an economical and effective seismic isolation method, especially in recent years.
- EPS beads contribute to the formation of a composite soil environment by using them solely or with additional binding materials in varying sizes and contents with sand, clay or different soil types in order to improve their mechanical and engineering properties.
- They can be used to reduce settlement or stability problems encountered in road fills on weak soils, and to improve the shear strength of the soil.

**References**

- Abbasimaedeh, P., Ghanbari, A., O'Kelly, B.C., Tavanafar, M., & Irdmoosa, K.G. (2021). Geomechanical Behaviour of Uncemented Expanded Polystyrene (EPS) Beads–Clayey Soil Mixtures as Lightweight Fill. *Geotechnics* 1:38–58. <https://doi.org/10.3390/geotechnics1010003>
- AbdelSalam, S.S., & Azzam, S.A. (2016). Reduction of lateral pressures on retaining walls using geofom inclusion. *Geosynth Int* 23:395–407. <https://doi.org/10.1680/jgein.16.00005>
- Alaie, R., & Chenari, R.J. (2018). Cyclic and Post-Cyclic Shear Behaviour of Interface between Geogrid and EPS Beads-Sand Backfill. *KSCE J Civ Eng* 22:3340–3357. <https://doi.org/10.1007/s12205-018-0945-2>
- Alaie, R., & Chenari, R.J. (2019). Dynamic properties ofEPS- sand mixtures using cyclic triaxial and bender element tests. *Geosynth Int* 26(6):563–579
- Arellano, D., Stark, T.D., Horvath, J.S., & Leshchinsky, D. (2011). Project No. 24-11(02) COPY NO. Guidelines for Geofom Applications in Slope Stability Projects ACKNOWLEDGEMENT OF SPONSORSHIP. 11.
- Athanasopoulos-Zekkos, A., Lamote, K., & Athanasopoulos, G.A. (2012). Use of EPS geofom compressible inclusions for reducing the earthquake effects on yielding earth retaining structures. *Soil Dyn Earthq Eng* 41:59–71. <https://doi.org/10.1016/j.soildyn.2012.05.004>
- Chauhan, V.B., & Dasaka, S.M. (2017). Assessment of lateral earth pressure reduction using EPS geofom-A numerical study. Conference on Numerical Modeling in Geomechanics.
- Chenari, J.R, Fard, K.M., Maghfirati, P.S., et al. (2016). An investigation on the geotechnical properties of sand-EPS mixture using large oedometer apparatus. *Constr Build Mater* 113:773–782.
- Deng, A., & Xiao, Y. (2010). Measuring and modeling proportion- dependent stress–strain behavior of EPS-sand mixture 1. *Int J Geomech* 10(6):214–222.
- Edinçliler, A., & Özer, A.T. (2014). Effects of EPS bead inclusions on stress-strain behaviour of sand. *Geosynth Int* 21:89–102.

- <https://doi.org/10.1680/gein.14.00001>
- El-Sherbiny, R.M., Ramadan, S.H., & El-Khouly, M.A. (2018). Dynamic properties of sand-EPS bead mixtures. *Geosynth Int* 25:456–470. <https://doi.org/10.1680/jgein.18.00021>
- Ertugrul, O.L., & Trandafir, A.C. (2011). Reduction of Lateral Earth Forces Acting on Rigid Nonyielding Retaining Walls by EPS Geofoam Inclusions. *J Mater Civ Eng* 23:1711–1718. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0000348](https://doi.org/10.1061/(asce)mt.1943-5533.0000348)
- Ertuğrul, Ö.L., Trandafir, A.C., & Özkan, M.Y. (2012). Yanal Zemin Basınçlarının EPS Köpük Kullanımı Vasıtasıyla Azaltılması. *İMO Teknik Dergi*, 23, 5885-5901. (In turkish).
- Ertugrul, O.L., & Ozkan, M.Y. (2012). Influence of EPS Geofoam Buffers on the Static Behavior of Cantilever Earth-Retaining Walls. *Pamukkale Univ J Eng Sci* 18:173–181. <https://doi.org/10.5505/pajes.2012.09709>
- Fard, K.M., Chenari, J.R., & Soheili, F. (2015). Shear strength characteristics of sand mixed with EPS beads using large direct shear apparatus. *Electron J Geotech Eng* 20(8):2205–2220.
- Golpazir, I., Ghalandarzadeh, A., Jafari, M.K. & Mahdavi, M. (2016). Dynamic properties of polyurethane foam-sand mixtures using cyclic triaxial tests. *Construction and Building Materials*, 118, 104-115.
- Giuliani, F., Autelitano, F., Garilli, E., & Montepara, A. (2020). Expanded polystyrene (EPS) in road construction: Twenty years of Italian experiences. *Transp Res Procedia* 45:410–417. <https://doi.org/10.1016/j.trpro.2020.03.033>
- Hazarika, H., & Okuzono, S. (2004). Modeling the Behaviour of a Hybrid Interactive System Involving Soil, Structure and EPS Geofoam”, *Soils and Foundations* 44 (5), 149-162.
- Hongmei, Gao., Jinyuan, Liu, & Hanlong, L. (2011). Geotechnical properties of EPS composite soil, *International Journal of Geotechnical Engineering*, 5:1, 69-77, DOI: 10.3328/IJGE.2011.05.01.69-77
- Horvath, J.S. (1992). 'Lite' products come of age; new developments in geosynthetics. *Standardization News, ASTM*, 20(9), 50-53.
- Horvath, J.S. (1997). The compressible inclusion function of EPS geofoam.

Geotext Geomembranes 15:77–120. [https://doi.org/10.1016/s0266-1144\(97\)00008-3](https://doi.org/10.1016/s0266-1144(97)00008-3)

Ibrahim, Y.E.H., Abdelsalam, S.S.A, Nabil, M.N.A., & Elsayed, M.E. (2020). Earth pressure reduction on retaining walls using EPS geofoam. *Mag Civ Eng* 99:<https://doi.org/10.18720/MCE.99.4>

Inglis, D., Macleod, G., Naesgaard, E., & Zergoun, M. (1996). Basement wall with seismic earth pressures and novel expanded polystyrene foam buffer layer. Tenth Annual Symposium of the Vancouver Geotechnical Society, Vancouver, BC, pp. 18.

Jutkofsky, W. S., Sung, J. T., & Negusse, D. (2000). Stabilization of an Embankment Slope with Geofoam. *Transportation Research Record*, 1736, 94-102.

Karpurapu, R. & Bathurst, R.J. (1992). Numerical investigation of controlled yielding of soil- retaining wall structures. *Geotextiles and Geomembranes*, 11, 115–31.

Khajeh, A., Jamshidi, C.R, & Payan, M. (2020). A Review of the Studies on Soil-EPS Composites: Beads and Blocks. *Geotech Geol Eng* 38:3363–3383. <https://doi.org/10.1007/s10706-020-01252-2>

Leo, C. J., Ameratunge, J., Taylor, B., & Patten, M. (2007). EPS geofoam: an engineering material for geotechnical applications. *Common Ground : Proceedings Of The 10Th Australia New Zealand Conference On Geomechanics : Australian Geomechanics Society And The New Zealand Geotechnical Society Inc., Hilton Hotel, Brisbane, Queensland, Australia, 21-24 October 2007.*

Maleki, S., & Ahmadi, F. (2011). Using expanded polystyrene as a seismic energy dissipation device. *J Vib Control* 17(10):1481–1497

Matsuda, T., Ugai, K., & Gose, S. (1996). Application of EPS to Backfill of Abutment for Earth Pressure Reduction and Impact Absorption. *Proceedings of the International Symposium on EPS Construction Method*, Tokyo, Japan, pp. 327-332.

Meguid, M.A., & Khan, M.I. (2019). On the role of geofoam density on the interface shear behavior of composite geosystems. *Int J Geo-Engineering* 10: <https://doi.org/10.1186/s40703-019-0103-9>

- Miao, L., Wang, F., Han, J., & Lv, Weihua. (2013). Properties and Applications of Cement-Treated Sand-Expanded Polystyrene Bead Lightweight Fill. *J Mater Civ Eng* 25:86–93. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0000556](https://doi.org/10.1061/(asce)mt.1943-5533.0000556)
- Monahan, E.J. (1993). Weight-credit foundation construction using artificial fills. *Transportation Research Record*, Washington, DC, No. 1422, 1-6.
- Negussey, D., & Jahanandish, M. (1993). Comparison of some engineering properties of expanded polystyrene with those of soils. In *Transportation Research Record* (1418 ed., pp. 43-48)
- Partos, A.M. & Kazaniwsky, P.M. (1987). Geoboard reduces lateral earth pressures. In: *Proceedings of Geosynthetics'87*, Industrial Fabrics Association International. New Orleans, LA, USA, 628–39.
- Rehman, S.E. & Broms, B.B. (1972). Lateral pressures on basement wall; Results from full-scale tests. In *Proceedings of the Fifth European Conference on Soil Mechanics and Foundation Engineering*, pp. 189-197.
- Sheely, M. (2000). Slope Stabilization Utilizing Geofoam, Master's Thesis, Syracuse University, New York.
- Srirajan, S. (2001). Recycled Content and Creep Performance of EPS Geofoam in Slope Stabilization, Master's Thesis, Syracuse University, New York.
- Stark, T.D., Arellano, D., Horvath, J. S., & Leshchinsky, D. (2004). Geofoam Applications in the Design and Construction of Highway Embankments. *Transportation Research Board*, Washington, D.C., 792.
- Tizpa, P., Jamshidi, C.R., & Farrokhi, F. (2019). A Note on the Compressibility and Earth Pressure Properties of EPS Beads-Rigid Particulates Composite. *Geotech Geol Eng* 37:5231–5243. <https://doi.org/10.1007/s10706-019-00977-z>
- Trandafir, A.C., & Bartlett, S.F. (2010). Seismic performance of double EPS geofoam buffer systems. *Missouri University of Science and Technology*
- Trandafir, A. C., Moyles, J. F., & Erickson, B. A. (2010). "Finite- element

analysis of lateral pressures on rigid non-yielding retaining walls with EPS geofoam inclusion.” Proc., 2010 Earth Retention Conf., ASCE, Reston, VA, 756–763.

Zarnani, S., & Bathurst, R.J. (2008). Numerical modeling of EPS seismic buffer shaking table tests. *Geotext Geomembr* 26(5):371–383

# DECOLORIZATION OF LEATHER INDUSTRY WASTEWATER BY SONOCATALYTIC FENTON

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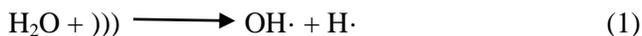
## 1. Introduction

The leather industry is one of the oldest industries in the world and the problem of treating and disposing of these wastes is probably as old as the industry itself. Leather industry wastewater is very difficult to treat because it contains high amounts of pollution. Leather processing industry wastewater contains high organic pollutants, high suspended solids, organic nitrogen and ammonia, dyestuff and high salinity. For this reason, leather industry wastewaters are very toxic and pose a risk to human, animal and plant health if disposed to the environment without treatment (Sawalha et al., 2019). The organic pollutions in leather industry wastewater are difficult to remove by conventional processes. Biological treatment methods are

generally preferred for leather industry wastewater that needs to be treated effectively. Biological treatment is known to be inefficient for the leather wastewater (Du et al., 2020). For this reason, advanced oxidation processes are preferred in the treatment of leather industry wastewater in recent years.

Advanced oxidation processes can be successfully used in wastewater treatment to reduce toxicity, convert toxic pollutants into degradable byproducts, provide decolorization and remove organic pollutants. Advanced oxidation processes are based on the formation of hydroxyl radicals with high electrochemical oxidation potential. Hydroxyl radicals ( $\text{OH}\cdot$ ) are not selective and react rapidly with many organic and inorganic chemicals in the environment. Therefore, they are strong oxidizers for synthetic and natural organic compounds that are resistant to degradation by other processes in natural waters (Wang and Xu, 2011).

The sono-Fenton process (US-Fenton) is an advanced oxidation process that leads to the rapid degradation of chemical pollutants in water. Ultrasound is an acoustic wave in a solid, liquid or gas environment. Ultrasound causes acoustic cavitation, which involves the formation and expansion of high energy micro bubbles under the influence of periodic pressure. When these bubbles collapse, the increase in pressure and temperature forms highly reactive hydrogen atoms and hydroxyl radicals. This situation facilitates the cleavage of toxic compounds in the environment (Lin et al., 2016).



The use of ultrasound alone requires a long time to break down organic pollutants; for this reason, solid catalysts are used to accelerate the oxidation process. When the accelerating effect of the catalyst is combined with ultrasound, more hydroxyl radicals are produced and the efficiency of wastewater treatment increases (Zhou et al., 2015). Clays are catalysts used in oxidation processes due to their easy availability in nature and their iron content (Ausavasukhi and Sooknoi, 2014).

In the experimental study, sonocatalytic Fenton method were applied in the treatment of leather industry wastewater. Clay supplied from the brick factory in Eskişehir was used as a catalyst in the study. The iron ion content of the clay used is 8-9%, easily available in nature and is quite cheap. The effects of pH, clay amount and reaction time were also examined and optimum points were determined for leather industry wastewater.

## 2. Experimental

### 2.1. Materials and Reagents

Leather industry wastewater was used which was supplied from a leather production enterprise serving in the Tekirdag region in experimental studies. The wastewater was obtained after the tanning process. Table 1 presented the properties of the wastewater. The wavelength at which the maximum absorbance value was measured was determined by wavelength scanning in the spectrophotometer. The decolorization efficiencies in the samples taken in all treatment studies were determined by making measurements at the specified wavelength.

**Table 1.** The characteristics of wastewater.

pH	$\lambda_{\max}$ (nm)	Color (Abs)	TSS (mg/L)	Oil and grease (mg/L)
2.58	595	3.83	539	374

In sonocatalytic Fenton processes clay containing 8-9% iron ions was used as a catalyst. The clay used in the experimental studies was obtained from a brick factory in Eskişehir. Hydrogen peroxide ( $\text{H}_2\text{O}_2$ , 30 wt%) and sodium hydroxide (NaOH) were purchased from Sigma Aldrich Company (Germany). Sulfuric acid ( $\text{H}_2\text{SO}_4$ , content 98%) was obtained from Merck Company (Germany).

### 2.2. Sonocatalytic Fenton Experiments

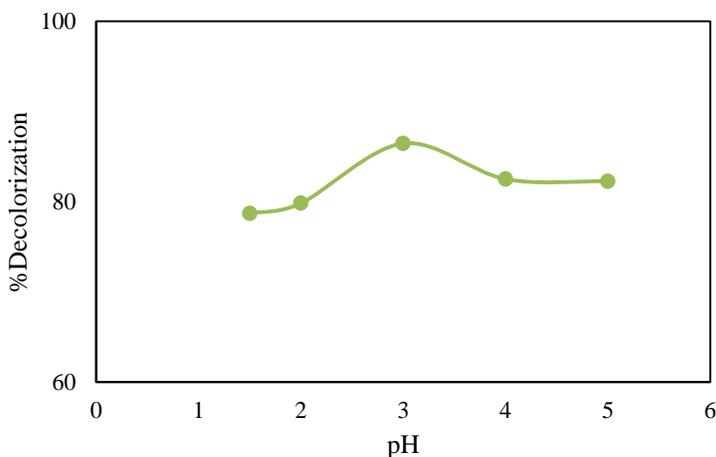
As the ultrasound source, Sonics VCX 750 brand ultrasonic homogenizer device which have features as 20 kHz frequency and 750 W power was used.

After the pH of the wastewater sample was adjusted to the desired value, the desired amount of clay was added to the sample. Then, hydrogen peroxide solution was prepared and added to the sample. The 13 mm probe of the device was dipped into the prepared sample and it was operated. At the end of the experiment, 2 M NaOH was added to the sample to stop the oxidation reaction. Then, the clear part on the sample was separated and the color analysis was made in the spectrophotometer.

### 3. Results and Discussion

#### 3.1. Effect of Initial pH

In advanced oxidation processes, pH is one of the most important parameters effecting reaction efficiency. Therefore, performing experimental studies at optimum pH value will increase process efficiency. Experiments to determine the pH effect were carried out in a constant amount of clay, hydrogen peroxide concentration, temperature and reaction time. In experimental studies, pH values were changed as 1.5, 2, 3, 4 and 5 and its effect on decolorization efficiency was examined. Figure 1 represented the results.

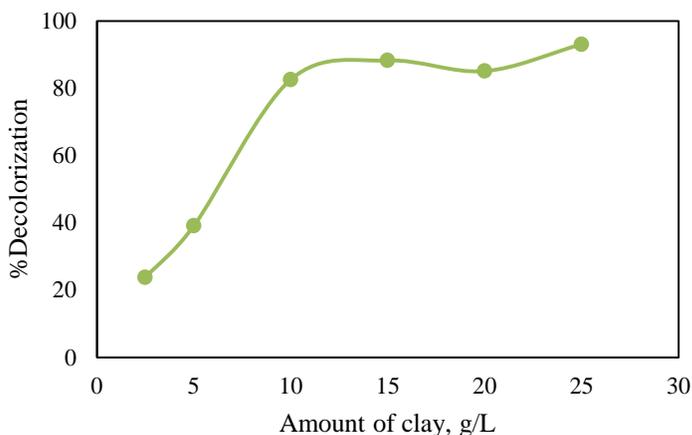


**Figure 1:** The effect of initial pH on decolorization efficiency (amount of clay 10 g/L,  $H_2O_2=200$  ppm, temperature  $30^\circ C$ ).

According to Figure 1, it was seen that the decolorization efficiency increases until pH 3, and decreases after pH 3. Therefore, the optimum pH was determined as 3 for the sonocatalytic Fenton process. Under neutral and alkaline conditions, ferric oxyhydroxide and ferric hydroxide types are easily formed. In this case, due to the presence of less free iron ions, the reaction with hydrogen peroxide does not take place effectively and less hydroxyl radicals are produced. In addition, the ferric species formed reduce the oxidation potential of hydrogen peroxide by breaking down hydrogen peroxide into oxygen and water (Xu et al., 2020). It has been reported in scientific studies that the optimum pH for the Fenton reaction is 3 regardless of the target substrate. When the pH value is below 3, a decrease in the degradation efficiency is observed. Especially at pH values below 2, hydrogen peroxide acts as a hydroxyl radical scavenger. In addition, hydrogen peroxide forms the stable oxonium ion  $[H_3O_2]^+$  in the presence of high concentrations of  $H^+$  ions. Oxonium ions make hydrogen peroxide less stable and reduce its reactivity with iron ions. Therefore, the efficiency of the Fenton process to decompose organic compounds decreases at both high and low pH. Determining the optimum pH in advanced oxidation processes increase process efficiency (Rahmani et al., 2019; Sohrabi et al., 2014).

### **3.2 Effect of the Clay Amount**

Clays are widely used as catalysts in advanced oxidation processes due to their abundance in nature, their large surface area and suitable pore size distribution. In the experiments performed to determine the effect of clay amount in sonocatalytic Fenton processes, the amount of clay as 2.5, 5, 10, 15, 20 and 25 g/L was investigated. The other parameters were kept constant as pH 3,  $H_2O_2$  concentration 200 ppm, temperature 30°C and reaction time 120 minutes.

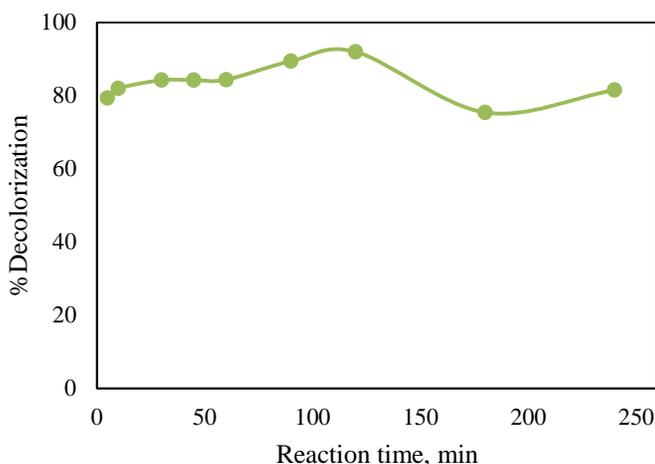


**Figure 2:** The effect of clay amount on decolorization efficiency (pH=3, H<sub>2</sub>O<sub>2</sub>= 200 ppm, temperature 30°C).

Considering the experimental results in Figure 2, as the amount of clay increased up to 10 g/L, the color removal increased and 83% yield was obtained, and then there was no significant change. However, although higher yields were obtained at 25 g/L, excess clay was not taken optimally as it would cause environmental pollution. With the increase in the amount of clay used as a catalyst, the active areas available on the clay surface increase and more hydrogen peroxide is broken down. Catalytic reactions occur at active sites on the clay surface and more hydroxyl radicals are generated. Accordingly, the efficiency of decolorization from wastewater also increases. However, excessive use of clay creates pollution by increasing the dissolved solid content of the waste water. Therefore, it is important to determine the optimum amount of clay (Liu, 2017; Gholami, 2020).

### 3.3. *Effect of the Reaction Time*

The experimental studies were carried out at different reaction times such as 5, 10, 15, 30, 45, 60, 90, 120, 180 and 240 minutes. The experimental results obtained existed in Figure 3.



**Figure 3:** The effect of reaction time on decolorization efficiency.

For sonocatalytic Fenton processes, the optimum reaction time was determined as 120 minutes at which the maximum decolorization efficiencies were achieved. Although the reaction time varies according to the contamination amount of the wastewater, it generally provides high removal efficiency at lower reaction times compared to other methods. Generally, the optimum reaction time determined for advanced oxidation processes ranges from 30 minutes to 3 hours (Tengrui et al., 2007).

#### 4. Conclusions

In the experimental study carried out for the treatment of leather industry wastewater, sonocatalytic Fenton processes were applied. The clay, which was easily found in nature and has advantages such as large surface area and iron ion content, was used as a catalyst. The optimum experimental conditions were determined as pH 3, clay amount 10 g/L and reaction time 120 minutes. The effect of ultrasound in the sonocatalytic Fenton process is the formation of more hydroxyl radicals with cavitation bubbles formed in the water. In addition, a large surface area is obtained by activating the catalyst surface more with the effect of mechanical force. The diffusion of the adsorbed molecules through the pore is achieved faster with the effect of mechanical

force originating from ultrasound. Thus, a good yield is obtained with less chemicals in the sonocatalytic Fenton process. The sonocatalytic Fenton process can provide effective treatment for leather industry wastewater due to the high color removal efficiencies achieved.

### **Acknowledgements**

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### **REFERENCES**

- Ausavasukhi, A. & Sooknoi, T. (2014). Catalytic activity enhancement by thermal treatment and re-swelling process of natural containing iron-clay for Fenton oxidation, *Journal of Colloid and Interface Science*, 436, 37-40.
- Du, Z., Tian, W., Qiao, K., Zhao, J., Wang, L., Xie W., Chu, M. & Song, T. (2020). Improved Chlorine and Chromium Ion Removal From Leather Processing Wastewater by Biocharcoal-Based Capacitive Deionization. *Separation and Purification Technology*, 233, 116024.
- Gholami, P., Dinpazhoh, L., Khataee, A., Hassani, A. & Bhatnagar, A. (2020). Facile hydrothermal synthesis of novel Fe-Cu layered double hydroxide/biochar nanocomposite with enhanced sonocatalytic activity for degradation of cefazolin sodium. *Journal of Hazardous Materials*, 381, 120742.
- Lin, M., Ning, X.A., An, T., Zhang, J., Chen, C., Ke, Y., Wang, Y., Zhang, Y., Sun, J. & Liu, J. (2016). Degradation of polycyclic aromatic hydrocarbons (PAHs) in textile dyeing sludge with ultrasound and Fenton processes: effect of system parameters and synergistic effect study, *J. Hazard. Mater.* 307, 7–16.
- Liu, Y., Jin, W., Zhao, Y., Zhang, G. & Zhang, W. (2017). Enhanced Catalytic Degradation of Methylene Blue by Alpha-Fe<sub>2</sub>O<sub>3</sub>/Graphene Oxide Via Heterogeneous Photo- Fenton Reactions. *Appl. Catal.* 206, 642–652.
- Rahmani, A. R., Mousavi-Tashar A. & Masoumi, Z. (2019). Azarian, G. Integrated advanced oxidation process, sono-Fenton treatment, for

- mineralization and volume reduction of activated sludge, *Ecotoxicology and Environmental Safety*, 168, 120-126.
- Sawalha, H., Alsharabaty, R., Sarsour, S. & Al-Jabari, M. (2019). Wastewater from Leather Tanning and Processing in Palestine: Characterization and Management Aspects. *J. Environ. Manag.* 251, 109596.
- Sohrabi, M.R., Khavaran, A., Shariati, S. & Shariati, S. (2014). Removal of carmoisine edible dye by Fenton and photo Fenton processes using Taguchi orthogonal array design. *Arab. J. Chem.* 10, S3523–S3531.
- Tengrui, L., Al-Harbawi, A., Jun, Z. & Bo, L.M. (2007). The Effect and Its Influence Factors of the Fenton Process on the Old Landfill Leachate. *Journal of Applied Sciences*, 7, 724–727.
- Wang, J. & Xu, L. (2011). Advanced Oxidation Process for Wastewater Treatment: Formation of Hydroxyl Radical and Application. *Critical Reviews in Environmental Science and Technology*, 42, 251-325.
- Xu, L., Zhang, X., Han, J., Gong, H., Meng, L., Mei, X., Sun, Y., Qi, L. & Gan, L. (2020). Degradation of emerging contaminants by sono-Fenton process with in situ generated H<sub>2</sub>O<sub>2</sub> and the improvement by P25-mediated visible light irradiation, *Journal of Hazardous Materials*, 391, 122229.
- Zhou, M., Yang, H., Xian, T., Li, R.S., Zhang, H.M. & Wang, X.X. (2015). Sonocatalytic degradation of RhB over LuFeO<sub>3</sub> particles under ultrasonic irradiation, *J. Hazard. Mater.* 289 149–157.



## CHAPTER XII

# REMOVAL OF DIRECT ORANGE 26 FROM AQUEOUS SOLUTION BY SONO-FENTON METHOD

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### 1. Introduction

The most important global environmental problem is water. Increasing industrialization, population density and deforestation significantly threaten the health of both humans and the many organisms they live with. Although the basis of water pollution is human-induced, large sectors consume large amounts of water and produce significant amounts of wastewater with activities such as population explosion, indiscriminate rapid urbanization and waste-generating industrial and technological expansion in the textile industry. Wastewater from textile processes is highly polluted. The pollution in these waters, which are difficult to characterize, is not constant and varies from day to day and even from hour to hour (Patel and Vashi, 2015). Even a small amount of dye interferes with the transmittance of light, impairing the photosynthetic process. It affects the fauna and flora negatively by preventing the dissolution of oxygen in the water (Mahmoud, 2007).

It is estimated that 2,8,10<sup>5</sup> tons of textile dyes are discharged as industrial wastewater worldwide every year (Erkmen, 2022). Azo group dyes, which make up more than half of the dyes produced all over the world, are also preferred in the textile industry (Park and Choi, 2003). Synthetic azo dyes come into prominence as they are inexpensive and resistant to washing (Harichandran and Prasad, 2016).

Wastewaters from these dyes contain various organic content, active metal, color, etc. contains impurities. While water cannot be biodegraded under aerobic conditions, it can be reduced to even more dangerous forms under anaerobic conditions (Grau, 1991).

Dyes are characterized according to their chemical structures as triaryl methane, azo, anthraquinone, heterocyclic and phthalocyanine. It is also characterized as vat, reactive, direct, acidic, disperse and cationic according to application methods (Xu et al., 2004). Wastewaters from the textile industry are generally acidic and at high temperature with high dye concentrations. It also has very high COD and TOC values with organic and inorganic chemicals (Liu et al., 2007). Advanced wastewater methods (AOP), which are environmentally friendly in wastewater treatment, oxidize non-biodegradable molecules and convert them into forms such as carbon dioxide, water and inorganic salts (Bayar and Erdogan, 2019; Primo et al., 2008).

One of these AOPs is the Fenton process. In Fenton, hydroxyl radicals are produced from hydrogen peroxide using Fe<sup>+2</sup> as a catalyst under acidic conditions (Özdemir et al., 2011a; Walling, 1975).



In some studies, it has been noted that ultrasound accelerates the conversion of Fe<sup>+3</sup> to Fe<sup>+2</sup> and oxidation (Toprak and Şener, 2021). Ultrasound has been a remarkable method since 1990 for the removal of organic pollutants, high permeability, safe and no additional contaminants (Geng et al., 2021a; Petrier et al., 1998).

Gas and vapor bubbles are formed in the liquid, which grow with ultrasonic rays. This is called acoustic cavitation. These cavitations can be easily created at 20-40 kHz frequency, high temperature (500 K) and high pressure (1000 atm) (Özdemir et al., 2011a). Ultrasonic cavitation creates oxygen radicals with "hot point" and "sonoluminescence" and provides removal of stubborn organic compounds (Geng et al., 2021b). Bubbles formed by cavitation in the ultrasonic environment form oxidizing radicals such as  $H\cdot$ ,  $OH\cdot$ ,  $O\cdot$  and  $H_2O_2$  with the effect of internal/external pressure (Toprak and Şener, 2021). Pollutants are decomposed by two mechanisms, by direct pyrolysis of volatile compounds in the bubbles and oxidation of non-volatile compounds (Özdemir et al., 2011b). The following equations are chain reactions that occur during the sonication of pure water Eqs (3)-(7) (Basturk and Karatas, 2014).



The use of the ultrasound method together with Fenton reagents is called the sono-Fenton method (Babuponnusami and Muthukumar, 2014). In this study, it is aimed to treat the synthetic wastewater of the textile industry with the sono-Fenton process. For this reason, optimum experimental conditions were determined by examining parameters such as pH,  $H_2O_2$ , Fe(II) concentration, time and initial concentration.

## 2. Materials and Methods

### 2.1 Materials

Direct Orange 26 (DO26) azo dye was used in this study. Direct Orange 26 azo dye is widely used in the textile industry and obtained from the Bursa,

Burboya Ltd. company. The characteristic of DO26 is given in (Aşçı, 2013). Sodium hydroxide (NaOH) (Sigma Aldrich) and sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) (Merck) were used for pH adjustment of the samples. Iron (II) sulfate heptahydrate (FeSO<sub>4</sub>.7H<sub>2</sub>O) (Merck) was used in the sono-Fenton experiment. 30% by weight hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) (Sigma Aldrich) was used in all oxidation experiments.

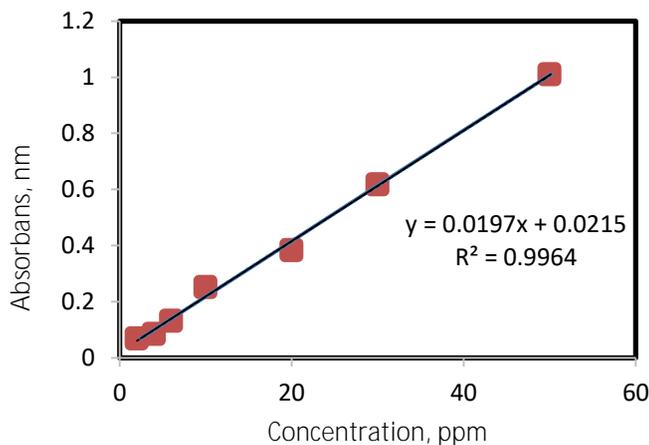
## 2.2. *Sono-Fenton Experiments*

In Sono-Fenton experiments, firstly, 1 g of Direct Orange 26 azo dye was weighed and completed to 1 L with distilled water, and the experiments were carried out by dilution from this stock solution. Experiments were carried out with a total solution volume of 200 ml. First of all, the pH of the dye solution prepared at a certain concentration was adjusted, and certain amount of H<sub>2</sub>O<sub>2</sub> and FeSO<sub>4</sub>.7H<sub>2</sub>O were added and placed in the sonication device (Sonics VCX 750 brand ultrasonic homogenizer (750 W, 20 kHz)) without waiting. The probe 13 mm of device was immersed 4 cm in to the solution and the device was started. All experiments were carried out at room temperature. When the reaction was completed after a certain time, the sample was taken from the device and 2 M NaOH was added and a certain period of time was waited for sufficient precipitation. After the appropriate waiting time, the absorbance values of the samples were read in the UV-spectrophotometer device the next day.

## 2.3. *Analytical methods*

The maximum wavelength of DO26 was determined as 494 nm with the Hach Lange DR 3900 spectrophotometer device. Then, to read the absorbance values of the samples after the reaction, 2, 4, 6, 10, 20, 30 and 50 ppm solutions were prepared from the stock solution and a calibration line was created (Figure 1). The concentration values of the samples were calculated from the obtained calibration line. The color removal efficiency of DO26 was calculated with the following formula.

$$\frac{\text{initial consantration} - \text{remaining consantration in solution}}{\text{initial consantration}} \times 100 \quad (8)$$

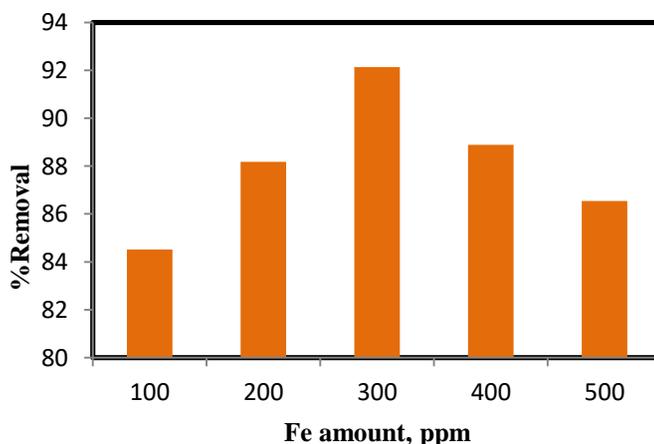


**Figure 1:** Calibration line of Direct Orange 26 azo dye

### 3. Results and Discussions

#### 3.1 *The effect of Fe amount*

In order to determine the optimum amount of Fe, it was studied at pH=2 and different amounts of Fe. As seen in Figure 2, when the amount of Fe increased from 100 ppm to 300 ppm, the DO26 removal efficiency increased and then decreased. Therefore, the optimum amount of Fe was determined as 300 ppm.



**Figure 2:** Effect of Fe amount on DO26 removal ( $[\text{DO26}]_0=50$  ppm [pH=2],  $[\text{H}_2\text{O}_2]=200$  ppm and  $[t]=60$  min.).

The removal efficiency is determined by the generation of hydrogen peroxide by the hydroxyl radical in the cavitation bubble of sonolysis (Chand et al., 2009).



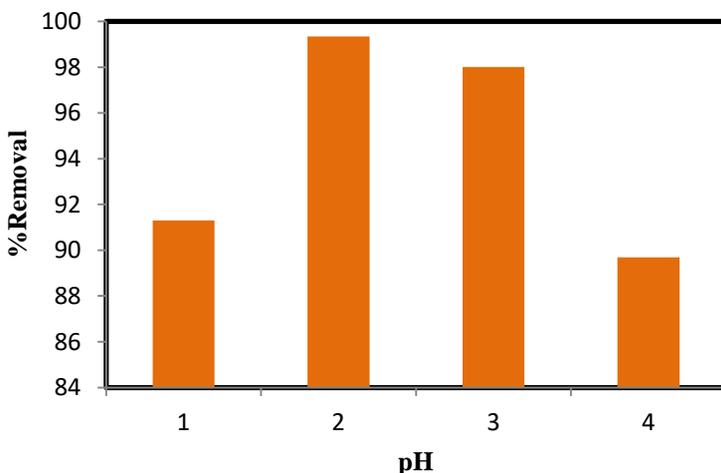
$\text{Fe}-\text{OOH}^{+2}$  can be converted to  $\text{Fe}^{+2} + \text{HOO}\cdot$  by sonolysis (Song et al., 2009).

Increasing the concentration of  $\text{Fe}^{+2}$  after the optimum  $\text{Fe}^{+2}$  addition creates a brown turbidity that causes a decrease in removal and has a scavenging effect on  $\text{Fe}^{+2}$  hydroxyl radicals (Sundararaman et al., 2009; Harichandran ve Prasad, 2016).



### 3.2 The effect of pH

The experiments were carried out by adjusting the pH of the 50 ppm dye solution to 2, 3, 4 and 5 in order to find the optimum pH value. As seen in Figure 3, optimum pH=3 was found.



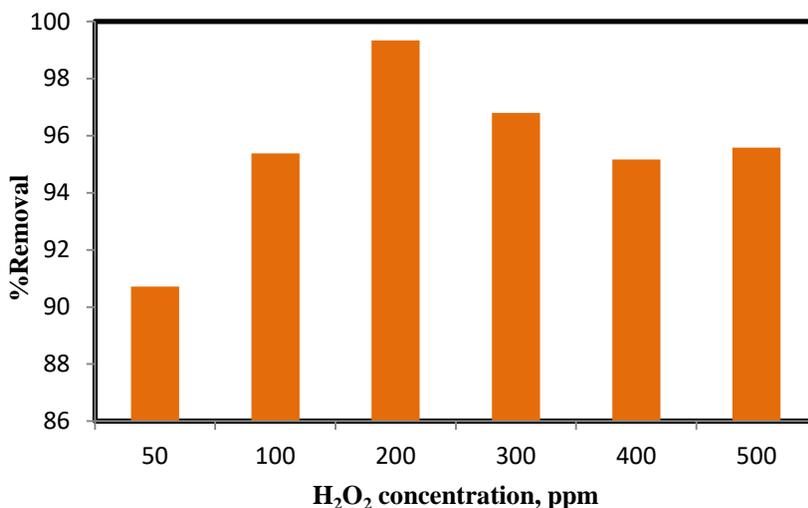
**Figure 3:** Effect of pH on DO26 removal ( $[\text{DO26}]_0=50$  ppm,  $[\text{FeSO}_4 \cdot 7\text{H}_2\text{O}]=300$  ppm,  $[\text{H}_2\text{O}_2]=200$  ppm and  $[t]=60$  min.).

pH is one of the key parameters in Fenton reactions. In the literature, the ideal pH range for treatment in Fenton processes has been reported as 2-3. As higher pHs are raised, the oxidation efficiency of Fenton's reagent may decrease as ferric ions ( $\text{Fe}(\text{OH})_3$ ) are formed. Since  $\text{Fe}(\text{OH})_3$  has low activity, it does not react with hydrogen peroxide (Neyens and Baeyens, 2003). When  $\text{pH} > 4$ , the formation of  $\text{Fe}(\text{II})$  complexes reduces the formation of free radicals (Harichandran and Prasad, 2016). When the pH is too low, the concentration of hydrogen ions is too high and slows down the formation of  $\text{FeOOH}^{2+}$ . It also reduces the ratio of hydroxyl radicals and iron ions (Neyens and Baeyens, 2003).

The Sono-Fenton process, on the other hand, is slightly different from the Fenton process, and it gives good results in basic conditions due to the effect of ultrasound (Ranjit et al., 2008). As can be seen in Figure 3, an efficiency of 90% was obtained even at  $\text{pH}=5$ . Being able to work in alkaline waters also creates a less dangerous environment for aquatic organisms. As a result, ultrasound+fenton (sono-fenton) process has eliminated the necessity of operating only in acidic conditions of the Fenton process.

### ***3.3. Effect of $\text{H}_2\text{O}_2$ concentration***

After determining the optimum  $\text{pH}=3$  and the optimum Fe amount as 300 ppm, experiments were carried out with 50, 100, 200, 300, 400 and 500 ppm  $\text{H}_2\text{O}_2$  to find the optimum  $\text{H}_2\text{O}_2$  concentration. As seen in Figure 4, the  $\text{H}_2\text{O}_2$  concentration increased up to 200 ppm and then decreased. The removal efficiency was determined as 99.34% at 200 ppm, which is the optimum  $\text{H}_2\text{O}_2$  concentration.



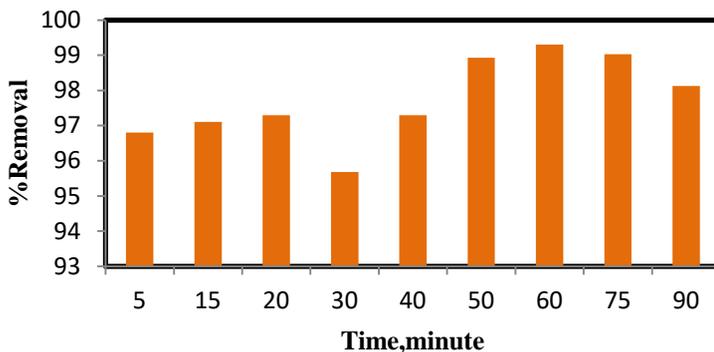
**Figure 4:** Effect of H<sub>2</sub>O<sub>2</sub> concentration on DO26 removal ([DO26]<sub>0</sub>=50 ppm, [FeSO<sub>4</sub>.7H<sub>2</sub>O]= 300 ppm, [pH]=3 and [t]=60 min.).

In Sono Fenton reactions, decolorization increases with increasing H<sub>2</sub>O<sub>2</sub> concentration. The reason for the decrease after the optimum level; It is the accumulation of dissociated hydrogen peroxide and undissociated hydrogen peroxide to form hydroxyl radicals. This results in the formation of hydroperoxyl, which is less active than the hydroxyl radicals. At higher H<sub>2</sub>O<sub>2</sub> concentration, hydroxyl radicals react with peroxide, reducing dye removal (Siddique et al., 2014).



### 3.4. The effect of reaction time

After determining the optimum pH=3, the optimum Fe amount as 300 ppm and the optimum H<sub>2</sub>O<sub>2</sub> concentration as 200 ppm, experiments were carried out at various times in order to determine the appropriate reaction time. As seen in Figure 5, the DO26 removal efficiency was 96% even at the fifth minute. However, after the 50th minute, the yield increased to 99% and then remained stable at this value. Therefore, the optimum removal time was taken as 50 minutes.

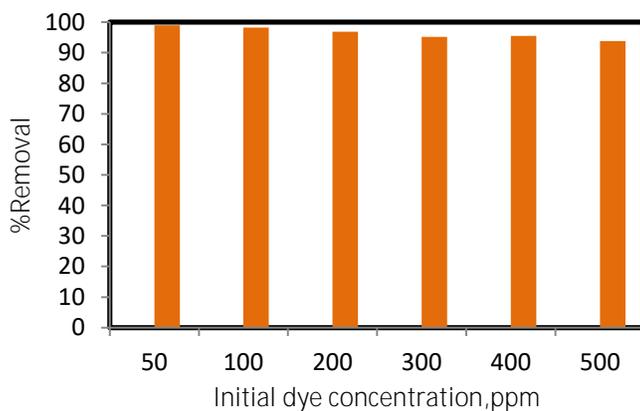


**Figure 5:** Effect of time on DO26 removal ( $[\text{DO26}]_0=50$  ppm,  $[\text{FeSO}_4 \cdot 7\text{H}_2\text{O}] = 300$  ppm,  $[\text{H}_2\text{O}_2]=200$  ppm and  $[\text{pH}]=3$ ).

In the removal of bisphenol A by the Sono Fenton method, Ioan et al. (2007) stated that the removal was less than 60 minutes. Toprak and Şener (2021), on the other hand, achieved the highest color removal efficiency of 96.6% after 45 minutes of reaction.

### 3.5. Effect of initial dye concentration

Experiments were carried out by keeping the effect of initial concentration on Direct Orange 26 removal, different dye concentrations between 50-500 ppm and other determined optimum conditions constant. The highest yield was obtained at the initial dye concentration of 50 ppm, as seen in Figure 6.



**Figure 6:** Effect of initial dye concentration on DO26 removal ( $[\text{DO26}]_0=50$ ppm,  $[\text{pH}]=3$ ,  $[\text{FeSO}_4 \cdot 7\text{H}_2\text{O}] = 300$  ppm,  $[\text{H}_2\text{O}_2]=200$  ppm,  $[\text{pH}]=3$  and 50 min.).

Increasing the initial dye concentration reduces color and COD removal. The reason is the increase in the number of inorganic anions that prevent the dye molecules from reacting with OH radicals (Karami et al., 2016).

#### **4. Conclusion**

In this study, parameters such as pH, Fe amount, H<sub>2</sub>O<sub>2</sub> concentration and the effect of the initial concentration of the dye on the removal of DO26 azo dye by sono Fenton method were investigated. The optimal operational parameters were found to be a pH of 3.0, a 200 ppm H<sub>2</sub>O<sub>2</sub> concentration, a 300 ppm Fe amount, and a dye concentration of 50 mg/L for a time of 50 min. In these conditions, the efficiency was 99%. The ultrasound device is known to be an expensive piece of equipment (Geng et al., 2021a). However, it was noted that the reaction time decreased by 40% with ultrasound-Fenton compared to the Fenton method (Toprak and Şener, 2021). As a result, we can say that sono fenton is suitable for the removal of direct group azo dyes.

#### **Acknowledgements**

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#### **5. References**

- Aşçı, Y. (2013). “Decolorization of Direct Orange 26 by heterogeneous Fenton oxidation”. *Desalination and Water Treatment*, 51(40–42), 7612–7620.
- Babuponnusami, A., ve Muthukumar, K. (2014). “A review on Fenton and improvements to the Fenton process for wastewater treatment”. *Journal of Environmental Chemical Engineering*, Elsevier Ltd, 2(1), 557–572.
- Basturk, E., ve Karatas, M. (2014). “Advanced oxidation of Reactive Blue 181 solution: A comparison between Fenton and Sono-Fenton Process”. *Ultrasonics Sonochemistry*, Elsevier B.V., 21(5), 1881–1885.
- Bayar, S., ve Erdogan, M. (2019). “Removal of COD and color from reactive red 45 azo dye wastewater using fenton and fenton-like oxidation

- processes: Kinetic studies”. *Applied Ecology and Environmental Research*, 17(2), 1517–1529.
- Chand, R., Ince, N. H., Gogate, P. R., ve Bremner, D. H. (2009). “Phenol degradation using 20, 300 and 520 kHz ultrasonic reactors with hydrogen peroxide, ozone and zero valent metals”. *Separation and Purification Technology*, 67(1), 103–109.
- Erkmen, J. (2022). “Acid red-20 sentetik endüstriyel boyar maddenin elektro-oksidadasyon yöntemi ile sulu çözeltiden uzaklaştırılması Removal of acid red-20 synthetic industrial dyestuff from aqueous solution by electro oxidation method”. 11(2), 363–371.
- Geng, N., Chen, W., Xu, H., Ding, M., Lin, T., Wu, Q., ve Zhang, L. (2021a). “Insights into the novel application of Fe-MOFs in ultrasound-assisted heterogeneous Fenton system: Efficiency, kinetics and mechanism”. *Ultrasonics Sonochemistry*, Elsevier B.V., 72.
- Geng, N., Chen, W., Xu, H., Ding, M., Lin, T., Wu, Q., ve Zhang, L. (2021b). “Insights into the novel application of Fe-MOFs in ultrasound-assisted heterogeneous Fenton system: Efficiency, kinetics and mechanism”. *Ultrasonics Sonochemistry*, Elsevier B.V., 72, 105411.
- Grau, P. (1991). “Textile industry wastewaters treatment”. *Water Science and Technology*, 24(1), 97–103.
- Harichandran, G., ve Prasad, S. (2016). “SonoFenton degradation of an azo dye, Direct Red”. *Ultrasonics Sonochemistry*, Elsevier B.V., 29, 178–185.
- Ioan, I., Wilson, S., Lundanes, E., ve Neculai, A. (2007). “Comparison of Fenton and sono-Fenton bisphenol A degradation”. *Journal of Hazardous Materials*, 142(1–2), 559–563.
- Karami, M. A., Sharafi, K., Asadi, A., Bagheri, A., Yosefvand, F., Charganeh, S. S., Mirzaei, N., ve Velayati, A. (2016). “Degradation of reactive red 198 (RR198) from aqueous solutions by advanced oxidation processes (AOPS): O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub>/O<sub>3</sub> and H<sub>2</sub>O<sub>2</sub>/ultrasonic”. *Bulgarian Chemical Communications*, 48(SpecialIssueD), 43–49.
- Liu, R., Chiu, H. M., Shiau, C. S., Yeh, R. Y. L., ve Hung, Y. T. (2007). “Degradation and sludge production of textile dyes by Fenton and

- photo-Fenton processes". *Dyes and Pigments*, 73(1), 1–6.
- Mahmoud, A. S., Ghaly, A. E. and Brooks, M. S. (2007). "Removal of Dye from Textile Wastewater Using Plant Oils Under Different pH and Temperature Conditions". *BMJ (Clinical research ed.)*, 342(4), 205–218.
- Neyens, E., ve Baeyens, J. (2003). "A review of classic Fenton's peroxidation as an advanced oxidation technique". *Journal of Hazardous Materials*, 98(1–3), 33–50.
- Ranjit, P. J. D. Palanivelu, K. & Lee, C.S. (2008). Degradation of 2,4-dichlorophenol aqueous solution by sono-Fenton method. *Korean Journal of Chemical Engineering*, 25(1), 112- 117.
- Özdemir, C., Öden, M. K., Şahinkaya, S., ve Güçlü, D. (2011a). "The sonochemical decolorisation of textile azo dye CI Reactive Orange 127". *Coloration Technology*, 127(4), 268–273.
- Özdemir, C., Öden, M. K., Şahinkaya, S., ve Kalipçi, E. (2011b). "Color Removal from Synthetic Textile Wastewater by Sono-Fenton Process". *Clean - Soil, Air, Water*, 39(1), 60–67.
- Park, H., ve Choi, W. (2003). "Visible light and Fe(III)-mediated degradation of Acid Orange 7 in the absence of H<sub>2</sub>O<sub>2</sub>". *Journal of Photochemistry and Photobiology A: Chemistry*, 159(3), 241–247.
- Patel, H., ve Vashi, R. T. (2015). "Introduction". *Characterization and Treatment of Textile Wastewater*, Elsevier, 1–20.
- Petrier, C., Jiang, Y., ve Lamy, M. F. (1998). "Ultrasound and environment: Sonochemical destruction of chloroaromatic derivatives". *Environmental Science and Technology*, 32(9), 1316–1318.
- Primo, O., Rivero, M. J., ve Ortiz, I. (2008). "Photo-Fenton process as an efficient alternative to the treatment of landfill leachates". *Journal of Hazardous Materials*, 153(1–2), 834–842.
- Siddique, M., Farooq, R., ve Price, G. J. (2014). "Synergistic effects of combining ultrasound with the Fenton process in the degradation of Reactive Blue 19". *Ultrasonics Sonochemistry*, Elsevier B.V., 21(3), 1206–1212.
- Song, Y. L., Li, J. T., ve Chen, H. (2009). "Degradation of C.I. acid red 88

- aqueous solution by combination of fenton's reagent and ultrasound irradiation". *Journal of Chemical Technology and Biotechnology*, 84(4), 578–583.
- Sundararaman, T. R., Ramamurthi, V., ve Partha, N. (2009). "Decolorization and COD Removal of Reactive Yellow 16 by Fenton Oxidation and Comparison of Dye Removal with Photo Fenton and Sono Fenton Process". *Modern Applied Science*, 3(8), 15–22.
- Toprak, D., ve Şener, S. (2021). "Acid Blue 264 azo boyasının Fenton ve ultrasones-Fenton oksidasyon yöntemleri ile renk ve KOİ gideriminin araştırılması Investigation of color and COD removal of Acid Blue 264 azo dye by Fenton and ultrasound-Fenton oxidation methods". 10(2), 487–494.
- Walling, C. (1975). "Fenton's Reagent Revisited". *Accounts of Chemical Research*, 8(4), 125–131.
- Xu, X. R., Li, H. Bin, Wang, W. H., ve Gu, J. D. (2004). "Degradation of dyes in aqueous solutions by the Fenton process". *Chemosphere*, 57(7), 595–600.



## CHAPTER XIII

# WELDING METALLURGY OF STRUCTURAL STEELS

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### 1. Introduction

**I**ron is one of the ancient used metals in the world. Carbon is the most effective and important element for strengthening iron (Ashby et.al., 1998; Thelning, 2000). The first step in processing iron into steel involves blast furnaces by alloying operation (Guthrie R.I.L. et.al., 1990). Based on the carbon and alloying elements in steels, steels are mainly grouped as ‘Plain carbon steel’ or ‘Alloy steel’. Plain carbon steels are divided into three main classes as low, medium and high carbon steels having carbon ratios to maximum values of 0.25, 0.25-0.60 and 0.60-1.0% by weight respectively. Alloy steels are also grouped as low and high alloy steels. The main classification of alloy steels depends on the percentage of alloying elements whether higher than 5% by weight is defined as high alloy steel. (Mandal S. K, 2016). Carbon steels comprise 90% of whole steel production. The remaining types include low alloyed steels, tool steels and stainless steels (Ashby et.al., 1998). Steel is assumed to be carbon steel when no minimum

content is defined for aluminum, boron, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium and zirconium elements for providing alloying effects besides maximum content of the following elements should not exceed these limits; manganese <1.65%, silicon <0.60%, copper <0.60% (Dossett and Boyer, 2006).

The common chemical composition of carbon steels are listed in Table 1 (Guthrie H.I.L., et.al, 1990). Among them the steel groups are assumed to be hardened by transformation according to the amounts of carbon element whether more than 0.25% by weight. (Mandal S.K.;, 2016).

**Table 1.** Carbon steels chemical composition ranges

<i>Elements</i>	<i>Amounts of specified element</i>	<i>Range%</i>
Carbon	≤0.12	...
	0.12-0.25	0.05
	0.25-0.40	0.06
	0.40-0.55	0.07
	0.55-0.80	0.10
	>0.80	0.13
Manganese	≤0.40	0.15
	0.40-0.50	0.20
	0.50-1.65	0.30
Phosphorus	0.040-0.08	0.03
	0.08-0.13	0.05
Sulfur	0.050-0.09	0.03
	0.09-0.015	0.05
	0.15-0.23	0.07
	0.23-0.35	0.09
	0.35-0.50	0.10
Silicon	≤0.15	0.08
	0.15-0.20	0.10
	0.20-0.30	0.15
	0.30-0.60	0.20
Copper	0.20 (when required)	
Lead	0.15-0.35 (when required)	

## **2. Structural Steels**

Structural steels (also named as fine grained structural steels) are preferred for their availability and cheapness especially among construction industries. These alloys consist mainly of carbon, manganese, silicon with minor amounts of phosphorus and sulfur (Brandes, 1992). As these steels are also grouped as unalloyed and/or low alloyed steels, their properties strongly depends on the amounts of carbon element. They are widely selected in bridges, pressure vessels, automotive and construction industries (Topbaş, 1998). Structural steels having carbon amounts frequently between 0,10-0.25% by weight are preferred mostly for structural applications as reinforced steel bars for building and factory constructions and also as plate steels for vessels and containers, tanks etc. that requires strength besides having good weldability (Mandal S.K., 2016).

### ***2.1. Types of structural steels***

Structural steels are grouped basically according to their mechanical properties (yield strength values) at designated conditions of delivery by standard documents as listed in Table 2 (EN 10027-1; 2016).

**Table 2.** Structural steels designation system (EN 10027-1; 2016)

		'G' or 'S' ( . . . ) Additional symbols <b>An</b>				
Principal symbols		Additional symbols				
Letter	Mechanical property	For steel				
		Group 1		Group 2		
G steel casting S structural steel	Specified min. yield strength in MPa in three digits ( . . . ) for the smallest thickness range	Impact Energy (J)		Temperature	C: special cold forming D: Hot dip coating E: Enamelling F: Forgings H: Hollow section L: Low temperature M: Thermomechanically rolled N: Normalized or normalized rolled P: Sheet Pilling Q: Quenched and tempered S: Ship building T: Tubes W: Water resistant <b>An:</b> chemical symbol of specified additional elements	
		27	40	60		°C
		JR	KR	LR		20
		J0	K0	K0		0
		J2	K2	K2		20
		J3	K3	K3		30
		J4	K4	K4		40
		J5	K5	K5		50
		J6	K6	K6		60
		A: Precipitation hardening M: Thermomechanically rolled N: Normalized or normalized rolled Q: Quenched and tempered G: other characteristics				

These alloys are commonly joined by riveting, screwing and various types of welding techniques. Fusion welding processes are widely preferred in joining of the structural steels.

## 2.2. *Joining structural steels by fusion welding processes*

The amounts of heat that used for melting the materials for joining by fusion welding processes of structural steels must be as lower as possible in consequence of grain size coarsening effects as it reduces the toughness values of weldments. These fusion welding processes are broadly classified in three main groups as given below.

### (a) **Gas welding**

Oxy-gas welding

**(b) Arc welding**

Shielded metal arc welding

Gas tungsten arc welding

Plasma arc welding

Gas metal arc welding

Flux cored arc welding

Submerged arc welding

Electro-slag welding

**(c) High energy beam welding**

Electron beam welding

Laser beam welding

These joining methods differ by power densities among themselves (ASM Handbook Vol. 6, 1993). Power density increases from gas welding to electric arc and high energy beam welding techniques. Higher power density increases depth of penetration and welding speed.

Carbon and low alloy steels are frequently joined by one of these fusion welding methods because of their widespread structural applications globally. Fusion welding modifies the main structure of the weld regions in metals in consequence of applied heat input values.

Increasing heat input also increases the risk of deformation and distortion of parts that welded. Orientation of microstructures, mechanical values such as hardness, impact energy, tensile and yield strength can be seriously affected by the heat input in fusion welding processes.

Heat input in fusion welding processes is estimated by Equation 1 (ASM Handbook Vol. 6, 1993; Jenney et. al., 2001).

$$\text{Heat input (J/mm)} = \eta \times \frac{V \times I}{v} \quad (1)$$

$V$ : welding voltage (volts),

$I$ : welding current (amperes),

$v$ : welding speed (mm/second),

$\eta$ : arc efficiency (related with the heat transfer capability of the welding method).

Arc efficiency values ( $\eta$ ) for various fusion welding methods are listed in Table 3. as examples.

**Table 3.** Arc efficiency values for common fusion welding methods

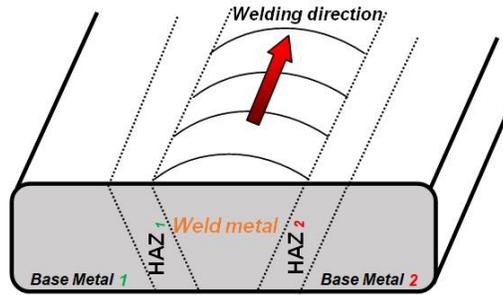
<i>Fusion welding method</i>	<i>Arc efficiency * +</i>
Shielded metal arc welding	0.90
Gas metal arc welding	0.90
Flux-cored arc welding	0.90
Submerged arc welding	0.95
Gas tungsten arc welding	0.70

During fusion welding the heat source transfers the heat energy directly to the work piece but the whole heat load cannot be 100% transferred onto the work piece for melting; hence the heat is transferred also as a loss to atmosphere and to colder regions of parts. Therefore arc efficiencies given in Table 3 varies according to the amounts of heat losses related with welding techniques.

Excessive heat input values coarsen the grain sizes of microstructures therefore decrease the toughness values of welded parts. Besides; residual stresses and distortions originating from extreme heat input values directly change the service life of parts as a result of welding operations (Kou, 2003).

The heat source that used in fusion welding plays an important role on determining the final characteristics of weld zones in steel alloys. Heat encountered to a transformable alloy results in phase transformations with major changes in microstructure (Callister et.al., 2009).

During the fusion welding operation the heat source transfers the heat energy directly to both of the parts joining regions and provides them to melt. A welded couple of parts consist of three main regions as given in Figure 1.



**Figure 1.** Main regions in a fusion welding

These regions are as follows:

1. (unaffected) base metals (part 1 and/or part 2),
2. Heat affected zones (HAZ),
3. Weld metal

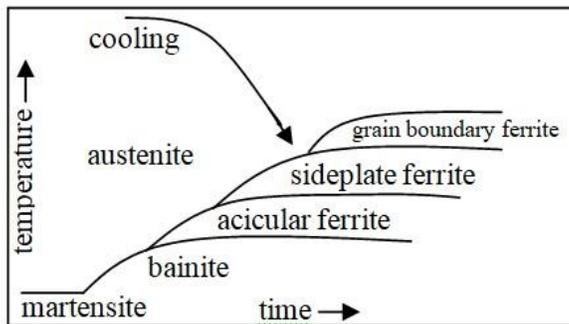
Base metal regions are not affected from heat sources causing to any transformation of phases in consequence of being adequately far away from heat source. However heat affected zones are seriously affected from heat sources during the welding operation encountering probable phase transformations where possible. Crystallographic structure of many metals can be changed according to specific phase transformation temperatures. Allotropic transformation is a good example for some metals to change their structures due to the temperature encountered. The final structure of welding area depends on the composition of base metals, filler materials (if used), welding processes and procedures. The welding phenomenon can also be thought as a typical casting operation.

Weld metals generally solidify rapidly resulting in a dendritic microstructure. The weld metal consists of melted base metal and filler material (if used) as preferred especially for thicker sections of materials to be joined (Jenney, 2001; ASM Handbook Vol. 4, 1993).

However the filler material is also preferred for determining the physical and chemical requirements related with weldment. The chemical composition of a filler material to be selected for a given construction or a component must include alloying elements at least or if possible almost equal

to base metals to be joined in order to provide the requirements of mechanical and/or corrosion properties.

The cooling rate is important in welding. The speed of cooling determines the final phases to be formed in weld regions. As the cooling rates increase the amounts of harder and brittle phases such as bainite and/or martensite also increase. Figure 2 shows the probable phases that can be formed after the fusion welding operations of structural steels.



**Figure 2.** Cooling rate-transformation diagram for weld metal regions of low and unalloyed steels.

After welding operation; increasing cooling rate transforms the austenite phase into martensite phase side while decreasing cooling rate transforms the austenite phase into grain boundary ferrite phase side as visible in Figure 2 (Kou, 2003; Jenney et. al, 2001).

During welding operation the peak temperature is encountered in weld metal centerlines throughout the welded regions as a result of maximum intensity front of the heat sources. The peak temperatures lead to coarsen the grain sizes of the weld metals. As the welding operation continues, the previous yet joined regions start cooling.

In fusion welding, the thermal cycles produced by the moving heat source result in physical property changes, metallurgical phase transformations, thermal stresses and metal transfers. After welding is finished, the product may have discontinuities/faults that are due to very rapid solidification or uncontrolled cooling circumstances (ASM Handbook Vol. 4,

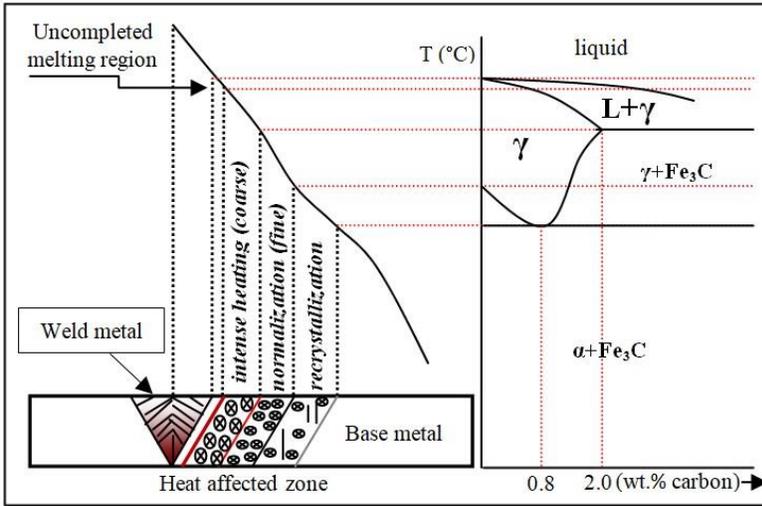
1993).

However in fusion welding whether the heat input is increased the cooling rate decreases. Besides if the material thickness increases the cooling rate also increases in consequence of thicker material having much more colder regions away from the fusion boundary. Additionally increasing welding speed decreases the heat input values per unit joint length resulting in increasing cooling rates of weldments. The cooling rate of welded joints has to be reduced in order to prevent formation of probable harder and brittle phases in weld regions.

For thicker parts to be joined, they can be safely heated below the critical phase transformation temperatures of joining materials. This precaution before the welding operation is mainly called 'pre-heating' as selected according to types of steels. Pre-heating temperature depends on the composition of the alloy. As the probability of transformation to harder phases increases according to the alloys composition, pre-heating temperature also increases. However this temperature is always below the critical phase transformation limit for all steels. Standard referenced documents guarantees to limit the levels of such harder phases according to the hardness differences compared by Vickers hardness testing method for ensuring safe welds (CR ISO 15608, 2000; EN ISO 15614-1, 2017).

Maximum hardness values of welded parts are limited according to EN ISO 15614-1 and with other related standards owing to materials type and classes. For instance; hardness values of welded parts made from low or unalloyed steels are limited up to 380HV10 and 320HV10 with or without heat treated conditions respectively.

Figure 3 represents the transformation of phases encountered in low or un-alloyed structural steels according to weld regions.



**Figure 3.** Transformation of phases in a low alloyed structural steel according to weld regions.

Weld metal seems like a dendritic cast microstructure as a result of the maximum temperatures occur in this region. During welding, on heating, the weld metal is suddenly melted whether the temperature is high enough for melting for that region and as soon as the welding operation finishes, suddenly cooling lets the weld metal to get solidified rapidly depending on welding circumstances such as peak temperatures, metals physical and chemical properties, welding method, dimensions and shape of the joint etc. Uncompleted melting region next to weld metal is a type of semi-melting area as a result of inadequate heat transferred section for melting.

The solid phase heat affected zone is composed of 4 distinct regions as seen in Figure 3.

The intense heat absorbed region near to uncompleted melting area is called coarse grained intense heated region. The maximum amounts of heat transfer and therefore maximum cooling rate is encountered in this region. As a result of rapid cooling and coarse grains; the flaws, cracks and various types of probable discontinuities are mostly expected in this region.

The third region consists of fine grained normalized grains. The highest toughness values are found in this region.

The fourth region is semi re-crystallized as a result of moderate temperatures fitting with re-crystallization heat treatment. The end of this region meets with unaffected base metal boundary. Base metal region is not affected from the heat source so that there are no changes in micro-structural, physical, chemical or mechanical properties. The temperatures are below the critical phase transformation limits depending on the alloy types.

### 2.3. *Weldability of structural steels*

Weldability is defined as an alloy to be joined to perform a specific designed structure for a given welding operation in order to meet the service requirements (Jenney et. al, 2001; Groover, 2010). American welding Society defines the weldability as *'The capacity of a material to be welded under fabrication conditions imposed into a specific suitably designed structure and to perform satisfactorily'* (Lippold and Kotecki, 2005).

Weldability is influenced by parts shape, dimensions, chemical and physical properties of joining materials basically. For each type of metal, there are welding procedure limits within which sound weldments with satisfactory properties can be fabricated. If these limits are wide and there is no need to take care for extra precautions the material has good weldability whether some precautions have to be taken before, after or during the joining operation this material is called as weldable. Heat treatment applications are the most preferred precautions in joining by fusion welding of low or unalloyed steels. Preheating, inter-pass heat control and stress relief annealing heat treatment techniques are mostly desired. These methods are all applied below the critical phase transformation temperatures for every low and unalloyed steel alloys (Jenney et. al, 2001).

Preheating and inter-pass heat controls are used in order to decrease the cooling rates of the weldments. Stress relief annealing is applied for decreasing the internal stresses originating from rapid cooling of weld area (Thompson S, 1999).

However filler material is also a major factor in joining of metal alloys as can be selected from standard documents (ASME Part C, 2010). Chemical composition of a filler metal can change the final microstructure of low or

unalloyed steel. The chemical composition of filler materials whether possible matching or approximately close matching types must be preferred for safe weldments.

#### ***2.4. Weldability testing methods of structural steels***

Weldability testing of structural steels can be applied by both destructive and non destructive tests. Tested samples cannot be used anymore in destructive tests while the specimens can be used safely after the non-destructive testing methods.

Destructive tests are;

##### ***Chemical tests,***

Chemical composition uniformity

Corrosion resistance

##### ***Metallographic tests,***

Macro and micro structural analysis (EN ISO 17639, 2022; ASTM E381, 2020)

##### ***Mechanical tests,***

Hardness tests (EN ISO 9015-1, 2011),

Tensile tests (EN ISO 4136, 2011),

Impact Energy tests (EN ISO 9016, 2022; ASTM E23, 2018),

Fracture tests (EN ISO 9017, 2018),

Bending tests (EN ISO 5173, 2010).

Non-destructive tests are;

Visual inspection (EN ISO 17637, 2017),

Liquid penetrant test (EN ISO 3452-1; 2021),

Magnetic particle inspection (ASTM E 1444),

Radiographic inspection (EN ISO 17636-1, 2013),

Ultrasonic inspection (ASTM E2375, 2016),

The selection of the test method depends on the circumstances of the construction that welded (AWS Welding inspection handbook, 2015). The type of the standard document (whether ASTM or EN) depends on the parties as agreed between themselves.

### **3. Conclusions**

Structural steels are broadly used by many industries in huge amounts as they are cheaper than other groups of iron based alloys. They are classified among the low and unalloyed steels.

Structural steel alloys are joined by riveting, screwing and numerous different welding techniques. Fusion welding methods are mostly preferred for joining of these alloys as these methods are widespread and conventional in related industries.

The weldability of structural steels is generally good in consequence of their low amounts of alloying elements especially their carbon content is usually lesser than 0.2% by weight so that hardening problems in weld regions are encountered rarely.

Heat input values according to welding methods have important effects on microstructural, mechanical and chemical properties of weldments in structural steels.

However the dimensions of joining construction have also major effect on weldability because of increasing cooling rates. Increasing dimensions of joining parts increase the cooling rates at weld regions resulting in formation of harder and brittle phases such as martensite, bainite etc.

Weldability performance of structural steels is determined by various types of destructive and non destructive testing methods. Engineers have to decide which suitable testing method/methods to be used for determining the approval of weldments ruling to the standard documents.

**References**

- Ashby M.F, Jones D.R.H, Engineering Materials Volume 2, p:113, Butterworth Heinemann (1998) ISBN: 0750640197, USA.
- ASM Handbook Committee, ASM Metals Handbook Volume 4, (1993), pp.22, 113, ASM International.
- ASM Handbook Committee, Welding, brazing and soldering, ASM Metals Handbook Volume 6, (1993), pp. 17, ASM International.
- ASME Boiler and pressure vessel code, (2010), II Part C, Specifications for welding rods, electrodes and filler metals, Materials, p.3, USA.
- ASTM E23, (2018), Standard test methods for notched bar impact testing of metallic materials, ASTM International, USA.
- ASTM E381, (2020), Standard practice for macro-etch testing of steel bars billets, blooms and forgings, ASTM International, USA.
- ASTM E2375, (2016), Standard practice for Ultrasonic testing of wrought products, ASTM International, USA.
- AWS Committee on Methods of Inspection, 4<sup>th</sup> Edition, (2015), Welding Inspection Handbook, p. 65-125, USA.
- Brandes E.A., Brook G.B., Metals Reference book, 7<sup>th</sup> Edition, , section: 22-10, (1992), Butterworth Heinemann, ISBN 0-750636246.
- Callister W.D., Retwisch R.G., Materials Science and Engineering, An Introduction, (2009), 8<sup>th</sup> Edition, p.344, John Wiley and Sons, USA.
- CR EN ISO 15608, Welding, guidelines for a metallic material grouping system, (2000), International Standards Organization.
- Dossett J.L., Boyer H.E., Practical Heat Treating, Second Edition, p. 100, (2006), ASM International, Materials Park, Ohio, USA. ISBN: 0 87170 829 9.
- EN ISO 3452-1, (2021), Non destructive testing, Penetrant testing, Part 1, General principles.
- EN ISO 4136, (2011), Destructive tests on welds in metallic materials, Transverse tensile test.
- EN ISO 5173, (2010), Destructive tests on welds in metallic materials-Bend Tests.

- EN ISO 9015-1, Destructive test on welds in metallic materials-Hardness testing Part 1, (2011), Hardness test on arc welded joints.
- EN ISO 9016, (2022), Destructive tests on welds in metallic materials, Impact tests, test specimen location, notch orientation and examination.
- EN ISO 9017, (2018), Destructive tests on welds in metallic materials-Fracture Test.
- EN 10027-1, (2016), Designation systems for steels: Part 1 Steels, , European standard.
- EN ISO 15614-1, (2019), Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloy, International Standards Organization.
- EN ISO 17636-1, (2013), Non destructive testing of welds-Radiographic testing, Part 1, X and gamma ray techniques with film.
- EN ISO 17637, (2017), Non destructive testing of welds-visual testing of fusion welded joints.
- EN ISO 17639, (2022), Destructive tests on welds in metallic materials, Macroscopic and microscopic examination of welds.
- Groover M.P., (2010), Fundamentals of Modern manufacturing, materials processes and systems, 4<sup>th</sup> edition, John Wiley and Sons Publications, USA, p. 702, 711,742, ISBN 978-0470-467002.
- Guthrie H.I.L. et.al, Steel processing technology; Properties and selection, Irons, steels and high performance alloys, (1990), ASM Metals Handbook Volume 1, 10<sup>th</sup> edition, electronic version, p.182, 233, 235, ASM International Handbook Committee, USA.
- Jenney C.L., O' Brien A., (2001), Welding Handbook, Volume 1, 9<sup>th</sup> Edition, American Welding Society, pp. 89, 99,100,119, 130, 131, 140, 351, USA.
- Kou S., Welding Metallurgy, (2003), 2<sup>nd</sup> edition, Wiley Inter-science, p. 37, 393, ISBN: 0 471 43491 4, USA.
- Lippold J.C., Kotecki D.J., Welding metallurgy and weldability of stainless steels, (2005), p. 309-329, Wiley Interscience Publications, USA.

Mandal S.K., Heat Treatment of Steels, McGraw Hill Education, pp:15-19, 24 (2016), ISBN (13): 978-93-392-2106-5, India.

Thehning K.E., Steel and its heat treatment, Bofors Handbook, reprinted, (2000), pp.2-4, Butterworth Heinemann.

Thompson S.; Handbook of mold tool and die repair welding, (1999), William Andrew Publishing, pp. 49-96, England.

Topbaş M. A., Steel and Heat Treating Handbook, (1998), p.102, Prestij Publication, Istanbul, Turkey.

## CHAPTER XIV

# A REVIEW OF RECENT ADVANCES IN NEXT-GENERATION GENOME EDITING METHODS

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### 1. Introduction

**W**ith the completion of the human genome project, there has been a rapid development in determining genome sequences of other organisms. The science of bioinformatics, where available data can be stored and used, and compared, was born as a solution to the need. These rapid improvements in genetic engineering methods have facilitated the use of genome editing technologies.

By making a mutation at the loci of sequences obtained through structural genomics studies, the nucleotides can be replaced by insertion and deletion. Today, the use of synthetic biology makes it possible to acquire desired traits at the dimensions of the genome. At this point, a new era has begun in the fields of functional genomics in terms of plant breeding.

In light of advances in technology, the first-generation genome editing methods are Meganucleases, Zinc finger nucleases technology/ZFN. The Transcription Activator-like Effector Nucleases/TALEN is a genome-editing tool used as a second-generation genome editing technique. Also, Clustered Regularly Interspaced Palindromic Repeats/CRISPR is the third-generation genome editing technique. Current deficiencies have been addressed with the

genome editing techniques today, and the multiplexed accurate genome editing with short, trackable, integrated cellular barcodes/MAGESTIC technique has also found a place for itself. The basis for genome editing technologies in terms of working principles is that sequence-specific nucleases can cut through DNA. At this point, DNA repair mechanisms take charge. DNA can be repaired by the mechanisms of the HR/Homologous Recombination and Non-homologous DNA end joining.

Thus, genome integrity can be preserved. At this time, different mutations and modifications can be seen in the genome. This study will highlight the mechanisms and details of five methods that have found more use in plants in recent years in light of advances in genome editing technology.

## **2. Genome Editing Methods**

### **2.1. Meganucleases**

Meganuclease technology is one of the first methods used in genome editing. It is a method used from the 1990s until now. Here > 14 bp length natural meganucleases work functionally in the target locus (Smith et al. 2006). The most common meganucleases used in genome modifications are I-SceI (discovered in the mitochondria of *Saccharomyces cerevisiae* - baker's yeast), I-CreI (in the chloroplasts of *Chlamydomonas reinhardtii*-green algae) and I-DmoI (in archaeobacteria-*Desulfurococcus mobilis*). Directed Nuclear Editor (DNE) meganucleases designed by biotechnology companies in 2012 for a defined target began to be used in plants. The LAGLIDADG meganuclease (LMN) family is widely used for genome editing (Taylor et al., 2012). Most of these endonucleases are found as dimeric proteins. Meganucleases recognize special DNA sequences and cut the double-stranded DNA.

Numerous meganuclease members have been identified in eukaryotes. Meganucleases can be synthesized by both the nuclear genome and the mitochondrial genome (Stoddard, 2005). Their biggest advantage is that it reduces the number of DNA cut loci with long target sequence recognition domains. Its disadvantage is that a natural enzyme suitable for every region

may not be possible. To resolve this situation, locus-based enzyme systems need to be produced. This can be achieved through different technics applied to meganucleases. With individual-specific treatment methods, new hopes emerge for metabolic disorders and certain types of cancer (Marcaida et al. 2009). The model organism *Arabidopsis* is used to detect DNA insertions in most plant taxa (Rinaldo & Ayliffe, 2015).

## **2.2. Zinc Finger Nucleases/ZFN technology**

It was first used in the plant genome in 2005 (Lloyd, 2005). It binds to the DNA region by forming two domains as protein motifs. These include Binding and Cleavage domains (Samanta et al., 2016). ZFNs are preserved protein motif domains involved in transcription factors. In addition to having different configurations, it basically contains 30-60 amino acids that are bound to 1 zinc atom. ZFN sequences can form 18-24 bp recognition domains and recognize nucleotides (Akbulak, & Kontbay, 2017).

Novel techniques are being developed that facilitate ZFN design. The most favored are techniques such as Oligomerized Pool ENgineering (OPEN) and Context-Dependent Assembly (CoDA) (Foley et al, 2009; Sander et al., 2011). With kits developed in recent years, ZFN design can be made easier. The enzyme FokI endonuclease can form a cut point from upside-down strands in DNA. This structure enables the re-modification of the target area. It alerts NHEJ and HR cell repair pathways and are involved in repair in the cut area (Wu et al., 2013). In ZFN techniques, when off-target cutting zones are formed and there are difficulties in repairing them, cell toxicity is experienced and causes the death of the organism. This is the limitation and restrictive aspect of ZFN technology. Many research has been completed using this technique in plant breeding (Lloyd et al., 2005; Ramirez et al., 2008; Shukla et al., 2009; Townsend et al., 2009; Zhang et al., 2010; Kumar et al, 2015).

## **2.3. Transcription Activator Like Effector Nucleases/TALEN technology**

It was first used in 2011 in the editing of plant genomes as an alternative to the ZFN system (Cermak et al., 2011). The molecules Transcription

Activator-Like Effector/TALE, which provide binding in DNA, were first discovered in *Xanthomonas* bacteria that is a plant pathogen (Budhagatapalli et al., 2015). Research is also underway on the development of natural TALE proteins from different bacterial species (Lee et al. 2016). These effector domains that regulate biological activity bind to special gene promoters and made genes function (Boch et. al., 2009). TALE proteins consist of copies of 30 to 35 amino acids. With the combination of these sequences and FokI endonuclease, TALENs act as a modifier of genes (Moscou & Bogdanove, 2009).

TALEN cuts the target area by binding to upside-down strands in DNA (Miller et al., 2011). These regions enable the expression, and silencing of genes in the genome (Pattanayak et al., 2014; Baltes et al., 2015). The nuclease can create double-stranded breaks that can be repaired with non-homologous end joining (NHEJ) in the target region, resulting in gene degradations by adding small insertions or deletions. Variable di-residues repeated in 12 and 13 amino acid positions are preserved in every repeat except for what is called Repeat Variable Di-residues/RVDs. RVDs determine the DNA sequence to which the TALE will be bound (Tufan & Keleş, 2019). This simple one-on-one correspondence between TALE repeats and the corresponding DNA sequence facilitates the process of piecing together repeat sequences to recognize new DNA sequences.

TALEN structures have 3 advantages The structure of DNA binding is easier for domains, DNA binding specificity is higher and off-target effects are lower. Genome editing with TALENs has been successfully achieved in the model plants such as *Arabidopsis* (Cermak et al., 2011), rice (Li et al., 2012), tobacco (Zhang et al., 2013), and *Brachypodium* (Shan et al., 2013), as well as barley (Wendt et al., 2013) and corn (Char et al., 2015).

#### ***2.4. Clustered Regularly Interspaced Palindromic Repeats/CRISPR technology***

It was first discovered in the *E. coli* genome by Ishino et al (1987). The name, description, and function of these repetitive gene sequences were not defined in those years. With evolving technology, it was explained that these repeat

loci found in 2002 were linked to CRISPR-Associated (Cas) genes (Jansen et al., 2002; Barrangou, 2013). These sequences were also detected in different organisms (Mojica et al., 1995). Bacterial genomes were found to contain 55% CRISPR sequences and the archaea genome 85%, providing detailed information about the mechanism (Amitai & Sorek, 2016). The lack of open reading frames (ORF) in the leader sequence, the number of palindromic repeat sequences, and the presence of spacer DNA region mediator loci give CRISPR gene repeat regions an advantageous functional structure (Al-Attar et al., 2011; Hsu et al., 2014).

Trans-activating crRNA (tracrRNA) gene and precursor crRNA (pre-crRNA) genes can be synthesized with sequences belonging to CRISPR/Cas loci (Deltcheva et al. 2011; Barrangou, 2013; Xing et al., 2014; Belhaj et al., 2015; Yin et al. 2019). With this complex structure, targeted mutations can be realized by cutting DNA (Xing et al., 2014; Pauli et al., 2016). The main advantage of CRISPR technology is that homologous genes can be silenced simultaneously with a single sgRNA (Endo et al., 2015). In addition, by using Cas9/sgRNA expression vectors containing multiple sgRNAs, the functional structure of the pathways in which members of the gene family are involved can be studied (Xing et al., 2014).

### ***2.5. Multiplexed accurate genome editing with short, trackable, integrated cellular barcodes/MAGESTIC technology***

*Saccharomyces cerevisiae* is a species of budding yeast. It is a kind of yeast that has been used in bread making for many years. It is estimated that it is isolated from the skin of grapes. It is the yeast that is a component of the white layer on the peels of dark-skinned fruits. MAGESTIC was first obtained from this type of yeast in 2018. MAGESTIC is a new kind of cellular barcode. Since barcodes are integrated into chromosomes in MAGESTIC, it is a technology that is more stable and easy to find and count later (Roy et al., 2018).

### 3. Conclusion

Due to the long duration of classical plant breeding methods, genome editing techniques that are fast, easy, reliable, and inexpensive have started to be used in engineering studies to the extent of the possibilities provided by today's technology. Especially with the change in the level of nucleotides used in recent years, successful outcomes that are resistant to biotic and abiotic stresses are obtained, and efficiency and quality can be increased.

### References

- Akbudak, M. A., Kontbay, K. (2017). Yeni Nesil Genom Düzenleme Teknikleri: ZFN, TALEN, CRISPR'lar ve Bitkilerde Kullanımı. *Tarla Dkvmkngtk" Ogtmg/" Ctc v, toc" GpukvÄuÄ" Fgt ikuk*, 26 (1) , 111-126. DOI: 10.21566/tarbitderg.323614
- Al-Attar, S., Westra, E.R., Van Der Oost, J., Brouns, S.J.J. (2011). Clustered regularly interspaced short palindromic repeats (CRISPRs): The hallmark of an ingenious antiviral defense mechanism in prokaryotes. *Biol Chem*; 392(4):277–89.
- Amitai, G., Sorek, R. (2016). CRISPR–Cas adaptation: insights into the mechanism of action. *Nature Reviews Microbiology* 14(2), (2016), 67.
- Barrangou, R. (2013). CRISPR-Cas systems and RNA guided interference. *Wiley Interdiscip, Reviews: RNA*, 4(3): 267-278.
- Belhaj, K., Chaparro-Garcia, A., Kamoun, S., Nekrasov, V. (2013). Plant genome editing made easy: targeted mutagenesis in model and crop plants using the CRISPR/Cas system. *Plant Methods* 9:(1) 1–10.
- Boch, J., Scholze, H., Schornack, S., Landgraf, A., Hahn, S., Kay, S., Lahaye, T., Nickstadt, A., and Bonas, U. (2009). Breaking the code of DNA binding specificity of TAL-type III effectors. *Science*, 326, 1509-1512.
- Budhagatapalli, N., Rutten, T., Gurushidze, M., Kumlehn, J., & Hensel, G. (2015). Targeted Modification of Gene Function Exploiting Homology-Directed Repair of TALEN-Mediated Double-Strand Breaks in Barley. *G3 (Bethesda, Md.)*, 5(9), 1857–1863. <https://doi.org/10.1534/g3.115.018762>

- Cermak, T., Doyle, E. L., Christian, M., Wang, L., Zhang, Y., Schmidt, C., Baller, J. A., Somia, N. V., Bogdanove, A. J. and Voytas, D. F. (2011). Efficient design and assembly of custom TALEN and other TAL effector-based constructs for DNA targeting. *Nucleic Acids Research*, 39: e82.
- Char, S. N., Unger-Wallace, E., Frame, B., Briggs, S. A., Main, M., Spalding, M. H., Vollbrecht, E., Wang, K., Yang, B. (2015). Heritable site-specific mutagenesis using TALENs in maize. *Plant Biotechnol Journal*, 13, 1002-1010.
- Deltcheva, E., Chylinski, K., Sharma, C.M., Gonzales, K. (2011). CRISPR RNA aturation by trans -encoded small RNA and host factor RNase III. *Nature*;471(7340):602–7.
- Endo, M., Mikami, M., Toki, S. (2015). Multigene knockout utilizing off-target mutations of the CRISPR/Cas9 system in rice. *Plant & cell physiology*, 56(1), 41–47. <https://doi.org/10.1093/pcp/pcu154>.
- Foley, J. E., J. R. Yeh, M. L. Maeder, D. Reyon, J. D. Sander, et al. (2009) Rapid mutation of endogenous zebrafish genes using zinc-finger nucleases made by Oligomerized Pool ENgineering (OPEN). *PLoS ONE* 4: e4348.
- Hsu, P.D., Lander, E.S., Zhang, F. (2014). Development and Applications of CRISPR-Cas9 for Genome Engineering. *Cell*, 157(6):1262–1278.
- Ishino, Y., Shinagawa, H., Makino, K., Amemura, M., Nakata, A. (1987). Nucleotide sequence of the *iap* gene, responsible for alkaline phosphatase isozyme conversion in *Escherichia coli*, and identification of the gene product. *J. Bacteriology*, 169(12): 5429–5433.
- Jansen, R., Embden, J.D.A., Van Gastra, W., Schouls, L.M. (2002). Identification of genes that are associated with DNA repeats in prokaryotes. *Mol. Microbiology*, 43(6): 1565–1575.
- Kumar, S., AlAbed, D., Worden, A., Novak, S., Wu, H., Ausmus, C., Beck, M., Robinson, H., Minicks, T., Hemingway, D., Lee, R., Skaggs, N., Wang, L., Marri, P., Gupta, M. (2015). A modular gene targeting system for sequential transgene stacking in plants. *Journal of Biotechnology*, 207, 12-20.

- Li, T., Liu, B., Spalding, M. H., Weeks, D. P., Yang, B. (2012). High-efficiency TALEN-based gene editing produces disease-resistant rice. *Nature Biotechnology*, 30, 390-392.
- Lloyd, A., Plaisier, C. L., Carroll, D., Drews, G. N. (2005). Targeted mutagenesis using zinc-finger nucleases in Arabidopsis. *Proceedings of National Academy Sciences of the United States of America*, 102: 2232–2237.
- Mahfouz, M. M., Li, L., Shamimuzzaman, M., Wibowo, A., Fang, X. Zhu, J. K. (2011). De novo-engineered transcription activator-like effector TALE hybrid nuclease with novel DNA binding specificity creates double-strand breaks. *Proceedings of National Academy Sciences of the United States of America*, 108: 2623–2628.
- Marcaida, M.J., Munoz, I.G., Blanco, F.J., Prieto, J., Montoya, G. (2009) Homing endonucleases: from basics to therapeutic applications. *Cellular and Molecular Life Sciences*, 67(5): 727–748.
- Miller, J. C., Tan, S., Qiao, G., Barlow, K. A., Wang, J., Xia, D. F., Meng, X., Paschon, D. E., Leung, E. and Hinkley, S. J. (2011). A TALE nuclease architecture for efficient genome editing. *Nature Biotechnology*, 29: 143–148.
- Mojica, F.J.M., Ferrer, C., Juez, G., Rodríguez-Valera, F. (1995). Long stretches of short tandem repeats are present in the largest replicons of the Archaea *Haloferax mediterranei* and *Haloferax volcanii* and could be involved in replicon partitioning. *Molecular Microbiology*, 17(1): 85–93.
- Moscou, M. J. Bogdanove, A. J. (2009). A simple cipher governs DNA recognition by TAL effectors. *Science*, 326: 1501–1501.
- Pattanayak, V., Guilinger, J.P. Liu, D.R. (2014). Determining the Specificities of TALENs, Cas9, and Other Genome-Editing Enzymes. Use of CRISPR/Cas9, ZFNs, and TALENs in Generating Site-Specific Genome Alterations. *Methods in Enzymology*, 546:47-78.
- Pauli, C., Liu, Y., Zhou, F., Gerloff, D., Rohde, C., Mueller-Tidow, C. (2016). A focused CRISPR/CAS9 screen identifies snoRNAs that are required for clonal growth of leukemia cells. *In Oncology Research And Treatment*, 39: 143–143.

- Ramirez, C. L., Foley, J. E., Wright, D. A., Muller-Lerch, F., Rahman, S. H., Cornu, T. I., Winfrey, R. J., Sander, J. D., Fu, F., Townsend, J. A., Cathomen, T., Voytas, D. F. and Joung, J. K. (2008). Unexpected failure rates for modular assembly of engineered zinc fingers. *Nature Methods*, 5: 374–375.
- Rinaldo, A. R., Ayliffe, M. (2015). Gene targeting and editing in crop plants: a new era of precision opportunities. *Molecular Breeding*, 35(1), 40.
- Roy, K. R., Smith, J. D., Vonesch, S. C., Lin, G., Tu, C. S., Lederer, A. R., Chu, A., Suresh, S., Nguyen, M., Horecka, J., Tripathi, A., Burnett, W. T., Morgan, M. A., Schulz, J., Orsley, K. M., Wei, W., Aiyar, R. S., Davis, R. W., Bankaitis, V. A., Haber, J. E., ... Steinmetz, L. M. (2018). Multiplexed precision genome editing with trackable genomic barcodes in yeast. *Nature biotechnology*, 36 (6), 512–520. <https://doi.org/10.1038/nbt.4137>
- Samanta, M.K., Dey, A., Gayen, S. (2016). CRISPR/Cas9: an advanced tool for editing plant genomes. *Transgenic Research*, 25(5):561-73
- Sander, J. D., Dahlborg, E. J., Goodwin, M. J., Cade, L., Zhang, F., Cifuentes, D., Curtin, S. J., Blackburn, J. S., Thibodeau-Beganny, S., Qi, Y., Pierick, C. J., Hoffman, E., Maeder, M. L., Khayter, C., Reyon, D., Dobbs, D., Langenau, D. M., Stupar, R. M., Giraldez, A. J., Voytas, D. F., Peterson, R. T., Yeh, J. R., Joung, J. K. (2011). Selection-free zinc-fingernuclease engineering by context-dependent assembly CoDA. *Nature Methods*, 8: 67–69.
- Shan, Q., Wang, Y., Chen, K., Liang, Z., Li, J., Zhang, Y., Zhang, K., Liu, J., Voytas, D. F., Zheng, X., Zhang, Y., Gao C. (2013). Rapid and efficient gene modification in rice and *Brachypodium* using TALENs. *Molecular Plant*, 6, 1365-1368.
- Shukla, V. K., Doyon, Y., Miller, J. C., DeKolver, R. C., Moehle, E. A., Worden, S. E., Mitchell, J. C., Arnold, N. L., Gopalan, S., Meng, X., Choi, V. M., Rock, J. M., Wu, Y. Y., Katibah, G. E., Zhifang, G., McCaskill, D., Simpson, M. A., Blakeslee, B., Greenwalt, S. A., Butler, H. J., Hinkley, S. J., Zhang, L., Rebar, E. J., Gregory, P. D. and Urnov, F. D. (2009). Precise genome modification in the crop species

- Zea mays using zinc-finger nucleases. *Nature*, 459: 437–441.
- Smith, J., Grizot, S., Arnould, S., Duclert, A., Epinat, J. C., Chames, P., Prieto, J., Redondo, P., Blanco, F. J., Bravo, J., Montoya, G., Pâques, F. Duchateau, P. A. (2006). combinatorial approach to create artificial homing endonucleases cleaving chosen sequences. *Nucleic Acids Research*, 34, e149,5.
- Stoddard, B.L. (2005). Homing endonuclease structure and function. *Quarterly Reviews of Biophysics* 38(1): 49–95.
- Taylor, G. K., Petrucci, L. H., Lambert, A. R., Baxter, S. K., Jarjour, J., Stoddard, B. L. (2012). LAHEDES: the LAGLIDADG homing endonuclease database and engineering server. *Nucleic acids research*, 40(Web Server issue), W110–W116. <https://doi.org/10.1093/nar/gks365>
- Townsend, J. A., Wright, D. A., Winfrey, R. J., Fu, F., Maeder, M. L., Joung, J. K., Voytas, D. F. (2009). High-frequency modification of plant genes using engineered zinc-finger nucleases. *Nature*. 459: 442–445.
- Tufan, F., Keleş, E. N. (2019). “Genom Düzenleme Teknolojileri ve Bitkilerdeki Uygulamaları”, *Haliç Üniversitesi Fen Bilimleri Dergisi*, 2/1: 113-133.
- Wendt, T., Holm, P. B., Starker, C. G., et al. (2013). TAL effector nucleases induce mutations at a pre-selected location in the genome of primary barley transformants. *Plant Molecular Biology*, 83 (2013), 279-285.
- Wu, Y., Liang, D., Wang, Y., Bai, M., Tang, W., Bao, S., Yan, Z., Li, D., Li, J. (2013). “Correction of a genetic disease in using ZFNs and TALENs”. *Science*, 333, 307.
- Xing, H.L., Dong, L., Wang, Z.P., Zhang, H.Y., Han, C.Y., Liu, B., Wang, X.C., Chen, Q. J. (2014). A CRISPR/Cas9 toolkit for multiplex genome editing in plants. *BMC Plant Biology*, 14(1): 327
- Yin, Y., Hao, H., Xu, X., Shen, L., Wu, W., Zhang, J., Li, Q. (2019). Generation of an MC3R knock-out pig by CRISPR/Cas9 combined with somatic cell nuclear transfer (SCNT) technology. *Lipids Health Dis.*, 18(1): 1-8
- Zhang, F., Maeder, M. L., Unger-Wallace, E., Hoshaw, J. P., Reyon, D.,

- Christian, M., Li, X., Pierick, C. J., Dobbs, D., Peterson, T., Joung, J. K. and Voytas, D. F. (2010). High frequency targeted mutagenesis in *Arabidopsis thaliana* using zinc finger nucleases. *Proceedings of National Academy Sciences of the United States of America*, 107: 12028–12033.
- Zhang, Y., Zhang, F., Li, X., Baller, J. A., Qi, Y., Starker, C. G., Bogdanove, A. J., Voytas, D. F. (2013). Transcription activator-like effector nucleases enable efficient plant genome engineering. *Plant Physiology*, 161, 20-27.

